FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

General Electric Company
Circleville Lamp Plant
Circleville, Ohio

Preliminary Survey Report
for the Site Visit of
October 6, 1981

Contract No. 210-81-7107

February 19, 1982

Submitted to:

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REPORT NO.:
ECTB 109-18a

FOREWORD

A Control Technology Assessment (CTA) Team consisting of members of the National Institute for Occupational Safety and Health (NIOSH) and Enviro Control, Inc. (ECI) met with representatives of the General Electric Company, Circleville Plant in Circleville, Ohio on October 6, 1981 to conduct a preliminary survey on the techniques used to control worker exposure to mercury. Participants in the survey were:

Enviro Control, Inc.

Donato Telesca, Program Manager
David D'Orlando, Engineer
Robert Reisdorf, Industrial Hygienist

National Institute for Occupational Safety and Health

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Arnold Rathje, Group Industrial Hygienist
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John Raterman, Manager of Manufacturing Engineering
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The preliminary CTA survey was completed in one day. The study included a review of the fluorescent lamp manufacturing process, a tour of the production facility, and an investigation of engineering controls, work practices, and monitoring programs.

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INTRODUCTION

CONTRACT BACKGROUND

The Mercury Control Technology Assessment Study has been initiated to assess the current technology used to protect the worker from exposure to hazardous levels of mercury. The objective is to identify and evaluate the exemplary 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 of controlling emissions and exposures. This report will be available to companies which handle mercury to transfer technology within the major mercury using industries. The study will also identify directions where additional research is necessary.

JUSTIFICATION FOR PRELIMINARY SURVEY

Preliminary surveys are intended to generate information about the control strategies used at various facilities and they will be used to determine where in-depth surveys will be conducted. The General Electric Circleville Lamp Plant was selected for a preliminary survey because of the controls in effect to protect the worker from exposure to mercury vapor. The concern for worker protection at this plant has resulted in a continuous effort to maintain control of mercury vapor through ventilation and process equipment modifications.

SUMMARY OF INFORMATION OBTAINED

An opening meeting was held during which the objectives of the program were discussed with plant representatives. Information on the construction and operation of fluorescent lamps was obtained and a detailed process tour was given to the members of the survey team. The plant's engineering controls were reviewed and a diagram of process equipment showing these controls was supplied. Discussions were held on air and health monitoring, work practices and personal protective equipment in effect at the plant.

PLANT DESCRIPTION

The major products produced at the G.E. Circleville, Ohio facility are straight, U-shaped (Moduline TM), and circular (circline) fluorescent lamps. These lamps are manufactured in different sizes and some types are available in several shades or colors. The facility is an assembly plant which uses materials produced at sister plants in other locations.

The plant has been in operation since 1948. It currently occupies an area of 600,000 ft^2. The production buildings are constructed of tile block and brick with wood ceilings. Building A (Figure 1), which is part of the original facility, has roof exhaust fans and air supply vents along the walls of the entire length of the building. The first plant expansion, Building C, was made in 1958. The second major expansion, on Building C, was made in 1966. Both of the expansions had ventilation similar to that of the original facility. Major mercury control renovations were made 8 to 10 years ago. A direct expenditure of approximately $400,000 was made on an additional air supply system, draft hoods, and process equipment modifications.

Production is conducted on all three shifts, but primarily on first and second shifts. Maintenance and clean-up is performed on third shift. There are 20 workers considered to be exposed daily full time and 10 workers periodically exposed to mercury during maintenance and clean-up.

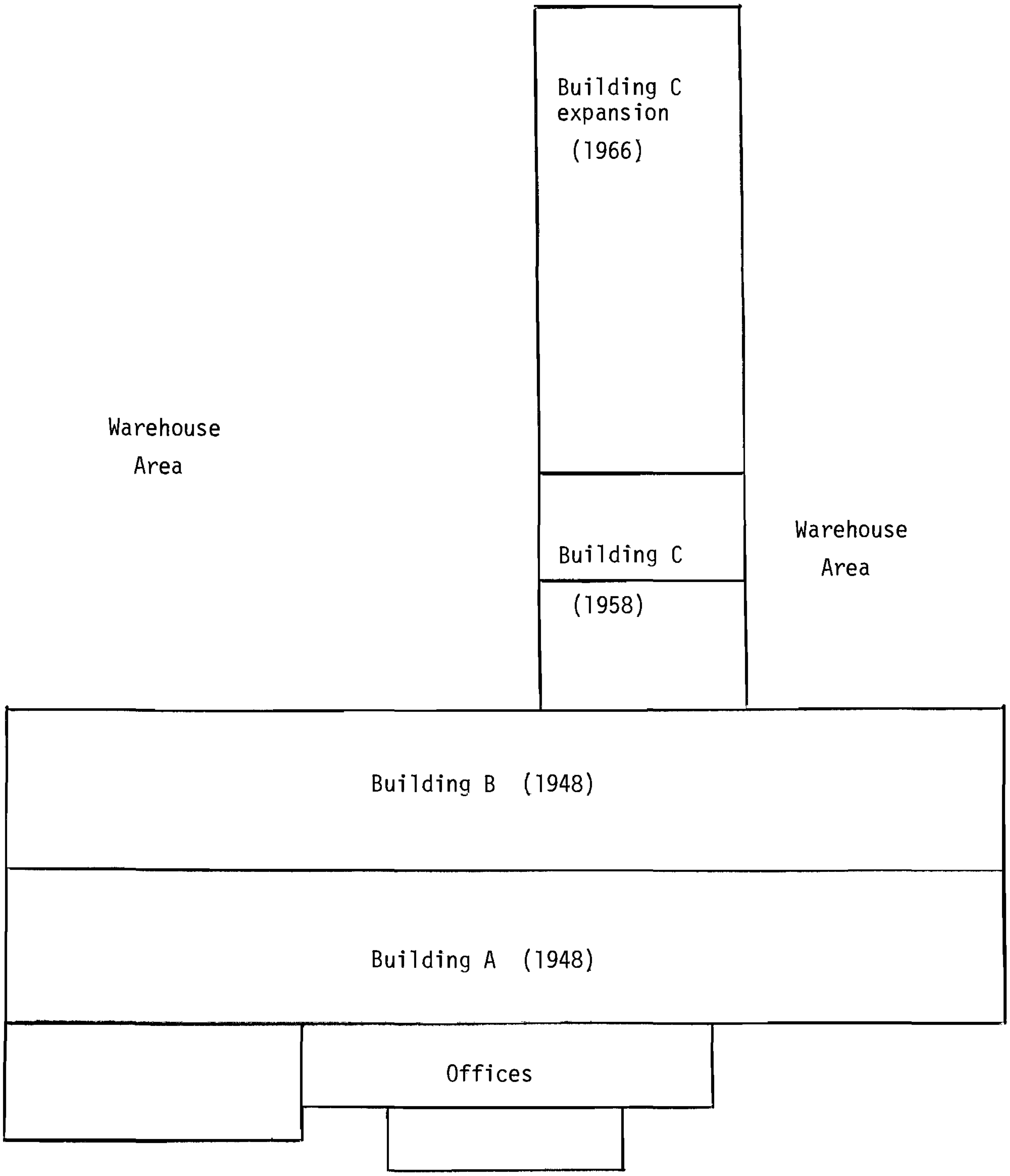

Figure 1. G. E. Circleville Lamp Plant Layout

PROCESS DESCRIPTION

TUBE COATING

Glass tubes for the fluorescent lamps arrive at the plant pre-cut and are loaded onto a coating machine. Each tube goes through the following process sequence inside of the machine.

- A monogram is printed and fired into the tube.
- The tube is washed to remove impurities.
- The tube is dried with hot air.
- A liquid coating (phosphor in a liquid suspension) is poured through the tube, uniformly coating the inside.
- The tube is heated to dry the coating

The tube is then loaded horizontally into a Lehr oven where coating additives and impurities are evaporated. This results in a fine layer of phosphor compound on the inside of the tube.

MOUNT ASSEMBLY ATTACHMENT

The mount is a glass piece used to contain the lead wires plus cathode. The assembly consists of a flared funnel-shaped piece of glass with an "exhaust tube" running through the middle of it. Attached to the exhaust tube are two lead wires. The spiral wound cathode wire is attached between these two wires. Lead wires are nickel plated and are bimetallic where fused to the glass.

Mount assemblies are attached to both ends of the glass tube by heat sealing the flared ends of the mount to the perimeter of the tube.

MERCURY INJECTION AND TUBE EXHAUSTING

The function of mercury vapor in a fluorescent bulb is to emit ultra-violet light at a wavelength of 2537 Å when excited by an arc developed between the hot cathodes mounted at each end of the tube. The phosphor coating on the interior of the tube converts the ultra-violet light to visible light.

Mercury is injected into the lamp tube on the Exhaust Machine. The Exhaust Machine is a multi-stationed unit in which tubes are exhausted, filled, and sealed. The operating sequence of the machine is as follows.

- Each lamp tube is mounted vertically onto the machine.
- The bottom exhaust tube is heat sealed and the excess glass is removed.
- Air is removed from the lamp tube through the top exhaust tube.
- The lamp tube is heated in an oven.
- The cathodes in the bottom and the top of the lamp tube are heated by putting a current through them.
- A piston type doser introduces a drop of mercury into the tube (The piston is lifted into a mercury reservoir by a solenoid activated magnet where it receives a mercury dose, and then falls to deliver it to the lamp tube).
- The mercury drop falls to the bottom of the lamp tube and vaporizes when it reaches the hot cathode, causing the tube to glow with a bluish color.
- Additional vacuum is drawn in the tube by a mercury diffusion pump.
- The tube is filled with low pressure Argon.
- The top exhaust tube is sealed closed and tipped off. The tips fall through a chute and drop into a water-filled waste container.
- The tube is removed from the machine.

BASING

Lamp tube bases, consisting of metal caps with leads, are attached to the lamp tube ends on the Basing Machine.

SEASONING, TESTING, AND PACKAGING

The completed lamps coming off of the Basing Machine are coated with a layer of silicone in order to keep moisture and dust off. Each lamp is "seasoned" and tested by automatically lighting the lamp. Lamps are packaged in preparation for shipping.

MERCURY CONTROL STRATEGY

ENGINEERING CONTROLS

Engineering controls at the G.E. Facility have been designed with three major goals in mind:

- -reducing mercury vapor levels in the work environment.
- -reducing operator exposure to the mercury present.
- -removing operators from the mercury exposure areas.

Air Supply

Original Air Supply System--
A major air supply system was built into each fluorescent lamp production building (Buildings A and C) to provide the dilution ventilation necessary to control mercury vapor during production of fluorescent lamps.

Building A has three 152,000 cubic feet per minute (cfm) units and one 128,000 cfm unit (Figure 2). The intakes for these units are located on the roof between Buildings A and B. Below each intake is a blower room with a set of filters through which the air is drawn. The supply air from each unit splits so that one half flows through vents along the wall between Buildings A and B and the other half flows through a tunnel to the other side of Building A where it is also distributed through wall vents. Wall vents from the four supply units extend the entire length of the walls on both sides of Building A.

Building C has two 105,000 cfm supply units, two 289,000 cfm units, and two 198,000 cfm units. These units are similar to those in Building A except that the intakes are on the sides of the building, thereby eliminating the need for a ventilation tunnel.

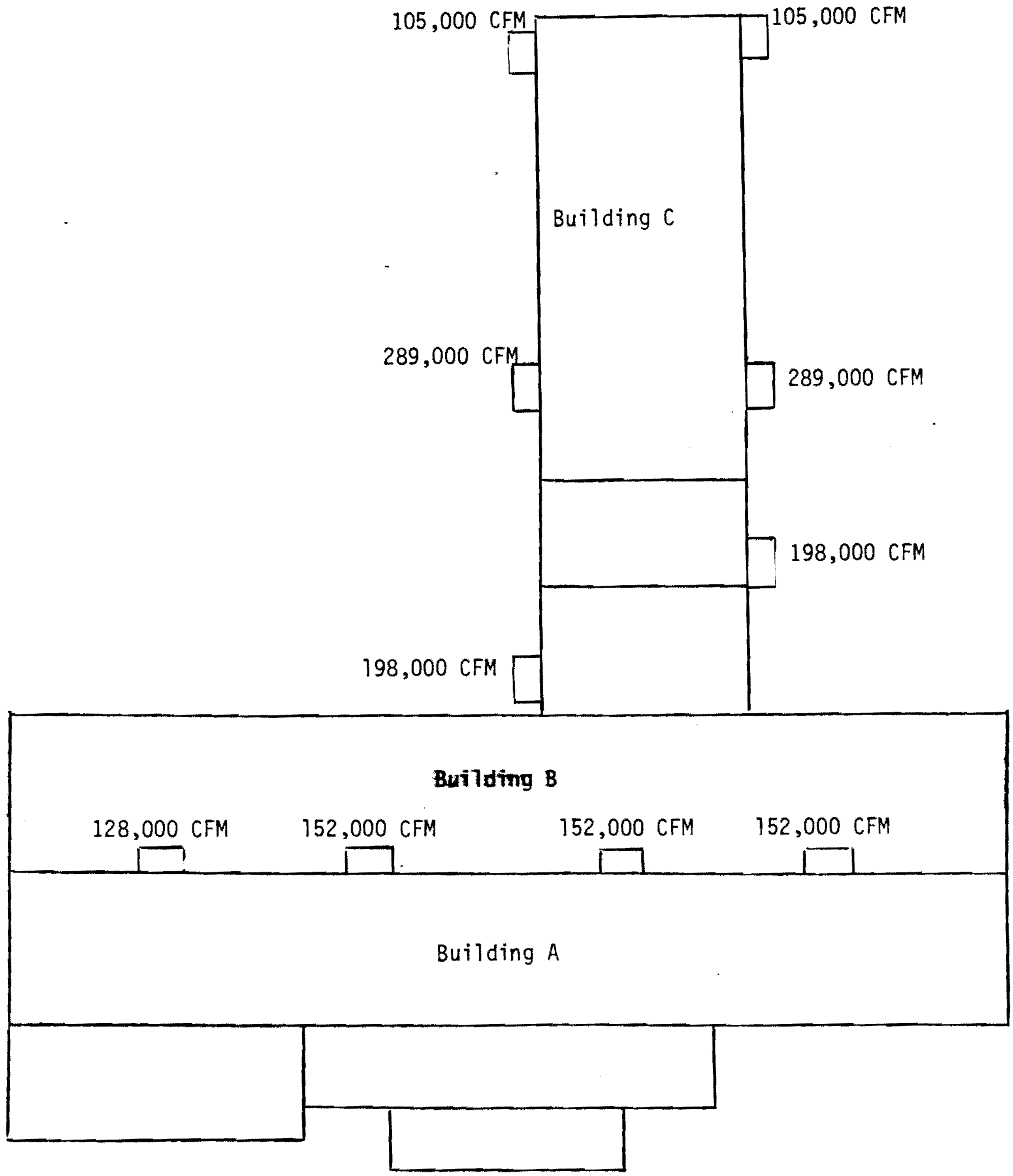

Figure 2: Plant Layout Showing Air Supply System Intakes.

Local Fresh Air Supply System--

A local fresh air supply system was installed in Building A in 1972 at a cost of $80,000. This system supplies dilution air to work stations which typically have higher concentrations of mercury vapor associated with them (Figure 3). Examples of these areas are the tip-off area on the Exhaust Machine and the loading area at the Basing Machine. The Basing Machine area has a potential for somewhat elevated mercury vapor concentrations because of its proximity to the Exhaust Machine. The local air supply is designed to reduce the exposure of the operator working at this station.

Air Exhaust

Original Air Exhaust System--

A major air exhaust system was built into each fluorescent lamp production building. Building A has thirty-six 18,000 cfm (design) exhaust fans located along the length of the roof. Building C has 23 exhaust fans. Information on the capacities of these fans was unavailable. The exhaust fans, coupled with the wall vent air supply described previously, provide dilution air flow from the sides of the buildings up through the center of the ceiling. Exhaust fans are operated according to the number of production groups which are running at a particular time. This exhaust fan schedule minimizes the loss of heated air in the winter. In the summer, all of the exhaust fans may be operated at the same time. The production buildings exhaust more air than is supplied. The resulting negative pressure causes additional air to be drawn into the production building from the warehouses.

Draft Hoods--

In 1978, G.E. installed Fyrepel shrouds over Exhaust Machines in the area where 8' lamps are produced (Figure 4). The total cost of this installation was approximately $20,000. The shrouds are similar to large exhaust ducts leading from above the machines to certain roof exhaust fans. They create a chimney effect which directs the exhaust air flow from the points of mercury vapor and heat generation to the roof exhaust fans.

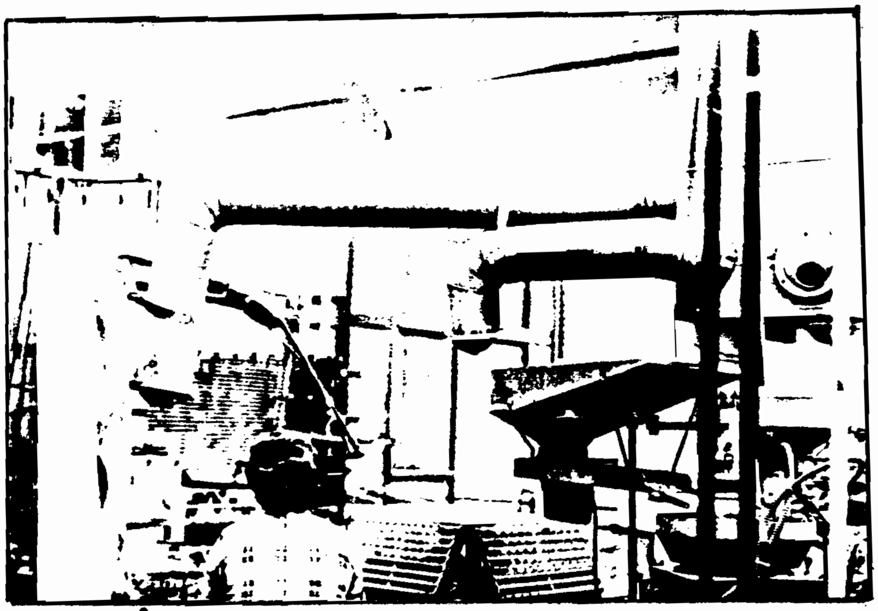

Figure 3. Local Fresh Air Supply

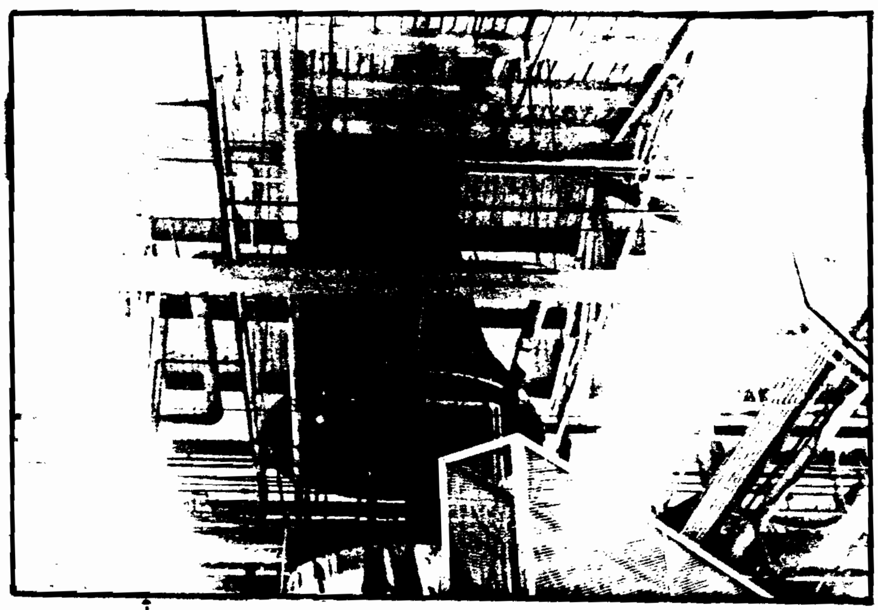

Figure 4. Shrouds Over Exhaust Machine

Process Modifications

Tube Catchers--

The highest potential emission of mercury vapor is the Exhaust Machine station at which the exhaust tubes are sealed closed by flame and the hot glass tips are discarded. These hot glass tips, and the compression holders which hold them in place through the vacuum sequences on the machine, may contain mercury. In 1975, G.E. installed new more efficient "tube catchers" to remove and contain the mercury-containing glass tips. The estimated cost of this process modification was $80,000. The tube catcher is a mechanically operated movable chute which, when activated in sequence, reaches up and out from the center of the Exhaust Machine and catches the hot glass tip which is released from the compression piece after the exhaust tube is sealed. The tip falls through the chute into a disposal container (Figure 5). A water level is maintained in the container to reduce mercury vaporization. The waste glass is disposed of by an outside contractor and the mercury is reclaimed from the water by plant personnel.

Nitrogen Blow and Extended Compression Holder--

In 1975, a nitrogen blow system and extended compression holders were installed on each Exhaust Machine at a total cost of approximately $10,000. The extended compression holder is a special silicone rubber seal used to connect the exhaust tube of the lamp to the mercury diffusion pump. It forms an effective seal for the vacuum at high temperatures. The nitrogen blow system was designed to clear out any residual mercury in the compression piece. As the tube catcher rises to collect the glass tip, nitrogen is injected through the tip and mercury is blown into the chute.

Tube Catcher Vacuum Traps and Air Exhaust--

In 1980, a system was installed at a cost of $20,000 to reduce mercury vapor present in the tube catching system. A local exhaust ventilation (LEV) duct, with an in-line trap (Figure 6) was connected from each tube catcher to an existing exhaust fan. This LEV maintains a negative pressure in the catcher, thereby reducing the potential for mercury vapor emission.

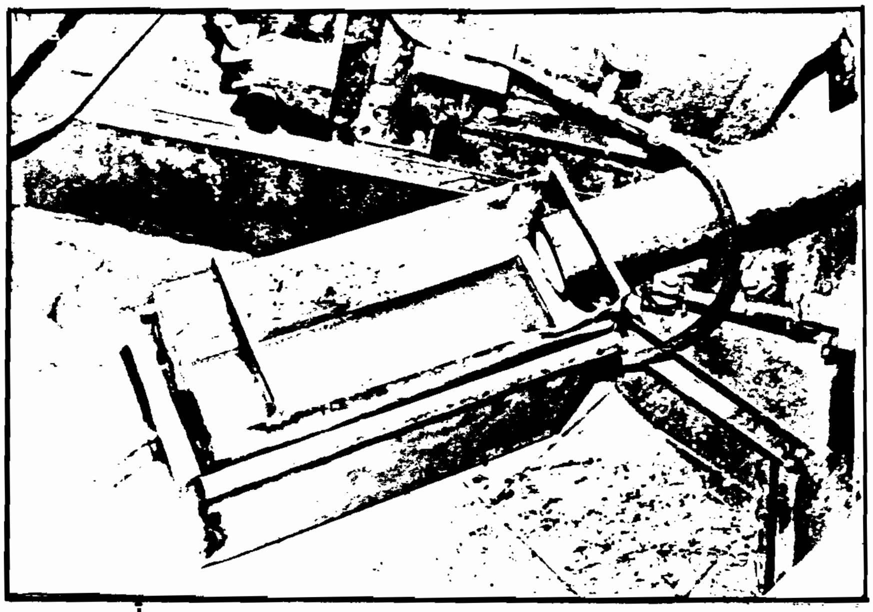

Figure 5. Tube Tip Disposal Container

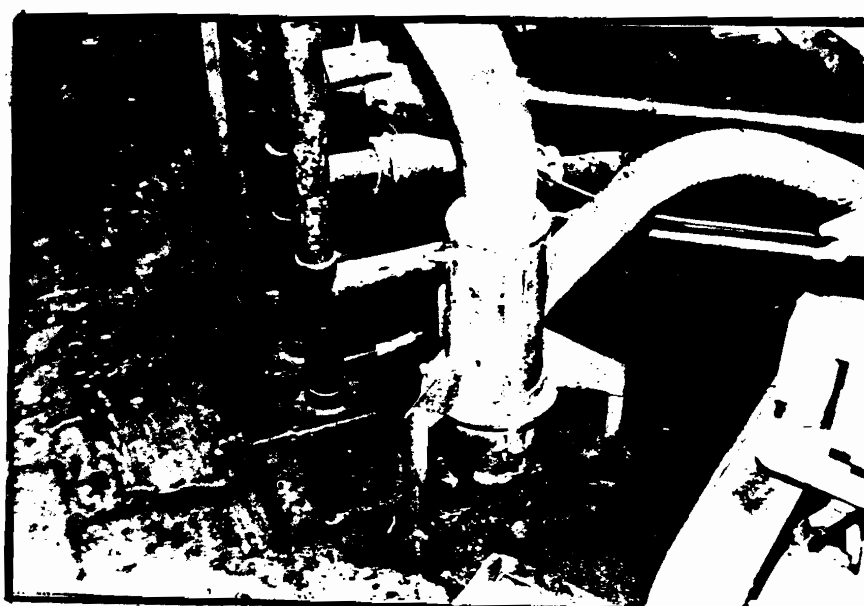

Figure 6. Tube Catcher Vacuum Trap

Exhaust Machine Load/Unload Conveyors--
In 1976, G.E. installed automatic loading and unloading conveyors for the Exhaust Machines on three lines at a total cost of approximately $140,000. This equipment eliminated the need for two operators per machine working in this higher potential exposure area.

Work Stations

Mercury Fill Station--
The mercury dosers used to introduce the mercury into the lamp tubes are cleaned and filled at a mercury fill station. The Station is enclosed in a three-sided exhaust hood with a sliding plexi-glass door (Figure 7). Other features of the work station include the following:

- a stainless steel work surface with a lipped edge to prevent mercury from falling off the bench.
- a grated section covering a sink filled with 1 to 2 inches of water. Mercury spilled during the fill process falls into this sink.
- an air supply vent at the outside of the hood to provide dilution air to the worker.

Each doser is cleaned under the hood with compressed air from a foot operated air source. Mercury is allowed to flow from a storage container through a stop cock valve and into the clean doser. The doser is capped with a rubber sealed top and is transported (in batches) to the Exhaust Machine.

Oxifying Station--
The mercury used to fill the dosers is purified through an oxification process conducted inside a three-sided hood with a plexiglass door (Figure 8). As in the Mercury Fill Station, this station has a grated section over a water-filled sink.

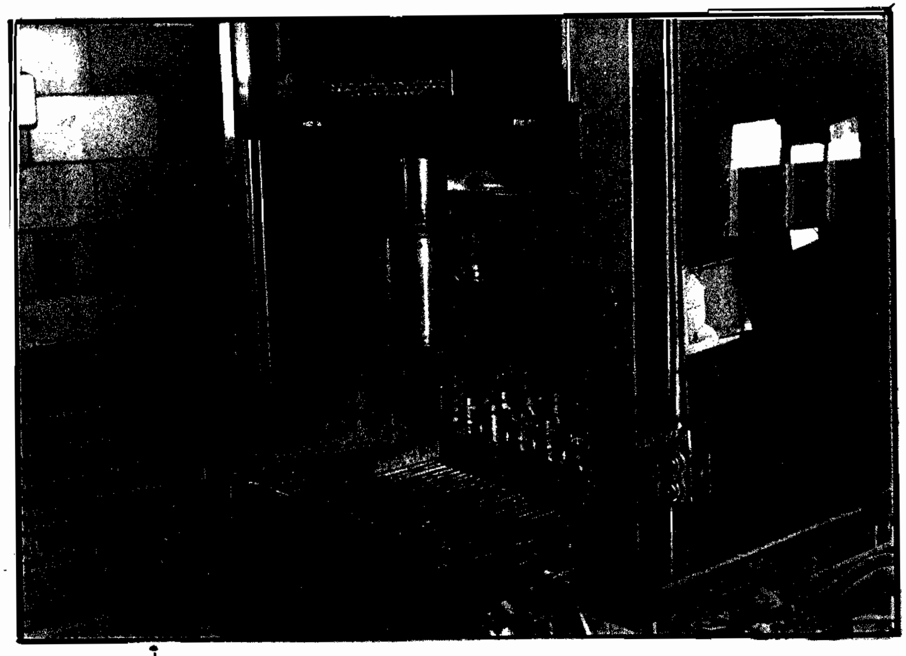

Figure 7. Mercury Fill Station

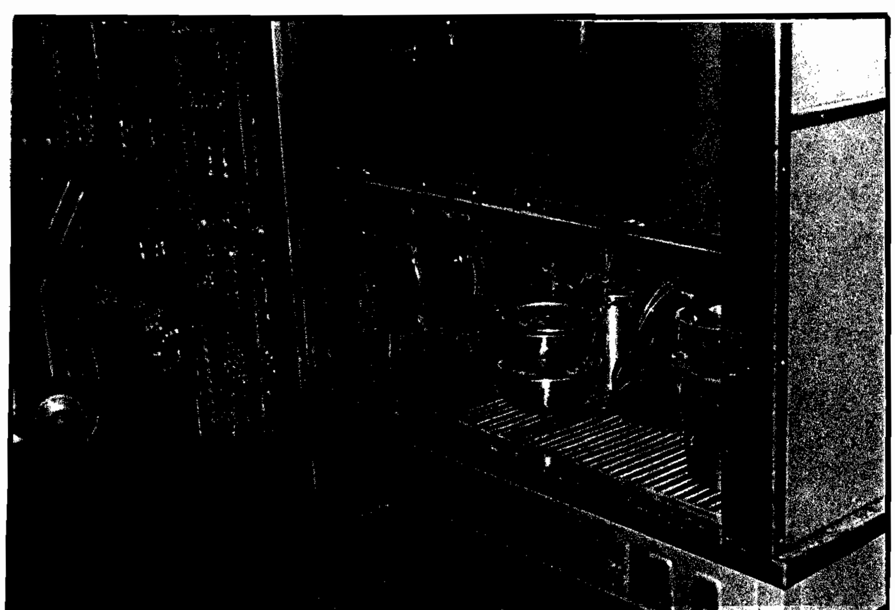

Figure 8. Oxifying Station

Glass Tube Cleaning Station--
Reject tubes which may contain mercury are washed in specially designed sinks. The tubes are put into a tray with a screened bottom and water is run over them. Water and mercury wash through the screen into a sink. Mercury settles to the bottom of the sink and is removed through a trap below.

Vacuum Cleaners

Since 1975, G.E. has purchased 10 Nilfisk vacuum cleaners specially designed for mercury use at an approximate cost of $3,000 per unit. Each cleaner has a large activated carbon filter and a mercury trap. G.E. reports that the filter medium needs to be replaced approximately every two years under routine use at this facility.

PERSONAL PROTECTIVE EQUIPMENT

Plant representatives have identified activities which have a high potential for exposure to mercury. These activities involve maintenance workers performing routine and other maintenance on the exhaust machine, especially maintenance on the pumping system and the dosers. For these activities maintenance workers wear disposable coveralls made of Dupont Tyvek®, and apply a barrier cream to their hands to reduce dermal absorption of mercury. The coveralls are changed weekly or more often if visibly contaminated. Double lockers are provided to minimize contamination of worker's own clothing.

In addition, maintenance workers wear respirators when performing activities where mercury vapor may be encountered. Air purifying, half-mask respirators (MSA Comfo-II with Mersorb® cartridge) have been used at this facility for approximately five years.

Work Practices

Practices which have been implemented at the facility to reduce worker exposure to mercury are as follows:

- Employees must wash hands or any exposed part of their body after handling mercury.
- Tobacco products must be stored in the employee's locker away from mercury contamination.
- Spills of mercury must be cleaned up immediately using a Nilfisk vacuum cleaner.
- Broken lamps are cleaned up by picking up and discarding the large broken peices and vacuuming the area at the end of the work day using the Nilfisk vacuum cleaner.
- Workers who wear respirators must take part in the respirator protection program which emphasizes the correct use and cleaning of respirators.

MONITORING PROGRAMS

Biological Monitoring

The biological monitoring program has been in effect at this facility for approximately 20 years. All mercury-exposed employees participate in the program, which includes urinalysis for mercury at least once per year. Maintenance employees are monitored on a more frequent basis. Single voiding samples rather than 24-hour composite samples are collected. Based on the results of the urine-mercury analysis, the following actions are taken by plant representatives:

- If the mercury concentration is above 0.20 milligrams per liter (mg/L), the individual's work area, working techniques, and job requirements are carefully reviewed to try to determine and minimize the source of exposure. Obtain another sample within two months.
- If the concentration is above 0.25 mg/L, the employee is counseled about his personal hygiene, use of respirators, use of barrier cream, etc. and another sample is taken within one month.

- If the concentration is above 0.30 mg/L, the procedures outlined in a and b are followed and also a medical evaluation is performed on the employee.
- If three successive samples are above 0.30 mg/L, or two successive samples are above 0.40 mg/L, repeat the medical evaluation is repeated and the employee from further mercury exposure after consulting with the Group Medical Director.
- The employee is not returned to a job involving potential mercury exposure until two successive specimens taken no less than one week apart are below 0.15 mg/L and another medical evaluation is performed with medical approval given.

Air Contaminant Monitoring

Periodic monitoring to determine the concentration of mercury vapor is conducted using a Jerome Model 401 Mercury Vapor Detector. This monitoring is conducted on a monthly basis. Comprehensive monitoring is conducted once per year. This includes personal monitoring to determine the time-weighted average exposure concentrations of mercury vapor.

CONCLUSIONS AMD RECOMMENDATIONS

Based on the information obtained on worker exposure levels, the existing control strategies appear to be effective in maintaining mercury vapor levels below the Occupational Safety and Health Administration (OSHA) standard of 0.10 mg/M^3. This has been achieved through a combined effort in providing extensive dilution ventilation, modifying process equipment for mercury control, and developing the proper work practices for handling mercury.

The recent effort (since 1975) in controlling mercury in the workplace was an aggressive attack to stop the problem at its source. The process modifications on the Exhaust Machine addressed each problem associated with hot mercury in the lamp tubes.

A significant amount of information was obtained during this preliminary survey, and it is recommended that an in-depth survey not be made at this facility. Discussions with the G.E. representatives yielded the following suggestions for additional research or information regarding mercury control technology.

- develop a small portable vacuum cleaner which would be effective in safely cleaning mercury spills.
- develop a procedure to reprocess mercury-laden oil.
- develop a comfortable and light weight powered air puirifying helmet for respiratory protection against exposure to mercury vapor.