FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

North American Philips Lighting Company
Lynn, Massachusetts

Indepth Survey Report
for the Site Visit of
April 13-15, 1982

Contract No. 210-81-7107

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Submitted to:

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FOREWORD

A Control Technology Assessment (CTA) team consisting of members of the National Institute for Occupational Safety and Health (NIOSH) and Dynamac Corporation, Enviro Control Division, met with representatives of North American Philips Lighting Company (Norelco) in Lynn, Massachusetts, on April 13-15, 1982, to conduct an indepth survey on the techniques used to control worker exposure to mercury. Participants in the survey were:

North American Philips Lighting Company
- Jay Corbett, Industrial Relations Manager
- Dale Tracey, Corporate Safety Administrator
- Walter Donatelli, Fluorescent Manufacturing Engineer
- Edward Schmidgall, Facilities Engineer
- Janice Smullen, Plant Nurse
- Robert Higginbothem, Fluorescent Superintendent

National Institute for Occupational Safety and Health
- Alfred Amendola, Project Officer

Dynamac Corporation
- Robert Reisdorf, Industrial Hygienist
- Andrew Reyburn, Industrial Hygienist
- David D'Orlando, Environmental Engineer

The indepth CTA survey was completed in 3 days. The study included personal and area air monitoring and detailed inspections of mercury controls.

CONTENTS

INTRODUCTION

CONTRACT BACKGROUND

The Mercury Control Technology Assessment Study has been initiated to assess the current technology used to protect workers from exposure to mercury. The objective is to identify the methods employed by industries in controlling worker exposure to elemental mercury and mercury compounds. A result of the study will be the publication of a comprehensive document describing the most effective means to control emissions and exposures. This report will be available to companies that handle mercury in order to transfer technology within the major mercury-using industries. The study will also identify areas where additional research is necessary.

JUSTIFICATION FOR SURVEY

The North American Philips Lighting Company was selected for a survey because of the controls in effect to protect workers from exposure to mercury vapor. The plant is relatively new compared with most fluorescent lamp plants, and it has a unique control for containment of mercury in its newer production lines.

SUMMARY OF INFORMATION OBTAINED

An opening conference was held during which the objectives of the program were discussed with plant representatives. A tour of the lamp manufacturing facility was made, and information on mercury controls was obtained from the plant engineers. Area and personal monitoring was conducted in the plant, and historical information on air and biological monitoring was obtained.

PLANT DESCRIPTION

North American Philips Lighting Company (Norelco), a division of North American Philips Corporation, is located in Lynn, Massachusetts. The major products manufactured at the plant are incandescent lamps, lamp filaments, and fluorescent lamps. Most of the fluorescent lamps manufactured are 2, 4, or 8 feet long. The most common model (accounting for 80-90 percent of the lamps produced at the plant) is a 4-foot-long, 40-watt lamp.

The fluorescent lamp building (90,000 square feet) is 10 years old and is constructed almost entirely of concrete. It was purchased from Champion (a division of ITT) in January of 1974. In 1975, 1976, 1978, and 1980, new production lines were added that incorporated a unique mercury control. In addition, the plant's ventilation system has been continuously modified to improve airflow around the manufacturing equipment.

Approximately 200 people, including supervisors, work in the fluorescent lamp plant. Lamps are produced during the first and second shift, and equipment maintenance is conducted during the third shift.

PROCESS DESCRIPTION

Fluorescent lamps are manufactured at this facility using two basic processes. A "horizontal" process is used for the manufacture of 4-foot lamps. This process is almost fully automated and has been in operation for 7 years. A "vertical" process is used for manufacturing other sizes of lamps (including the 8-foot lamp). This is a semiautomatic process that has been in operation for 10 years. Both processes provide similar production functions with the exception of the mercury addition operation.

TUBE PREPARATION

Glass lamp tubes of specified length are brought into the plant, washed, set in racks, and transported to the Coating Room. In the Coating Room, a phosphor emulsion is allowed to flow through the tubes, coating the inside glass surface. The tubes are then dried, and a layer of phosphor remains inside the tube.

MOUNT ASSEMBLY

The end piece (or mounts) to be attached to the outside ends of the tubes are manufactured separately. Each assembly consists of a glass tube stem (exhaust tube); a flared (funnel-shaped) glass piece; wire leads; a carbonate-coated, tungsten coil filament; and a cathode shield.

LAMP MANUFACTURING

The coated lamp tubes are loaded onto a conveyor and passed through a Lehr oven that bakes the phosphor coating and removes impurities. The mounts are then attached to the ends of the tubes by heating, forming a glass-to-glass seal. The mount on one end of each tube is sealed closed by melting the tip of the exhaust tube stem. The lamp assembly is exhausted through the exhaust tube in the other mount, and an inert gas is injected into the tube.

A small amount of mercury (15-250 mg, depending on the application) is released inside the lamp by one of two processes:

Vertical process - Mercury is added to the lamps on the exhaust machine station by gravity feeding a specified amount down through the open exhaust tube.

Horizontal process - Mercury is released into the lamps on the horizontal machine from enclosed mercury-containing capsules attached to one of the mount assemblies on each lamp tube. This process is described in more detail in the Mercury Control Techniques section.

The open exhaust tube is sealed closed by a flame in a process known as tipping off. Glass tips from the exhaust tubes fall into a collection bin and are removed for disposal.

Metal bases are attached to the ends of each lamp tube and are cemented in place by heating. Current is applied to the lamp contacts to light the lamp and ensure proper performance. A silicone coating is applied to the outside of the tube to prevent moisture from accumulating on the lamp, and the lamp is packaged in preparation for shipping.

MERCURY CONTROL TECHNIQUES

PROCESS MODIFICATIONS

The major source of emission of mercury vapor in the lamp manufacturing process is at the exhaust tube after mercury is added. The plant has implemented a major process modification that eliminates this point of emission on the 4-foot lamp manufacturing equipment (horizontal machines). As a result, exposure to mercury from the injection operation has been virtually eliminated in the production of 80 to 90 percent of the lamps manufactured at the plant. The process modification is the use of mercury containing capsules, or "pills," for release of mercury in the lamp tube after the tube has been sealed. The pill is a small, sealed glass tube (approximately 1/2-inch long and 1/16-inch in outer diameter) that contains a specified quantity of elemental mercury. It is manufactured at the plant using a proprietary process equipped with separate mercury controls (local exhaust ventilation and vapor suppression using water). The pill is attached to the outside of the cathode shield on the mount assembly (Figure 1). A thin wire is placed across the pill and is attached on either side to the cathode shield.

Of the two mount assemblies used in each lamp, only one contains a mercury pill. When the exhaust tubes are tipped off, the pill is contained inside the sealed lamp tube. Mercury is released into the lamp tube by splitting open the glass pill at its center.

The use of the mercury pill results in the complete enclosure of the mercury addition process. The presence of mercury vapor in the production area where the mercury pill is used can presumably be attributed to lamp tube breakage and cross-contamination of air from the section of the plant where the conventional mercury injection technique is used (at the "vertical" machines).

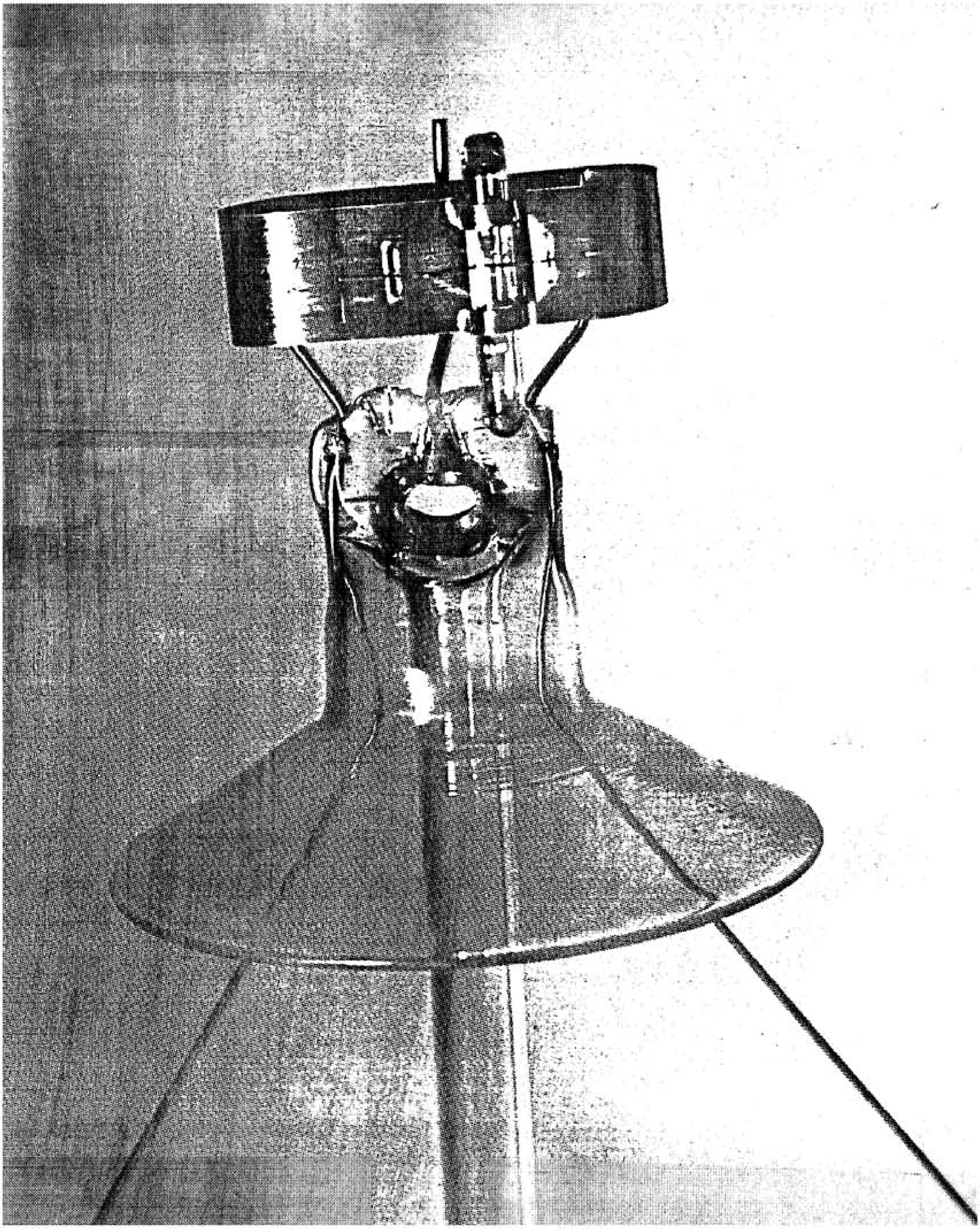

Figure 1. Mount Assembly with Mercury Pill.

The use of the mercury pill also results in a reduction in mercury usage. This is because the enclosed release process does not result in the mercury waste typically associated with the mercury addition operation.

VENTILATION

Exposure to mercury vapor generated at the point of mercury addition on the "vertical" lamp manufacturing machines is controlled through the use of dilution and local exhaust ventilation. The objective is to exhaust the hot air around the exhaust machine and to supply fresh outside air to the breathing zones of the workers situated adjacent to the exhaust machine. A general dilution ventilation system is used to condition the air and to provide air movement to prevent the buildup of pockets of mercury vapor.

Air Supply

Supply air for the fluorescent lamp plant is provided by 10 ITT Nesbit heating and ventilating units. They provide heated outside air in the winter and untempered outside air in the summer.

Six of the units are rated at 25,000 cubic feet per minute (cfm). Four of these are located at the south end of the building and two are located in the northeast section. Each of the six units distributes supply air through a ceiling duct with vertical distributors that extend approximately 6 feet below ceiling level.

Four of the supply units are rated at 14,000 cfm each and are located along the north end of the building. Each unit has ductwork leading to eight supply air distributors.

A 10,000 cfm (actually measured to be 8,200 cfm) personnel cooling air supply unit also contributes to the general plant supply air. This unit is located at the south end of the building. An underground duct system connects the air handler to supply air outlets near the "vertical" manufacturing area. These outlets connect to rectangular and circular local supply vents situated at worker breathing zones and underneath working platforms (Figure 2).

There are several other low capacity blowers used for local supply air. One such blower provides air for adjustable 2-inch circular supply vents located in front of each worker on one of the "vertical" machines (Figure 3). Information on the flow rate through these vents is provided in the Survey Data section of this report.

Additional outside air is drawn into the plant through nine nonmechanical louvered wall vents. These vents have an area of 15 square feet each, and plant representatives have measured the average air velocity through them to be 400 feet per minute (fpm). This provides an additional 54,000 cfm of outside supply air for the plant.

Exhaust Air

Air is exhausted from the plant through 16 high-capacity roof fans and several lower capacity fans. Eight of the roof fans have a capacity of 24,000 cfm each. They are located in a straight line along the north end of the building. The other eight roof fans have a capacity of 23,000 cfm each and are located just south of the first set of fans. These fans provide exhaust for a network of local exhaust hoods connected to them.

Other exhaust systems contributing to the removal of air from the plant include the following:

- 3 silicoating exhausters - 5,000 cfm each
- 1 sintering oven exhauster - 8,000 cfm
- 5 bulb washer exhausters - 1,000 cfm each
- 1 vertical machine exhauster - 12,000 cfm
- 1 vertical machine exhauster - 9,000 cfm
- 1 combined air exhaust system - 23,000 cfm.

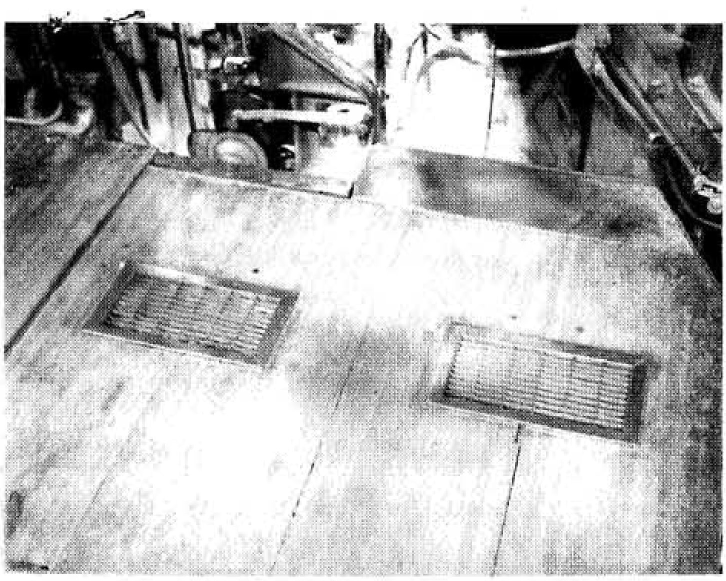

Figure 2. Suppy Air Vent from Underneath Working Platform

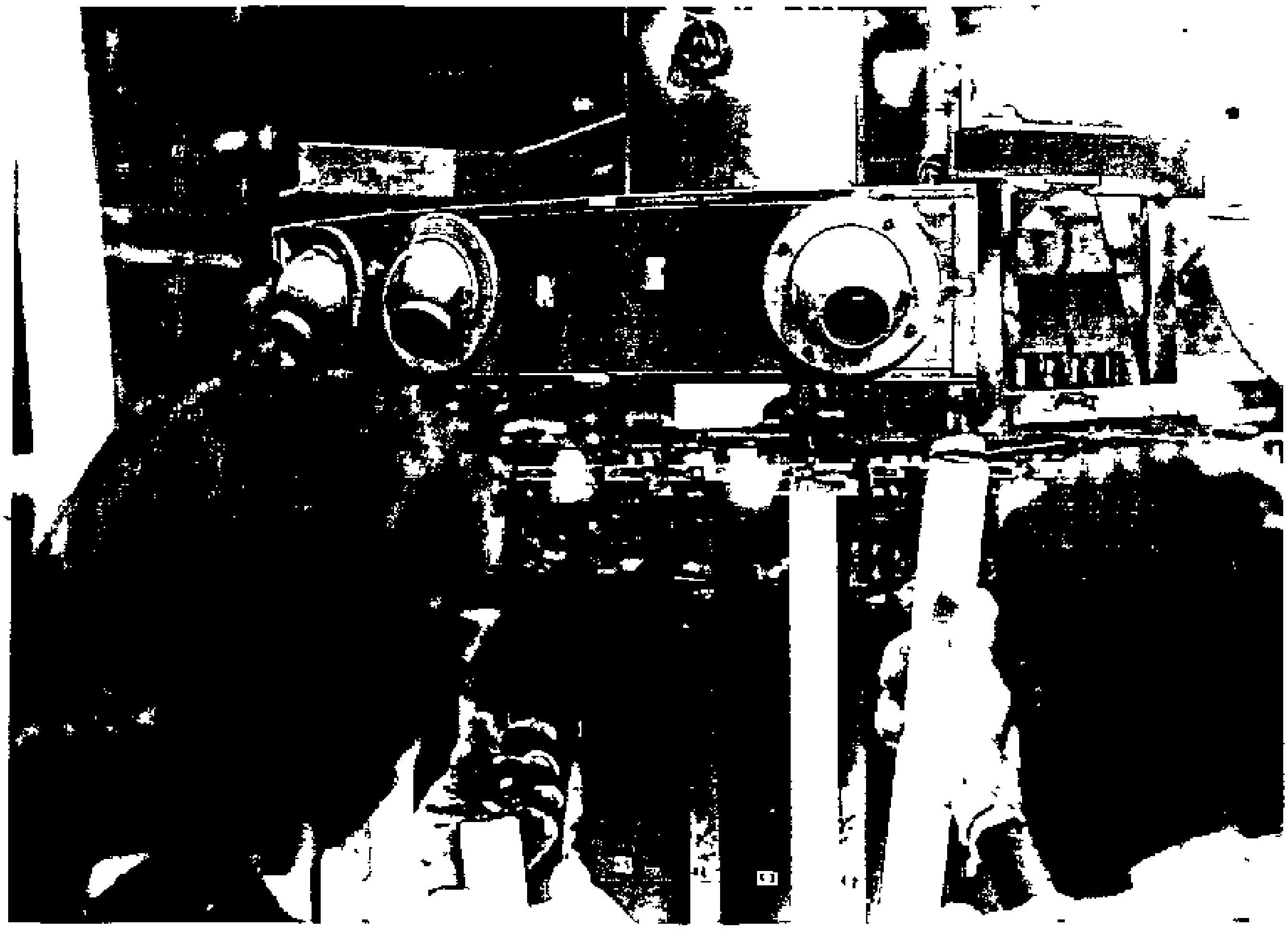

Figure 3. Adjustable 2-inch Supply Air Vents.

The total exhaust airflow from the plant is approximately 448,000 cfm (design), and the total air supply including airflow through the nine wall vents is 273,000 cfm. This imbalance results in a strong negative pressure. A problem associated with the pressure differential is that the plant experiences inefficient heating in the winter because of the cold air drawn into the building. This influx of air also negatively affects the flames in the lamp manufacturing process.

The ventilation system was designed so that the general movement of air is in through the south side of the plant and out through the north side.

PERSONAL PROTECTIVE EQUIPMENT

Safety and health personnel have identified locations and operations that have an increased potential for mercury exposure. Areas of concern are the basing and unloading platform of the vertical machines and the pill manufacturing area. Exposure on the vertical machine platform is primarily controlled by dilution ventilation, whereas respiratory protection is employed at the pill manufacturing area. Specific operations in this area are designated as having high exposure potential, and the use of mercury vapor respirators (3M #8707) is required during these activities. Operations requiring the use of respirators are:

- filling mercury doser reservoir
- cleaning visible mercury from machinery (with brushes, etc.)
- vacuuming area.

The respirators used for this purpose contain iodine-impregnated charcoal to adsorb mercury vapor.

Gloves are used in the pill manufacturing area and in other areas when mercury is handled directly. Gloves are intended to reduce dermal contact with mercury and to limit the potential spread of mercury by contaminated hands. The gloves used by workers at the pill manufacturing area are made of heavy cloth. In addition, the use of protective hand cream is required for mechanics and machine cleaners.

Lockers are available for workers to store clothing and personal items not allowed in the work area. Lavatories are readily accessible for workers to wash their hands prior to lunch and breaks.

WORK PRACTICES

A program of appropriate work practices and housekeeping procedures has been instituted at the facility to minimize exposure to liquid mercury and mercury vapor. These practices and procedures are summarized as follows:

- Personal hygiene - hands are to be thoroughly washed before eating, drinking, smoking, or leaving work; fingernails are to be scrubbed; long hair is to be tied back; a clean change of clothing is to be worn to work each day.
- Isolation of personal articles - unnecessary clothing, food, smoking materials, cosmetics, etc. must be stored in lockers and not brought into the work area.
- Use of protective devices - respirators, gloves, hand creams, etc., must be used wherever required.

Housekeeping activities consist of general janitorial duties and special procedures for mercury. The two areas requiring the most attention for mercury control are the vertical machine manufacturing area and the pill manufacturing area. The floor around the vertical machines is a problem area that has proved difficult to clean. The area is contaminated with machine oil and is difficult to access. Chlorothene (1,1,1-trichloroethane) solvent was formerly used to clean this area, but its use was discontinued because of potential health implications. Detergent was found to be unsatisfactory because it induced rusting of machinery. No other product has been found to satisfactorily clean the area.

Visible mercury in the pill manufacturing area is removed using small brushes and a special vacuum cleaner designed to trap liquid mercury and adsorb mercury vapor. A similar vacuum cleaner is also employed for cleaning mercury spills in other areas.

MONITORING PROGRAM

Air monitoring is conducted on an irregular basis. The facility uses a Bacharach Model MV-2 mercury vapor detector for this purpose, but has encountered problems with the operation of the apparatus.

A review of historical sampling data demonstrated that mercury vapor concentrations were similar to those found during the survey. A brief summary of the plant's data is presented in Table 1.

TABLE 1

Historic Data from Company-Conducted Surveys
(Bacharach Model MV-2 Mercury Vapor Detector)

Location	Mercury Vapor Concentration Range (mg/m^3)
Horizontal Machine Manufacturing Area	0.02-0.06
Vertical Machine Manufacturing Area	0.02-0.10
Pill Manufacturing Area	0.02-0.80

Biological monitoring in the form of mercury urinalysis is performed on all employees semiannually. Baseline samples are taken along with a completed medical evaluation at the beginning of an individual's employment. Two categories have been identified as having a high exposure potential:

- Mechanics and machine cleaners are required to have urinalyses performed every 3 months.
- Vertical machine and pill manufacturing operators are required to have monthly urinalyses performed.

Individuals whose test results demonstrate elevated mercury levels are required to be retested weekly. When an elevated mercury concentration is detected, the employee is reminded of the personal hygiene and other work practices for handling mercury. In the event of continued elevated levels, employees are removed to another job until the levels subside. The plant follows the new State health directives regarding mercury exposure. The State of Massachusetts requirements are presented in Table 2.

TABLE 2

Mercury Exposure Limits and Required Action for the State of Massachusetts

Urine-Mercury Concentration (mg/L)	Condition	Action
0.00-0.05	No or insignificant exposure	Repeat urinalysis annually if exposure to mercury continues.
0.05-0.15	Insignificant exposure	Repeat urinalysis semi-annually.
0.15-0.30	Significant exposure	Repeat urinalysis in 30 days.
0.30-0.50	Definitely harmful exposure	Conduct medical examination. Repeat urinalysis again in 2 weeks.
Over 0.50	Hazardous condition	Remove from exposure.

Historical data of urinalyses at the facility reflect the company's concern about exposures of different groups of workers. The pill manufacturing area workers showed the highest levels, followed by mechanics. Of the mechanics, those responsible for the pill manufacturing area had the highest urine-mercury concentrations. Workers on the vertical and horizontal machines had considerably lower concentrations, although the vertical machine workers had the highest of the two. Averages for sample populations of recent urinalyses were as follows:

- Pill manufacturing area worker 0.20 mg/L
- Mechanics 0.09 mg/L
- Vertical machine workers 0.04 mg/L
- Horizontal machine workers 0.02 mg/L

SURVEY DATA

AIR SAMPLING RESULTS

Two methods were used for mercury vapor sampling at the facility. Direct reading samples were taken using a Bacharach Model MV-2 mercury vapor detector. Time-weighted average (TWA) samples were obtained by using sampling pumps to draw air through Hopcalite solid sorbent tubes. Analyses were conducted using flameless atomic absorption spectroscopy.

Time-weighted sampling results (Table 3) indicate the vertical machine and pill manufacturing areas as the areas of highest concentration. Personal samples at both locations showed higher levels than the corresponding area samples. Area samples were taken approximately 3-5 feet from workers' breathing zones.

The mercury vapor concentrations at the horizontal machine manufacturing area were significantly lower than those found at the vertical machine manufacturing area. The lowest concentrations detected were in the central area of the plant.

Direct reading sampling results (Table 4) were consistent with the time-weighted sample results. As with the TWA samples, the vertical machine and pill manufacturing areas demonstrated the highest concentrations. Wide variation was noted in both these areas, particularly at the pill manufacturing area. Meter readings fluctuated greatly over short periods of time. The source of this variability was not determined, although air currents may account for this. Direct reading samples taken at floor level in the vertical machine and pill manufacturing areas showed very high concentrations, and contamination of the floor is presumably the major source of exposure in these areas. Mercury was visible on the floor and at the base of equipment, and was especially noticeable in the pill manufacturing area. Additional sources of exposure in the vertical machine manufacturing area were the exhaust machine doser (the top of which showed high levels) and lamps that were not sealed completely.

TABLE 3

TWA Mercury Vapor Area and Personal Sampling Results
(4/13/82 - 4/15/82)

Location or Worker Sampled	Full-Shift TWA Concentration (mg/m^3) Range	Average
Horizontal Machine (pill activation)	0.027-0.040 (5)*	0.034
Vertical Machine (baser platform)	0.020-0.059 (3)	0.041
Vertical Machine (lamp aging)	0.027	--
Central Area of Plant (near foreman's office)	0.018	--
Pill Manufacturing Area (above head)	0.015	--
Horizontal Machine Workers (threader operator, mechanic)	0.008-0.045 (6)	0.026
Vertical Machine Workers (loaders, basers)	0.039-0.100 (5)	0.060
Pill Manufacturing Worker	0.065	--

*Numbers in parentheses indicate number of samples taken.

TABLE 4

Direct Reading Mercury Vapor Sampling Results
(4/13/82 - 4/15/82)

Location	Concentration (mg/m³) Range	Average
Horizontal Machine	0.015-0.040 (9)*	0.029
Horizontal Machine (BZ)[1]	0.020-0.035 (6)	0.024
Horizontal Machine (floor)	0.030-0.045 (3)	0.038
Horizontal Machine (pill mounting)	0.010-0.020 (5)	0.014
Vertical Machine (baser platform)	0.020-0.060 (7)	0.038
Vertical Machine (BZ)[1]	0.018-0.600 (16)[3]	0.106
Vertical Machine (floor)	0.080-1.000 (5)[3]	0.496
Vertical Machine (aging)	0.020-0.030 (3)	0.024
Vertical Machine (top of exhaust unit)	0.400-0.500 (2)	0.450
Vertical Machine (fresh air supply)	ND[2]	--
Central Plant (near foreman's office)	0.010-0.020 (3)	0.015
Central Plant (inside foreman's office)	0.030-0.050 (4)	0.039
Central Plant (foreman's office floor)	0.050-0.060 (2)	0.055
Pill Manufacturing Area (general area)	0.010-0.300 (17)[3]	0.059
Pill Manufacturing Area (floor)	0.150-1.000 (4)[3]	0.388

*Numbers in parentheses indicate number of samples taken.

[1]Breathing zone of workers.

[2]None detected.

[3]Certain data points reflect emission source sampling.

Mercury vapor was not detected in the air ducts that supplied clean air for the vertical machine workers. Breathing zone samples were quite variable, but generally were below 0.01 milligrams per cubic meter (mg/m^3) when the fresh air ducts were properly directed. Some of the fresh air ducts were not directed at employees' breathing zones during the survey. The aging area of the vertical machine had uniformly lower concentrations.

Direct reading concentrations at the horizontal machine were consistently below 0.04 mg/m^3. Mercury was not visible on the floor in the horizontal machine manufacturing area. Exposures at the horizontal machine area are presumably an effect of cross-contamination from the vertical machine area. Levels in the central area of the plant were low, although sample results indicate contamination of the floor inside the offices located there, accounting for slightly higher mercury vapor concentrations inside the offices than outside.

VENTILATION MEASUREMENTS

Measurements were made to verify reported design airflows and to determine airflows from local supply vents.

A 35-point, velocity pressure traverse was made on the 20-inch by 40-inch main duct of the personnel cooling air blower using a Pitot tube and inclined manometer. The blower is rated at 10,000 cfm. Average air velocity through the duct was 1,400 fpm, resulting in an actual airflow of 8,200 cfm--close to design specifications.

Velocity readings taken at the adjustable 2-inch circular supply vents on the personnel cooling air system using a thermoanemometer averaged 3,580 fpm. This results in 78 cfm of local supply air at each worker's breathing zone. Additional local supply air in the same area is provided by two vertical retangular diffusers (1.9 and 2.8 square feet) with measured airflows of 579 and 823 cfm, respectively (Figure 4).

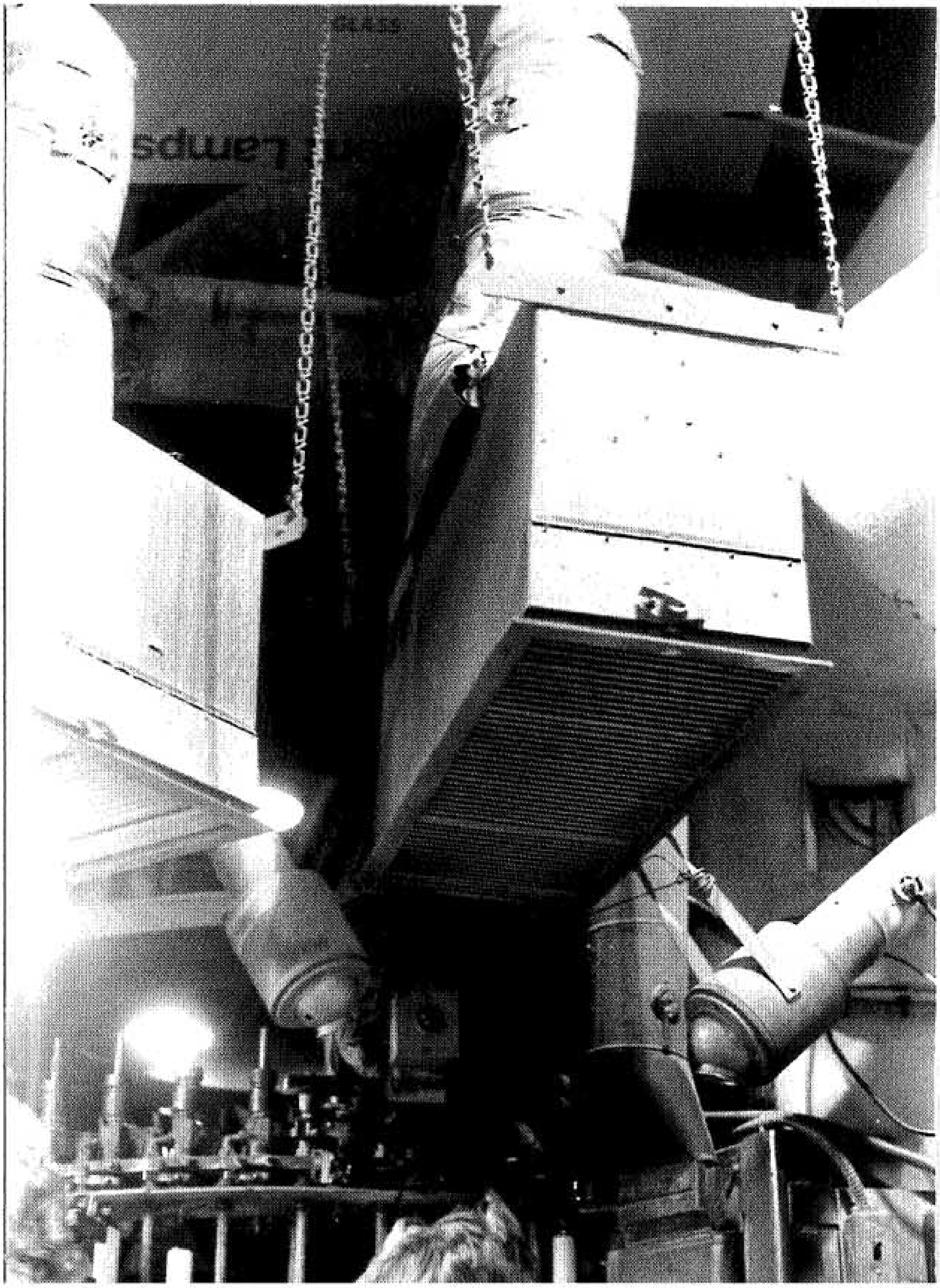

Figure 4. Local Supply Air Diffusers.

CONCLUSIONS AND RECOMMENDATIONS

Survey results indicate relatively effective control of worker exposure to mercury at the facility. Problem areas have been identified by plant management, and continued efforts are underway to improve the situation in these areas. The ventilation systems were found to be functional and operating well. Medical surveillance at the plant was adequate, and an appropriate set of contingencies for dealing with high urine-mercury levels is in practice.

Problem areas at the plant include the pill manufacturing area and the vertical machine manufacturing area. Direct reading mercury vapor samples in these areas showed some values above 0.1 mg/m^3.

Examination disclosed visible liquid mercury on the floor and on the equipment in the problem areas. Housekeeping practices should be improved in these areas. Plant representatives are investigating the use of several cleaning agents (degreasers) for these areas, and have not yet found an acceptable substitute for chlorothene. Additional control measures that are recommended include:

- instituting a routine personal monitoring program to determine TWA exposure to mercury vapor
- ensuring that fresh air ducts at the vertical machine work stations are directed at employees' breathing zones
- investigating the use of mercury pills in the vertical machine manufacturing process.

The effectiveness of the mercury pills in reducing both mercury vapor concentrations and contact with liquid mercury is demonstrated by the survey data, plant monitoring records, and general observations. This control was instituted primarily for its cost-effectiveness and has resulted in significant savings through the reduction in mercury consumption and mercury waste. This control also is applicable to other fluorescent bulb manufacturers; however, it is not easily adaptable to other industries.