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FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

Jay Instruments and Specialties Company
Cincinnati, Ohio

Indepth Survey Report
for the Site Visit of
March 4-5, 1981

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 the Jay Instruments and Specialties Company in Cincinnati, Ohio, on March 4 and 5, 1981, to conduct an indepth survey on the techniques used to control worker exposure to mercury. Participants in the survey were:

Dynamac Corporation

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

National Institute for Occupational Safety and Health

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Jay Instruments and Specialties Company

Robert Kreutz, President
William Farmer, Thermometer Manufacturing Supervisor
Jaynee Keuffer, Foreman
Patricia Colier, Thermometer Production Worker

The indepth CTA study was conducted over 2 days. The study included a process tour, review of mercury controls, interviews with personnel, instantaneous sampling, area and personal monitoring, and ventilation flow measurements.

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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

Indepth surveys are intended to generate information about specific control systems that are believed to be effective in controlling worker exposure to mercury based on preliminary surveys or other studies, design descriptions, operating parameters, and quantitative evaluations.

The Jay Instruments and Specialties Company (Jay Instruments) was selected for an indepth survey because this plant has developed a mercury control program to reduce previously high exposures to mercury by incorporating both engineering and administrative controls.

PLANT DESCRIPTION

Jay Instruments is a small manufacturing facility located in Cincinnati, Ohio. The major products manufactured at this plant include industrial items and mercury-filled instruments (thermometers, barometers, manometers, and absolute pressure gauges).

The mercury-filled products are manufactured in the Thermometer Department, which is isolated from the rest of the plant. This department is divided into two major areas (Figure 1):

1. Tube Fabrication Area
2. Assembly and Storage Area

The Tube Fabrication Area contains two rooms: the Glass Forming Room (Glass Room) and the Mercury Filling Room (Fill Room). The Fill Room is a separate room within the Glass Room. The Tube Fabrication Area has a ventilation system that is separate from that of the Assembly and Storage Area.

The Assembly and Storage Area is separated from the Tube Fabrication Area by a partial wall that rises to within 18 inches of the ceiling. The Assembly and Storage Area contains the thermometer and barometer assembly benches, an inspection station, storage shelves, a darkroom (no longer in use), a shipping and receiving area, loading dock, and foreman's office. A large door connects this area to the rest of the building.

Major renovations to the facility were made in 1977 following evaluations of mercury vapor levels. These included the erection of the partial wall, the installation of ventilation controls, process equipment renovations, and work station modifications.

The plant operates one shift per day, 5 days per week. There are 30 production workers and 10 administrative, management, and engineering per-

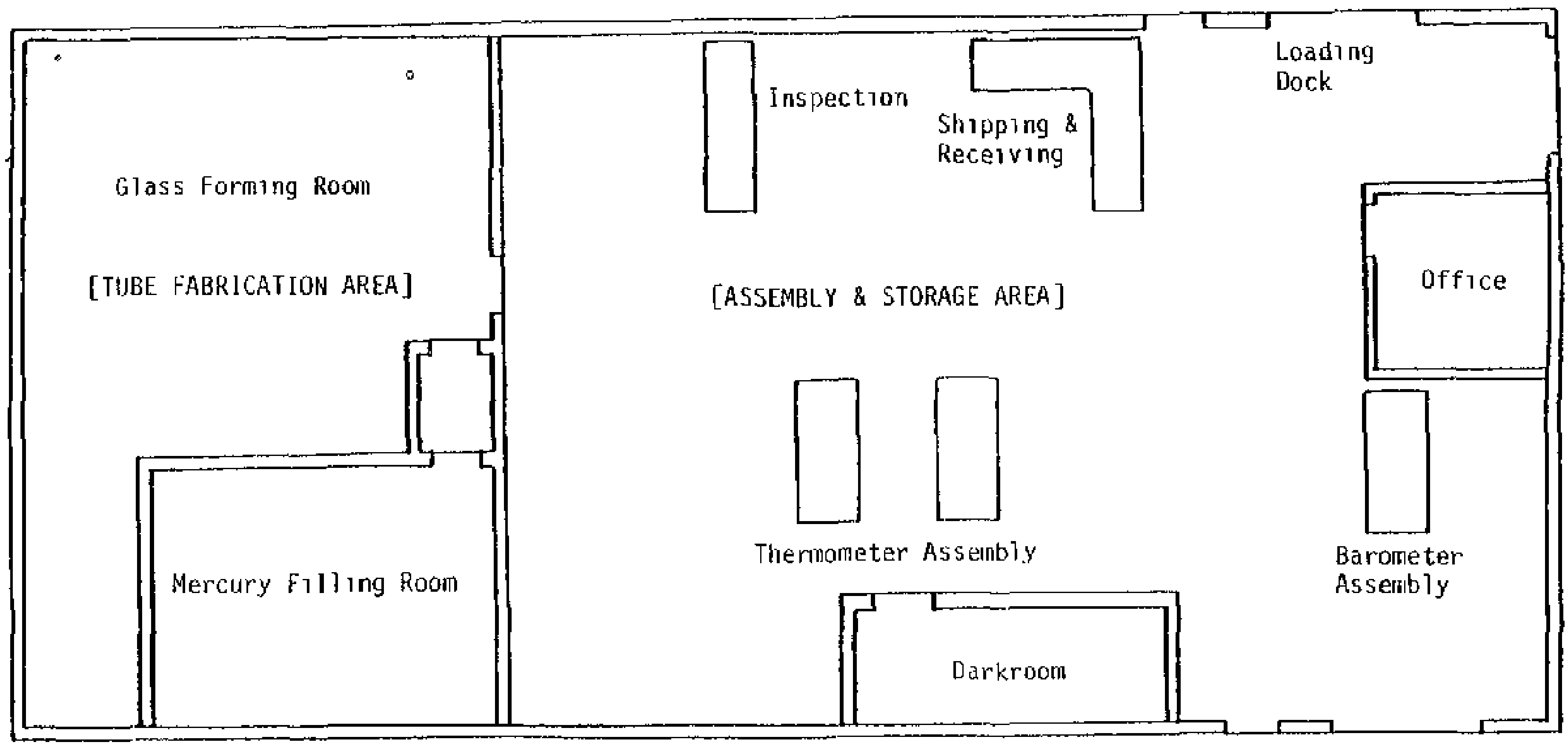

Figure 1. Layout of the Thermometer Department.

sonnel. Eight persons work in the Thermometer Department, including two who work in the Vapor Dial Room where mercury or mercury-containing products are not used. Four persons work in the Assembly Room where closed thermometers are handled. Two persons work in the Glass Room and adjacent Fill Room where both liquid mercury and "open" thermometers are handled.

PROCESS DESCRIPTION

Thermometers and other mercury-filled instruments are produced in job order lots. Since all the mercury-filled instruments are manufactured in a similar way, this process description is presented with an emphasis on the production of thermometers.

TUBE FABRICATION

Tube Preparation

The tube fabrication process (Figure 2) begins with the cutting of glass tubes into 12- or 15-inch lengths from a 54-inch cane of Corning glass. The canes are delivered in batches having bore holes within a specified range. Bore hole size is measured in terms of the length (in millimeters) that a specified amount of mercury occupies within each glass tube.

Mercury is introduced into the tube which is to be tested, and a small amount of nitrogen gas is used to force the mercury down into the tube. The resulting length of the line of mercury is used to classify the bore hole sizes so that they can be matched with metal bulbs of the correct size.

Metal bulbs, with an attached capillary extension approximately one-eighth inch in diameter, are cut to a size determined by the bore size of each tube. One assembly is fused to one end of each glass tube. The tubes are grouped in batches of 50, and are heated in an oven for 2 hours in preparation for mercury filling.

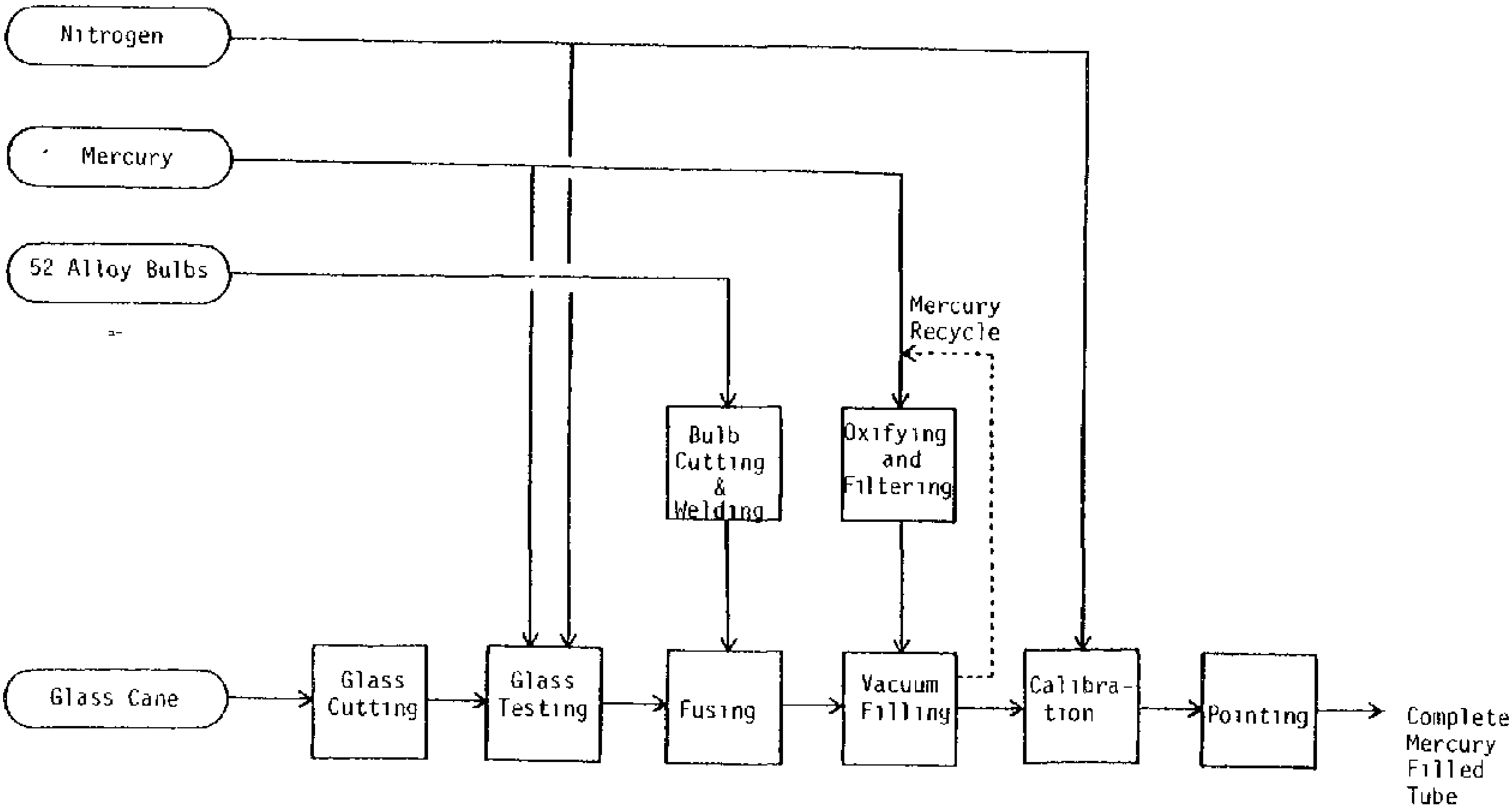

Figure 2. Tube Fabrication Process.

Mercury Filling

The batch of tubes is placed vertically in a high-sided pan that is set into the lower portion of a vacuum chamber. A valved gravity-feed container (couplet) is placed over the vacuum chamber and is clamped in place. When the valve is shut, this couplet acts as a seal over the tubes inside the vacuum chamber. A vacuum is then drawn overnight.

The following day, 40-50 pounds of mercury are poured into the couplet and allowed to enter the evacuated chamber. The pump is turned off. As air enters the chamber, mercury is forced up into the tube assembly. The couplet is removed and mercury is brushed off of it. The pan of tubes is removed and the mercury on the outside of the tubes is brushed off. Excess mercury, which should be approximately 80 percent of the mercury initially poured into the couplet top, is poured into a glass jar and brought to the oxifying and filtering station for repurification.

Oxifying and Filtering

Elemental mercury is oxified and filtered before it is put through the mercury-filling process. The oxifier is a sealed chamber that contains two stainless steel, wheel-shaped agitators. Mercury (500 mm) is poured into the chamber and the chamber is sealed. Air is pumped into the chamber by a handheld rubber bulb and the agitators are started. After 4 hours of agitation, the mercury is drained into a metal pan. It is three-stage filtered and stored in a metal container.

Calibration, "Running Out," and "Closing Off"

The bulb ends of the filled tube assemblies are placed in hot water or oil baths to run out excess mercury. The tube is then calibrated according to the length of the mercury column, and the open end is torched closed. A temperature scale is matched to the tube and assembly is complete.

THERMOMETER ASSEMBLY

Thermometer assembly is conducted in the Assembly and Storage Area. Two types of thermometers are manufactured. one for industrial use and one for use in submarines. Barometers, manometers, and absolute pressure gauges are also made in the Assembly Area. The methods of assembly of each of these units are similar, with only a few special variations for each product. The process involves the insertion of the tube and bulb assembly into a protective casing.

MERCURY CONTROL TECHNIQUES

The controls in effect at Jay Instruments are all in the Tube Fabrication Area. These controls are described in detail in this section, and the engineering controls are referenced on a diagram of the area (Figure 3). The black arrows on the diagram indicate direction of airflow.

TEMPERATURE CONTROL

To reduce mercury vaporization in the Fill Room, two Dayton air-conditioners (Figure 3, Reference 1) are used to cool the workplace air. The purchase price of both units was $449 in 1977

DILUTION VENTILATION

Exhaust Air

Air is exhausted from the Glass Room by two wall exhaust fans (Figure 3, Reference 2)· one 24-inch-diameter fan and one 42-inch-diameter fan. Information on fan capacities and prices was not available

Supply Air

Outside air is supplied to the Glass Room through a 20-inch by 24-inch wall vent (Figure 3, Reference 3). Because the Fill Room is at negative pressure relative to the Glass Room, air enters the Fill Room through two 2-foot-square screened windows (Figure 3, Reference 4). In addition, air is supplied to the Fill Room through a 12-inch-diameter wall fan (Figure 3, Reference 5). The wall fan has a measured face velocity of 770 feet per minute (fpm) through a 1-square-foot louvered opening, resulting in an airflow of 770 cubic feet per minute (cfm).

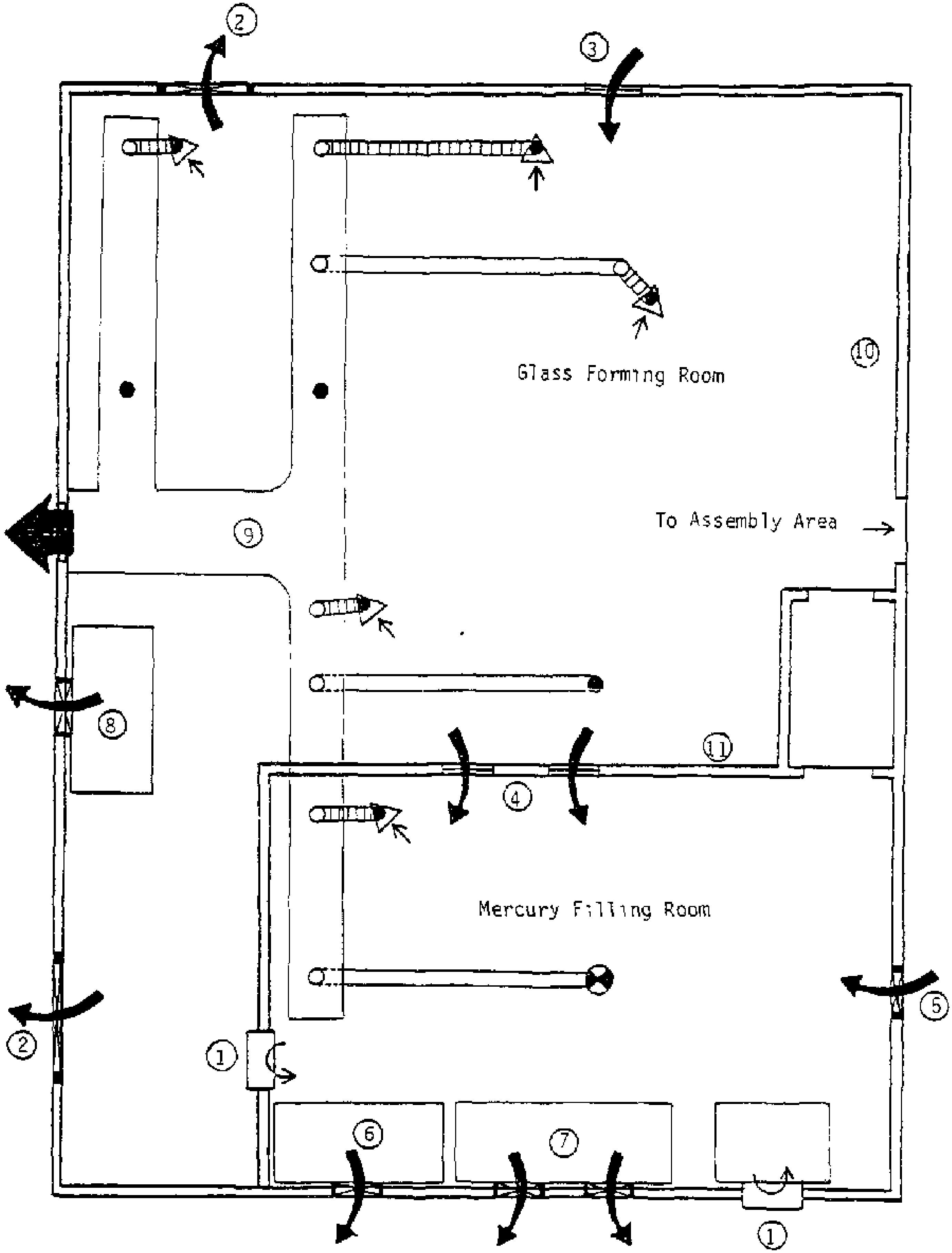

Figure 3 Tube Fabrication Area Engineering Controls

LOCAL EXHAUST VENTILATION

Oxifying Station (Figure 3, Reference 6)

Purpose of control:	- remove mercury vapors emitted during oxification and filtration of elemental mercury
Control components:	- stainless steel tabletop work booth with exhaust hood
	- 16-inch-diameter exhaust fan rated at 870 cfm
	- Plexiglas doors
Manufacturer:	- work booth and doors - fabricated in-house
	- exhaust fan - Dayton
Dimensions:	- work booth: 48 inches wide x 36 inches high x 32 inches deep
	- face: 35-1/2 inches wide x 22-1/2 inches high
Measured performance:	- face velocity: 60 ft/min (average of 6 readings across face)
	- airflow: 330 cfm
Maintenance required:	- standard motor maintenance of fan
Total cost of control.	- $1,230 (1977)

Calibration Station--Fill Room (Figure 3, Reference 7)

Purpose of control:	- provide efficient work station for thermometer calibration along with a hood for removal of mercury vapor emitted during the process
Control components:	- stainless steel tabletop work booth with exhaust hood
	- two 10-inch-diameter exhaust fans rated at 520 cfm each
	- six-bed, calibration tank
Manufacturer:	- work booth and calibration tank: fabricated in-house
	- exhaust fans: Dayton

Dimensions:	- work booth: 80 inches wide x 48 inches high x 22 inches deep
	- face: 80 inches wide x 28 inches high (slant face)
Measured performance:	- face velocity: 21 ft/min (average of 18 readings across face)
	- airflow: 330 cfm
Maintenance required:	- standard motor maintenance of fan
Cost of control:	- calibration tank: $1,800 (1977) hood and fans: $1,060 (1977)

Calibration Station--Glass Room (Figure 3, Reference 8)

Purpose of control:	- exhaust hood originally designed for removal of mercury vapor from calibration station. Although this calibration station is no longer used, the exhaust fan is still operated to aid in ventilating the Glass Room.
Control components.	- stainless steel tabletop work booth w/exhaust hood
	- 16-inch-diameter exhaust fan
Dimensions	- work booth. 86 inches wide x 44 inches high x 23 inches deep
	- face. 86 inches wide x 28 inches high
Measured performance:	- face velocity 21 ft/min (average of 8 readings across face)
	- airflow: 350 cfm
Maintenance required:	- standard motor maintenance of fan

Exhaust Air System (Figure 3, Reference 9)

Purpose of control	- provide exhaust air ventilation at work benches and at various ceiling locations
Control components and Dimensions.	- sheet metal duct system
	- 20-inch-diameter exhaust fan
	- three, 4-inch-diameter plain opening ducts

- one ceiling exhaust fan leading to 4-inch-diameter duct
- five bench-mounted tapered exhaust hoods with horizontal intake. These hoods have a 4-inch x 10-inch horizontal face with a 4-inch-diameter flexible hose duct leading to the central duct system. Each hood is mounted approximately 9 inches off the surface of the workbench.

Manufacturer:	- Northgate Heating and Air Conditioning
Measured performance:	- bench-mounted hoods face velocity: 180 ft/min airflow: 50 cfm
Maintenance required:	- standard
Cost of system:	- $1,503 (1977)

ISOLATION

The plant has taken steps to separate the mercury use area from the rest of the manufacturing areas. A partial wall (Figure 3, Reference 10) was constructed of hard surface panels (2 feet by 4 feet) to separate the Tube Fabrication Area from the Assembly and Storage Area. This was constructed in 1977 at a cost of $578. In addition to this, a wall (Figure 3, Reference 11) was constructed of the same material to separate the Fill Room from the Glass Room. This was also done in 1977 at a cost of $900.

CONTAINMENT

Mercury Vacuum Cleaner

The plant uses a Dayton stainless steel vacuum cleaner with a charcoal filter for vacuuming elemental mercury from work surfaces and floors. Purchase price of the unit in 1977 was $254.

Mercury Disposal Program

Jay Instruments has a mercury disposal program designed to minimize worker exposure to mercury-containing waste. All scrap material in the wet buckets is emptied into a plastic-lined 55-gallon drum at the end of each day. A 6- to 8-inch level of water is maintained above the scrap in the drum. The drum is kept covered with a lock-ring top. The drum is ready for disposal when it has accumulated approximately 20 pounds of mercury scrap. At present, Jay Instruments contracts with the Chemical Environmental Conservation Systems Company to dispose of about three drums of scrap each year.

SUBSTITUTION

Elimination of Vacuum Filling and Oxifying Process Steps

Jay Instruments is exploring the feasibility of having the glass tubes filled with mercury by an outside contractor. This would eliminate mercury handling during the tube filling and the oxifying and filtering processes. The only remaining mercury handling tasks would be glass testing and "running-out." Jay Instruments has indicated that it may be more economical to subcontract the work to a vendor who deals with mercury on a much larger scale.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment is used in the Tube Fabrication Area at Jay Instruments and the practices include the following:

- Cloth smocks are worn while the worker is inside the Mercury Filling Room; the smocks are changed daily.
- Disposable hair bonnets (Du Pont Tyvek^R) are worn; these are changed daily.
- Gloves are worn when workers are handling mercury.
- Respirators are worn during the mercury filling and "running-out" processes.

Jay Instruments is currently using Scott continuous-flow, demand-type, Model #802230 respirators (NIOSH Approval No. TC-196-73). The system includes a mask, hose, gauges, and air tanks. It provides 60-120 pounds per square inch (psi) of breathing air. The respirator was purchased in 1977 for $408. Jay is considering the use of Racal air-supplied respirators because they are lighter and easier to work with.

WORK PRACTICES

Work practices in effect at Jay Instruments to control worker exposure to mercury include the following:

- Smoking and eating are not permitted in the Tube Fabrication Area.
- Hands are washed before exiting the Tube Fabrication Area.
- Workers must change into work shoes as they enter the Tube Fabrication Area. They must then change back into street shoes whenever they exit.
- All exhaust hoods are kept on through the entire shift.
- Excess mercury is drained from the borosilicate tube into a bucket containing 5-6 inches of water.
- Mercury is carefully brushed off of all thermometer tables into a receptacle filled with water.

Jay Instruments is planning to develop a job rotation program in which workers would rotate in and out of high exposure positions.

The following housekeeping practices are employed at Jay Instruments:

- Work surfaces are washed daily with soap and water.
- Floors and work surfaces are washed with HgX^R (a mercury vapor suppressant) twice a week.
- Floors are painted black so that mercury spills are more visible.
- Floors are repainted once a year.
- All containers used for mercury are washed after use.
- All tubes are washed before being brought to the Assembly Area.
- The mercury trap in the sink is emptied once a week.

- Broken thermometers and other contaminated waste glass are submerged in water and are later disposed of in containers having lids.

- Covered trash cans are used for wastes that may contain mercury. These are emptied twice a week.

- Dry sweeping is not permitted; a Dayton stainless steel vacuum cleaner equipped with a charcoal filter is used for spills and for daily cleanup. (The charcoal filter was not in place during this survey.)

- Resisorb[R] mercury absorber is spread over mercury spills until the vacuum cleaner is available.

- The inside and outside of each hooded area, as well as the bench below the work station, are vacuumed daily.

MONITORING PROGRAMS

Biological Monitoring

A biological monitoring program was initiated in 1974. This involves periodic (1-3 times per year) monitoring for the levels of mercury in the urine of workers in the Tube Fabrication Area. If levels of mercury are elevated (based on the physician's report that accompanies the laboratory results), the worker is removed from the Tube Fabrication Area. The urine-mercury level at which workers are removed from their jobs has not been well defined in the past at this facility. The current urine-mercury level for determining worker removal at Jay Instruments is 0.15 milligrams per liter (mg/L). Workers' urine is rechecked in 6-8 weeks, and workers are reinstated when urine-mercury levels are below 0.15 mg/L. A current review of plant biological monitoring data shows that workers' urine-mercury levels are at or below 0.15 mg/L.

Air Monitoring

Jay Instruments does not conduct air monitoring to determine mercury vapor concentrations.

SURVEY DATA

AIR SAMPLING METHODS

Monitoring of the workplace air was conducted using two methods: (1) a direct reading instrument that provides an instantaneous measurement of mercury vapor, and (2) a long-term sampler to determine the integrated time-weighted average (TWA) exposure over the workshift. The former method employed the dual-range Jerome Model 401 Mercury Vapor Detector. This instrument has a sensitivity of 0.001 milligrams per cubic meter (mg/m^3) and a range of 0.001-0.5 mg/m^3.

For the latter method, both personal and area samples were collected. Samples were obtained by using personal monitoring pumps (MSA Model C-200) to draw air through a Hopcalite solid sorbent tube. For personal samples, the tube was attached to the shirt collar or lapel of the employee. The flow rates set at 75 ml of air per minute were determined both before and after sampling using a buret (soapbubble meter). Analyses of samples were done by flameless atomic absorption.

AIR SAMPLING RESULTS

Personal sampling was conducted in the Tube Fabrication Area to determine airborne concentrations of mercury. Both of the Fill Room workers were selected for personal sampling. Area samples were taken in the Tube Fabrication Area and in the Assembly Room to determine the concentration of mercury vapor resulting from various operations.

Numerous direct reading measurements were made with the Mercury Vapor Detector. The results, which are presented in Table 1, show that mercury vapor was detected throughout the Thermometer Department.

TABLE 1

Mercury Vapor Concentrations
Determined with Jerome Model 401 Mercury Vapor Detector

Location/Operation	Average Concentration (mg/m^3)
Assembly Room (center of room)	0.005 (2)*
Assembly Room (mechanical glass table)	0.047 (2)
Assembly Room (submarine thermo table) (BZ)**	0.013 (2)
Assembly Room (near floor - inspection area)	0.050
Glass Forming Room (no production)	0.043
Assembly Room (worker's hands - indust. thermo)	0.015
Glass Forming Room (worker A's hands - after washing)	0.040
Glass Forming Room (worker A's smock sleeves)	0.025
Glass Forming Room (worker B's shirt sleeve)	0.018
Background (about 1 meter away from employees A & B)	0.004
Mercury Filling Room (after thermometers are cleaned and sealed)	0.021 (3)
Mercury Filling Room (while using vacuum) (BZ)**	0.500 (2)
Glass Forming Room (no production)	0.011
Vapor Dial Department (adjacent to Assembly Area)	0.004
Welding Department	0.002
Outside Air	0.001

*Numbers in parentheses indicate number of samples taken at that location.

**BZ = worker's breathing zone.

Many of the sample locations were selected to identify areas and processes within the plant that may be sources of mercury vapor. Samples taken near the floor range from 0.022 to 0.050 mg/m^3 indicating widespread contamination in certain areas of the Thermometer Department. Vacuum cleaners are used throughout the Thermometer Department to remove excess mercury and to clean up spills. The results show that when the vacuum cleaners in the Tube Fabrication Area are used, a higher concentration of mercury (actual level exceeded the instrument's upper limit of measurement) was obtained in that area, indicating a potential for worker exposure during vacuuming.

Measurements taken near workers' hands and clothing during breaks indicated higher concentrations of mercury vapor than room background air samples taken about 1 meter away from each worker These results show that workers' (in particular, tube fabrication workers) hands and clothing may be an additional source of mercury exposure. In addition, workers may be leaving the plant with mercury-contaminated hands and clothing, thus prolonging or increasing their exposure to mercury. Several workers smoke cigarettes at their Assembly Room work stations and during their breaks. This practice, if conducted with mercury-contaminated hands, is likely to increase worker exposure to mercury.

The direction of general air currents in the process areas was determined during the survey with the use of smoke tubes. Air flowed into the Fill Room (an enclosed room within the larger Glass Room) through the two screened windows. However, the general airflow from the Glass Room was toward the Assembly Room for part of the day and reversed later in the day. A partial wall separates the Glass Room from the Assembly Room. Some activities involving the use of mercury are conducted in the Glass Room; consequently, worker exposure in the Assembly Room may be increased due to the possible carryover of mercury vapor.

Direct reading measurements were not taken in the Fill Room during production. The plant management considers this a high exposure process, and air-supplied respirators must be worn during all process activities.

Results of personal and area sampling to determine TWA concentrations are presented in Table 2. Thermometer filling operations were conducted on the afternoon of 3/4/81 and on the morning of 3/5/81. The assembly area operations were conducted throughout both days. Area concentrations in the Assembly Room ranged from none detected to 0.007 mg/m^3. Area concentrations in the Fill Room ranged from 0.006 to 0.023 mg/m^3.

Two Fill Room operators were monitored during the survey. The NIOSH recommended limit and the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) were not exceeded during the sampled periods. The samples are representative of daily mercury vapor exposures in that they encompass all of the routinely performed activities associated with thermometer filling. Therefore, the sampling period TWA concentrations represent a reasonable approximation of an 8-hour TWA for the operation. The results of area samples collected in the Fill Room are generally similar to those of personal samples, indicating that the use of a supplied-air respirator during the fill process may not be necessary.

VENTILATION SYSTEM

During the survey, measurements of the ventilation systems were made using a velometer. The results are included in the Mercury Control Techniques section. Measurements were also made using smoke tubes to determine the capture of each system. The results of these measurements show that the local exhausts at the Oxifying and Calibration Stations are capable of controlling mercury vapor. However, the mounted, tapered exhaust hoods are not capable of controlling mercury vapor that is generated more than several inches from the face of the duct. Consequently, these units do not effectively control mercury vapor generated at the operations conducted at these benches.

TABLE 2

Results of Area and Personal Samples to Determine
TWA Concentrations of Mercury Vapor
(3/4/81 - 3/5/81)

Location	Concentration (mg/m^3)
Fill Room (on table near hood)	0.006
Fill Room (near fill unit)	0.018
Assembly Room (near submarine thermometer table)	none detected
Fill Room (on workbench)	0.023
Fill Room (near fill unit)	0.009
Fill Room (on table near hood)	0.019
Assembly Room (center of room)	0.007
Glass Room (during high-range calibrations)	0.010
Fill Room Operator A	0.015
Fill Room Operator B	0.015

CONCLUSIONS AND RECOMMENDATIONS

Based on results of sampling and observations, the controls in effect at Jay Instruments are effective in maintaining mercury vapor levels below the OSHA PEL and the NIOSH-recommended limit. The only significant deviation from this standard was the high mercury vapor concentration (>0.5 mg/m^3) associated with the use of the vacuum cleaner. This emission source may be minimized by replacing the charcoal filter on the vacuum cleaner more frequently.

Of the controls in use at this facility, the most effective are dilution ventilation; certain local exhaust ventilation systems; and the isolation of the mercury fill process. Certain other controls were found to be ineffective. The bench-mounted local exhaust ventilation system was ineffective in controlling contaminants generated more than several inches from the individual local exhaust units (most bench operations were conducted a foot or more from each unit). The partial wall between the Tube Fabrication Area and the Assembly Area permits the carryover of air, and most likely mercury vapor, into the Assembly Area, possibly increasing worker exposure in the area.

The following recommendations are presented.

- The partitioning wall between the Assembly Area and the Tube Fabrication Area should be extended to the ceiling.
- An air monitoring program should be implemented at the plant to periodically monitor the effect of the control programs and to establish personal exposure levels.