FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

Wiring Devices of Puerto Rico
Ponce, Puerto Rico

In-depth Survey Report
for the Site Visit of
March 16-18, 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 Wiring Devices of Puerto Rico (WDPR) in Ponce, Puerto Rico, on March 16-18, 1982, to conduct an indepth survey on the techniques used to control worker exposure to mercury. Participants in the survey were:

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Robert Reisdorf, Industrial Hygienist
David D'Orlando, Environmental Engineer

<u>National Institute for Occupational Safety and Health</u>

Stephanie Spottswood, Associate Project Officer

<u>Wiring Devices of Puerto Rico</u>

Robert Schauseil, President
Jerry Morrison, Plant Manager
Solange Figueroa, Industrial Hygienist
Efraim Guilbe, Supervisor

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

CONTENTS

CONTENTS (Continued)

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 Wiring Devices of Puerto Rico (WDPR) plant in Ponce, Puerto Rico, was selected for an indepth survey because of the isolation and control techniques used in its mercury filling operation. The plant has reduced its mercury vapor concentrations by continuously implementing engineering controls and work practices specifically designed to reduce worker exposure to mercury. Almost every major method of mercury control is practiced at this facility.

SUMMARY OF INFORMATION OBTAINED

An opening conference was held during which the objectives of the program were discussed with WDPR representatives. A tour of the mercury button manufacturing operation was made, and information on mercury controls was obtained from the plant manager and industrial hygienist. Area and personal monitoring was conducted in the Mercury Fill Room. Historical information on control implementation and urine-mercury levels was obtained.

PLANT DESCRIPTION

The WDPR plant, located in Ponce, Puerto Rico, manufactures silent wall switches and other wiring devices. The wall switches contain a mercury button that is assembled at the plant. The plant, opened in 1971, occupies a building constructed of cement walls and floors and wooden ceilings. In 1976, the plant management realized that a mercury exposure problem existed and a corporate consultant was called in to solve the problem. Between 1977 and 1979, the mercury button filling operation was isolated in a separate room with a specially designed ventilation system. Local exhaust ventilation (LEV) was added to the manufacturing equipment and mercury work practices were established. Mercury vapor emissions have been controlled so that the only area of the plant where mercury exposure is a concern is the Mercury Fill Room (Figure 1).

Mercury buttons are produced in batch quantities. During operation, the buttons are manufactured two shifts a day (6 a.m. to 2 p.m. and 2 p.m. to 10 p.m.). Six operators per shift work in mercury button manufacturing; of these, only three operators per shift work in the Mercury Fill Room.

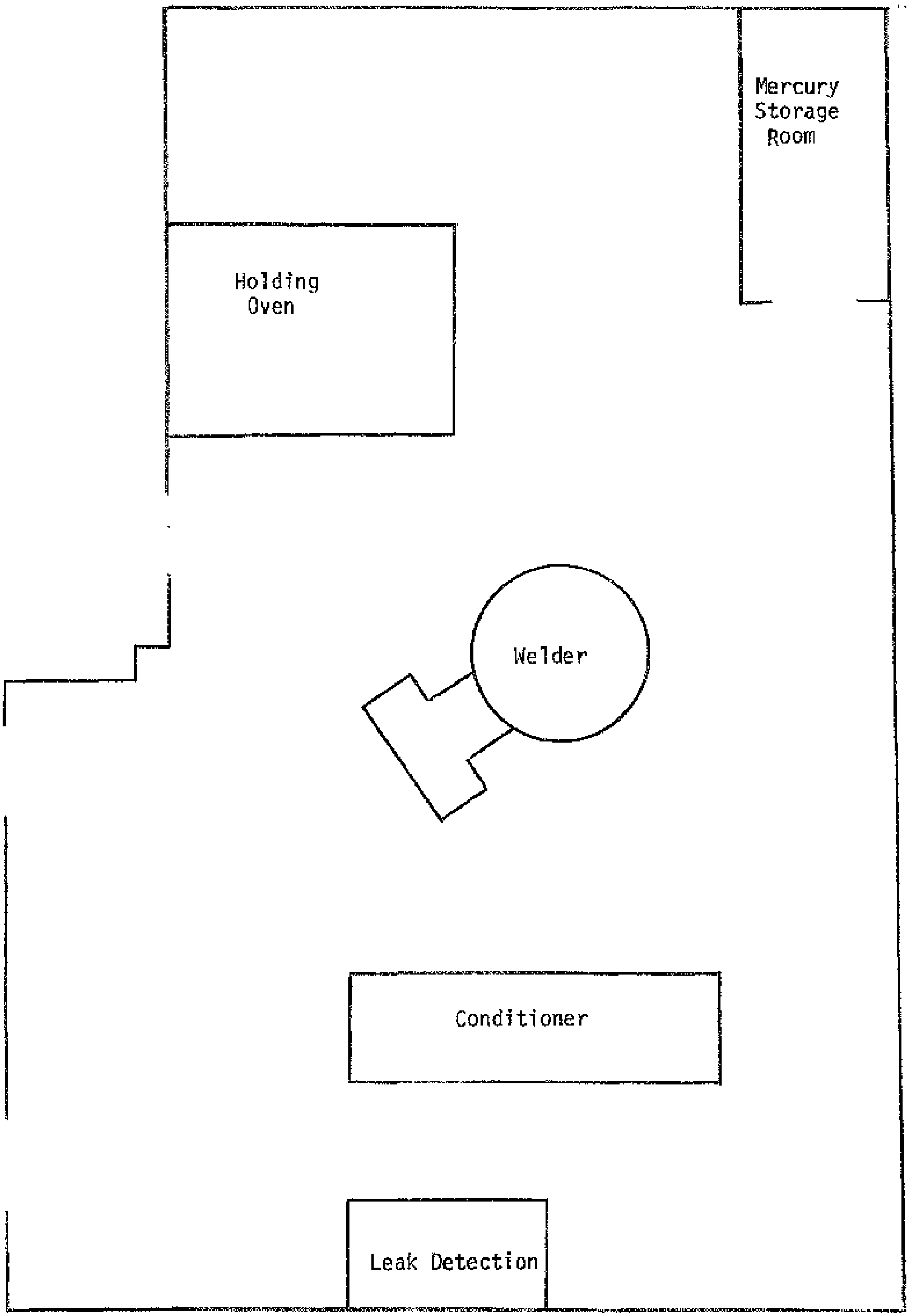

Figure 1. Mercury Fill Room.

PROCESS DESCRIPTION

Each silent wall switch manufactured at the plant contains a mercury button for use as an electrical contact. The button contains a metal shell, metal ring, ceramic center, glass preform center contact, and some elemental mercury.

All parts, with the exception of mercury, are degreased, cleaned ultrasonically, washed with acid, washed in water, dried, and stored in ovens to reduce the possibility of contamination. The metal ring, glass preform, ceramic center, and center contact are assembled on a semiautomatic loader and the subassembly is fused together in a sealing furnace. The fused subassembly and the metal can are stored in ovens in preparation for final assembly in the Mercury Fill Room.

The mercury fill operation is conducted on a rotating multistation welding machine. Metal cans are gravity fed into carrier cups on the machine. The cups rotate through several stations in which the following operations are performed:

1. Mercury is dispensed into the can.
2. The fused subassembly is manually placed in the can.
3. The carrier cup is evacuated.
4. The subassembly is welded to the can.
5. The button cell is removed from the carrier cup and deposited into a storage bin.

The completed button cell is electrically tested on a "conditioner" by rotating it for 45 seconds at 100 revolutions per minute. Cells are then 100 percent leak tested to determine the integrity of the seal on the cell. The cells are cleaned and sent to another plant for zinc plating. The cells are returned to the plant where they are used as a component for the switch assembly.

The mercury addition system is completely enclosed up to the point of insertion into the metal can. Mercury is moved through tubes from an 800-pound storage container to a 3-gallon hold tank. This is accomplished by pressurizing the container with helium at 15 pounds per square inch (psi). Mercury is released from the hold tank and dropped through a metal tube into the metal can.

MERCURY CONTROL TECHNIQUES

ISOLATION

Because of some mercury contamination during the early years of plant operation, the mercury use area has been isolated from the rest of the switch manufacturing area. There is now a separate room (Mercury Fill Room) for the mercury fill operation. The doors to this room are kept closed, and the room ventilation system is designed so that mercury vapor will not leak out into the adjacent rooms.

TEMPERATURE CONTROL

Plant management places a high priority on maintaining temperatures between 18 and 20 C (64 and 68 F) at all times in the Mercury Fill Room. Maintaining temperatures in this range lowers the vapor pressure of mercury and helps to reduce the vaporization of elemental mercury exposed to the ambient air in the process. There are four thermometers in the room, and if the temperature of any one of them is found to exceed 21 C (70 F), the operation is shut down and employees are evacuated. Air in the room is maintained at this temperature by a General Electric (GE) air-conditioner incorporated into the air handling unit. Temperature is set and monitored along with humidity on a master control panel located in the Mercury Fill Room. Plant representatives feel that temperature control is their most significant control for the prevention of worker exposure to mercury.

DILUTION VENTILATION

The Mercury Fill Room has a separate ventilation system consisting of a 5,000 cubic feet per minute (cfm) (design) air supply system and a 5,500 cfm (design) air exhaust system. The 500 cfm difference between air exhausted and supplied was designed to maintain a negative pressure in the Fill Room, preventing mercury vapor from escaping into adjacent assembly areas. Testing of air movement with a smoke tube verified that this negative pressure was being achieved.

The air supply system consists of an intake louver, a filter box, and a GE Air Handler. Air is supplied through five circular ceiling diffusers. During operating hours (6 a.m. to 10 p.m.), supply air is 100 percent outside air. The air exhaust system consists of a Powerline Fan powered by a 1.5-horsepower motor. It operates at a suction pressure of 0.25 inches of water. Air is exhausted from the room through three local exhausts (described below in the Local Exhaust Ventilation section) and five floor exhausts. The floor exhausts are rectangular ducts that extend from ceiling level to within 5 inches of the floor. The exhaust vent for the entire system is located on the roof.

To conserve energy, the ventilation system in the Fill Room is operated in a partial recirculation mode during nonproduction hours (10 p.m. to 6 a.m.). There are no workers in the room during this period, and mercury is not exposed to the ambient air. Recirculation is accomplished through the use of an exhaust vent situated at ceiling level in the Fill Room. This vent connects through ductwork to the suction side of the air handler. At 10 p.m., an automatic control system closes the outside air louver on the supply system and opens a louver between the recirculation exhaust vent and the air handler. Part of the conditioned air is now recirculated, reducing the energy costs of conditioning outside air.

LOCAL EXHAUST VENTILATION

To remove mercury vapor at its source, the plant has installed local exhaust ventilation systems at the three points in the process where mercury vapor is potentially present (Figure 2). In each case, air is pulled from the mercury source to a point away from the workers' breathing zones. All three local exhaust ventilation systems are exhausted through the room exhaust system.

Welding Machine Exhaust

A circular slot hood is used to draw air away from the mercury-containing metal cans riding in carrier cups on the welding machine. The circle is 40 inches in diameter with a 1-inch-high slot around its periphery. A 16-inch circular exhaust duct extends from the center of the circular slot hood to the exhaust network at ceiling level.

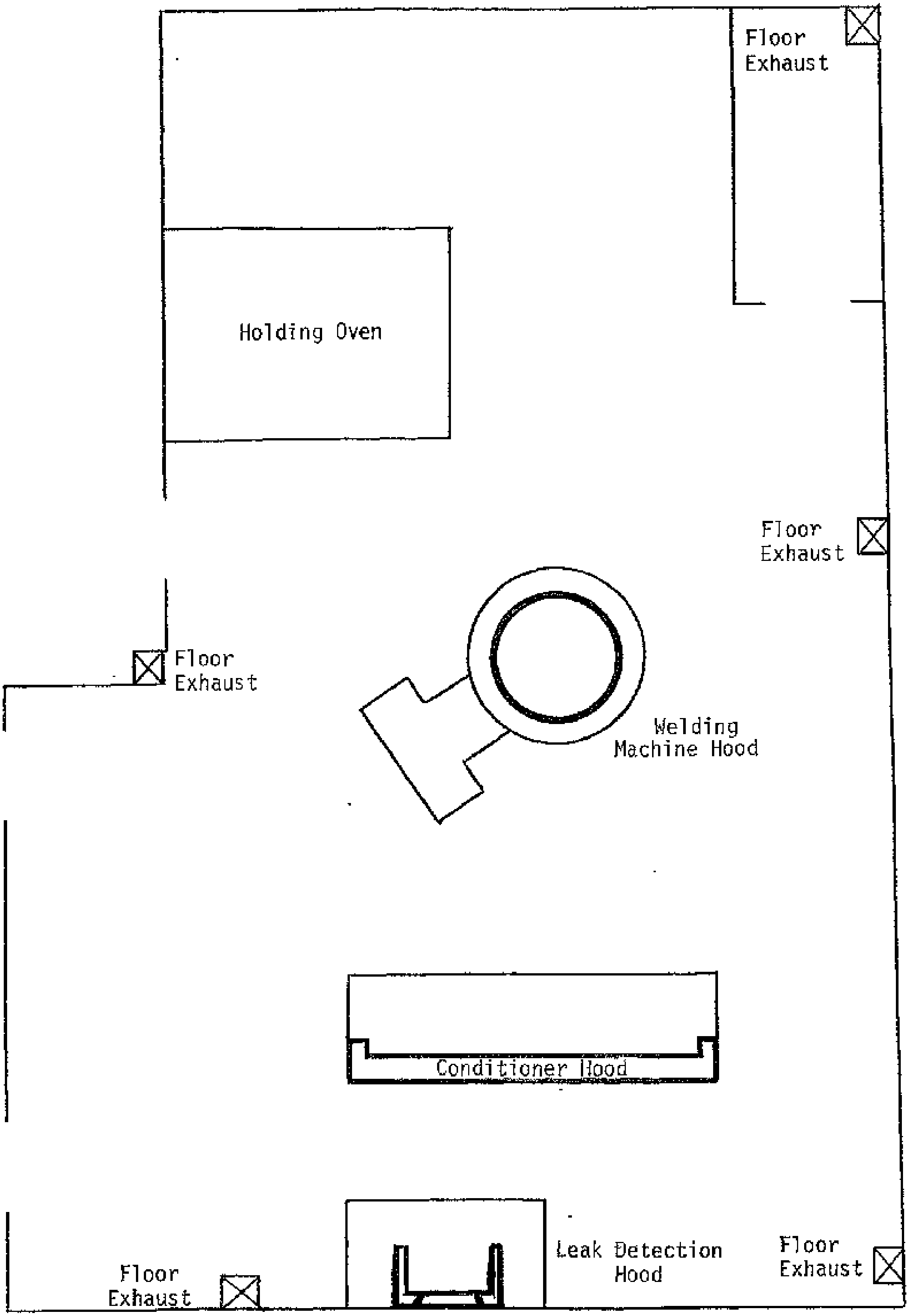

Figure 2. Mercury Fill Room Exhausters.

Conditioner (Testing Machine) Enclosure

Local exhaust is provided at the testing machine to help remove mercury vapor that may escape from leaking cells. The conditioner has a Plexiglas door that closes over the machine during testing, resulting in an enclosed operation. Air is exhausted from the front of the unit, thereby removing mercury vapor from the equipment before it can reach the operator's breathing zone. The opening of the hood is 4.5 inches high and 10 feet wide. It is situated at bench level and extends the entire length of the machine. Takeoff ducts for the hood are located at either end of the machine.

Leak Detection Hood

There is a 1-inch slot exhaust hood around three sides of the top of the tank. The slot on the back side of the tank is 14 inches long. Of the two side slots, one is 11 inches long and the other is 7 inches long. Air is exhausted through the slots and into a collection duct leading to the room exhaust system. The hood removes fumes and mercury vapor that rise out of leaky cells in the bath.

CONTAINMENT

Mercury Storage Containers

The plant has eliminated a step of mercury handling by using mercury containers designed by Bethlehem Apparatus Company. These containers (Figure 3) are made of stainless steel and are capable of holding 800 pounds of mercury. Each container is mounted in a steel frame that has welded angle-iron attachments to allow for lifting and moving by forklift. The plant receives the filled container of mercury from the supplier and puts it into service by lifting it on top of a holding frame using a forklift. The supply tube from the container is hooked up to the inlet of the mercury hold tank at the welding machine. Another tube connected to the container is hooked up to a tank of pressurized helium. By opening a valve on the supply line, mercury flows into the hold tank under the pressure of the helium.

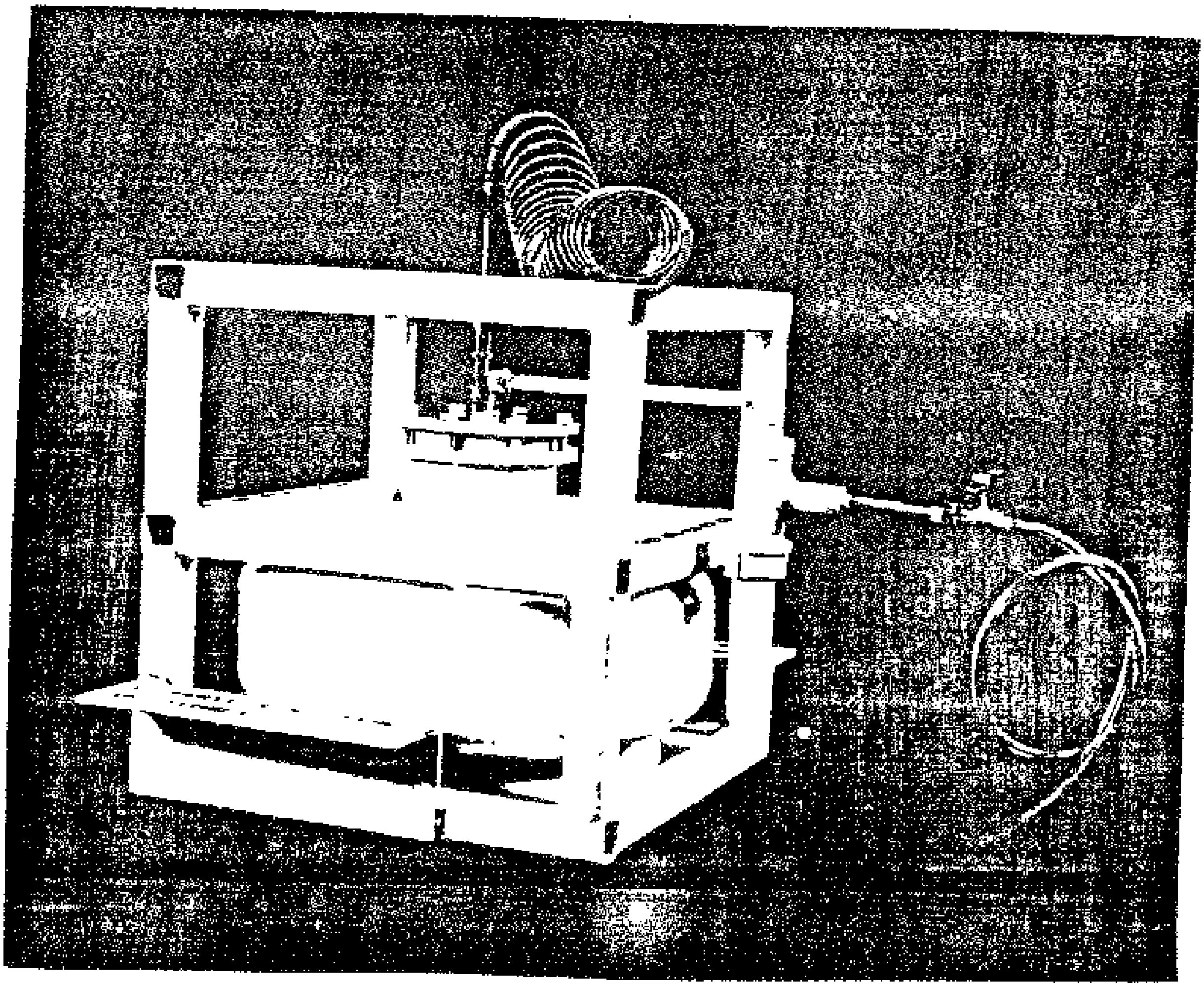

Figure 3. Mercury Storage Container.
Reference: Bethlehem Apparatus Co. photograph

The step of transferring mercury from 76-pound flasks to the hold tank has been eliminated, thereby eliminating a potential mercury vapor source. This completely contained system could be applicable to most mercury filling operations.

Mercury Vacuum Cleaner

For vacuuming of floors and work surfaces in the Mercury Fill Room, the plant uses a Mer-Vac mercury vacuum cleaner with an in-line mercury trap on the suction hose. The unique feature of the vacuum cleaner is that approximately 90 percent of the vacuum exhaust air is vented to the outside of the building through a flexible rubber hose. This reduces emission of mercury vapor in the workplace during vacuuming.

Floor Coating

The floors of the Fill Room are coated with an epoxy sealant to prevent mercury from permeating the cement. The floors are dark green to allow for easy detection of liquid mercury. The epoxy coating is also used as a coping against the walls. This creates a 1-inch lip where the floor meets the walls, thereby minimizing seepage of mercury between these two surfaces.

General Containment

Other controls used in the Fill Room for containment of mercury include the following:

- A large steel pan with a 1-inch lip situated under the welding machine to contain mercury that may fall to the floor during the mercury dispensing stage.
- Covered trash cans
- Covered product bins
- Sink traps
- Storage cabinets with doors kept closed.

PERSONAL PROTECTIVE EQUIPMENT

In the Mercury Fill Room, workers wear disposable coveralls made of Tyvek^{R} (a lightweight, spill-resistant, synthetic fabric). The coveralls are usually worn for 2 days before disposal. Disposable rubber gloves are worn by the Welding Machine Operator. A disposable respirator (3M #8707 containing iodine-impregnated charcoal as the primary adsorption medium) is used by the operator when filling the mercury dispensers on the welding machine. Operators who work in the Mercury Fill Room are not permitted to wear their work shoes home at the end of the day.

WORK PRACTICES (Including Housekeeping)

Work practices that have been implemented to reduce worker exposure to mercury vapor and liquid are as follows:

- Smoking, eating, and drinking are not permitted in the Mercury Fill Room.
- Employees must wash their hands before leaving the work area.
- Spills of mercury must be cleaned up immediately. A vacuum cleaner designed for this purpose is kept in the Mercury Fill Room.
- Floors and equipment must be washed periodically. Water or soap and water is usually used for washing.
- The two Welding Machine Operators alternate jobs so that only every other day is spent in the Mercury Fill Room.

MONITORING PROGRAMS

Biological Monitoring

Workers are monitored yearly (or more frequently if requested by the nurse or physician) to determine the concentration of mercury in their urine. Samples are usually collected during or immediately following a process run. Spot samples, rather than 24-hour composite samples, are collected. The action level, or urine-mercury concentration at which action is taken on the part of the employer, is 100 micrograms per liter (ug/L). This ususally consists of counseling the employee with regard to work practices. The urine-mercury level at which an employee may be removed from his/her job at this facility is 200 ug/L (this level was determined by the plant physician). A review of recent plant biological monitoring records showed that most employees' urine-mercury levels were 25 ug/L or lower. Analysis of samples is conducted at a corporate analytical laboratory.

Air Contaminant Monitoring

Personal and area sampling to determine the concentration of mercury vapor is conducted at this facility. Personal monitoring to determine employees' time-weighted average (TWA) exposure has been conducted for the last 3 years. Samples are usually collected once per year during a process run in the Mercury Fill Room. Personal samples are collected on Hopcalite solid sorbent tubes using sampling pumps. Recent TWA monitoring results were 0.062 milligrams per cubic meter (mg/m^3) for the Leak Detector Operator and 0.023 mg/m^3 for the Welding Machine Operator.

Area monitoring is conducted daily using a mercury vapor detector (Bacharach MV-2) at specified locations throughout the Mercury Fill Room. Mercury vapor concentrations found at the sampling locations in this room typically range from none detected to a high of 0.05 mg/m^3 (at the Welding Machine).

OTHER PROGRAMS

Medical Program

The biological monitoring program at this facility is part of a medical program and is directed by a consulting physician. The medical program includes annual physical examinations with emphasis on neurological function for workers associated with mercury. No signs of mercurialism have been detected since the program began in 1976.

Training Program

Employees are trained in the handling and use of mercury before starting a job in the Mercury Fill Room. Training is reemphasized whenever a worker's urine-mercury concentration exceeds 100 ug/L.

SURVEY DATA

Grab sampling using a mercury vapor detector (Jerome Model 401) was conducted during the survey. The areas sampled and the results are shown in Table 1. These results represent the concentration of mercury vapor at the instant that the samples were taken. Periodic fluctuations in concentrations are not reflected in these results.

TABLE 1

Grab Sampling Results Using Jerome Model #401 Mercury Vapor Detector

(3/16/82 - 3/17/82)

Area	Average Concentration of Mercury Vapor (mg/m^3)
Welding Machine	0.040 (2)*
Conditioner	0.024
Inspecting Bench	0.025
Mercury Storage Room	0.020 (2)
Near Holding Oven	0.034
Switch Assembly Line (outside Fill Room)	0.006
Tumbling Machine (outside Fill Room)	0.022
Welding Machine Operator (BZ)**	0.036 (2)
Background (3 ft from Welding Machine Operator)	0.018 (3)
Leak Detector Operator (BZ)	0.024 (2)
Background (3 ft from Leak Detector Operator)	0.016 (2)
Wash-up Area	0.033 (2)
Subassembly Area	0.008

*Number in parentheses indicates number of samples taken.

**BZ = Worker's breathing zone.

Results show that most areas sampled had mercury vapor concentrations below 0.03 mg/m^3. Exceptions to this were the welding machine area and the breathing zone concentration of the Welding Machine Operator. Background concentrations at approximately 3 feet away from the Welding Machine Operator were consistently lower than breathing zone concentrations, indicating possible contamination of this employee's clothing.

Results of sampling to determine TWA concentrations are presented in Table 2.

TABLE 2

Daily TWA Concentrations of Mercury Vapor

Employee/Location	Concentration of Mercury Vapor (mg/m^3)	
	3/17/82	3/18/82
Welding Machine (backside)	0.005	0.010
Welding Machine (above process)	0.014	0.014
QC Area Table (near leak detector)	0.009	0.010
QC Area (near conditioner)	0.017	0.007
Near Mercury Storage Area	0.010	0.012
Welding Machine Operator A (personal sample)	0.046	--
Leak Detector Operator A (personal sample)	0.060	0.010
Welding Machine Operator B (personal sample)	--	0.048

Area concentrations of mercury vapor ranged from 0.005 mg/m^3 to 0.017 mg/m^3 throughout the Mercury Fill Room. Personal TWA exposures to mercury vapor ranged from 0.046 to 0.048 mg/m^3 for Welding Machine Operators and 0.01 to 0.06 mg/m^3 for the Leak Detector Operator. The Permissible Exposure Limit (PEL) set by the Occupational Safety and Health Administration (OSHA) for mercury vapor is 0.1 mg/m^3 (as a TWA).

Both grab sample and TWA sample results show that employee personal exposure to mercury vapor was higher than corresponding area samples (taken in the vicinity of the employee but not in the employee's breathing zone). Disparity between personal sample concentrations and concurrent area sample concentrations is not uncommon in industries that use inorganic mercury. The differences may reflect a "microenvironmental" exposure to mercury vapor, presumably from contaminated clothing or hands (1).

This difference may be further demonstrated in a comparison between the personal exposure of Leak Detector Operators over the 2 days of the survey. On the first day of sampling, the worker was wearing the same disposable uniform that was worn on the previous day. On the second day of sampling, the operator wore a new uniform. Exposure on the second day was 0.010 mg/m^3 compared with 0.060 mg/m^3 on the first day.

LOCAL EXHAUST VENTILATION STUDY

Velocity measurements using an Alnor velometer were conducted on the local exhaust ventilation on the welding machine. The average velocity through the segmented circular slot was found to be 1,500 feet per minute (fpm), which indicates an exhaust airflow of 1,300 cfm. Contaminant capture distance measured using a smoke tube shows effective capture across all of the carrier cups on the welding machine.

The average velocities through the three slots on the leak detector exhaust were measured at 1,150, 2,100, and 1,100 fpm. These velocities indicate airflows of 55, 200, and 85 cfm through the slots, which result in a total exhaust airflow of 340 cfm from the unit. Contaminant capture, as measured by a smoke generation tube, indicates effective control of contaminants coming off of the leak detector equipment.

(1) Stopford, Woodhall, M.D., S. Bundy, L. Goldwater, J. Bittikofer. Microenvironmental Exposure to Mercury Vapor. American Industrial Hygiene Association Journal (39) May 1978.

CONCLUSIONS AND RECOMMENDATIONS

The results of air sampling conducted during the survey as well as the plant's historical air sampling records show that the PEL set by OSHA of 0.1 mg/m^3 (as a TWA) is not being exceeded. It is difficult to identify the control that contributes the greatest to this achievement due to the multifaceted control approach taken at the plant. The most important principles of mercury control are all practiced at this facility. These include temperature control, movement of large volumes of air through the workplace, removal of mercury vapor at its source, enclosure and containment of mercury, isolation of the mercury workplace, worker rotation at the point of highest exposure, and sound mercury work practices. All of these methods would be applicable for many operations involving a mercury fill process.

Survey data suggest that personal exposure to mercury at this facility is due in part to contaminated clothing. The exposure could be reduced to even lower levels if workers adhered more stringently to work practices and changed disposable clothing more often.

The mercury control strategy at this facility is an excellent model of an integrated mercury control program. It is a good example of a plant that previously experienced a mercury contamination problem and implemented a methodical plan for resolving it.