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LANGERS BLACK HILLS
SILVER JEWELRY, INC.
SPEARFISH, SOUTH DAKOTA

NIOSH INVESTIGATORS:
Max Kiefer, CIH

## SUMMARY

On February 14, 1992, the National Institute for Occupational Safety and Health (NIOSH) received a confidential request to conduct a health hazard evaluation (HHE) at the Langer Black Hills Silver and Jewelry Company in Spearfish, South Dakota. The request asked NIOSH to determine if exposure to workplace chemicals presents a health hazard to employees. The request indicated about 15 employees were exposed to chemicals, identified as carbon monoxide and "fumes," for 4-8 hours per day while working at this facility.

In response to this request, background information regarding the facility's manufacturing processes, layout, and chemical use was reviewed. On April 22-23, 1992, a site evaluation was conducted at the jewelry manufacturing facility. During the opening conference, the NIOSH investigator reviewed historical information regarding hazards associated with jewelry manufacturing, and discussed specific health and safety issues that may be of concern at this facility. Following the opening conference, the building was inspected and all manufacturing processes reviewed. Personal air sampling was conducted to evaluate employee exposure to carbon monoxide (CO), crystalline silica, and metal fume in the Casting Department, styrene in the Gems by Jim Department, and toluene and xylene in the Box Filler Department. Additionally, the ventilation systems used for contaminant control were evaluated, informal interviews were conducted with employees, and chemical handling practices were observed.

Real-time personal monitoring results for the Casting Department operator, obtained during the melting of silver-copper alloy, did not show a CO exposure hazard. The time-weighted average (TWA) concentration of CO during this 90 minute activity was 1.73 parts per million (ppm). The NIOSH Recommended Exposure Limit (REL) for CO is 35 ppm as a 10-hour TWA. A maximum CO concentration of 3.49 was detected. A bulk settled-dust sample of "investment," used to construct molds for jewelry, showed the material contains 37% cristobalite (a form of crystalline silica). Air sampling during the preparation of these molds, however, indicated less than detectable concentrations of respirable dust and cristobalite. The NIOSH REL for cristobalite is 0.05 milligrams per cubic meter (mg/m$^3$). NIOSH also considers crystalline silica to be a potential occupational carcinogen and recommends controlling exposures to the lowest feasible level. Personal air sampling for metal fume showed that the operator melting silver-copper alloy in the Casting Department was exposed to 0.05 mg/m$^3$ silver and 0.004 mg/m$^3$ copper for this 90 minute activity. Assuming no exposure to silver fume for the remainder of the workshift, the full-shift TWA exposure is below the NIOSH REL for silver (0.009 mg/m$^3$, REL = 0.01 mg/m$^3$). The NIOSH REL for copper fume is 0.1 mg/m$^3$. Sampling in the Gems by Jim room showed that the operator working in this room was exposed to a TWA concentration

of 0.5 ppm styrene during the work-shift. The NIOSH REL for styrene is 50 ppm as a 10-hour TWA. Monitoring conducted in the Box-Filler room showed that the worker sampled was exposed to 1.14 ppm toluene, and less than detectable levels of xylene for the work-shift. The NIOSH REL for both toluene and xylene is 100 ppm as a 10-hour TWA.

A limited assessment of a recently installed local exhaust ventilation (LEV) system showed that the canopy hood in the Casting Department was not operating at maximum efficiency. Measurements indicated the hood was exhausting less than one-half the volume recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). Additionally, workers were observed bending over the process being ventilated, thus placing themselves between the point of contaminant generation and the hood. The LEV hoods at workstations in the Gems by Jim and Solder rooms were based on room air-changes per hour (AC/h), and not capture velocity. Velocity measurements and worker observations indicated the hoods were not being operated efficiently. The LEV is integrated into a heat-reclaim system and the exhaust hoods are controlled by a thermostat-type device with an on-off switch in the Gems by Jim room. With this system, the LEV in one room could be shut off by workers attempting to control temperature in another room. This is an inappropriate configuration for any LEV system used for contaminant control.

Other than concerns regarding solvent odors, employees interviewed did not suggest the presence of work-related health complaints. No formal safety program (e.g., training, procedures) exists at this facility. Although respirators were being used by some employees, a respirator program, including proper selection, fit-testing, and employee training has not been implemented.

Except for silver fume, personal air sampling results showed exposures to be well below recommended levels for all tasks monitored. Although the full-shift TWA exposure shows the concentration of silver fume to be less than the NIOSH REL or OSHA PEL, the level detected is of concern and action should be taken to reduce exposure. Local exhaust ventilation systems, installed to control worker exposure to contaminants, were based on inappropriate design criteria and are not functioning effectively. Informal employee interviews did not indicate the presence of health problems or concerns attributable to workplace conditions. Recommendations to reduce exposure to silver fume, to more efficiently use existing ventilation systems, and to implement employee training and respiratory protection programs are provided in the Recommendations section of this report.

KEYWORDS: SIC 3911 (Jewelry, Precious Metal) carbon monoxide, crystalline silica, styrene, toluene, silver, copper, cadmium, lead

## INTRODUCTION

NIOSH received a confidential request from employees of Langers Black Hills Silver Jewelry on February 14, 1992, to investigate potential health hazards at the silver jeweler's manufacturing facility. Specifically, the request asked NIOSH to determine if exposure to workplace chemicals presents a hazard to employees. The business had recently moved to a new building, and the requesters were concerned about the proper function of local exhaust ventilation systems installed to control exposure to contaminants.

An initial site visit to evaluate the manufacturing facility was conducted on April 22-23, 1992. The objectives of this visit were to inspect the facility, evaluate ventilation systems used for contaminant control, conduct personal sampling to assess exposures to airborne contaminants, interview employees, and observe chemical handling practices. Pre- and post-survey meetings were held with employee and employer representatives to review the actions planned and taken by the NIOSH investigator, as well as discuss preliminary findings and recommendations.

An initial response letter providing preliminary results, recommendations, and future actions regarding this survey was issued to the facility owner and HHE requesters on June 11, 1992. A report regarding the results of air monitoring in the Casting department was sent to the facility owner on June 26, 1992.

## BACKGROUND

### Facility/Process Description

The Black Hills Silver Jewelry manufacturing facility was occupied in September 1991, and employs 21-23 workers. Most jewelry is manufactured by the "Lost Wax" or "investment casting" process. With this process, heated wax is dispensed into hand-carved rubber molds and allowed to harden. After removing the mold, the wax patterns are placed on bases ("spruing"). The wax bases are then encased in a plaster slurry ("investment") and allowed to harden. Investment is prepared by mixing water with the plaster in a mechanical "egg-beater" mixing bowl. After hardening, the plaster blocks are placed in an oven and the melted wax drains out of a hole left in the bottom of the block. Silver alloy, prepared from 85% silver and 15% copper is melted in crucibles with oxy-natural gas and air-acetylene torches. The melted alloy is poured into the plaster casts, which are placed in a casting machine that uses centrifugal force to drive the alloy into the mold. The molds are cooled in water and the jewelry removed by breaking the cast. A sodium bisulfate pickling solution is used to remove oxidation from the jewelry and the product may be sandblasted and trimmed prior to grinding off burrs. Some soldering may also be necessary. Tumbling, polishing, and sealing with lacquer are the final process steps. There may be some additional processes (design, stone setting) before packaging.

In the Gems by Jim room, jewelry is manufactured by pouring small volumes of styrene-based resins in rubber molds and applying copper, silver or brass ("Dutch Gold") leaf. Final hardening takes place in a residential-type oven. There are 3-4 employees who support this operation.

There are three ventilation systems serving the facility. A heating, ventilating, and air-conditioning (HVAC) system provides conditioned air to occupants. A 4000 cubic-feet per minute (CFM) exhaust system serves various grinding stations for the purpose of reclaiming silver. A series of high-efficiency filters are used to collect silver dust, which are removed on 4-5 week intervals and shipped to a silver-recovery firm.

A local exhaust ventilation system is installed in the Casting, Gems by Jim, and Solder rooms. This system, which was the focus of the ventilation evaluation portion of this project, exhausts air through a heat exchanger on the roof. This entails passing exhaust air through a coil, or honeycomb, of aluminum channels where heat is transferred to outdoor supply air. The total capacity of the system is 2500 CFM. There is no cooling mechanism for supply air; however there is a gas-fired in-line duct heater.

## EVALUATION PROCEDURES

The NIOSH investigation consisted of the following:

1. A thorough facility inspection including a review of all manufacturing processes and chemicals used. Chemical handling practices and Industrial Hygiene related programs (employee training, hazard communication, labeling, respiratory protection) were assessed.

2. Air sampling to assess personal exposures for the following tasks/chemicals:

   - Carbon monoxide and nitrogen dioxide during the casting operation
   - Silver, copper, lead, and cadmium fume during the casting operation
   - Crystalline silica during the preparation of the investment slurry
   - Styrene during rubber mold casting in the Gems by Jim room
   - Toluene and xylene when using lacquer thinner during jewelry assembly in the Box Filler room

3. An assessment was made of the local exhaust ventilation system recently installed to control contaminants in the Casting, Gems by Jim, and Soldering room. Installation and design criteria for this system were reviewed with the designer/installer.

**Environmental Monitoring**

Based on observation of work practices, chemicals used, and scheduled manufacturing activity, a sampling strategy to monitor workers with the highest potential for exposure was developed. Carbon monoxide monitoring was a priority as an incident in November, 1991, attributed to CO exposure, heightened concern regarding potential exposure to this gas during oxy-natural gas and air-acetylene torch use in the Casting room. This activity is conducted daily, usually in the morning, for 1-2 hours. Because of this concern, management installed continuous CO monitors and a loss-of-ventilation alarm system.

On April 23, 1992, environmental monitoring was conducted to assess airborne personal exposures to various compounds using established NIOSH analytical protocols.[1] Calibrated air sampling pumps were attached to selected workers and connected, via tubing, to sample collection media placed in the employees' breathing zone. Monitoring was conducted throughout the employees' work-shift, or for the length of the activity being evaluated. After sample collection, the pumps were post-calibrated and the samples submitted to the NIOSH contract laboratory (Data Chem, Salt Lake City, UT) for analysis. Field blanks were submitted with the samples. The employees' monitored stated that workloads and tasks conducted during the monitoring period were consistent with a normal work day.

Specific sampling and analytical methods used during this survey were as follows:

A. Carbon Monoxide

CO monitoring during the casting operation was accomplished by using a Brüel and Kjaer model 1302 multi-gas continuous monitor. The principle of detection is infrared absorption at a specific wavelength with subsequent analysis via the photoacoustic effect. This type of monitor was used to negate potential acetylene interference problems that affect many common CO monitors (e.g. electro-chemical sensors, detector tubes). The monitor, which records CO concentrations in parts per million (ppm) every minute, was calibrated prior to use. After sampling, the monitor was cross-checked with a known concentration of CO to verify proper calibration.

Concurrent with the continuous CO monitoring, instantaneous measurements during the casting operation were periodically obtained using an Industrial Scientific CO monitor. This hand-held, direct-reading, continuous monitor uses an electrochemical cell as the principle of detection. Air is sampled passively through a diffusion grid on the monitor. The unit's digital display reads in 1 ppm increments. The limit of detection is 1 ppm. Prior to use, the monitor was calibrated with known concentrations of CO. This sampling was conducted to determine if there were significant differences, possibly attributable to acetylene, between the readings of the two monitors.

B. Nitrogen Dioxide

Sampling for nitrogen dioxide ($NO_2$) was conducted using direct-reading colorimetric indicator tubes (Dräger $NO_2$ tube 0.5/c CH30001) and a bellows pump. With this sampling technique, a known volume of air is drawn through the tube and the media inside the indicator tube changes color in proportion to the concentration of contaminant. According to the manufacturer, the relative standard deviation for this particular sampling method is 10-15%.[2] Samples were collected directly over the casting activity.

C. Solvents

Integrated air samples for solvents (toluene and xylene in the Box Filler room, styrene in the Gems by Jim room) were collected using constant-volume SKC model 223 low-flow sampling pumps. Because of the short (less than 5 minutes) time of the basement lacquer activity, no sampling was conducted for this task. Nominal flow rates of 100 cubic centimeters per minute (cc/min) were used to collect the samples. Sampling time ranged from 6 to 7 hours. The pumps are equipped with a pump stroke counter and the number of strokes necessary to pull a known volume of air was determined during calibration. This information was used to calculate the air per pump-stroke "K" factor. The pump stroke count was recorded before and after sampling and the difference used to calculate the total volume of air sampled. Samples for styrene, xylene and toluene were obtained using standard charcoal tubes (100 milligrams front section/50 milligrams backup) and analyzed according to NIOSH method 1501.[1]

D. Crystalline Silica

Personal air sampling for respirable crystalline silica during the preparation of investment was conducted using Gilian HFS 513A air sampling pumps. A flow rate of 1.7 liters per minute (lpm) was used to draw sample air through an MSA cyclone and a tared, 37 millimeter, 5 micron pore size, polyvinyl chloride filter. The cyclone removes the non-respirable fraction of particulate so the filter will collect only that portion of the dust (<10 micrometers) that penetrates to the deeper areas of the lung. A bulk sample of settled dust taken from the work area was submitted to the analytical laboratory to determine the percent and type of silica present. Analysis was conducted according to NIOSH 7500 and 0500.[1]

E. Metal Fume

Air sampling for silver, copper, cadmium, and lead fume was conducted during the casting operation using Gilian HFS 513A sampling pumps with a flow rate of approximately 2 lpm. Sample time was approximately 1.5 hours. The samples were collected on 0.8 $\mu$m pore size mixed cellulose ester filters and analyzed according to NIOSH method 7300.[1]

**Ventilation Evaluation**

A limited local exhaust ventilation assessment was conducted in the Casting, Gems by Jim, and Solder rooms. A comprehensive characterization of the facility's ventilation system was not conducted. The ventilation assessment consisted of measuring the air velocity at the exhaust hood opening (face velocity) or point of contaminant generation. Critical dimensions were measured where necessary (hood size, slot dimensions, duct diameters, distance from hood opening to point of contaminant generation), and work practices of employees regarding the use of these systems were observed. Air velocity was measured using a Kurz series 490 mini-anemometer. This instrument measures air velocity in feet-per-minute (fpm).

## EVALUATION CRITERIA

**General**

As a guide to the evaluation of the hazards posed by work place exposures, NIOSH field staff use established environmental criteria for the assessment of a number of chemical and physical agents. These criteria suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It should be noted, however, that not all workers will be protected from adverse health effects if their exposures are below the applicable limit. A small percentage may experience adverse health effects due to individual susceptibility, pre-existing medical conditions, and/or hypersensitivity (allergy).

Some hazardous substances or physical agents may act in combination with other work place exposures or the general environment to produce health effects even if the occupational exposures are controlled at the applicable limit. Due to recognition of these factors, and as new information on toxic effects of an agent becomes available, these evaluation criteria may change.

The primary sources of environmental evaluation criteria for the work place are: 1) NIOSH Criteria Documents and recommendations, 2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor Occupational Safety and Health Administration (OSHA) standards.[3-5] Often, NIOSH recommendations and ACGIH TLVs may be different than the corresponding OSHA standard. Both NIOSH recommendations and ACGIH TLVs are usually based on more recent information than OSHA standards due to the lengthy process involved with promulgating federal regulations. OSHA standards also may be required to consider the feasibility of controlling exposures in various industries where the hazardous agents are found; the NIOSH recommended exposure limits (RELs), by contrast, are based primarily on concerns relating to the prevention of occupational disease.

**Substance Specific Criteria**

Carbon Monoxide

CO is a colorless, odorless gas that is a product of incomplete combustion. Engine exhaust, tobacco smoking, and inadequately ventilated combustion products from heaters that use hydrocarbon fuel are sources of exposure to CO. CO exposures can also result from the reduction of carbon dioxide used for shielding in gas metal arc welding, and has been reported during flame cutting of primed steel in confined spaces.[6] Overexposure to CO may cause initial symptoms such as headache, dizziness, drowsiness, and nausea. These symptoms may progress to vomiting, loss of consciousness or collapse if high exposures are encountered.[7] The NIOSH REL for CO is 35 ppm as a time-weighted average for up to 10 hours per day. NIOSH also recommends a ceiling level of 200 ppm for CO.[3]

Organic Solvents

Exposure to organic solvents can occur through inhalation of the vapors, skin contact with the liquid, or ingestion. As many organic solvents have relatively high vapor pressures and readily evaporate, inhalation of vapors is considered a primary route of exposure. Overexposure to many organic solvents can result in irritation, central nervous system depression, headache, nausea, and possible effects on the liver, kidney or other organs.[(8-10)] Many industrial solvents are primary irritants, and can cause defatting of the skin and dermatitis. Solvents are among the leading causes of occupational skin disease.[9] Biological effects of exposure can range from practically non-toxic (e.g. some chlorofluorocarbons) to highly toxic (e.g. carbon tetrachloride) or carcinogenic (e.g. benzene).[10] The ability to detect the presence of a solvent by the sense of smell will vary widely depending on the specific substance, and individual sensitivity. Substances are considered to have good warning properties if an average person with normal sensory perception can detect the presence of the chemical at a level below the recommended exposure limit. The following table summarizes the principle health effects associated with the solvents evaluated, and lists the NIOSH RELs and odor detection thresholds for these compounds.

| Chemical | NIOSH REL | Odor Threshold & Description[11] | Principle Health Effects[(12-13)] |
|---|---|---|---|
| toluene | 100 TWA 150 ppm STEL | 1.6 ppm: sour, burnt | eye/respiratory irritation, fatigue, headache, central nervous system effects |
| xylene | 100 TWA 150 ppm STEL | 20 ppm: sweet | eye/respiratory irritation, drowsiness, headache, dermal effects |
| styrene | 50 TWA 100 ppm STEL | 0.15 ppm: sharp/sweet | eye/mucous membrane irritation, drowsiness, headache, nausea |

Note: TWA = time-weighted average concentration for up to 10 hours/day
C = ceiling limit not to be exceeded
STEL = short-term exposure limit - 15 minute average

Note that many solvents have similar toxic effects. When there are exposures to two or more substances that act upon the same organ system, their combined effect should be evaluated. Unless there is scientific evidence to the contrary, the effects are considered to be additive (as opposed to potentiating, synergistic, or antagonistic), and are calculated as follows:

$$\text{Combined REL} = \frac{C_1}{REL_1} + \frac{C_2}{REL_2} + \ldots \frac{C_n}{REL_n}$$

Where: C = measured atmospheric concentration
REL = corresponding recommended exposure limit

If the sum of the above fractions exceed unity (1), the combined REL is considered exceeded.

Nitrogen Dioxide

Nitrogen Dioxide ($NO_2$) is a reddish/dark-brown gas, liquefying at 21°C, with a pungent, acrid odor. $NO_2$ is a respiratory irritant and can cause pulmonary edema.[12] Severe breathing difficulties attributable to exposure to $NO_2$ are usually delayed in onset and may cause death.[13] The NIOSH REL for $NO_2$ is 1 ppm as a 15 minute short-term excursion limit.[3] $NO_2$ has been detected as a by-product of oxyacetylene welding, although in lower concentrations than that found in other welding techniques (e.g., shielded arc welding).[6] Most reported cases of severe illness due to $NO_2$ have been from accidental exposures to the explosion or combustion of nitroexplosives, nitric acid, arc or gas welding (particularly in confined spaces), or entry into unvented agricultural silos.[12]

Silver Dust and Fume

Exposure to silver dust or fume can cause local or generalized impregnation of the mucous membranes, skin, and eyes with silver, a condition termed *argyria*.[12] This condition results in an unsightly, widespread blue-grey discoloration of the skin that can persist for long periods of time.[14] *Argyria* may manifest in the conjunctiva of the eye, which may cause lens and visual disturbances.[14] Lung damage with pulmonary edema has been reported in a workman exposed to high concentrations of heated silver vapor.[12] The NIOSH REL and OSHA PEL for silver, established to protect workers against *argyria*, is 0.01 mg/m$^3$.[3,14]

Copper

Adverse health effects are associated with exposure to copper dust, fume and mists of copper salts.[4] One of the chief industrial exposures to which there are potential health effects is the fume. Health effects consist of irritation of the upper respiratory tract, metallic or sweet taste, nausea, metal fume fever, and in some instances discoloration of the skin and hair. [4,12] Metal fume fever is typically characterized as a 24-48 hour illness involving chills, fever, aching muscles, dry mouth, and headache.[12] The NIOSH REL for copper fume is 0.1 mg/m$^3$, and 1 mg/m$^3$ for copper dusts and mists.[3]

Crystalline Silica

Silica exists in several forms, but only exposure to crystalline, or "free" (as opposed to amorphous) silica forms can produce the pulmonary condition called silicosis.[10] Silicosis is a disabling, progressive, and sometimes fatal pulmonary fibrosis characterized by silicotic nodules.[13] These nodules are thought to be formed by the death of macrophages laden with fine silica. The silica particles are ingested by new macrophages which are in turn killed, thereby releasing intracellular enzymes to promote further fibrosis; thus, the process becomes progressive even if exposure is terminated.[7,15] The exposure conditions can affect the occurrence and/or severity of silicosis. Silicosis usually occurs after 15 or more years of exposure; however, silicosis has developed after only a few years of exposure to high concentrations. Initially, silicosis may not produce symptoms. However, as the disease progresses it is characterized by shortness of breath and a reduction in pulmonary function. Individuals with silicosis are also at increased risk of developing tuberculosis.

Quartz is the most common crystalline form of silica. Cristobalite and trydimite are other major forms of crystalline silica, and can be formed from quartz under certain temperature and pressure conditions. Tripoli is a naturally occurring microcrystalline form of quartz.[4] Cristobalite and trydimite are considered to have greater fibrogenic potential than quartz, and both the ACGIH and OSHA have set the TLV/PEL for these substances at one-half the value of quartz (0.05 mg/m$^3$ vs 0.1 mg/m$^3$, respirable fraction).[10,4,14] The NIOSH REL for respirable silica (all forms), is 0.05 mg/m$^3$.[3] The respirable fraction is considered to be that portion of inhaled dust which penetrates to the nonciliated portions of the lung.[16] In general, particles greater than 7-10 micrometers ($\mu$m) in diameter are all removed in the nasal passages and have little probability of penetrating to the lung. Particles smaller than this can reach the air-exchange regions (alveoli, respiratory bronchioles) of the lung, and are considered more hazardous.

The National Toxicology Program has concluded that respirable silica may reasonably be anticipated to be a carcinogen, based on laboratory animal studies which showed significant increases in lung cancer incidence in rats exposed to quartz via inhalation.[17] NIOSH considers silica to be a potential occupational carcinogen and recommends controlling exposure to the lowest feasible level.[3]

### Ventilation Criteria

Local exhaust ventilation (LEV) is commonly used to control contaminants at the point of generation to reduce the potential for employee exposure. Ventilation assessments, in conjunction with exposure monitoring results, help determine the adequacy of controls at a workstation. This information also assists with deciding if additional controls, or modification of existing controls, is warranted. The principle design parameter for LEV systems is capture velocity. Capture velocity is the velocity necessary to overcome opposing air currents and capture contaminated air by causing it to flow into the exhaust hood. Recommended capture velocities will vary depending on the contaminants' toxicity and volatility, the manner in which the material is used (e.g., heated, agitated), and room conditions (e.g., air currents). Criteria commonly used for evaluating LEV systems is from the ACGIH publication, *Industrial Ventilation: A Manual of Recommended Practice*.[18]

## RESULTS AND DISCUSSION

### Workplace Observations/Industrial Hygiene Programs

No formal safety program exists at the facility. Although material safety data sheets (MSDSs) were available for some chemicals, a comprehensive hazard communication program has not been implemented (written program, MSDS collections, employee training, hazardous materials labeling). MSDSs were not present for some commonly used chemicals (e.g. lacquer thinner, lacquer) and containers of hazardous materials were not properly labeled (e.g. lacquer thinner in Box-Filling room). Respirators were being used by some employees (e.g. 3M 9900 Dust-Mist, TC-21C-176 when preparing investment). However, a respirator program, including proper selection, fit-testing, and employee training has not been implemented.

Gloves are provided for workers in the Gems by Jim room for protection against the solvents and resins.

Lacquer and lacquer thinner is occasionally applied to some jewelry components in the basement. This task takes less than 5 minutes when conducted, and the jewelry is often brought up to the main work area prior to completely drying. A flexible hose (5" diameter) connected to the exhaust system is available in this room; however, it is not routinely used. There was a noticeable lacquer (toluene) odor in the main work area that was attributed to vapors volatilizing from partially dried jewelry. In the Box-Filler room, lacquer and lacquer thinner, from an open 1-pint jar, is applied with a brush to parts being assembled. This activity takes place throughout the work-shift.

Other than comfort concerns regarding the presence of styrene and toluene (lacquer thinner) odors, informal employee interviews did not identify any work-related adverse health symptoms. Most employees were aware of the CO monitors, but expressed concern regarding the reliability of these devices.

**Environmental**

Carbon Monoxide

Personal breathing zone sampling was conducted for the Casting operator by attaching the sample tube inlet to the collar of the worker. The sample tubing was about 15 feet in length which allowed the employee to move freely in his work area. Continuous monitoring was conducted for the casting operation (using acetylene and natural gas torches) as well as during non-casting activities (no torch work involved). During the sampling all ventilation systems were operational (make-up air and local exhaust hood). Figures 1 and 2 depict the levels of CO detected during the casting (7:47 AM - 9:06 AM) and non-casting activities (9:07 AM - 10:30 AM). As shown in the figures, the levels of CO detected during the monitoring were well below the NIOSH REL of 35 ppm. The average concentration detected during casting was 1.79 ppm, with a peak of 3.49 ppm occurring at 9:04 AM. CO concentrations were somewhat lower during non-casting activities with an average of 0.93 ppm detected, and a peak of 2.42 occurring at 9:16 AM.

Instantaneous sampling conducted concurrently with the Industrial Scientific monitor showed that the levels detected with this device (1-2 ppm) correlated with those detected by the Brüel and Kjaer monitor. This suggests that the monitor was not responding to the presence of acetylene or, more likely, there were no significant acetylene concentrations present.

Nitrogen Dioxide

Sampling conducted directly over the casting operation while the air-acetylene and oxy-natural gas torches were active showed $NO_2$ concentrations to be at less than detectable levels ($<$0.5 ppm).

Solvents

Table 1 depicts the results of air sampling conducted to assess employee exposure to solvent vapors. The sampling conducted for styrene in the Gems by Jim room showed that the worker monitored was exposed to a TWA concentration (372 minutes) of 0.5 ppm during the sampling period. The results of the monitoring conducted in the Box Filler room showed that the worker sampled was exposed to a TWA concentration (439 minutes) of 1.14 ppm toluene, and less than detectable levels of xylene. These concentrations are well below the NIOSH RELs for these compounds.

Table 1
Personal Sampling Results: Solvents
Langer Black Hills Silver Jewelry, Inc.
April 23, 1992
HETA 92-097

| Task Monitored | Sample Number | Sample time (min) | Contaminants Sampled | Concentration (ppm)[1] | TWA[2] |
|---|---|---|---|---|---|
| Gems by Jim Operator | CT-1 | 8:40-10:15 (95) 10:30-12:30 (120) | Styrene | 0.4 | 0.5 |
| | CT-1A | 1:10-3:47 (157) | | 0.63 | |
| Box Filler Operator | CT-2 | 7:50-12:59 (309) | toluene | 1.08 | 1.14 |
| | | | xylene | ND[3] | |
| | CT-2A | 1:35-3:45 (130) | toluene | 1.28 | |
| | | | xylene | ND[3] | |

NOTES:

1. ppm = parts of gas or vapor per million parts of air
2. TWA = time-weighted average concentration computed as follows:

$$TWA = \frac{(C_1)(T_1) + (C_2)(T_2) + ... (C_n)(T_n)}{T_1 + T_2 + ... T_n}$$

Where: C = Contaminant concentration
T = Corresponding sampling time

3. None Detected on the sample. The analytical level of detection for xylene is 0.01 milligrams per sample

Crystalline Silica

Investment is prepared by manually dispensing the plaster (using a hand scoop) from 50 lb. bags into a residential type electric mixing bowl. Water is added and the mixture stirred until the proper consistency is reached. The slurry is then used to cast the wax molds. One operator performs this task. The bulk settled dust sample obtained in the casting room contained approximately 37% cristobalite by weight. The personal sample obtained during the preparation of investment indicated that the concentration of respirable dust during the 40 minute sampling period was at the analytical limit of detection of 0.02 milligrams per cubic meter ($mg/m^3$) when analyzed gravimetrically. This equates to about 0.007 $mg/m^3$ when adjusted for the percentage of cristobalite in the bulk sample. Analysis of the filter for cristobalite indicated that less than detectable levels (0.015 milligrams) were present on the filter. Sampling time was only 40 minutes as the potential dust generating (dispensing and mixing the investment to form the slurry) task is a short-term activity. During the sampling, and subsequent clean-up activities, the worker wore a disposable dust mask (3M 9900).

Metal Fume

The results of the personal sampling conducted to assess exposure to metal fume during the casting operation are depicted in Table 2. The results of this sampling show that the concentration of silver fume detected exceeded both the NIOSH REL and OSHA PEL of 0.01 $mg/m^3$ **for the monitoring period** (84 minutes). Assuming no exposure to silver fume or dust for the remainder of the workshift, the employees full-shift TWA exposure is 0.009 $mg/m^3$, which is slightly below the NIOSH REL. Sampling was only conducted for 84 minutes because that was the length of the silver-copper alloy melting activity. During this activity, the employee monitored used an air-acetylene and oxy-natural gas torch to melt 100 ounces of alloy (85% silver, 15% copper) in crucibles. The alloy melting task was conducted under the canopy hood in the Casting Department. Sampling was terminated after the torches were turned off and the melted alloy processed. The remainder of the workshift the employee engaged in non-silver fume/dust generating activities.

The concentration of copper fume detected in the sample, 0.004 $mg/m^3$ for the monitoring period, is well below the NIOSH REL of 0.1 $mg/m^3$. No lead or cadmium was detected in the sample.

Table 2
Personal Sampling Results: Metal Fume
Langer Black Hills Silver Jewelry, Inc.
April 23, 1992
HETA 92-097

| Task Monitored | Sample Number | Sample time (min) | Contaminants Sampled | Concentration ($mg/m^3$)[1] | TWA[2] |
|---|---|---|---|---|---|
| Casting Operation | CA-1 | 7:43-9:07 (84) | Silver<br>Copper<br>Lead<br>Cadmium | 0.054<br>0.004<br><0.005<br><0.003 | 0.009<br>0.001<br><0.001<br><0.001 |

1. mg/m3 = milligrams of contaminant per cubic meter of air
2. TWA = time-weighted average concentration computed as follows:

$$TWA = \frac{(C_1)(T_1) + (C_2)(T_2) + \dots (C_n)(T_n)}{T_1 + T_2 + \dots T_n}$$

Where: C = Contaminant concentration
T = Corresponding sampling time

< = less than (no contaminant detected), the concentration listed is the analytical limit of detection

**Ventilation**

According to the system installer, the design of the system in the Gems by Jim and Solder room was based on room air changes per hour (AC/h). However, the system was intended for local exhaust ventilation (LEV) control of contaminants. That is, a plenum, with exhaust grilles was installed at the work-tables of both rooms. The design of the canopy hood in the Casting room was apparently based on CFM per square foot. Specific design parameters were not available.

A ventilation monitor (visual only) has been installed in the Gems by Jim room. This consists of 2 lights which depict the operational status of the exhaust and make-up air fan. This monitor was installed after the previously referred to incident in November, 1991. Subsequent investigation after the incident showed that the make-up air fan was not functioning, and it was hypothesized that the lack of make-up air starved the canopy hood over the casting process, rendering the system non-functional. The entrance to the casting room, however, has no door and is open to the main manufacturing area, which would be a source of make-up air. Ventilation monitors are not present in the Casting or Soldering rooms.

The ventilation system can be controlled through a thermostat device in the Gems by Jim room. With this device, workers in the Soldering or Casting rooms could be unaware that the exhaust system had been shut off.

Casting Department

Casting Department

Exhaust flow measurements indicated that the canopy hood in the Casting room was ventilating significantly less air than what would be required to maintain an effective capture velocity of 100 feet per minute (fpm) at the point of contaminant generation. Capture velocity is the velocity necessary to overcome opposing air currents and capture contaminated air by causing it to flow into the exhaust hood. The ACGIH recommends a minimum of 100 fpm as necessary for operations where contaminants are released at low velocity into moderately still air.[18] Measurements indicated that approximately 500 CFM is exhausted through this hood. The formula for determining exhaust requirements for canopy hoods is as follows:

$Q = 1.4PDV$ Where:

$Q$ = Minimum flow rate, CFM
$P$ = Perimeter of the process, feet (4 ft.)
$D$ = Distance from process to hood (3 ft.)
$V$ = Capture velocity (100 fpm)

Based on this formula, the minimum exhaust requirement for this hood is 1680 CFM.

It was observed that workers may occasionally bend over the torching activity, thus placing their breathing zone between the hood and the point of contaminant generation.

Gems by Jim/Solder Room

The local exhaust systems in the Gems by Jim and Solder room consist of plenums, extending the length of the work table and positioned against the wall, with louvered vents spaced approximately 3 feet apart. There are two of the 17" X 5" vents on the 8 foot hood in the Gems by Jim room, and 3 such vents on the 12 foot hood in the solder room. Plenum dimensions are 10" in height, 9.5" wide at the top, and tapering down to 4" at the bottom to angle the vents towards the work table.

In the Gems by Jim room, the exhaust system is intended to capture solvent vapors during the use of adhesives or resins, which are dispensed in small quantities with a brush or directly from the container. Ventilation measurements indicated that the Gems by Jim room system exhausts approximately 340 CFM. A canopy hood in this room, positioned over an oven used for curing finished jewelry, exhausts approximately 165 CFM. Velocity measurements, taken at various areas (1-2 ft.) from the hood where solvent work was being conducted, showed capture efficiency to be negligible. Work with volatile materials does not always occur on that portion of the table serviced by the hood and there is a noticeable styrene odor in this room. The release of styrene vapors from parts drying on unventilated areas of the work table may contribute to the noticeable odor.

The hood in the solder room was found to exhaust approximately 310 CFM. Work practices were not observed as there were no activities in this room during the survey.

**CO Monitor**

Wall mounted (approximately 5 ft. above the floor) continuous CO monitors have been installed in the main work area and casting room. Information regarding the principle of detection, calibration frequency, alarm settings, maintenance, or response protocols were not available at the facility. A manual was not available, and no facility representative was familiar with the operation of the monitors.

## CONCLUSIONS

With the exception of silver fume, the sampling results showed exposures to be well below recommended levels for all tasks monitored. Although the full-shift TWA exposure shows the concentration of silver fume to be less than the NIOSH REL or OSHA PEL, the level detected is of concern and action should be taken to reduce exposure at this workstation. The basis for this conclusion is as follows:

- The length of the silver-copper melting activity could vary considerably, which could possibly increase exposures (e.g., if the task took 3 hours instead of 1.5, the TWA exposure would be approximately 0.02 $mg/m^3$).

- Work-practices during the silver-copper melting activity may vary from operator to operator, which could possibly result in higher exposures.

- Day-to-day variability in exposure levels for the same task can be considerable. Therefore, because the levels detected during the actual casting activity were on the order of 5X the REL/PEL, it is reasonable to conclude that 8-hour TWA exposures could exceed the OSHA PEL.

- Even though there is no short-term excursion limit (STEL) for silver, excursions above the REL should be controlled even when the full-shift TWA is within recommended limits. A general recommendation of the ACGIH regarding excursion limits for materials that do not have STELs is that exposures should not exceed 3 times the REL for no more than 30 minutes a work-day, and under no circumstances should they exceed 5 times the REL.[19] Processes exhibiting variability greater than this are not under good control.

Although monitoring during this survey did not identify a CO problem in the Casting room, high CO levels were reportedly the cause of the incident in November, 1991. It appears unlikely, however, that the failure of the make-up air fan would create this situation as the Casting room is contiguous to the main facility and there appears to be adequate make-up air from other sources. One possibility that should be considered is the potential for backdraft of flue gas from the in-line duct heater.

The CO monitors that were installed after the November, 1991 incident are not being utilized efficiently. Personnel at the facility are not familiar with the monitor's operational parameters, nor have protocols been developed regarding the proper response to alarm conditions.

The primary solvents used at this facility (styrene, lacquer, lacquer thinner) are volatile and have low odor thresholds. Although air monitoring did not indicate the presence of health threatening concentrations, the manner in which these chemicals are used (open containers, insufficient ventilation) is such that solvent odors are present throughout the manufacturing area.

The canopy hood in the Casting department is not functioning effectively. In general, canopy hoods require large exhaust volumes to be effective, and should only be used for certain applications. An additional common problem with canopy hoods in general, and the Casting department hood specifically, is that workers often bend over the process being ventilated, thus placing themselves in the contaminant pathway.

The exhaust hoods in the Gems by Jim and Solder rooms are not functioning efficiently. Basing an LEV system on room AC/h is not consistent with good design principles. Capture velocity should be the target parameter for LEV systems. Employees are not utilizing the hoods in the most efficient manner, and are conducting solvent vapor generating activities outside the envelope of the hood.

Other than the previously referred to incident in November, 1991, informal employee interviews did not indicate the presence of health problems or concerns attributable to workplace conditions. Employee training regarding chemical health and safety needs improvement. Most of the employees interviewed had not received any chemical or respirator training. Workers who are provided respirators without proper training or selection may feel protected when they are not, thus potentially placing themselves in hazardous situations.

## RECOMMENDATIONS

1. Implement controls to reduce exposure to silver fume during the casting operation. The optimum control strategy is to improve the Casting room LEV system to ensure efficient capture of contaminants during casting. Options for improving this ventilation system include: modifying the hood to better enclose the torching activity; lowering the canopy hood or redesigning to another configuration; or increasing air-flow. Modifying the hood to better enclose the process would more efficiently use the existing ventilation capacity. Examples of welding hood configurations from the ACGIH Ventilation Manual were provided with the interim report.

   If respiratory protection is used as an interim control, or as a control supplement, full-face respirators equipped with high-efficiency particulate air (HEPA) filters are the minimum level of protection permitted. A complete respiratory protection program is necessary (see Recommendation # 7).

The results of the silver fume monitoring should be reviewed with the worker monitored, as well as other potentially exposed employees. Work practices that can be modified to reduce the potential for exposure should be discussed and implemented. After controls are implemented, additional monitoring should be conducted to assess the effectiveness of the controls, and to further characterize exposures during this activity. Note that employee exposure records must be maintained by the employer for a minimum of 30 years (29 CFR OSHA 1910.20).[20]

2. Modify the LEV systems in the Gems by Jim and Solder room to ensure they are functioning as efficiently as possible. Suggestions for improving these systems include: Replacing the louvers with slots to more evenly distribute air flow; installing side, and possibly top, baffles to better enclose the ventilated area; ensuring that all solvent activity is restricted within the hood. Additional exhaust capacity may be necessary for these hoods. Although an overexposure was not identified during the monitoring, these modifications would further reduce the potential for solvent exposure, make more efficient use of the hoods, and reduce solvent odors in the work area.

3. The use of a thermostat controller for the LEV system is not appropriate and should be discontinued. This problem exists because contaminated LEV exhaust air is used in a heat-reclaim system for conditioned room make-up air. To ensure that the LEV is not shut off during contaminant generating activities, the fan controller should be secured such that only authorized personnel are allowed to make adjustments. A protocol should be developed regarding this system (e.g. review processes, notify workers).

4. The potential fire hazard of using a residential type oven for curing fiberglass parts in the Gems by Jim room should be investigated. This oven is not explosion proof and may not be appropriate for this use.

5. The potential for flue gas from the in-line duct heater to backdraft through the make-up air duct should be investigated and appropriate controls (e.g. backdraft dampers) installed if necessary.

6. Ensure the flexible exhaust vent is positioned over the point where lacquer is applied to jewelry in the basement. All components should be allowed to dry completely before transferring them upstairs.

7. A respiratory protection program, as defined in 29 CFR 1910.134 (OSHA General Industry Regulations), should be developed and implemented where respirators are used. Employees should be properly trained and fit-tested. This applies even

to those situations where employees are using respirators for comfort reasons.

8. Employees should be educated regarding the proper use of LEV systems. This includes informing employees of the need to position work as close as possible to the hood inlet, and not to position themselves between the task and the hood.

9. To ensure the CO monitor is used effectively, the unit must be calibrated and maintained. A monitor manual should be obtained, the alarm settings verified, and the system periodically tested. A protocol should be developed and all employees informed of the proper response to an alarm.

10. The availability of non-crystalline silica containing investment should be investigated and used if possible. Although an overexposure was not detected during the NIOSH monitoring, the potential for exposure could be eliminated by substituting a safer product. In the interim, to reduce the potential for exposure to cristobalite, investment preparation should be conducted under local exhaust ventilation.

11. Establish and implement an employee hazard communication program for chemicals used at the facility. Details of this program are specified in Occupational Safety and Health Administration regulations (29 CFR 1910.1200). The general elements of a good program include: written program; MSDS availability for all employees; employee training, and; hazardous material labeling.

12. Ensure all containers of hazardous materials are labeled with the name of the contents and appropriate hazard warnings.

13. Consider implementing the use of self-closing containers for use with solvents. For example, in the Box-Filler and Gems by Jim room, open glass jars of solvent are used. The use of commercially available self-closing containers or dispensers will reduce evaporation. This could provide both a safety (reduction in potential exposure) and economic (solvent loss) benefit. Examples of various types of containers that would be suitable for this purpose were provided in the interim report.

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|---|---|
| Evaluation Conducted and Report Prepared By: | Max Kiefer, CIH<br>Regional Industrial Hygienist<br>NIOSH, Region IV<br>Atlanta, Georgia |
| Technical Assistance Provided by: | Thomas Hales, MD<br>Medical Epidemiologist<br>NIOSH Region VIII<br>Denver, Colorado |
| Originating Office: | NIOSH Hazard Evaluations and Technical Assistance Branch<br>Division of Surveillance, Hazard Evaluations, and Field Studies<br>NIOSH<br>Cincinnati, Ohio |
| Laboratory Support | Staff<br>Measurements Research Support Branch, NIOSH<br>Cincinnati, Ohio |

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Figure 1

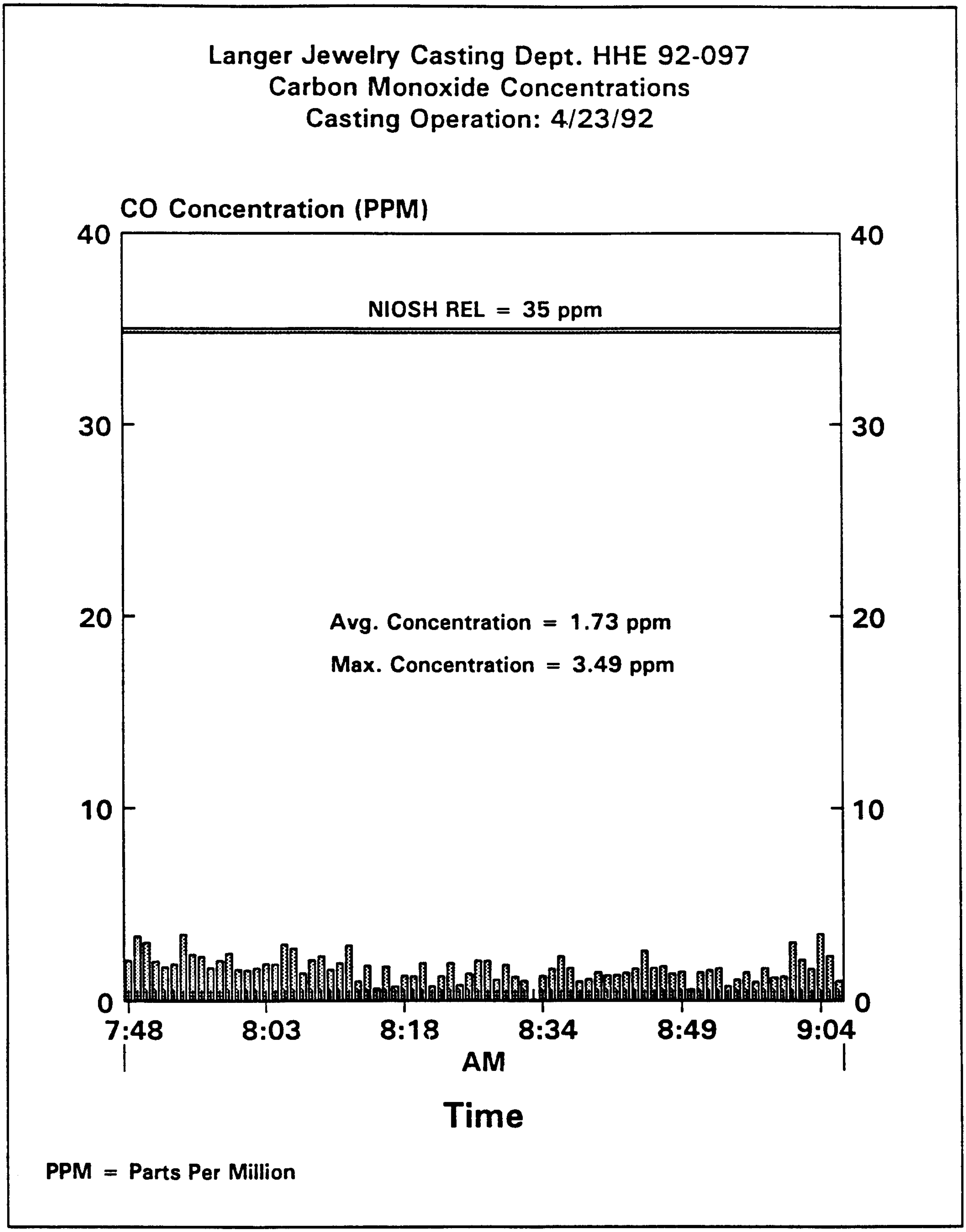
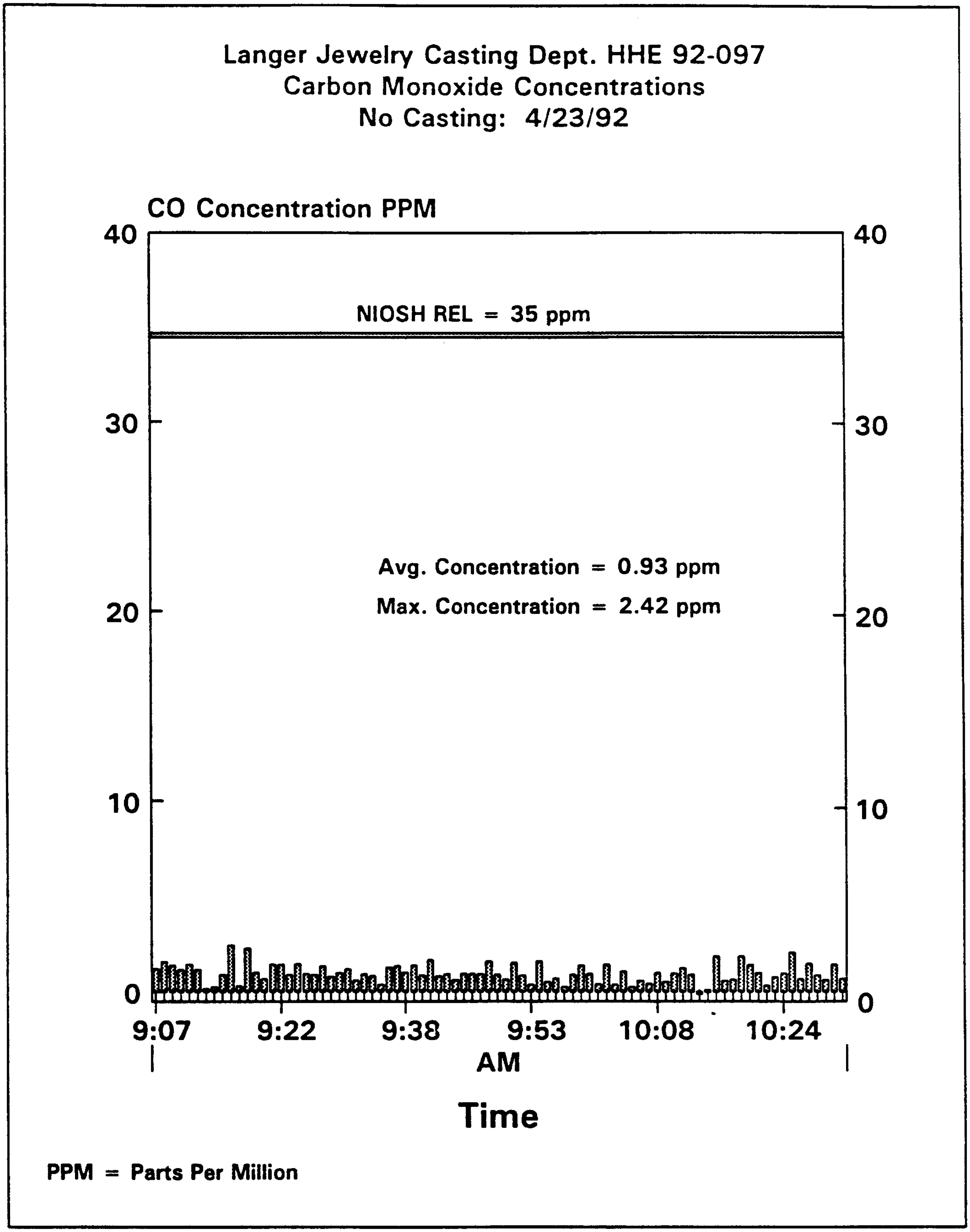

Langer Jewelry Casting Dept. HHE 92-097
Carbon Monoxide Concentrations
Casting Operation: 4/23/92
CO Concentration (PPM)
40
30
20
10
0
NIOSH REL = 35 ppm
Avg. Concentration = 1.73 ppm
Max. Concentration = 3.49 ppm
7:48
8:03
8:18
8:34
8:49
9:04
AM
Time
PPM = Parts Per Million

Figure 2


Langer Jewelry Casting Dept. HHE 92-097
Carbon Monoxide Concentrations
No Casting: 4/23/92
CO Concentration PPM
40
30
20
10
0
NIOSH REL = 35 ppm
Avg. Concentration = 0.93 ppm
Max. Concentration = 2.42 ppm
9:07
9:22
9:38
9:53
10:08
10:24
AM
Time
PPM = Parts Per Million