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**Case Studies**

# Hazards Associated with the Manufacture and Repair of Neon Lights

*Dawn Tharr, Column Editor*

Reported by Lynda Ewers, Elena Page, and Vincent Mortimer

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation from the owner of a small business that manufactures and repairs neon tubes for commercial signs or artwork. The owner (also the sole worker) was concerned about possible health effects related to his exposures to mercury, lead, and cadmium. In response to this request, a NIOSH industrial hygienist conducted a site visit. Full-shift, personal breathing zone (PBZ) air samples for mercury, lead, and cadmium were collected. Real-time air monitoring for mercury was conducted throughout the shop area. Wipe samples of the work tables were collected using moist cloth wipes for analysis of lead and other elements. In addition to the site visit, the worker's medical records, including a urine heavy metals screening, was reviewed by a NIOSH physician.

## Background

Neon tubes, more correctly called vacuum electric discharge tubes, are sealed glass cylinders containing an inert gas (not always neon) under low pressure. The gas emits a brilliant color when excited by an electric discharge. The tubes are manufactured from purchased glass tubing, which the worker heats in an open flame until it is malleable enough to be bent into the desired shape. Electrodes are sealed into the ends of the tubes, and a vacuum is applied to partially evacuate the tube through a smaller, temporary glass duct. Depending on the color desired, either neon (red) or argon (blue), or a mixture of the two, is added to the tube. Some commercial tubes have interior coatings to re-emit light, and, thereby, permit a wider range of colors than are available from the excitation of gases alone. Often, a small drop of mercury may be added to enhance the brilliance of the color. A high voltage is applied across the electrodes until the temperature reaches over 500°F, to remove impurities from the glass.[1] Finally, the lamp is sealed when the temporary duct is removed. Under normal operating conditions, the lamp glows when it receives 2,000 to 15,000 volts of electricity.[2]

Depending on commercial demand, the owner manufactured signs at least five days a week from 9:00 a.m. to 5:30 p.m. The facility produced its specialty product often, but not exclusively, for a larger sign company, which may install the neon tubes within other parts of signs, e.g., the tube may provide backlighting for metal letters. Sometimes, neon tubes are mounted and displayed without other components and then may be sold directly to the public. The owner also repaired used neon glass fixtures, a process that may require replacement of a cracked section of glass or damaged electrodes.

The physical facility consisted of one rented room (approximately 320 square feet), constructed largely of plywood, within a building containing a larger sign manufacturing company. The flooring in the room was wood overlaying concrete, with a small rug located near the corner of the room where most of the mercury was used. General ventilation of the neon shop was supplied by a ceiling-mounted propeller fan, which vented to the larger sign manufacturing facility. It was noted that the ceiling fan was not operating efficiently because it was not fitted tightly within the opening designed for it in the ceiling (i.e., there was an opportunity for the air to be short-circuited due to the gap around the fan). In addition, a window air conditioner, installed in the plywood wall, cooled the work area.

Work practices were variable depending on the types of work available. In general, the manufactured glass tubing was bent into appropriate shapes over gas burners in the center of the room. Glass cutting was performed on the tables along the sides of the room (see Figure 1). A drop of mercury was added, suction was applied, and the voltage was applied to the tubes in one corner of the room (see Figure 2). The artisan did not wear any respiratory or skin protection during production. When pieces of glass (possibly contaminated with mercury) were discarded, they were placed

**FIGURE 1**
Glass cutting.

**FIGURE 2**
Vacuum applied to evacuate tube.

in an open trash container. The owner reported that when the air compressor (used to create the low pressures within the neon tubes) was given its yearly cleaning, about a teaspoon of mercury was removed from its oil trap. However, the quantities of mercury present on-site were small because of the small quantity used in each lamp. The owner estimated that he used about one pound of mercury per year.

Several possible hazards have been reported in the neon glass tube manufacturing environment.(3) Some hazards are chemical in nature: The glass tubing contains lead to aid in softening the glass when heated; the inert gas within the tube often has mercury added to create a more intense color; and the interior coating of the tubes may contain cadmium compounds or other metallic compounds to produce a greater range of colors. In addition, physical hazards may be present due to the high voltages applied to the tubes, and near-ultraviolet radiation (UVA) passing through the glass.

According to the artisan, the day of the NIOSH site visit was typical. Three neon tubes, including the repair of one that had cracked glass, were worked. Tasks included the following phases of the production process: cutting of glass tubing; bending of glass over a flame; sealing of electrodes within the tube; introduction of neon gas into the tube; injection of mercury; and application of a high voltage to the tube.

## Methods

A full-shift PBZ sample for mercury was collected using tubes containing 200 milligrams (mg) of solid sorbent (SKC Anasorb® C 300) at a nominal flow rate of 200 milliliters per minute (mL/min). The tubes were analyzed using NIOSH Method 6009.(4) In addition, one full-shift PBZ sample for lead and other metals was simultaneously collected using a closed-face, mixed cellulose ester filter at a nominal flow rate of 2 liters per minute (L/min). This latter sample was digested and analyzed according to NIOSH Method 7300, using an inductively coupled plasma (ICP) emission spectrometer.(4) The ICP provided results for not only lead, but also 27 other elements including cadmium.

A Jerome® Gold Film Model 411 mercury vapor analyzer was used to obtain real-time measurements of mercury concentrations at various locations within the neon glass manufacturing room, and immediately outside the room entrance, but within the larger sign manufacturing facility.

Wipe samples for lead in surface dust were collected at two locations on the work surfaces using moist cloth wipes of two types (Ghost Wipes™ and Wash'n Dri®). A comparison of the two brands was of scientific interest for possible modifications to present recommended techniques. Samples were collected according to NIOSH Method 9100, with the exception that six vertical S-strokes (rather than the three recommended) were taken within a 10-inch by 10-inch template. The increased number of strokes was considered necessary because the Ghost Wipe™ is smaller than the more commonly used Wash'n Dri® recommended in the NIOSH method. Sample analysis for both types of wipes followed NIOSH Method 7300, using an ICP emission spectrometer, which analyzed for 25 different elements including lead and cadmium, but not mercury. However, digestion of the two types of wipes differed. Wash'n Dri® wipes were refluxed on hotplates with concentrated nitric acid and water, while the Ghost Wipes™ were digested in concentrated nitric acid in a microwave.

A VelociCalc® Plus hot wire anemometer (TSI, Inc., St. Paul, Minnesota) was used to measure temperature, relative humidity, and air flow in the room. Smoke tubes allowed qualitative observations of air movement.

## Evaluation Criteria

### *Mercury Exposure-Related Health Effects and Exposure Criteria*

Since metallic mercury is volatile at ambient temperatures, the majority of human exposure is by inhalation. In fact, inhalation exposure accounts for more than 95 percent of the absorbed mercury dose, whereas dermal exposure and ingestion contribute only 2.6 percent and 0.1 percent to this dose, respectively.(5) Eighty percent of inhaled mercury is retained in the lungs, while the remainder is exhaled. Due to its high degree of lipophilicity (attraction to fat), 74 percent of inhaled mercury rapidly diffuses across the alveolar membranes into the blood.(6–8) This lipophilicity also aids in its distribution to the many tissues and organs throughout the body; it can readily cross the blood-brain and placental barriers, and has a high degree of affinity for red blood cells. Mercury absorbed into the blood and other tissues is quickly oxidized into divalent mercury via the hydrogen peroxide-catalase pathway, and accumulates in the renal cortex of the kidney.[5,9] After a substantial exposure, mercury reaches peak levels within the various tissue reservoirs within 24 hours except in the brain, where peak levels are not reached for two to three days.[5,10] In fact, more than 50 percent of the initially absorbed dose is deposited in the kidneys, with the brain, liver, spleen, bone marrow, muscles, and skin being minor reservoirs for absorbed mercury.[11]

The major pathways for elimination of mercury from the body are via the feces and the urine. The half life for the whole body is 40 to 60 days, while the half life for the lungs is two days. Half lives for the blood, brain, and kidneys are 2 to 4 days, 21 days, and 40 to 60 days, respectively.[5] Thus, urine-mercury concentrations reflect chronic exposure, while blood-mercury concentrations reflect only recent exposure. Urinary mercury levels in the general population are typically less than 5 micrograms per gram of creatinine ($\mu$g/g creat.),[12,13] or 10 to 20 micrograms per liter ($\mu$g/L) of urine.[14–16] Symptoms generally are not present until levels of 200 to 300 $\mu$g/L are reached.[12–15] The World Health Organization (WHO) recommends a threshold level of 50 $\mu$g/g creat.,[17] and the American Conference of Governmental Industrial Hygienists (ACGIH®) has set a Biological Exposure Index (BEI®) of 35 $\mu$g/g creat.[18] Background mercury levels in the blood are less than 1 to 1.5 $\mu$g/deciliter (dL).[13,16]

The lung is the target organ of acute, high-level exposures to mercury vapor. Effects include cough, shortness of breath, chest pain, interstitial pneumonitis, bronchiolitis, and pulmonary edema. Nausea, vomiting, fever, stomatitis (sores and blisters around mouth), and gingivitis (inflammation of gums) can also occur.

The nervous system is the target organ of chronic exposures to mercury vapor. Effects include emotional lability, shyness, insomnia, irritability, and memory loss. This symptom complex is called erethism. Tremor and peripheral neuropathy can also occur, as can stomatitis and gingivitis. Other symptoms include fatigue, weakness, loss of appetite, and headache. These symptoms are usually reversible with cessation of exposure.[12–14] Mercury accumulates in the kidneys, but rarely produces significant renal injury.[12,13]

The Occupational Safety and Health Administration (OSHA) currently enforces a Permissible Exposure Limit (PEL) for mercury vapor of 0.1 mg/m$^3$ as an eight-hour time-weighted average (TWA).[19] (Legally, the PEL is designated as a ceiling value, but a directive has been issued by OSHA stating that this designation is incorrect and the value is, in fact, a TWA.[20] We are following the directive in this report.) The NIOSH Recommended Exposure Limits (RELs) for mercury vapor are 0.05 mg/m$^3$ as a TWA exposure for up to 10 hours per day, 40 hours per week, and a ceiling level of 0.1 mg/m$^3$, which should not be exceeded at any time. NIOSH and ACGIH® have a skin notation, indicating that skin exposure (from vapors or direct skin contact) can be a significant contributor to the overall worker exposure.[18,21] The ACGIH® Threshold Limit Value (TLV®) for mercury is 0.025 mg/m$^3$ (TWA exposure, 8 hours per day, 40 hours per week).

### *Lead Exposure-Related Health Effects and Exposure Criteria*

Lead adversely affects a number of organs and systems in the human body. The four major target organs and systems are the central nervous system, the peripheral nervous system, the kidneys, and the hematopoietic (blood-forming) system.[9] Inhalation or ingestion of inorganic lead can cause a range of symptoms including loss of appetite, metallic taste in the mouth, constipation, nausea, colic, pallor, a blue line on the gums, malaise, weakness, insomnia, headache, irritability, muscle and joint pains, fine tremors, and encephalopathy. Lead exposure can result in distal motor neuropathy (“wrist drop”), anemia, proximal kidney tubule damage, and chronic kidney disease.[22,23] Lead exposure is associated with fetal damage in pregnant women.[9,23] Finally, elevated blood pressure has been positively related to blood-lead levels.[24,25]

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 0.050 $\mu$g/m$^3$ (8-hour TWA).[26] The standard requires the following: lowering the PEL for shifts exceeding eight hours; medical monitoring for employees exposed to airborne lead at or above the action level of 30 $\mu$g/m$^3$ (8-hour TWA); medical removal of employees whose average blood-lead level (BLL) is 50 $\mu$g/dL or greater; and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 $\mu$g/dL. ACGIH® has a TLV® for lead of 50 $\mu$g/m$^3$ (8-hour TWA), with worker BLLs to be controlled at or below 20 $\mu$g/dL, and designation of lead as an animal carcinogen.[18]

### *Cadmium Exposure-Related Health Effects and Exposure Criteria*

Early symptoms of cadmium exposure may include mild irritation of the upper respiratory tract, a sensation of constriction of the throat, a metallic taste in the mouth, and/or cough. Short-term exposure effects of cadmium inhalation include cough, chest pain, sweating, chills, shortness of breath, and weakness. Short-term exposure effects of ingestion may include nausea, vomiting, diarrhea, and abdominal cramps.[23] Long-term exposure effects of cadmium may include loss of the sense of smell, ulceration of the nose, emphysema, kidney damage, mild anemia,[23] as well as an increased risk of cancer of the lung and possibly of the prostate.[27,28] The OSHA PEL (29 CFR 1910.1027) for cadmium is 5 $\mu$g/m$^3$ TWA.[29] ACGIH® has a TLV® for cadmium of 10 $\mu$g/m$^3$ (8-hour TWA), with worker cadmium blood levels to be controlled at or below 5 $\mu$g/dL, urine levels to be below 5 $\mu$g/g creat., and designation of cadmium as a suspected animal carcinogen.[18] NIOSH recommends that cadmium be treated as a potential occupational carcinogen, and that exposures be reduced to the lowest feasible concentration.[30]

## Results

### *Medical*

A review of the worker's medical records revealed no documentation of symptoms related to occupational exposures. A heavy metal screen on urine, collected on October 11, 2000, showed a urine-mercury level of 22 $\mu$g/g creat., which is below the BEI®. Urinary cadmium was 0.9 $\mu$g/g creat., which is consistent with levels found in the general population.[16] No lead was detected in the worker's urine. While blood is the preferred method used to monitor recent lead exposure, the fact that no lead was detected in the worker's urine indicates there was not excessive recent exposure to lead. However, the lead measurement may not be indicative of past exposures, or may not correlate with the total body burden of lead.

### *Industrial Hygiene*

The full-shift TWA personal air sample had a concentration of 0.03 mg/m$^3$ mercury vapor, which is below both the OSHA PEL of 0.1 mg/m$^3$ and the NIOSH REL of 0.05 mg/m$^3$, but above the ACGIH® TLV® eight-hour TWA of 0.025 mg/m$^3$. Lead and cadmium were not detected in the eight-hour personal air sample. The minimum detectable concentrations were 0.04 $\mu$g Pb/m$^3$ (lead) and 0.008 $\mu$g Cd/m$^3$ (cadmium) for this sample. The averages of three real-time samples, each taken in various locations using the Jerome® mercury vapor analyzer, are presented in Table I. Real-time monitoring indicated that mercury vapor up to 0.108 mg/m$^3$ was present in the neon glass room, especially in areas where mercury was added to glass tubes (Side A). The highest concentrations of mercury vapor (0.108 mg/m$^3$) were found above a floor mat on Side A. While this area air sample was obtained near the floor and not in the breathing zone of the artisan, it exceeded the NIOSH recommended ceiling value of 0.1 mg/m$^3$.

**TABLE I**
Real-time measurements of mercury vapor concentrations

| Location of sample | Hg vapor (mg/m$^3$) |
|---|---|
| Outside entrance door to neon glass room, but within the larger sign facility | 0.001 |
| Immediately inside entrance door of neon glass room | 0.024 |
| Side A: Near air compressor, close to the floor | 0.037 |
| Side A: Over work table where Hg was added to the tubes | 0.049 |
| Side A: Over a floor mat under the work table where artisan stands while adding Hg to tubes | 0.108* |
| Side A: Over floor under the work table where artisan stands while adding Hg to tubes | 0.071 |
| Side B: On paper protector on work table opposite where Hg was added to tubes | 0.022 |
| Side B: Over wood table opposite where Hg was added to tubes | 0.019 |
| Side B: Over floor under work table opposite where Hg was added to tubes | 0.015 |
| Side B: Over floor under work table opposite where Hg was added to tubes | 0.023 |

*Exceeds the NIOSH REL ceiling value of 0.1 mg/m$^3$.

**TABLE II**
Lead loading collected using two sequential wipe samples on work surfaces (micrograms Pb/ft$^2$)

| Side A | Side B |
|---|---|
| 170 | 21 |
| 140 | 16 |
| 160 | 19 |
| 120 | 21 |

The test of the two types of surface wipes (Wash'n Dri® versus Ghost Wipes™) revealed no differences between the two types with regard to the amount of lead that was collected from a standard area (lead loading). However, a marked difference existed between the two work surfaces sampled (see Table II). The location designated as Side A in this report was an area where cutting, heating, and other manipulations of the glass were performed; Side B was an area where primarily glass cutting occurred. Side A had a much higher range of lead levels (120–170 $\mu$g Pb/ft$^2$ of surface wiped) than Side B (16–21 $\mu$g Pb/ft$^2$ of surface wiped). Cadmium levels were also elevated over background (Side A = 1.1–2.9 $\mu$g Cd/ft$^2$ of surface wiped; Side B = 0.43–0.69 $\mu$g Cd/ft$^2$ of surface wiped). Other common elements that were found to be elevated in the wipe samples included the following: aluminum, iron, magnesium, phosphorus, zinc, cobalt, chromium, manganese, nickel, and other less common elements. No occupational standards or recommendations exist for lead, cadmium, or other elements on surface wipes.

## Discussion

On the day of the NIOSH site visit, PBZ air sampling revealed a mercury concentration that was below both the OSHA PEL and NIOSH REL, but above the ACGIH® TLV®. One important limitation of these data is related to the fact that temperature has an effect on the amount of mercury vapor in the air. For example, studies have shown that increasing the temperature of mercury from 75°F to 90°F almost doubles its air concentration (from 18 $mg/m^3$ to 34 $mg/m^3$).[31] The temperature recorded in the air-conditioned neon shop on the day of sampling averaged 73°F, but according to the owner, that temperature is often exceeded during the summer. Consequently, even with no increase in mercury surface contamination, it is reasonable to expect seasonally elevated air concentrations in the work area. When a tube containing mercury is heated in a flame, such as might occur if a broken neon tube was being repaired, mercury could reach excessive concentrations in the breathing zone. With these considerations, it is prudent to reduce general mercury exposures. OSHA has provided occupational safety and health guidelines for reducing mercury vapors. Recommendations include engineering controls, administrative controls, and use of personal protective clothing and equipment (including respirators); specific recommendations are made in the following sections of this report.[32]

## Conclusions

The primary concern at this worksite was the presence of mercury, which is volatile at room temperature. Mercury can enter the body through the skin, though the primary route of exposure is inhalation. Residual mercury on surfaces may be a significant contributor to airborne mercury levels. Decontamination of mercury requires special procedures and skin protection. Full-shift PBZ concentrations of lead and cadmium were low at the shop, although there was contamination of work surfaces with these and other elements. It is possible that this contamination is due to the breaking of the glass on these surfaces. Sealing and cleaning these surfaces requires some precautions because the lead or cadmium can be transported to the mouth through hand or food contact. However, lead and cadmium are not volatile at room temperature.

Medical record review from the single employee revealed that urine concentrations of mercury and cadmium were below occupational criteria, and lead was not detected.

## Recommendations

*Engineering Controls*

Engineering controls are generally the most effective way to reduce exposures, and ventilation can be improved at this shop. The existing ceiling fan was not an effective method to remove contaminants because the air was not cleaned of mercury vapor before it was released into the surrounding work area. Use of smoke tubes during the site visit demonstrated that the ceiling fan provided little air movement at the position of the worker. Even if air leaks around the fan were sealed to improve its efficiency, the fan's overhead location was such that any resulting movement of toxic vapors would be pulled through the worker's breathing zone. Instead, there should have been a properly designed ventilation hood that both enclosed the process and provided local exhaust ventilation (LEV) to remove the contaminant at the source before it mixed with the room air. The hood would also provide employee protection from the mercury vapor, as well as eye and skin protection from breaking glass, when installed in the area where mercury was added to the tubes and the high voltage was applied.

We suggested that the owner consult an experienced heating, ventilation, and air conditioning (HVAC) professional to adapt the following general plans into a specific design for this work space. Although the operation did not involve paint or spraying, a small tabletop booth design, similar to the paint spray booth portrayed in drawing VS-75-02 in the ACGIH® Industrial Ventilation Manual,[33] may be a practical way of providing protection (see Figure 3). The booth needs to be approximately 12 inches wider and 12 inches higher than the work space needed. In setting the height of the top of the booth, the position and the height of the worker should be considered. A typical booth is shown in the figure, but a differently sized booth will work as long as adequate ventilation is maintained. An added shatterproof barrier at the entrance to the hood could be utilized for physical protection when high voltages are applied during testing of the glass tubes. For a small booth, a minimum flow rate of 150 cubic feet per minute (CFM) for each square foot of open area is recommended.

The outlet of the booth must exit through the roof, sufficiently distant and downwind from any air intakes, so that exhausted vapors do not re-enter the building. Use a rain protection design similar to the one presented in Figure 4 (rather than an obstructing rain cap), and size the diameter of the stack so that the discharge velocity is 2,500 feet per minute.[34] Notice that there is a baffle (dashed line in the figure) angled within the booth, which aids in the proper airflow distribution. Booths using "Paint Collector" filters, which reduce the area through which air is exhausted at the back of the booth to approximately half the open area at the face of the booth, have been effective without a baffle.

After the addition of local ventilation, the general ventilation within the room must be balanced with make-up air. The owner of this shop was concerned with mercury being deposited in the outside environment, which was the reason he did not wish to vent the exhaust system to the outdoors. However, an indoor hazard is typically greater because the work space is enclosed and, with appropriate air cleaning, the ventilation can be exhausted to outdoor areas in accordance with state and local requirements. All air exhausting the building should be routed through a mercury scrubbing device; this can be done by using a sulfur- or iodine-impregnated carbon pack, or by bubbling the air into a tank that contains a mercury complexing agent in conjunction with a de-mister. Mercury tends to condense in ventilation ducts, and this condensation should be controlled by having smooth-walled ducts that slope toward a gravity collection trap.[35]

Real-time monitoring for mercury corroborated information provided by the owner that mercury accumulated in

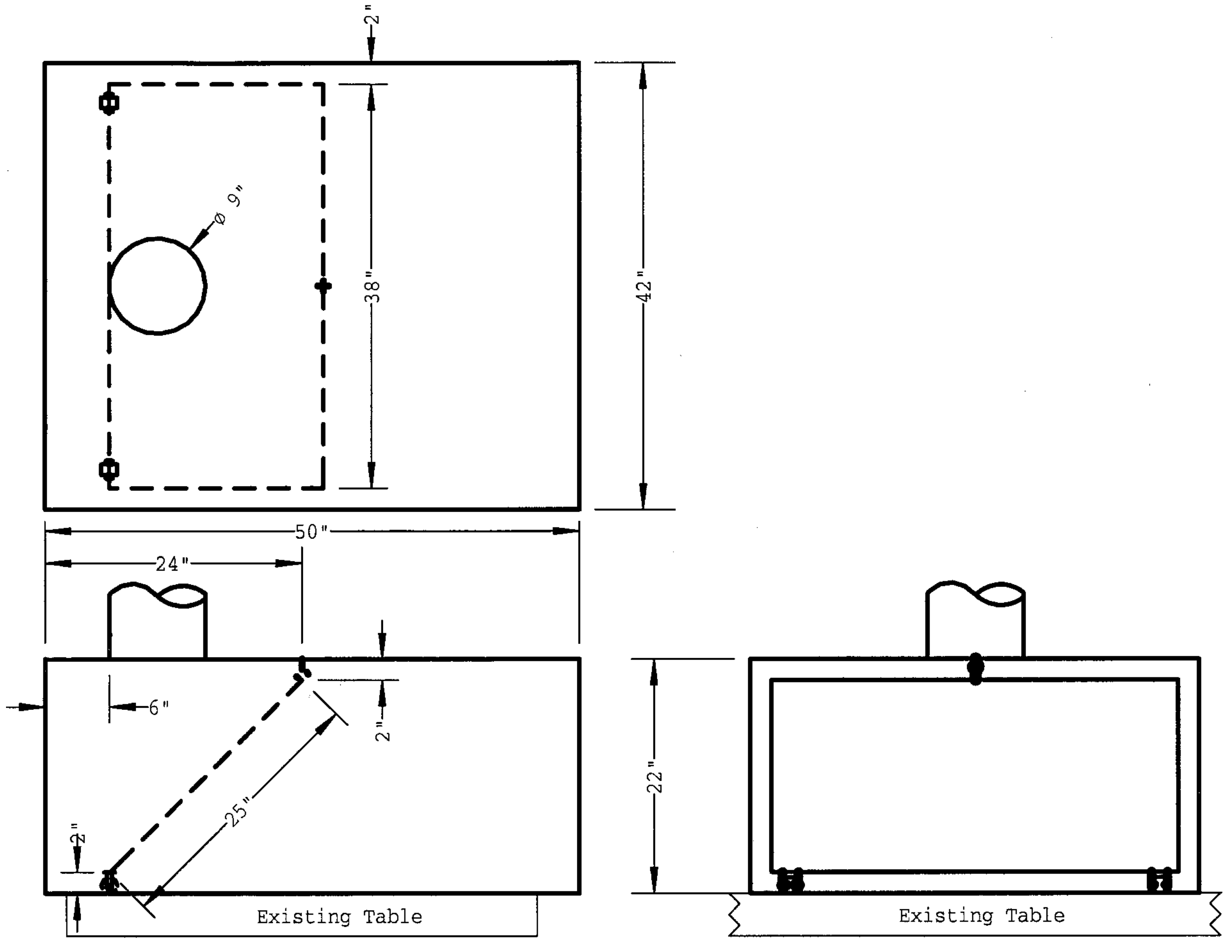


**FIGURE 3**
Design of a small booth. (Adapted from *Industrial Ventilation: A Manual of Recommended Practice,* 23rd ed.[33] Copyright 1998. Reprinted with permission.)

the oil of the air compressor and was a significant source of contamination in that area. Because the compressor creates a negative pressure within the tube, the mercury within it will volatize more rapidly than at normal room pressure. A mercury gravity trap can be installed before the air enters the compressor, which will help prevent the contamination of the compressor and allow easy monitoring of mercury accumulation as well as easier cleaning.

*Work Practices*

Changes in work practices and the work environment can aid in minimizing mercury exposures.[36] For example, simply maintaining a low room temperature (below 68°F) will reduce volatization of mercury and, therefore, reduce exposure. However, because it is more effective in the long-term to prevent mercury contamination, physical modifications to the environment will make prevention easier. Work table surfaces, especially any joints, should be impermeable (stainless steel), with a drainage trough along the front surface sloped to a collection bottle, and a lip along the other sides to prevent spillage. It is necessary for floors to be smooth and impermeable (epoxy, polyurethane, vinyl sheeting) so that the mercury is not absorbed into them; wood, carpeting, or doormats should be avoided. Dark colors are advised to facilitate perception of mercury if accidentally spilled. Caulk around table legs, joints between floors and walls, or other crevices. Store broken glass possibly contaminated with mercury in a receptacle that does not allow mercury vapors or liquid to escape into the room. Do not repair any used neon tubes that may contain mercury.

It is important to clean any metal contamination promptly. Cleaning procedures that might release mercury into the air, such as vacuuming or dry sweeping, should be avoided. A special mercury vacuum that has a gravity trap is commercially available for cleaning small mercury spills. Commercial cleaning kits specifically for mercury are available and convenient, but not necessary, especially if precautions are taken to make spills easy to clean. Beads of mercury can be maneuvered on a smooth surface

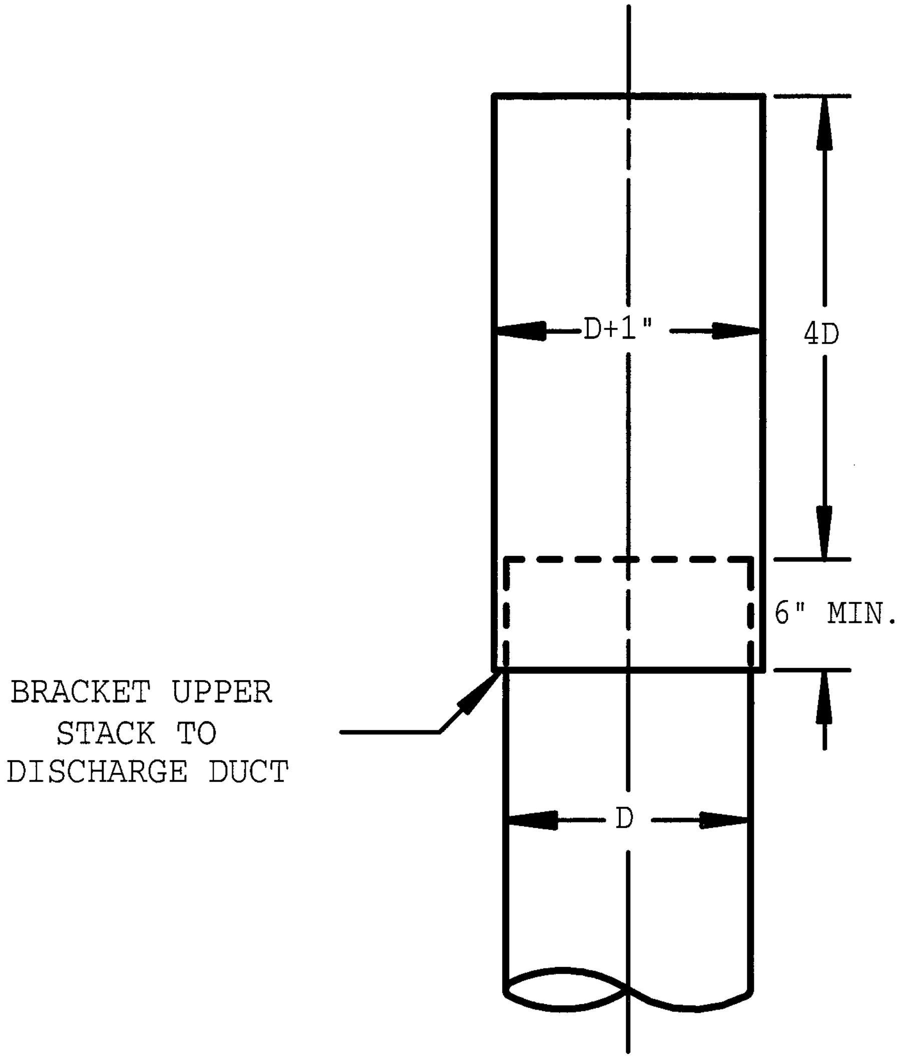


**FIGURE 4**
Recommended rain protection stackhead design. (Adapted from *Industrial Ventilation: A Manual of Recommended Practice*, 23rd ed.[33] Copyright 1998. Reprinted with permission.)

with a disposable squeegee until they are collected with a dust pan. Smaller mercury drops can be collected within a syringe or an eye dropper. Powdered zinc can amalgamate small amounts of mercury, thereby preventing it from vaporizing. The effectiveness of cleanup procedures can be confirmed with powdered sulfur, which, when sprinkled in a mercury-contaminated area, will turn from yellow to brown.

*Personal Protective Clothing and Equipment*

Both mercury and lead have the potential to be carried into vehicles or the home on work clothes and shoes; such items should not be carried outside of the workplace, and should be disposable or washed by a commercial firm that is aware of the nature of the potential contamination. Some examples of materials that provide sufficient protection (mercury breakthrough times of greater than 480 minutes) are Safety4 4H® or Dupont Saranex-23® 2-ply aprons and nonslip foot coverings.[37] Pets should not be allowed entry into areas where contamination may be present. Food, beverages, and tobacco products should not be permitted in the work areas. Because mercury can move through the skin into the body, protective gloves are important if skin contact with the mercury is possible. Rubber gloves are not sufficiently protective for mercury; brands such as Saranex™ and 4H™ are required and have been demonstrated to provide protection for greater than eight hours of mercury contact.[38] Some of these glove materials may not be sufficiently flexible, but often a tight-fitting neoprene glove over the protective glove will permit finger movement. Finally, a continuous, fixed mercury monitor will provide assurance that mercury concentrations are at safe levels, and should be set at half the PEL. A good source of additional information including a list of commercial firms that provide various products to monitor, control, or clean up mercury can be found on the Web site of the New Jersey Department of Health and Senior Services.[36]

If these improvements are made to the shop, we anticipate that mercury exposures will be reduced. At the time of NIOSH sampling, the PBZ exposures exceeded the ACGIH® TLV®. Thus, a respirator with a cartridge specifically for mercury should be worn until the improvements are made and a re-evaluation indicates that worker exposures are reduced below occupational exposure limits. If respirators are used, a complete respiratory protection program should be instituted that complies with the requirements of OSHA's Respiratory Protection Standard (29 CFR 1910.134). A program must include respirator selection, a medical evaluation, training, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning.

*Environmental Considerations*

It appeared unlikely that a major mercury spill would occur in this shop, because the owner reported that a total of only about one pound of mercury was used per year, and only a small vial of mercury was on hand. An employer who releases one pound or more of mercury within a 24-hour period in a manner that will expose persons outside the facility must notify the National

Response Center in Washington, D.C., immediately (800-424-8802 or 202-426-2675).

Finally, some consideration should be given to disposal of mercury-contaminated waste glass. According to the owner, this neon sign manufacturing facility generates much less than 100 kilograms (220 pounds) of hazardous waste per calendar month, and thus was categorized as a conditionally exempt small quantity generator of hazardous waste (CESQG).[39] Federal regulations state that CESQGs are not subject to hazardous waste management standards and may choose to send their wastes to a municipal solid-waste landfill or other facility approved by the state for the management of industrial or municipal non-hazardous wastes (40 CFR 261.5). Streamlined regulations took effect on December 30, 1996, in Georgia, which made voluntary recycling of waste mercury-containing light bulbs an option for CESQGs.[40] Commercial recycling programs are readily available from laboratory safety supply companies. They provide technical advice and (usually) proper disposal containers, which should be used in place of the open container observed at the time of the site visit. We encouraged the owner to use one of these programs to dispose of the waste.

*Medical Evaluations*

Because there is a continuing potential exposure to mercury and other metals in the workplace, we recommend continued medical evaluations from a qualified occupational medicine physician. Environmental sampling is used to guide medical screening. Medical screening complements environmental sampling and can help detect exposure to mercury, lead, cadmium, or other potential occupational hazards. Occupational physicians are trained to perform workplace surveillance. One way to locate occupational physicians in an area is through the Association of Occupational and Environmental Clinics at 202-347-4976 or www.aoec.org. Another source is the American College of Occupational and Environmental Medicine at 847-818-1800 or www.acoem.org.

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**EDITORIAL NOTE:** Lynda Ewers, Elena Page, and Vincent Mortimer are with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation is contained in Health Hazard Evaluation Report No. 2001-0081-2877, available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226; telephone: (800) 35-NIOSH; fax: (513) 533-8573.