108-04

FINAL REPORT

A SURVEY OF HEALTH HAZARD CONTROL SYSTEMS FOR MERCURY USE AND PROCESSING

Contract No. 210-81-7107

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway
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February 1984

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ABSTRACT

To document hazard controls in industries which use and process mercury, a study was conducted by NIOSH which surveyed methods used to control worker exposure to mercury. A total of 28 site visits were involved in the study and individual case study reports from these visits will be available from NTIS. Industries visited included battery manufacturing, temperature-sensing instrument manufacturing, fluorescent lamp manufacturing, electrical switch manufacturing processes using mercury, mercury chemical processing and production, and dentistry.

Results of this survey indicated that local exhaust ventilation, temperature control, and work practices are all effective techniques for controlling mercury vapor. Also observed routinely in most sites visited were biological monitoring programs. In most cases, airborne mercury vapor levels measured during the surveys were well below the OSHA PEL of 100 ug/m^3, and in some instances, the levels were below the NIOSH recommended level of 50 ug/m^3. Specific aspects of the various control methods studied are presented.

CONTENTS

CONTENTS (Continued)

TABLES

TABLES (Continued)

FIGURES

FIGURES (continued)

ACKNOWLEDGMENTS

The Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, supported this control system survey for mercury use and processing. Alfred A. Amendola, NIOSH Project Officer, participated in this study and worked closely with Donato R. Telesca, Program Manager, in the evolution of this report. The principal investigators responsible for collecting, analyzing, and reporting the information for this study were Robert P. Reisdorf and David C. D'Orlando.

The interest and cooperation of the mercury-using industries made this study possible. The manuscript was patiently and ably typed by Ms. Stella Lenis.

I. INTRODUCTION

Control technology is being developed and implemented in response to increased awareness of the need to prevent occupational exposure to hazardous materials. The National Institute for Occupational Safety and Health (NIOSH) is involved in studying and promoting the development of control technology that is effective in reducing occupational hazards. Since 1976, NIOSH has sponsored control technology assessments in the plastics and resins industry, primary and secondary smelting operations, foundries, pesticides manufacturing, drycleaning operations, tire manufacturing, raw cotton processing, pulp and paper processing, coal conversion processes, and other processes. The primary objective of these studies is to assist industry in improving worker protection, particularly when problems arise or when new health standards are promulgated.

Increased interest in the health effects resulting from exposure to mercury and mercury compounds led to the decision to survey the controls currently in use to reduce this exposure. The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) is 0.1 mg/m^3 as an 8-hour time-weighted average (TWA). NIOSH recommends that the TWA exposure limit be reduced to 0.05 mg/m^3. The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended a Threshold Limit Value (TLV) of 0.05 mg/m^3 as an 8-hour TWA for all forms of mercury except alkyl, and 0.01 mg/m^3 for alkyl compounds.

Major industries and activities in which mercury is used as a raw material or as a means of production include battery manufacturing, thermometer manufacturing, mercury switch manufacturing, fluorescent lamp manufacturing, chlor-alkali production, electroplating, metal sintering, electrical standards manufacturing, bactericide/fungicide manufacturing, catalyst manufacturing, pharmaceutical manufacturing, paint manufacturing, mercury processing, and dentistry. (Dentistry, for the purpose of this study, is also regarded as an industry.)

The material presented in this document is a compilation of information gathered from 28 site visits to 24 facilities. The number of site visits conducted in each industry were:

Battery Manufacturing	5
Temperature-Sensing Instrument Manufacturing	5
Fluorescent Lamp Manufacturing	3
Electrical Switch Manufacturing	2
Electrical Processes Using Mercury	5
Mercury Chemical Processing/Production	6
Dentistry	2

These sites were selected on the basis of good, transferable control concepts and practices. They do not, therefore, constitute a randomly selected sample of mercury-using industries, and conclusions regarding the general extent of exposure to mercury should not be drawn from this study.

In addition to the data gathered from industry, information on biological monitoring programs was obtained from Leonard Goldwater, M.D., of the Duke Medical Center. A text of this discussion is available from NIOSH.

Projected usage for the year 1985 (Table I-1) shows that over 82 percent of the total U.S. mercury demand will be from four industrial sectors: the chlor-alkali, dental, electrical equipment, and industrial instruments industries.

TABLE I-1

Projected U.S. Mercury Demand by End Use for 1985

Industrial Sector	Amount (metric tons)	Percent of Total
Chlor-alkali	482*	23
Dental	129	6
Electrical Equipment (includes battery lamps)	662	32
Industrial Instruments (includes switches and thermometers)	447	21
Other	371	18
TOTAL	2,091	100

*This amount may be affected by the development of new technologies in chlor-alkali manufacturing.

Source: Bureau of Mines, 1980.

This survey is designed to identify and assess control methods used in mercury-using industries for reducing worker exposure to inorganic mercury. The information will help provide an information source for (1) new plants designing a mercury control strategy and (2) existing facilities attempting to reduce exposure to mercury through the improvement of current controls or the implementation of new controls. Information is presented to assist a company or organization in selecting a control scheme according to its specific needs. Possible control limitations and disadvantages are also presented, to help industries avoid the installation of ineffective control systems. A level of detail is presented such that a competent designer could use the concepts and practices described as a source of data to help implement effective controls. The report is not intended to supplant the basic design and engineering skills which are necessary to translate controls from one specific context to another one, however, nor is it likely that all available controls are included in the report.

This report is intended to be a useful tool for industrial hygienists, plant engineers and managers, and labor organizations. It describes potential problems associated with the use of mercury in industry, and presents some control methods available to avoid these problems. The document is presented in three major sections

Health Hazards in Industries Using Inorganic Mercury
This section introduces the reader to the health effects in humans from exposure to different forms of mercury. It also describes biochemical mechanisms by which the mercury interacts with the human body.

Mercury Applications in Specific Industries
This section describes the role of mercury in seven different industries. Generic process descriptions are presented along with data on typical airborne mercury concentrations associated with the unit operations of the processes. The potential mercury vapor, liquid mercury, and mercury particulate emission sources are presented in a matrix with the generic control methods typically used to control these emissions.

Control Methods
This section documents the controls used to reduce worker exposure to mercury and its compounds. The methods applied to control the emission sources and dispersion of mercury discussed in the previous section are described in more detail. These control methods are presented in the recommended order of approach that an organization should take to reduce worker exposure. Some possible advantages and disadvantages of the specific controls are listed along with the potential applications in other industries. Also included in this section are the personal protective equipment, work practices and training, and air monitoring methods employed in achieving and documenting reduced worker exposure to mercury.

The final section of the report outlines conclusions and recommendations for further study of mercury controls and new applications for existing controls.

The information generated in this study is the result of onsite surveys conducted at various mercury-using facilities. Additional or more detailed information on the controls studied is contained in the individual site visit reports, which may be obtained on a limited basis from the Engineering Control Technology Branch of the National Institute for Occupational Safety and Health, Division of Physical Sciences and Engineering, 4676 Columbia Parkway, Cincinnati, Ohio 45226. These reports will be placed in the National Technical Information Service (NTIS) in the near future, and requests should be directed to this data base as a principal source for these reports.

II. SCOPE OF WORK

For this study, mercury is defined as elemental mercury, inorganic mercury compounds, and organic mercury compounds other than ethyl or methyl mercury.

The purpose of this study is to.

- o document methods used in controlling worker exposure to mercury
- o estimate the effectiveness of these methods of control
- o describe controls that are in the planning stages at facilities surveyed.

The control methods within the scope of this study are:

Engineering controls - elimination by substitution, equipment design changes, devices to control hazardous emissions, process modification, isolation of the worker, isolation of equipment, and plant design.

Personal protective equipment - respirators and protective clothing worn by workers to reduce physical contact with mercury.

Work practices - procedures prescribed by management to reduce worker exposure to mercury.

Monitoring programs - the determination of control effectiveness and actual worker exposure through air sampling and biological monitoring .

The investigation of mercury controls was conducted during preliminary and in-depth surveys. Preliminary surveys were made to determine the controls that warranted additional investigation. Information on these controls was obtained during in-depth surveys that included control documentation and air sampling to help determine control effectiveness.

Selection of plants for surveys was based on literature search, chemical inventory search, information obtained from academic experts and union contacts, and discussions with plant representatives.

III. HEALTH HAZARDS IN INDUSTRIES USING INORGANIC MERCURY

A. CHEMICAL AND PHYSICAL PROPERTIES OF MERCURY

The primary source of mercury is cinnabar ore. Its chemical symbol is Hg from the Greek word, hydrargyros, "water silver". Mercury is a silvery, mobile liquid at room temperature which explains its synonym, quicksilver. Its molecular weight is 200.6, boiling point (760 mm Hg) is 357°C (674°F), specific gravity (water=1) is 13.55, melting point is -39°C (-38°F), vapor pressure at 20°C (68°F) is 0.0012 mm Hg, and solubility in water (g/100g water at 20°C (68°F)) is 0.002 Mercury is a good conductor of electricity and has coefficient of cubical expansion of 181.86 at 20°C (68°F). Metals, other than iron and platinum, will dissolve in mercury. Mercury is not combustible, but when in contact with acetylene, acetylene products, or ammonia gases may form solid products that are sensitive to shock and can initiate fires of combustible materials. Mercury is odorless and has no warning properties.

B. WORKER EXPOSURE TO MERCURY

The primary route of exposure to mercury in the workplace is by the inhalation of vapor or particulate mercury. Mercury may also be introduced into the body through dermal absorption and ingestion.

The spread of mercury (particularly the elemental form) from contaminated hands to other parts of the body (including hair and clothing) may increase inhalation exposure to mercury vapor by creating a "microenvironmental exposure" (Stopford et al. 1978). A characteristic of this microenvironment is that mercury vapor is usually present at higher concentrations in the breathing zone of the worker than in the surrounding workplace air. Consequently, when determining worker exposure, performing only area monitoring may not provide an accurate indication of exposure. In addition, comparison of area values with the Threshold Limit Value (TLV) or PEL for mercury may provide a false indication of safe exposure.

The physical properties of mercury may make identification of sources of worker exposure difficult. For example, elemental and particulate mercury can be carried throughout a facility on workers' shoes and clothing and may be subsequently deposited on walkways, stairs, and floors. Mercury may also concentrate in cracks and crevices, especially in untreated wood and uncoated cement surfaces. Once dispersed throughout a plant or concentrated in cracks, elemental mercury, and to some extent inorganic salts of mercury, continues to vaporize into the workplace. Consequently, when evaluating exposure at a facility, all of these factors, as well as the industrial process being evaluated, must be considered.

C. HEALTH EFFECTS OF MERCURY EXPOSURE

Toxic effects of chemical agents depend on the exposure situation (route of administration and the duration and frequency of exposure), the susceptibility of the subject (age, sex, etc.), and the chemical and physical properties of the agent. In the case of mercury, the chemical form to which the worker is exposed is particularly important. The following forms of mercury are commonly used in industry

- o elemental mercury
- o inorganic mercury compounds
- o organic mercury--a diverse group of compounds including alkyl, alkoxyalkyl, and phenyl mercurial compounds. (Coverage in this report is limited to the nonalkyl mercurial compounds.)

Inhalation exposure is a primary concern when working with elemental mercury (Hg). The vapor pressure and high lipid solubility of mercury allows it to be readily retained and absorbed in the lungs. Conversely, absorption from the gastrointestinal tract is very poor and normally does not contribute appreciably to occupational exposure (Hammond and Beliles 1980).

Examples of inorganic mercurial compounds commonly found in industry for which control information is presented in this report include:

- o Mercuric oxide (HgO)--a red or yellow, water-insoluble powder. The finer particles (5 micrometers) appear yellow, and the larger particles are reddish. It is an important material in the battery industry.
- o Mercuric sulfide (HgS)--a red, water-insoluble material that reacts with oxygen at low heat to produce metallic mercury and SO_2.
- o Mercuric chloride ($HgCl_2$)--a highly toxic, water-soluble powder or crystalline substance, used in the preparation of mercuric oxide.

The basic biochemical mechanism whereby inorganic mercury compounds produce adverse health effects is not completely understood. However, their toxicity appears to depend on their dissociation capability in body fluids with all compounds probably acting by a single basic mechanism. The primary mode of action may be the association of Hg^{++} with membrane permeability and metabolic enzyme systems via binding to essential sulfhydryl groups, thus disrupting enzyme activity. Chronic mercury poisoning due to continued excessive exposure compounds may result in kidney damage (Hammond and Beliles 1980).

Phenylmercuric acetate (PMA) is a common phenyl mercurial for which control information is presented in this report. PMA is a highly irritating white crystalline material that is slightly volatile at room temperature, slightly soluble in water, and readily soluble in alcohol. Like other members of its class, the readily biodegradable PMA reacts in the body with sulfhydryl groups, thus interfering with essential cellular function. The toxic activity of these chemicals is essentially the same as that described for the inorganic mercurial chemicals (i.e., the action of the Hg^{++} cation).

Acute exposure to mercury at high levels causes severe respiratory irritation, digestive disturbances, and marked renal damage; chronic mercurialism, the form of intoxication most frequently caused by occupational exposure, is characterized by neurologic and psychic disturbances, anorexia, weight loss, and stomatitis. Skin absorption of inorganic mercury probably adds to the toxic effects of vapor inhalation. Intraperitoneal injection of metallic mercury in rats has produced sarcomas. Exposure of humans to mercury vapor in concentrations of 1.2 to 8.5 mg/m^3 causes cough, chest pain, and dyspnea, leading to bronchitis and pneumonitis. At low levels, the onset of symptoms resulting from chronic exposure is insidious, fine tremors of the hands, eyelids, lips, and tongue are often the presenting complaint. Coarse jerky movements and incoordination may interfere with the fine movements considered necessary for writing and eating. Psychic disturbances such as insomnia, irritability, and indecision occur, headache, excessive fatigue, anorexia, digestive disturbances, and weight loss are common, stomatitis with excessive salivation is sometimes severe, muscle weakness has been reported. Proteinuria may occur, but is relatively infrequent. Mercury has been reported to be capable of causing sensitization dermititis.

The OSHA PEL for mercury is based on the observation that, as the concentration of mercury vapor increases to approximately 0.1 mg/m^3, the frequency of the neuropsychiatric symptoms among workers increases significantly. The NIOSH-recommended limit of 0.05 mg/m^3 was selected based on evidence of toxicity at concentrations below 0.1 mg/m^3 (NIOSH 1973).

IV. MERCURY APPLICATIONS IN SPECIFIC INDUSTRIES

Generic descriptions of the mercury applications studied are presented in this section Each description is followed by a matrix of potential mercury emissions and the control methods used to reduce worker exposure. Workplace air concentrations of mercury, which were determined during some onsite surveys, are also presented.

A. BATTERY MANUFACTURING

Mercury and mercury compounds are used in the manufacture of button, zinc-carbon, and alkaline cells.

1. Button Cells

A typical button cell, commonly used to power digital watches and hearing aids, consists of a cathode, anode, electrolyte, insulators, and a containing can. Both the cathode and anode contain mercury.

a. <u>Cathode Production</u>
The cathode is a pellet consisting of a mixture of mercuric oxide, cadmium, and graphite. These powdered components are either added manually or metered through a hopper to a V-blender or planetary mixer. After blending, the mixture is densified using a process called "slugging" in which the mixture is compacted into tablets by an enclosed rotary pressing device. The tablets are then ground into uniformly sized particles and are pelletized to a specified size and density using a rotary press. Materials transfer from mixing to pelletization is by closed hoppers. Pellets are consolidated into small metal cans (0.5 inch in diameter) in preparation for assembly.

b. <u>Anode Production</u>
The anode is a zinc-mercury amalgam produced by blending zinc powder with elemental mercury. Components are metered into an enclosed blender from hoppers or hold tanks. The resulting amalgam, which is dried and screened to produce uniformly sized particles, is used in powdered or tablet form. Tablets are made by pelletizing the amalgam in a rotary press.

c. <u>Cell Assembly</u>
Assembly of the mercury cells is performed on either an automatic or semiautomatic process line. The cathode (can and pellet), anode (powder or tablet), electrolyte, and a top cover are assembled and sealed with a crimper. Other components, such as an insulator, an absorber, and a barrier, are added to the cell as required by design specifications.

2. Zinc-Carbon Cells

a. Cathode Production

Zinc-carbon cells contain an electrolyte produced by mixing mercuric chloride powder with a zinc chloride solution. Mercuric chloride is added to the solution manually. The electrolyte is blended into a dry cathode base mix consisting of zinc oxide and other proprietary components. The resulting moist cathode base mix has a consistency similar to brown sugar.

b. Cell Assembly

The cathode mix, which is transferred to a cell assembly area, is injected into paper-lined zinc cans. Mercury in the mix migrates through the paper lining and amalgamates with the zinc can, serving as a corrosion inhibitor. A carbon pencil (anode) is pressed through the center of the mixture, and a support washer is placed inside the can to contain the mixture. Asphalt is used to seal the cell, and a metal cap is added to the top of the can. The top of the can is crimped closed around the metal cap, completing the cell assembly.

3. Alkaline Cells

Alkaline cells are made with an anode gel containing zinc-mercury amalgam and a cathode consisting of manganese dioxide and graphite. Mercury is used to suppress the generation of gas in the cell and to improve the discharge rate.

a Anode Production

Anode gel is produced by mixing zinc oxide, liquid mercury, an electrolyte solution, and a gelling agent in a large blender. The blender is operated under vacuum.

After blending, the gel is allowed to stand for a specified time, is manually fed into a grinder to eliminate lumps, and then is transported to a cell assembly area.

b. Cell Assembly

The cell assembly process begins with the insertion of a preformed cathode (an annular, compacted mixture of manganese dioxide and graphite) into a steel can. A paper cylinder is inserted in the cathode along with a specified amount of electrolyte solution, and the anode gel is dispensed manually or automatically inside the cylinder. Current collectors are placed on top of the cell, the can is crimped closed, and the completed cell is enclosed in a battery casing.

Sampling Results, Emission Sources, and Control Methods

The results of sampling at three battery manufacturing plants surveyed are presented in Table IV-1. As this table shows mercury workplace area samples were below the OSHA PEL and NIOSH recommended level in most of the battery manufacturing process areas visited during the surveys, with two exceptions. (1) button cell cathode production areas; where mercury particulate concentrations in both slugging and consolidation operations typically averaged greater than the PEL, and (2) alkaline cell anode (amalgam/gel) production areas, where mercury vapor concentrations, as reported by the manufacturers, may exceed the PEL.

TABLE IV-1

Workplace Air Concentrations of Mercury in Three Battery Manufacturing Facilities

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	Mean	Type of Sample	Particulate Mercury Concentration (mg/m^3) Range	Mean	Comments
Button Cells							
Cathode production slugging	Direct Reading	0 020-0 100 (12)[1]	0 062	Full-shift TWA		>0 1[2]	Full-time use of respirators required
Cathode production consolidation	Direct Reading	0 040-0 050 (5)	0 045	Full-shift TWA		>0 1[2]	Full-time use of respirators required
Cell assembly	Full-shift TWA	0 011-0 041 (4)	0 024	Full-shift TWA	0 002-0 006 (4)	0 004	
Zinc-Carbon Cells							
Cathode mixing		NM[3]		Full-shift TWA	<0 002-0 005 (2)	0 003[4]	
Cell assembly		NM[3]		Full-shift TWA	0,002-0 003 (2)	0 002	
Alkaline Cells							
Anode production gel preparation	Full-shift TWA		>0 1[2]		NM		Full-time use of respirators required

[1]Numbers in parentheses indicate number of samples taken
[2]Based on information supplied by the plant
[3]Not measured, however, not expected to be a significant hazard under existing conditions.
[4]Lower limit of detection used in calculating mean concentrations

Typical emission sources and the methods used to control them are presented in Table IV-2.

TABLE IV-2

Mercury Emission Sources and Control Methods for Battery Manufacturing

Mercury Emission Sources/Concerns		Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Cathode Production	Particulate emission during loading of mixers and blenders	X	X		X		X	X	X	X
	Particulate emission from grinding, slugging, pelletizing			X	X		X		X	X
Anode Production	Vapor emission from blending, drying, pelletizing			X	X	X	X	X	X	X
	Particulate emission from drying, screening, pelletizing			X	X		X	X	X	
Cell Assembly	Vapor emission from product components		X	X	X	X	X		X	
	Dermal contact with mercury during assembly									X

B. FLUORESCENT LAMP MANUFACTURING

Elemental mercury is used in manufacturing fluorescent lamps. The production of the lamps begins with the preparation of the lamp tube. Precut glass tubes are loaded onto a coating machine. The tubes are washed to remove impurities, dried with hot air, and coated with a liquid phosphor emulsion that deposits a film on the inside of the tube. Additives in the coating are removed by passing the tubes through an oven. This results in a thin layer of dry phosphor compound on the inside of each tube.

Mount assemblies are fused to each end of the glass tube. Each assembly consists of a funnel-shaped piece of glass with an "exhaust tube" through the center, lead wires, and a spiral-wound "hot cathode" wire (tungsten coil).

A small amount of mercury (15-250 mg) is injected into the lamp tube on an exhaust machine. The exhaust machine is a multistationed unit in which lamp tubes are exhausted, mercury is added, and the tubes are sealed. The mercury is added to the lamp using a piston-type doser. The piston in the doser is lifted into a mercury reservoir (by an electromagnet) where it receives a mercury dose. The piston then falls to deliver the dose through the exhaust tube into the lamp tube. A vacuum is then drawn to exhaust the tube and the tube is filled with inert gas. The open exhaust tube is sealed closed and tipped off. Exhaust tube tips are discarded in a waste container, and the lamp tube is removed from the exhaust machine.

Following the sealing of the tubes, metal bases are attached to the ends of the lamp and cemented in place by heating. As a process check, current is applied to the lamp contacts to light the lamp. The final step is the application of a silicone coating to the outside of the tube to prevent moisture from accumulating on the lamp.

Elemental mercury, used for filling the lamp tubes, is oxified and filtered before it is put through the mercury-filling process. An oxifier is a sealed chamber that contains two stainless steel, wheel-shaped agitators. Mercury is poured into the chamber, which is then sealed. Air is pumped into the chamber and the agitators are started. The air oxidizes the contaminants in the mercury, causing them to float and separate out after agitation. After approximately 4 hours of agitation, the mercury is drained from the oxifier and is filtered.

Sampling Results, Emission Sources, and Control Methods

Air sampling results from a fluorescent lamp manufacturing plant surveyed are presented in Table IV-3. Two methods of mercury filling are used at this plant. Typical emission sources and the methods used to control them are presented in Table IV-4.

Worker exposure to mercury vapor at the plant was generally below the OSHA PEL during the survey. The difference between the personal and area concentrations at the mercury addition areas are significantly lower at the 95% confidence level in Process B, which used an enclosed mercury "pill" process of dosing lamps, as compared to the conventional doser exhaust machines used in Process A.

TABLE IV-3

Workplace Air Concentrations of Mercury in a Fluorescent Lamp Manufacturing Plant

Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	Mean
AREA SAMPLES			
Central area of plant (nonproduction area)	Full-shift TWA		0 018[1]
Process A[2]--exhaust machine work stations (mercury addition area)	Full-shift TWA	0 020-0 059 (3)[3]	0 041
Process A--lamp lighting	Full-shift TWA		0 027[1]
Process B[4] (mercury addition area)	Full-shift TWA	0 027-0 040 (5)	0 034
PERSONAL SAMPLES			
Process A Workers	Full-shift TWA	0 039-0 100 (5)	0 060
Process B Workers	Full-shift TWA	0 008-0 045 (6)	0 026

[1]One sample taken
[2]Production process in which traditional mercury filling techniques are employed
[3]Numbers in parentheses indicate number of samples taken
[4]Production process in which a new mercury addition system is employed (see description of mercury pill in "Modification in Mercury Filling Operation,")

TABLE IV-4

Mercury Emission Sources and Control Methods for the Fluorescent Lamp Manufacturing Industry

Mercury Emission Sources/Concerns		Control Methods: Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Mercury Handling	Vapor emission from mercury purification, transfer, parts repair		X		X	X	X	X	X	X
Lamp Production	Vapor emission from mercury injection operation	X			X	X	X			
	Vapor emission from broken lamps, spills, and waste materials	X	X	X	X	X				

C. DENTISTRY

Mercury is a component of the dental amalgam used to fill cavities in teeth. The amalgamation process is generally uniform across the industry, although some clinics use preenclosed dental capsules to reduce worker contact.

Dental amalgam is prepared by mixing mercury with an alloy. The alloy is in powder or pellet form and is usually composed of approximately 60 percent silver, 25 percent tin, and 15 percent zinc and copper. The alloy and an equal amount (by weight) of mercury are put inside a two-piece plastic capsule along with a pestle. By maintaining a 1 to 1 ratio of alloy to mercury, an optimal amalgam is formed with minimal residual mercury.

Mercury is added to the capsule using a hand-held mercury dispenser. The dispenser delivers a drop, or "spill," of mercury when the delivery button is pressed. One or two spills are usually used for each amalgam mixing, depending on the size of the filling to be made.

When the alloy pellet, mercury, and pestle have been put inside the open plastic capsule, the capsule is capped and placed in an amalgamator (an agitation device used for mixing). The capsule is agitated in the amalgamator for approximately 15 seconds. It is removed from the machine, uncapped, and emptied into a glass Dappen dish or stainless steel amalgam well in preparation for use.

Many dental facilities use preenclosed dental capsules that contain a pestle and enough mercury and alloy to complete an average tooth filling. The use of these capsules, which are available in bulk quantities, eliminates the handling of elemental mercury.

Sampling Results, Emission Sources, and Control Methods

Air sampling results from two dental clinics which use preenclosed capsules are presented in Table IV-5. Mean area mercury samples ranged from 0.001 to 0.002 mg/m^3, and mean personal samples ranged from 0.002 to 0.005 mg/m^3. Typical emission sources and the methods used to control them are presented in Table IV-6. Additional information is available from the American Dental Association, 211 East Chicago Avenue, Chicago, Illinois 60611, regarding mercury control in dental offices.

TABLE IV-5

Workplace Air Concentrations of Mercury in Two Dental Clinics

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	 Mean	Comments
Clinic A				
Dental operatory areas	Direct Reading	<0.001-0.002 (8)[1]	0.002[2]	Sampled periods include amalgam preparation
Nonoperatory areas	Direct Reading	<0.001-0.001 (3)	0.001[2]	
Clinic B				
Dental operatory areas	Direct Reading	<0.001-0.002 (7)	0.002[2]	Sampled periods include amalgam preparation
Nonoperatory areas	Direct Reading		0.001[3]	
PERSONAL SAMPLES				
Clinic B				
Dental Assistants	Full-shift TWA	<0.002-0.004 (4)	0.002[2]	Sampled periods include amalgam preparation
Dentists	Full-shift TWA	<0.002-0.008 (5)	0.003[2]	Sampled periods include tooth filling
Dentists	Direct Reading	<0.001-0.010 (5)	0.005[2]	During tooth-filling process (open amalgam)--5 min duration
Dentist	Direct Reading	0.002-0.002 (4)	0.002[2]	No amalgam in use
Dental Assistant	Direct Reading	0.002-0.004 (2)	0.003	During amalgam preparation and use

[1]Numbers in parentheses indicate number of samples taken
[2]Lower limit of detection used in calculation of mean concentration
[3]One sample taken

TABLE IV-6

Mercury Emission Sources and Control Methods for the Dental Industry

Mercury Emission Sources/Concerns	Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Vapor emission from transferring and dispensing elemental mercury	X				X	X			
Vapor emission from mercury amalgam		X			X	X			
Dermal contact with mercury during amalgam preparation	X								

Mercury vapor concentrations in Clinic A operating areas averaged approximately 0.002 mg/m^3. Breathing zone concentrations did not increase significantly during amalgam preparation or filling. At Clinic B, increases in breathing zone concentrations, compared with background levels, were noted during some filling operations. The general workroom background concentration at this clinic ranged from none detected (0.001 mg/m^3) to 0.002 mg/m^3.

Time-weighted average personal sampling results at Clinic B ranged from none detected to 0.008 mg/m^3; area sampling results ranged from none detected to 0.002 mg/m^3. The employee with the highest reported exposure to mercury vapor did not use preenclosed amalgam capsules or any other mercury or mercury amalgam product on the day of sampling. The source (or sources) contributing to this employee's exposure was not determined.

D. TEMPERATURE-SENSING INSTRUMENT MANUFACTURING

The manufacture of mercury-containing temperature instruments varies according to the type of bulb or probe used in the instrument. The mercury filling process also varies slightly among different manufacturers.

1. Glass Thermometer Manufacturing

The process of manufacturing glass thermometers begins with the cutting of glass tubes into specified lengths. The bore size of each tube is determined volumetrically by measuring the length of a specified volume of mercury that is injected into random samples of tubes. Tubes are then grouped into batches of equal bore sizes.

Either glass or metal bulbs may be used to contain the mercury at the base of the glass tube. The procedures for attaching these bulbs are as follows:

a. Glass Bulbs
One end of the tube is heated over a burner and a short glass tube is joined to it. This short tube is formed into a bulb by heating the open end, crimping it closed, breaking off the crimped piece of glass, and rounding off the remaining tip.

b. Metal Bulbs
Metal bulbs have an attached capillary extension approximately one-eighth inch in diameter that is cut to a size determined by the bore size of each tube The capillary extension is fused to one end of each glass tube. The sized tubes are grouped in batches and heated in an oven in preparation for mercury filling.

Mercury filling is conducted in an isolated room. A typical mercury filling process is conducted inside a bell jar. Each batch of tubes is set with open ends down into a pan. The pan is set under the bell jar, which is lowered and sealed. The tubes are heated to approximately 200 C (400 F) and a vacuum is drawn. Mercury is allowed to flow into the pan from either an enclosed mercury addition system or a manually filled reservoir. When the vacuum in the jar is released, air pressure forces the mercury into the bulbs and capillaries. The pan of filled tubes is then manually removed from the bell jar. Excess mercury in the bottom of the pan is refiltered and used again in the process.

Excess mercury in the tube stems is driven out the open ends by immersing the bulb ends of the tubes in a hot water or oil bath (heating-out process). The mercury column is shortened to a specific height by flame heating the open ends (burning-off process). The tubes are cut to finished length just above the mercury column and the ends of the tubes are sealed. A temperature scale is etched onto the tube, completing the assembly. All of these operations are done manually at various work stations.

2. Thermal Sensing Element Manufacturing

Some temperature-sensing instruments have a bulb and capillary temperature-sensing device that uses the force of an expanding liquid (mercury) to operate external controls and indicators (Figure IV-1). One such probe is manufactured as follows

Bulbs are made by cutting metal tubing to size and welding a plug to one end of the tube and a coupling piece to the other (open) end. A capillary is cut to a specified length and heliarc welded to the coupling at the open end of

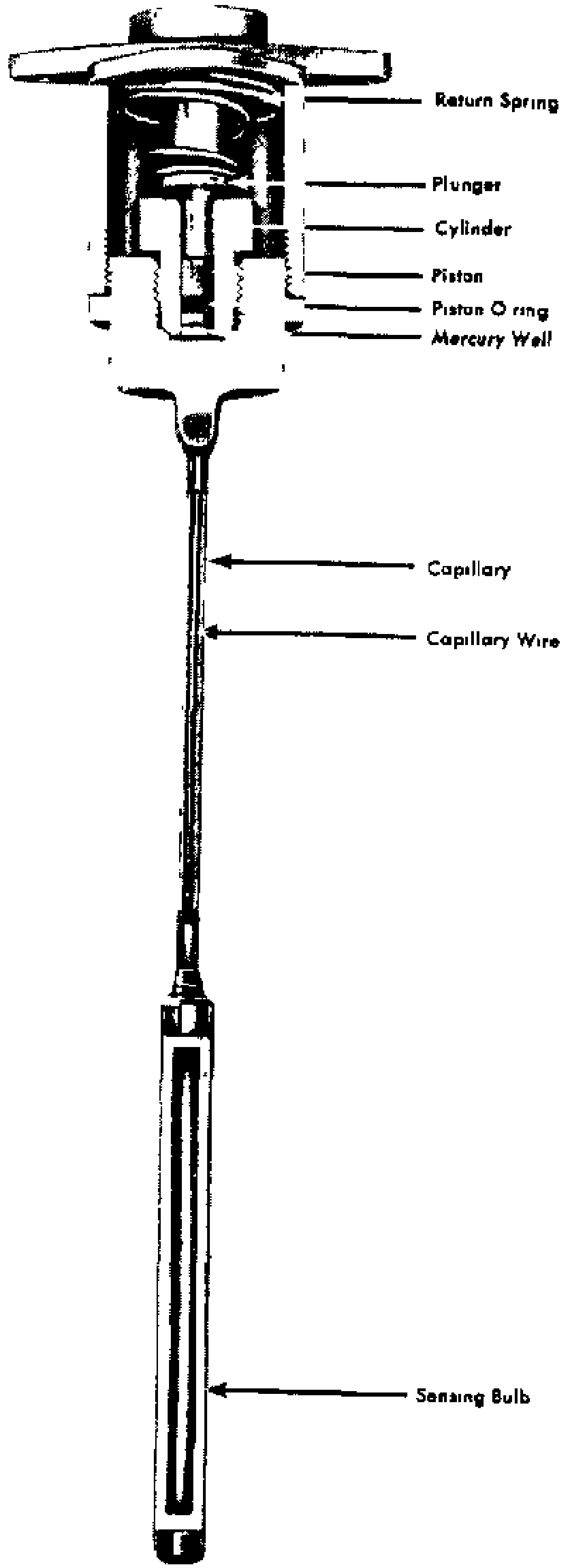

Figure IV-1. Temperature-Sensing Instrument.

the bulb. The other end of the capillary is welded to a "head" that houses the mechanical section of the sensor. Completed assemblies are grouped in job lots based on capillary length.

Filling the bulb and capillary assembly with mercury is performed in a ventilated and enclosed multistation mercury filling machine. Each station consists of fittings attached to a central manifold through which the mercury is introduced to the capillary bulb assemblies A wire is inserted the length of the capillary so that the volume of mercury required to fill the capillary is reduced. This improves the performance of the sensing element because a greater mechanical movement in the head results from small volume changes in mercury.

The sensor assembly is transferred from the wire pushing station to the final assembly station where a return spring and plunger are set into a temporary housing on the head of the sensor. The complete sensors with temporary housings are attached to controllers and/or indicating devices to complete the temperature instrument.

Sampling Results, Emission Sources, and Control Methods

Air sampling results from two glass thermometer manufacturing plants surveyed are presented in Table IV-7. Typical emission sources and the methods used to control them are presented in Table IV-8.

During the surveys average worker exposures measured were below the OSHA PEL and the NIOSH recommended level at both of the manufacturers surveyed. The Fill Room of manufacturer A had one fill unit that was used for one fill per day. Manufacturer B had nine fill units that were used throughout the workday.

TABLE IV-7

Workplace Air Concentrations of Mercury in Two Thermometer Manufacturing Plants

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	 Mean	Comments
Manufacturer A Fill Room	Full-shift TWA	0 006-0 023 (5)[1]	0 015	
Assembly Room	Full-shift TWA	<0 002-0 007 (2)	0 004	No open thermometers
Manufacturer B Fill Room (general workplace air)	Full shift TWA	0 018-0 054 (3)	0 040	
Fill Room (next to fill units)	Full-shift TWA	0 037-0 107 (3)	0 095	
PERSONAL SAMPLES				
Manufacturer A Fill Room Operators	Full-shift TWA	0 015-0 015 (2)	0 015	Sample time includes approximately 3 hr in Fill Room for each worker sampled
Manufacturer B Fill Room Operators	Full-shift TWA	0 036-0 061 (3)	0 049	Sample time includes approximately 1-1/2 hr in Fill Room

[1]Numbers in parentheses indicate number of samples taken

TABLE IV-8

Mercury Emission Sources and Control Methods for the Thermometer Manufacturing Industry

Mercury Emission Sources/Concerns	Control Methods: Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Vapor emission from mercury purification and transfer		X		X	X	X	X		
Vapor emission from bore sizing	X			X	X	X	X		
Vapor emission from mercury filling	X	X	X	X	X	X	X		X
Vapor emission from heating out and burning off				X	X	X			
Vapor emission from mercury spills		X			X	X			
Dermal contact with mercury during production									X

E. ELECTRICAL SWITCH MANUFACTURING

Mercury is used extensively in electrical switches for thermostats and for silent wall switches. The unique properties of the metal enable it to flow and make electrical contact upon actuation by an outside mechanical force or by gravity. Mercury switches for thermostats are small glass tubes containing mercury and metal electrodes (contacts). Mercury switches for wall switch application are button-shaped metal cans containing mercury, contacts, and an insulator. The manufacturing process descriptions for the two types of switches are presented below:

1. Mercury Switch for Thermostats

Metal electrodes used for contacts are inserted into small glass tubes (0.35-0.61 inch in diameter) and sealed in place prior to mercury filling by using an operation called pressing and sealing. The electrodes are placed and positioned inside the tubes. One end of the tube is heated, constricted, crimped closed around the electrodes, and sealed. The tubes are then cleaned in preparation for mercury filling.

Mercury is injected into the open end of the glass tubes on a multistation rotary fill machine. Each station has a device for holding a glass tube and a mercury reservoir.

The fill sequence is as follows:

- o Glass tubes are loaded on the machine.
- o Each tube is evacuated in preparation for filling.
- o Mercury is dispensed into the tube when it reaches the fill station.
- o Vacuum is released and residual mercury in the piston shaft is drawn into the tube.
- o The open end of the tube is heated, constricted, and sealed.
- o Excess glass is pulled away from the seal and discarded through a discharge chute into a bucket of water.
- o The completed filled tube falls into a transport container.

Low-volume products are filled with mercury at a manual fill station by using the same fill sequence. Wire leads are then attached to the contacts of the electrodes and the switch is complete.

2. Mercury Buttons for Wall Switches

The mercury button contains a metal shell, metal ring, ceramic center, glass preform, center contact, and approximately 3 g of elemental mercury. 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 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 three progressive assembly stations: (1) the cans are filled with approximately 3 g of mercury, (2) the subassemblies are then manually placed in the can, and (3) the can is evacuated and welded closed. The buttons are cleaned, zinc plated, and used as a component for wall switch assemblies.

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 pressurization with helium to 15 pounds per square inch. Mercury is released from the hold tank and dropped through a metal tube into the metal can. Controlled release is accomplished using a rotating slide gate synchronized to the speed of the welding machine.

Sampling Results, Emission Sources, and Control Methods

Air sampling results from two electrical switch manufacturing plants surveyed are presented in Table IV-9. Although the manufacturing processes used at each plant were different, the filling and sealing processes at both plants were conducted in an isolated Fill Room. In each process, welding machines were used in close proximity to mercury or parts contaminated with mercury, resulting in an increased potential for worker exposure to mercury vaporized by the heat of the machines. Typical emission sources and the methods used to control them are presented in Table IV-10.

Air sampling results from the two switch manufacturing plants show no mercury vapor airborne concentration above 0.060 mg/m^3, and the mean values below the 0.050 mg/m^3 NIOSH recommended level during the surveys.

TABLE IV-9

Workplace Air Concentrations of Mercury in Two Electrical Switch Manufacturing Plants

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	 Mean	Comments
Manufacturer A (various locations) Fill Room	Direct Reading	0.006-0.052 (11)[1]	0.014	Samples are taken at various locations throughout Fill Room
Switch Handling Area	Direct Reading	0.006-0.014 (2)	0.010	Switches are sealed
Manufacturer B (various locations) Fill Room	Direct Reading	0.016-0.040 (6)	0.026	
Fill Room	Full-shift TWA	0.005-0.014 (8)	0.010	
Subassembly Area	Direct Reading	0.006-0.008 (3)	0.007	Switches are sealed
PERSONAL SAMPLES				
Manufacturer B Welder Operator	Full-shift TWA	0.046-0.048 (2)	0.047	Workers spend approximately 8 hr/day in Fill Room.
QC Operator	Full-shift TWA	0.010-0.060 (2)	0.035	Workers spend approximately 8 hr/day in Fill Room.

[1]Numbers in parentheses indicate number of samples taken

TABLE IV-10

Mercury Emission Sources and Control Methods for the Electrical Switch Industry

Mercury Emission Sources/Concerns	Control Methods: Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Vapor emission from mercury purification and transfer	X	X		X	X	X	X		
Vapor emission from mercury filling				X	X	X			
Vapor emission from product testing			X	X	X	X			
Vapor emission from spills, product breakage, reject materials		X		X	X	X			
Dermal contact with mercury during filling									X

F MERCURY USE IN ELECTRICAL PROCESSES

Mercury is used in electrical applications in several manufacturing processes. Most of these processes do not constitute a significant percentage of mercury consumption, since mercury is not a part of the final product. However, in the chlor-alkali manufacturing process, large volumes of mercury are used in electrolytic cells. The process descriptions of a typical chlor-alkali operation and other mercury-using operations are presented below.

1. Chlor-Alkali

A concentrated brine solution is needed to produce chlorine and caustic in mercury cells. The solution is made by pumping spent (weak) brine through a salt saturator. The saturated brine is chemically treated and clarified to remove impurities. After clarification, the brine is pumped through a series of filters to the electrolytic mercury cells for use in the process.

The electrolytic mercury cell is a steel channel sloped at an angle of approximately 7 degrees. A typical chlor-alkali cell is shown in Figure IV-2. It is covered with a sheet of rubber, Teflon, or rubber-coated steel. Inside the steel channel are several sets of anodes that are attached under the cover by copper posts. Rubber seals are used to prevent leakage around the posts where they penetrate the cover. The depth of the anode in the mercury cell is controlled by adjusting the position of the copper posts. Anode depth must be adjusted constantly to optimize the electrolytic reaction taking place in the cell. Usually a computer system is used to actuate a positioner that adjusts the anode depth. At the lower end (outlet) of the mercury cell, there is an outlet box for removal of the brine solution, a decomposer (a cylindrical reaction vessel approximately 4-1/2 feet high and 3 feet in diameter) for the removal of hydrogen and caustic soda, and a mercury pump for returning the mercury to the high end (inlet) of the mercury cell.

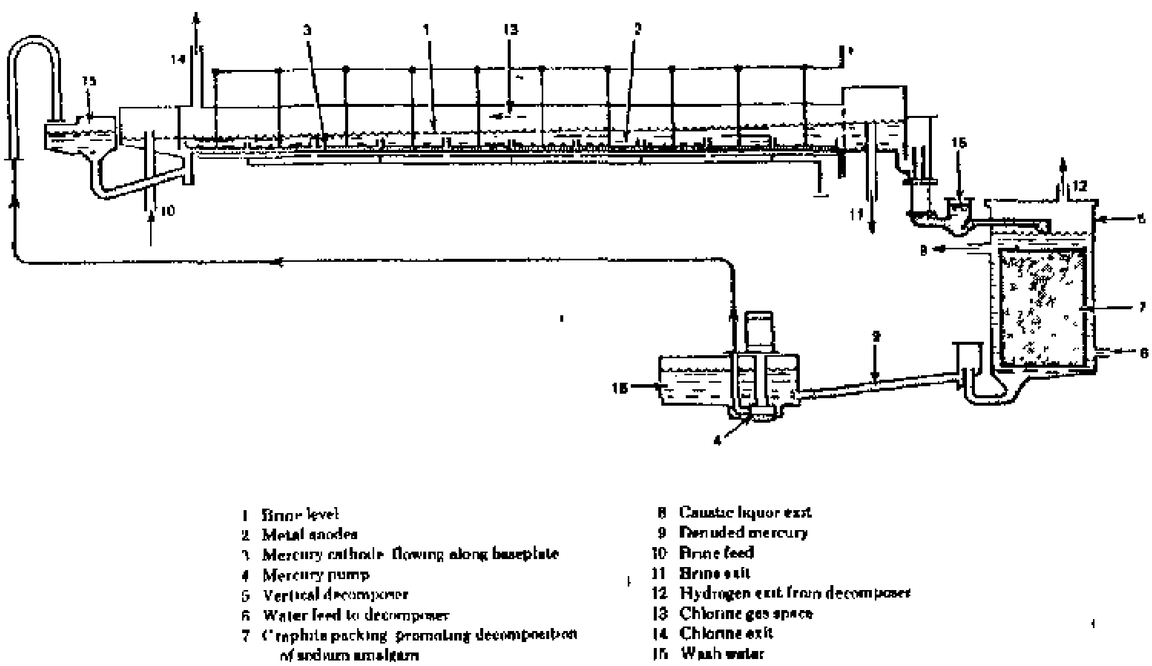

Figure IV-2. Typical Chlor-Alkali Cell.

Mercury, which acts as the cathode, flows along the cell bottom at a specified depth below the anode. The brine solution is introduced to the inlet end of the cell and flows between the anode and the mercury cathode. Voltage is applied between the anode and the mercury cathode through large electrical bus bars. The current causes an electrolytic reaction in which the chlorine ions in the solution lose an electron and the sodium ions gain an electron. Chlorine gas bubbles out of the solution and flows out of the cell through a collection header located at the inlet of the cell. The sodium combines with the mercury to form an amalgam that flows down towards the outlet box at the outlet of the cell. The heavy sodium amalgam flows below the weak brine. A submerged weir in the outlet box is designed so that only the amalgam can flow past it. Weak brine is decanted off the top of the stream through a drain pipe and is returned to the brine system. The amalgam passes through the outlet box into the decomposer where it reacts with water to form caustic soda and hydrogen gas. This is an exothermic chemical reaction. The concentration of the caustic soda produced is controlled to approximately 50 percent by regulating the flow of water into the decomposer. The caustic level is maintained in the vessel.

The caustic produced is drained from the decomposer, filtered, cooled, and stored. Hydrogen leaves the decomposer through the top and passes through a condenser to remove mercury vapor. After further mercury removal using a molecular sieve, the hydrogen is burned in the plant boilers. The chlorine gas from the cells is cooled, dried, liquefied, and stored

The mercury, stripped of sodium in the decomposer, flows through a pipe at the bottom of the decomposer and into a mercury hold tank. A centrifugal pump is used to return the mercury to the inlet end of the cell for reuse in the electrolytic process

Sampling Results

Air sampling results from a chlor-alkali production facility surveyed are presented in Table IV-11

TABLE IV-11

Workplace Air Concentrations of Mercury in a Chlor-Alkali Plant

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	Mean	Comments
Cell Room (various locations)	Full-shift TWA	0 002–0 037 (4)[1]	0 014	
PERSONAL SAMPLES				
Maintenance Worker	Full-shift TWA	0 006–0 009 (2)	0 008	Sample period did not include work on open cells
Cell Room Operator	Full-shift TWA		0 022[2]	
Cell Room Operator	Full-shift TWA		0 004[2]	

[1]Numbers in parentheses indicate number of samples taken
[2]One sample taken

Daily TWA concentrations in the workplace area ranged from 0.002 to 0.037 mg/m^3 with a mean of 0.014 mg/m^3. These area sampling results taken during the survey were in general agreement with recent plant air sampling results. Mean personal exposure concentrations ranged from 0.004 to 0.022 mg/m^3.

The personal sampling results include all routine activities for which a potential for exposure to mercury exists, including taking samples of cell solutions, opening cell inlet and outlet boxes, and contamination of clothing items with mercury droplets which may volatilize.

Maintenance workers are occasionally exposed to mercury vapor at concentrations in excess of cell room background levels. These occasions include maintenance work on open cells and cleaning cell bottoms. Respirators are required for both of these activities. Maintenance workers at this plant did not perform any activities associated with increased exposure to mercury during this survey.

2. Tungsten Bar Sintering

Tungsten, in the form of dense bars, is used as a raw material for the manufacture of incandescent lamp filaments. The manufacturing process begins with the pressing of tungsten powder into long, thin bars of specified weights. The bars, strengthened and densified by presintering in a muffle furnace, are sintered with a high-amperage electrical current. Mercury is used as a continuous electrical contact in the sintering process. It is contained in pools, called mercury cups, located inside each sintering unit. The sintering units (treating bottles) are located inside ventilated enclosures.

After sintering, the bars are cooled to room temperature and the tungsten density is determined Mercury is used for density measurements because of its high specific gravity. The bars are manually immersed in a pool of mercury and the weight of the displaced mercury is determined in order to calculate bar density. When the bar is removed from the mercury pool, the mercury is manually brushed off into a tray of water located in front of the pool.

3. Copper Plating

High-purity copper foil, used for laminate in printed circuit boards, is produced using an electrodeposition process that requires the use of mercury as an electrical contact.

The production process begins by dissolving scrap copper in sulfuric acid to form a copper sulfate solution. The solution is gravity fed to a series of plating drum units where copper ions are removed from solution as free copper by electrodeposition. Each plating drum unit consists of a concrete cell to contain the copper sulfate solution, a lead anode, a rotating titanium drum (cathode), and a winding roll. A current is passed through the solution by establishing a voltage potential between the lead anode (submerged in the solution) and the drum cathode (which rotates so that part of its surface is submerged in the solution). As the drum rotates, the copper is deposited on the drum surface as a continuous foil sheet.

The plated foil is peeled off of the drum and is wound on a variable-speed winding roll. When sufficient foil has been wound on a roll, the roll is removed from the plating drum unit. It is then specially treated, annealed, slit, wrapped, and prepared for shipping

The rotation of the cathode drum necessitates the use of a rotating electrical contact between the bus bars and the drum. The contact is established using elemental mercury as a continuous contact between the rotating copper shaft of the drum and the electrical connections. A pool of mercury, termed "mercury well," is situated at one end of the rotating drum shaft. Attached to the shaft is a series of copper discs that maintain constant contact with the mercury while rotating through the pool. Mercury in the wells tends to heat up because of the electrical current that passes through it.

Sampling Results

Air sampling results from a copper plating plant surveyed are presented in Table IV-12. Personal samples gave a mean of 0.025 mg/m^3. The mean for the area samples was 0 015 mg/m^3. These results agreed with historical plant data.

TABLE IV-12

Workplace Air Concentrations of Mercury in a Copper Plating Plant

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	 Mean	Comments
Drum Room	Full-shift TWA	0 005-0 022 (2)[1]	0 013	Mercury wells used as electrical contacts
Treating Room	Full-shift TWA		0 018[2]	Rotary electrical contact in use
PERSONAL SAMPLES				
Drum Operators	Full-shift TWA	0.024-0 026 (2)	0 025	

[1]Numbers in parentheses indicate number of samples taken
[2]One sample taken

4. Electrical Standard Calibration

Mercury is used as a contact in the calibration of electrical standards. A typical standard is a cylindrical wire-wound resistor, approximately 6 inches high and 2 inches in diameter (Figure IV-3) The standard has two U-shaped contact bars, each of which has one end attached to the top of the standard and the other end positioned out to the side. The outer ends of these bars are used to contact a box-shaped electrical ratio device. Electrical contact is made by placing the standard between two prongs attached to the side of the ratio device so that the contact bars on the standard rest inside recessed holes on the prongs. These recessed holes contain mercury (approximately 1 ml) to provide a low-resistance contact film between the bars and the prongs. Another set of prongs is mounted on the opposite side of the electrical ratio device. This set is used to make contact with a known standard (similar to the other standard). The instrument is used to determine the ratio of resistance of the standard being calibrated to the known standard by adjusting a set of percentage dials until the effective resistances are equal. The dial readings at this point show the ratio between the two standards. The actual resistance of the standard being calibrated is determined by multiplying the ratio by the actual resistance of the known standard.

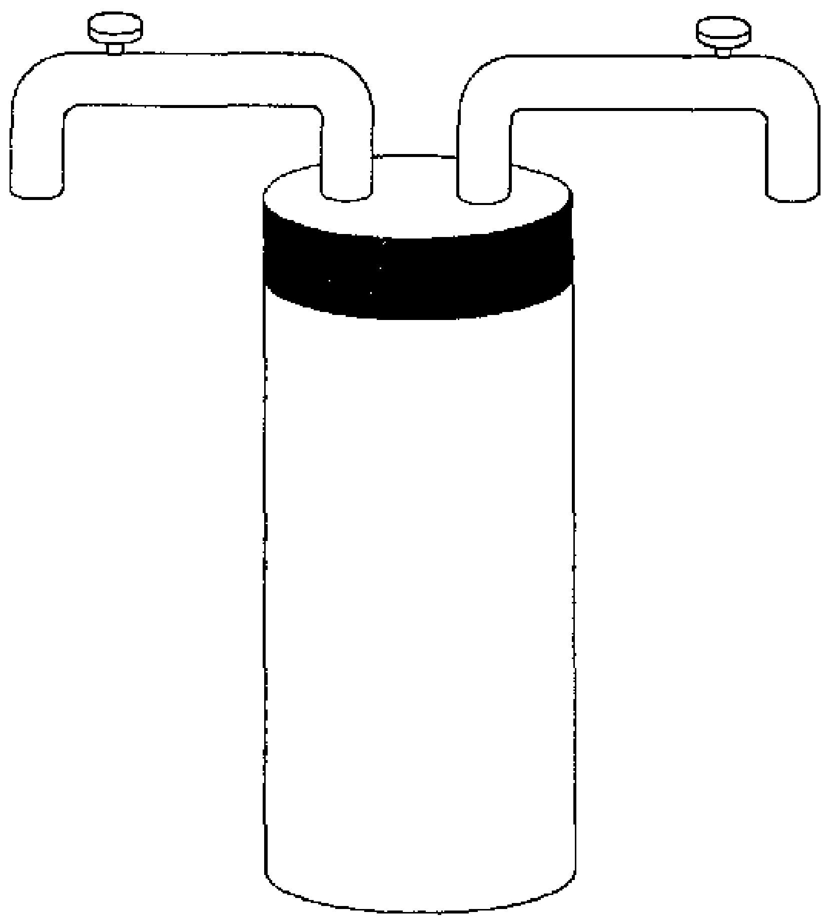

Figure IV-3. Typical Electrical Standard.

recessed holes on the prongs. These recessed holes contain mercury (approximately 1 ml) to provide a low-resistance contact film between the bars and the prongs. Another set of prongs is mounted on the opposite side of the electrical ratio device. This set is used to make contact with a known standard (similar to the other standard). The instrument is used to determine the ratio of resistance of the standard being calibrated to the known standard by adjusting a set of percentage dials until the effective resistances are equal. The dial readings at this point show the ratio between the two standards. The actual resistance of the standard being calibrated is determined by multiplying the ratio by the actual resistance of the known standard

The standardization process may also be conducted in a controlled temperature oil bath for greater accuracy. The oil bath method of calibration involves the same procedure described above except that the electrical ratio device has a different configuration and the contacts and mercury pools are immersed in an oil bath.

Air sampling was not conducted at this facility during the site visit. However, most of the historical plant air sampling data that was reviewed showed mercury vapor concentrations below the PEL.

Typical emission sources in electrical processes using mercury and the methods used to control them are presented in Table IV-13.

TABLE IV-13

Mercury Emission Sources and Control Methods for Electrical Processes

	Control Methods								
Mercury Emission Sources/Concerns	Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Vapor emission from mercury purification		X		X		X			
Vapor emission from mercury addition and transfer		X			X	X			
Vapor emission from mercury pools/wells due to heat generated by electrical current	X	X	X		X	X		X	
Vapor emission from process leaks and mercury spills		X			X	X			
Vapor emission from handling products contaminated with mercury (sintering and standards only)		X		X	X	X			
Dermal contact with mercury remaining on products (sintering and standards only)		X							X

C. MERCURY CHEMICAL PROCESSING/MANUFACTURING

Production of purified elemental mercury and mercury compounds involves distilling mercury and handling particulate mercury compounds. Descriptions of these purification and manufacturing processes follow.

1. Mercury Ore (Cinnabar) Processing

Mercury-containing clay ore is ground in a grinding mill into particles that are fine enough to permit separation and concentration of the mercury-containing minerals by flotation. The particles pass through a cyclone separator that returns oversized particles to the grinder, while the remaining particles are slurried into a series of flotation cells. Agitation of the slurry, after the addition of methyl isobutyl carbinol as a frothing agent and Cyanamid A-242 as a collector, causes the mercury-containing minerals to float and concentrate. The concentrate flows over the sides of the flotation units into launders that lead to a thickening tank. The concentrate is dewatered to 60 percent solids in the thickener and pumped to a concentrate storage tank. Thickened concentrate is slurried and pumped through a two-disc, multileaf filter where it is dewatered to 85 percent solids. It is then gravity fed to an enclosed screw conveyor that feeds the top of a multi-hearth furnace. CaO and Na_2S are added to chemically reduce the mercury containing minerals

The furnace discharge consists of dust, mercury vapor, water vapor, sulfur dioxide, chlorine compounds, and other products of combustion. Mercury, condensed from the gas stream in a series of 12 condensing tubes, is collected in fiberglass-lined launders. The mercury then flows through a cleaning bath and is pumped to bulk storage tanks. It is double filtered and bottled in 76-pound metal flasks or metal, metric-ton containers.

The underflow (waste slurry or "tailings") from the flotation process flows to a series of four settling ponds located adjacent to the plant site. The tailings are dewatered first by decantation and then by solar evaporation in the ponds.

Sampling Results

Air sampling results from a cinnabar processing facility are presented in Table IV-14. As this table shows, the personal samples were an order of magnitude higher than the area samples (0.23 mg/m^3 compared to 0.024 mg/m^3). The personal samples were similar to plant sampling data. The area samples were one-half to one-fourth of typical plant data. The discrepancy between area and personal samples indicates that behavioral components (such as work practices or mercury contamination of work clothing) may be an important factor in the total exposure. Prudent practice would indicate the need for additional sampling to identify these factors, and appropriate measures to mitigate them.

TABLE IV-14

Workplace Air Concentrations of Mercury in a Cinnabar Processing Plant

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m³) Range	 Mean	Comments
Flotation/Concentration Area	Full-shift TWA	0.007-0.040 (3)[1]	0.020	
Furnace Area	Full-shift TWA	0.023-0.036 (4)	0.028	
PERSONAL SAMPLES				
Furnace Operator	Full-shift TWA		0.260[2]	Full-time use of respirators is required
Concentrator Operator	Full-shift TWA		0.200[2]	Full-time use of respirators is required

[1]Numbers in parentheses indicate number of samples taken
[2]One sample taken

2. Mercury Retorting, Distilling, and Packaging

Waste materials containing mercury are frequently processed in retorts to reclaim the mercury. Reject materials (e.g., defective batteries, broken glass tubes containing mercury, reject mercury compounds, mercury sludges, etc.) are loaded onto metal trays and put into a furnace. When heated, the mercury vaporizes and rises into a condenser. The mercury that condenses into a collection chamber is usually impure and must be further distilled.

Distillation is conducted in an insulated distillation vessel (still). Mercury is heated in the still until it vaporizes and rises into a condenser. Condensed mercury falls into a receiver vessel from which the mercury is drained into containers.

Small-quantity bottlers of distilled mercury use special filling devices with a volumetric glass flask to control the amount of mercury put into each bottle. The mercury is poured into a hold tank above the filling device. The volumetric flask is connected to the hold tank by tubing. Mercury flows from the hold tank into the flask until the flask overflows through a tube into an overflow bottle. Mercury is dispensed from the flask to a bottle by opening a valve at the bottom of the flask. Each bottle is capped immediately after filling. The mercury is usually bottled in 1- or 5-pound quantities.

Sampling Results
Air sampling results from a mercury processing facility are presented in Table IV-15.

As this table shows, the facility exhibited ambient mercury vapor concentrations of 0.15 mg/m^3 in the fill room and 0.08 mg/m^3 in the adjacent room at the onset of the survey. An appraisal of control strategies initially showed minor deficiencies in housekeeping practices. Further investigation showed that the central ventilation system for the facility had been operating with 100 percent recycled air, which could result in a buildup of mercury vapors in the recycled air. This was not in accord with the specified operating procedures for the system, which required a 50 percent fresh air makeup. By adjusting air intake louvers during the NIOSH visit, the proper operating condition was achieved. The mean mercury concentration inthe fill room at these new conditions was 0.06 mg/m^3, and in the adjacent room 0.02 mg/m^3. This experience emphasizes the need for monitoring and alarm devices to measure and indicate proper performance of recirculation systems for exhaust air, since 100 percent recycle is, in any event, poor practice.

TABLE IV-15

Workplace Air Concentrations of Mercury in a Mercury Processing Plant

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m^3) Range	 Mean	Comments
Fill Room	Direct Reading	0 08-0 25 (21)[1]	0 15	100 percent recycled air
Adjacent Room	Direct Reading	0 05-0 11 (5)	0 08	100 percent recycled air
Fill Room (with makeup air)	Direct Reading	0 04-0 08 (4)	0 06	Approximately 50 percent fresh air makeup
Adjacent Room (with makeup air)	Direct Reading	0 01-0 03 (3)	0 02	Approximately 50 percent fresh air makeup

[1]Numbers in parentheses indicate number of samples taken

3. Mercury Compound Manufacturing

a. Mercuric Chloride
Mercuric chloride is produced by direct reaction of mercury with chlorine. Liquid mercury is pumped into a furnace and burned with chlorine gas. The combustion product is directed to a settling chamber where the dry mercuric chloride settles to the bottom. When the reaction and settling are complete, the dry product is raked out and packaged in drums.

b. Mercuric Oxide

Mercuric oxide precipitate may be produced using two different processes. In one process, liquid mercury is reacted with chlorine and brine to form mercuric chloride which is reacted with a caustic solution to form the mercuric oxide precipitate

In the second process, mercuric nitrate is formed by dissolving liquid mercury in nitric acid The mercuric nitrate is neutralized with caustic to produce the mercuric oxide precipitate.

Mercuric oxide precipitate from either process is washed, filtered, dried in ovens or in vacuum dryers, ground, sized, and packaged.

c. Phenylmercuric Acetate

Phenylmercuric acetate is usually produced by refluxing benzene and acetic acid with mercuric oxide at approximately 80 C (176 F). It is also produced by reacting mercuric acetate with benzene in a solution of acetic acid. The reactions take place in large (approximately 2,000-gallon-capacity), glass-lined reactors. PMA precipitate is filtered, dried in either a vacuum or a spray dryer, ground, and packaged. Liquid PMA is manufactured by mixing the PMA precipitate with low-molecular-weight glycol and adjusting the pH to 8 with ammonia.

Sampling Results, Emission Sources, and Control Methods

The results of air sampling at a mercury compound manufacturer are presented in Table IV-16. Typical emission sources and the methods used to control them are presented in Table IV-17.

As Table IV-17 shows personal samples for thr Reactor/Drummer Operator were 0.190 mg/m^3. The high area sampling result (up to 0.525 mg/m^3 near the floor, as indicated by direct reading instruments) indicate that general housekeeping may be a major contributor to this exposure. Housekeeping procedures used for handling mercury compounds are described in the sections on Behavioral Controls, p. 96.

TABLE IV-16

Workplace Air Concentrations of Mercury in a Phenylmercuric Acetate Manufacturing Plant

AREA SAMPLES Sample Location	Type of Sample	Mercury Vapor Concentration (mg/m³) Range	Mean	Type of Sample	Particulate Mercury Concentration (mg/m³) (as total mercury) Range	Mean	Comments
Reactor Room General Workroom Air	Direct Reading	0 070–0 150 (4)[1]	0 094				
Near Reactors	Direct Reading	0 085–0 180 (5)	0 120				PMC filtering and drumming
Near Reactors	Full-shift TWA	0 063–0 180 (4)	0 123	Full-shift TWA	<0 001–0 001 (2)	0 001	PMC filtering and drumming
Near Floor	Direct Reading	0 350–0 700 (2)	0 525				
Blending Room	Full-shift TWA		0 023[2]	Full-shift TWA	0 002–0 005 (2)	0 003	PMA bagging
Spray Drying Room	Direct Reading	0 028–0 060 (8)	0 045	Full-shift TWA	0 021–0 029 (2)	0 025	Product (containing PMA) drying
PERSONAL SAMPLES							
Reactor/Drummer Operator	Full-shift TWA	0 180–0 200 (2)	0 190				Conducting drumming operations
Spray Dryer Operator	Full-shift TWA	0 095–0 100 (2)	0 097				

[1]Numbers in parentheses indicate number of samples taken
[2]One sample taken

TABLE IV-17

Mercury Emission Sources and Control Methods for Mercury Chemical Production

Mercury Emission Sources/Concerns		Process Modification and Substitution	Containment	Ventilated Enclosure	Local Exhaust Ventilation	Temperature Control	Dilution Ventilation	Isolation	Mercury Removal from Airstream	Personal Protective Equipment
Mercury Processing	Particulate emission at a cinnabar processing facility from grinding ore, concentrating slurry, and filtering		X	X			X			X
	Vapor emission at a cinnabar processing facility from furnace and from particulate settled out in workplace	X					X	X		X
	Vapor emission from condensing, cleaning, and bottling operations		X							X
Retorting and Distilling	Vapor emission from hot retort or still		X		X		X	X		X
	Vapor emission from transferring mercury for distillation or bottling		X		X	X	X			
	Vapor emission from spills		X			X	X			
Compound Manufacturing	Vapor emission from mercury transfer to reactors		X							
	Vapor emission from reactors	X	X							
	Vapor emission from product spills, cleaning process lines, and particulate settled out in workplace		X			X	X			
	Particulate emission from chemical addition to reactors, particulate filtering, drying, grinding, and packaging		X		X		X		X	X

V. CONTROL METHODS

A. ENGINEERING CONTROLS

1. Process Substitution and Modification

Several plants have been able to substitute new processes for those that previously involved the use of mercury. This is usually possible only in industries that use mercury as a means for production rather than as a raw material for production (i.e., industries that use mercury as an electrical contact or electrode such as the chlor-alkali, electroplating, and electrical standardization industries). This technique has the advantage of completely removing mercury from the workplace, provided that old contamination is eliminated. Unfortunately, product requirements, process restrictions, and cost constraints, may limit the use of substitution as a control measure for mercury exposure. As an alternative, other plants have modified the use of mercury in their production operations to significantly reduce mercury emissions and eliminate the need for implementing costly ventilation controls. This section details several substitution and process modification controls implemented to reduce or eliminate mercury vapor or particulate emission.

a. Substitution for Mercury Electrical Contacts
Pools of mercury or "wells' are used as electrical contacts for rotating drums and rollers in the electroplating industry. The use of the pools for the rollers in the treating process at one plant surveyed has been eliminated by substituting rotary contact devices.

Representatives at this plant determined that the mercury wells that are used as continuous contacts for rotating shafts in the "treating" process were a source that contributed most to the high mercury vapor concentrations in the production area. Plant engineers found that heavy-duty rotary contact devices were commercially available that were capable of providing a current of up to 2,000 amps to a rotating shaft. These devices completely eliminated the need for mercury wells in the treating process and therefore eliminated mercury containment problems in the Treatment Room.

Two types of rotary contact devices are used at this facility. One type is the TWECO Roto-Ground (Figure V-1), a heavy-duty rotary grounding device typically used in welding applications. It consists of an annular head and a shaft (both made of copper) that fit around the rotating shaft and have a tension-adjusting bolt to maximize operating efficiency. Each head and shaft is provided with grease-cup lubrication. The plant formerly used copper-containing grease as a conductive lubricant between the Roto-ground and the shaft. They currently use a graphite-containing grease that provides the same conductance while reducing housekeeping problems typically associated with the copper grease. Up to three heads can be used on each end of the rotating shaft, depending on the range of electrical current desired. The total cost of substituting Roto-grounds for all of the mercury wells in the Treatment Room was reported to be approximately $9,000.

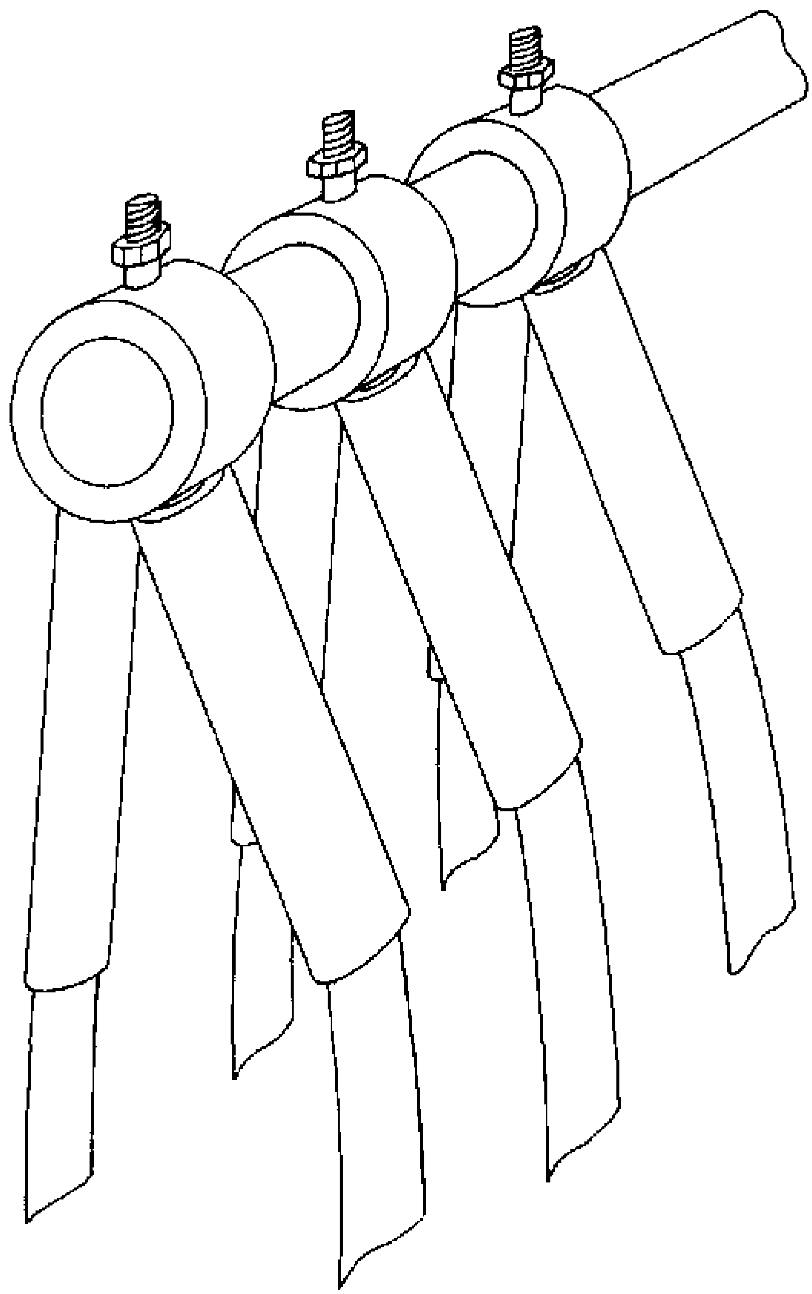

Figure V-1. TWECO Roto-Grounds Mounted on a Rotating Shaft.

The other type of rotary contact device used is a Japanese-manufactured NR series collector ring contact which is similar to the TWECO Roto-ground. The contact is made of a series of SAE 40 bronze rings that fit over the rotating shaft. The number of rings used depends on the range of current desired. Each ring has a set of internally mounted metal brushes for continuous contact with the shaft. The plant has found that this rotary grounding device performs better than the Roto-ground, but it is not possible to fit all treating machines with the NR series contacts due to physical limitations. The plant engineers are currently evaluating another series of all-purpose collector rings with copper alloy brushes. These units are manufactured in the United States by Industrial Electric Reels.

The rotary contact devices provide effective electrical contact for use in the treating process. Not only do they eliminate the need for using mercury in this process, but they have eliminated the costs previously incurred at this plant for replenishing mercury lost from vaporization in the mercury wells in the Treatment Room The rotary contacts do not, however, provide electrical contact sufficient to handle the high current demands for the rotating drums used for the initial electroplating process.

Mercury is also used as a contact in the electrical standardization process. The calibration of current shunts (resistance devices used to measure current) requires the use of high current supply (approximately 10,000 amps). One electrical standard manufacturer generates this current using a series of up to 60 batteries called a "battery board." These batteries are kept in a separate room. Varying currents are generated by adjusting contacts in a mercury pool so that the proper number of batteries are connected in series. The battery board is currently being replaced by a new current generator at an equipment and installation cost of approximately $6,000, which will eliminate the need for a mercury pool because the generator is equipped with a current regulator.

Substitution for mercury use in the chlor-alkali industry, one of the largest mercury-consuming industries, is an ongoing effort in which new expanded technologies are continually developing. New types of chlor-alkali cells, such as diaphragm cells, are currently in operation in some plants. Most facilities still find mercury cells to be the most cost-effective means of chlor-alkali production despite the expenses incurred for controlling the mercury vapor generated. Additional technological development coupled with stringent occupational and environmental health concerns may continue to provide an incentive for eliminating mercury from these plants, however.

b. <u>Dental Amalgam Handling Modification</u>

A major improvement for operatory convenience and mercury control in the dental industry has been the development of preenclosed dental amalgam capsules. Traditional formation of amalgams for use in dental applications involved open-air mixing of mercury and alloy powder. The mixed amalgam was often mulled by hand to obtain the proper consistency (by removing excess mercury). Handling amalgam in this manner increased the potential for exposure of dentists and dental assistants to mercury vapor in the ambient air of the dental office. It also increased the potential for dermal contact with mercury and subsequent ingestion of mercury. Some dentists still practice this type of amalgam formulation.

Instead of mixing a spill (drop) of mercury with the alloy powder inside a capsule, a premeasured spill of mercury is enclosed in a sealed capsule along with the proper amount of alloy powder. The process of filling the capsule with mercury is therefore eliminated by substituting the preenclosed capsules. The use of preenclosed dental capsules for amalgam formulation minimizes the release of elemental mercury to the ambient air.

Dermal contact with the amalgam is also minimized because the proportions of mercury and alloy powder are premeasured at amounts that will form the optimal amalgam. This usually eliminates the need for the worker to mull the amalgam before application, and also to dispose of small excess quantities of mercury.

Dispersalloy[R] Dispos-a-cap capsules, manufactured by Johnson and Johnson Dental Products Company, is one brand of preenclosed capsules used in dentistry. Each capsule is approximately 31.75 mm (1.25 inches) long and 15.87 mm (0.625 inches) in diameter. There are two chambers in each capsule (Figure V-2). The upper chamber (a two-piece plastic assembly) contains a predetermined amount of mercury--usually one, but possibly two or three spills. The bottom chamber contains a steel pestle and the amount of alloy powder required to amalgamate with the mercury. By pulling out the top portion of the top chamber assembly, mercury is allowed to flow through a hole into the bottom chamber to contact the alloy powder. The amalgam is now triturated by agitating the capsule in the "whirly-gig." The pestle ensures proper mixing inside the capsule. After trituration, the capsule is opened by separating the top chamber from the bottom chamber. The bottom chamber is emptied into the amalgam well, and the amalgam is ready for application. The capsule is closed and discarded.

c. Particulate Handling Modification

Controlling mercury particulate emissions when charging mix tanks and reactors can be a difficult problem, especially in batch chemical operations. One battery manufacturer, who uses 15-pound batches of mercuric chloride in producing its electrolyte solution for a cathode mixture, is investigating the use of water-soluble plastic bags for mercuric chloride addition. The plant would purchase the water-soluble bags containing 15-pounds of mercuric chloride from its supplier. The worker would be able to dump the unopened bag directly into the zinc-chloride solution where it would dissolve and release the mercuric chloride. The potential for exposure to mercury particulate when cutting open the bag would be eliminated. This control would be applicable to many industries (e.g. paint formulation) that use particulate mercury compounds as an ingredient or reactant in production, provided that the bag material does not introduce impurities into the process or product, and the mercury can be obtained in exact batch-sized quantities.

d. Modifications in Mercury Processing

A large-scale process modification is currently being investigated by a major mercury mining concern and the U.S. Bureau of Mines. The mine is attempting to eliminate mercury vapor emitted from heating mercuric sulfide in the mercury furnace A hydrometallurgical process is being evaluated to replace the pyrolysis operation currently in use. The new process involves

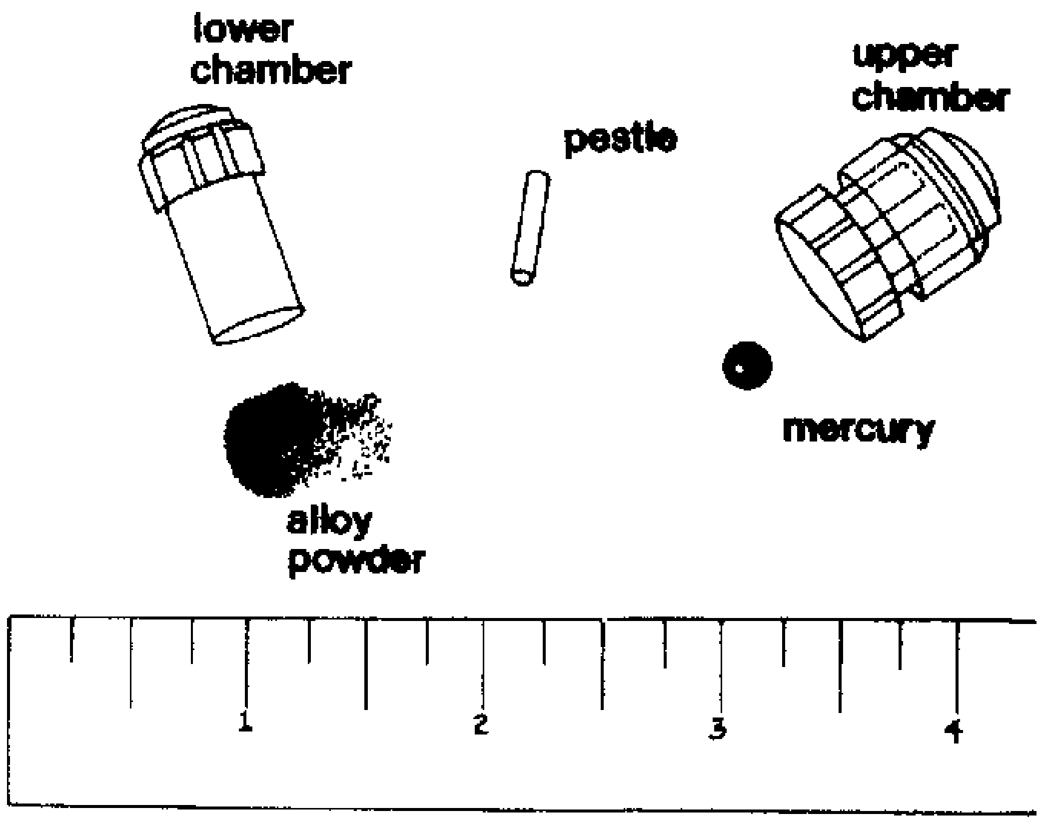

Figure V-2. Dispersalloy[R] Dispos-a-cap Component.

leaching mercuric sulfide concentrate with chlorine and oxygen at 100 C (212 F) and 40 psig. Mercury goes into solution as mercuric chloride and is then decomposed through aqueous electrolysis into elemental mercury and chlorine. This process modification is currently in the planning stage. If the technology proves successful and the process is put into operation, the major source of mercury vapor emission (the furnace) at the mine will be eliminated Potential exposures to chlorine will, of course, have to be controlled in this new process.

e <u>Modifications in Mercury Filling Operations</u>
Plants producing mercury-filled products are particularly concerned with mercury vapor emission because of the large amount of mercury consumed. In addition, there is typically a larger surface area of mercury exposed to the ambient air than there is in most mercury operations. This is because the operation involves a large quantity of production units, each filled with a small quantity of mercury (higher surface area to weight ratio).

It is difficult to control the mercury vapor emissions during the fluorescent lamp manufacturing process, since the lamp tubes are heated immediately after the mercury is added, increasing the propensity of the mercury to vaporize. One plant has implemented a major process modification that eliminates this point of emission on the manufacturing equipment used to produce 80-90 percent of the lamps. 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. The pill is attached to the outside of the cathode shield on the mount assembly (Figure V-3). 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. It also results in a reduction in mercury usage because the enclosed release process reduces mercury waste typically associated with the mercury addition operation.

Mercury vapor emission from the exhaust machines (where mercury is introduced into the glass tubes) in the fluorescent lamp manufacturing process may also be reduced using a mechanical device called a "tube catcher." This device immediately removes and contains the mercury-contaminated glass tips that result after the exhaust tubes are sealed closed by the flame. The tube catcher is a mechanically operated movable chute that reaches up and out from the center of the exhaust machine and catches the hot glass tip released from a compression piece after the exhaust tube is sealed. The tip falls through the chute into a disposal container (Figure V-4). A water level is maintained in the container to reduce mercury vaporization. The total cost of implementing the system on all of the exhaust machines at this

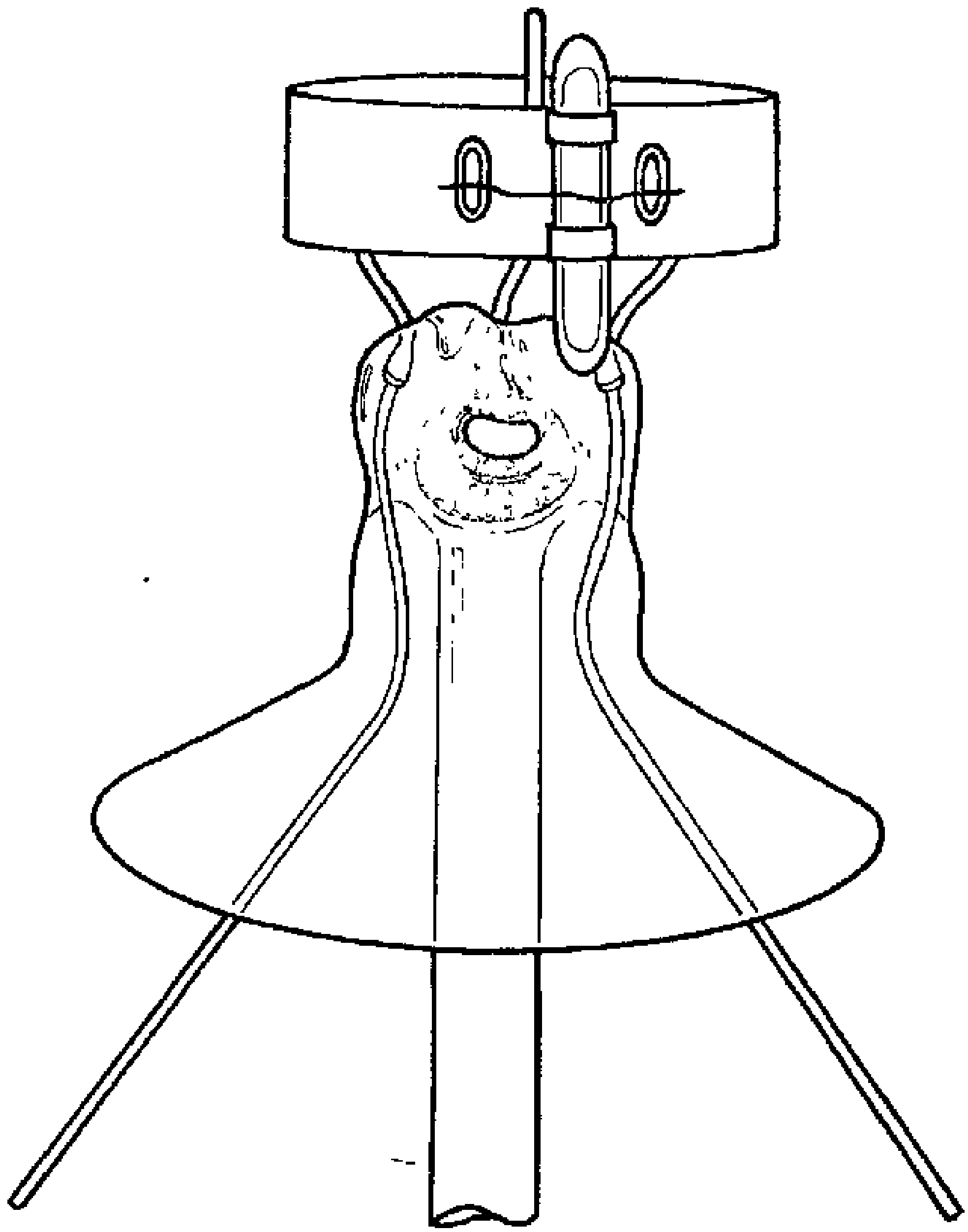

Figure V-3. Mount Assembly with Mercury Pill.

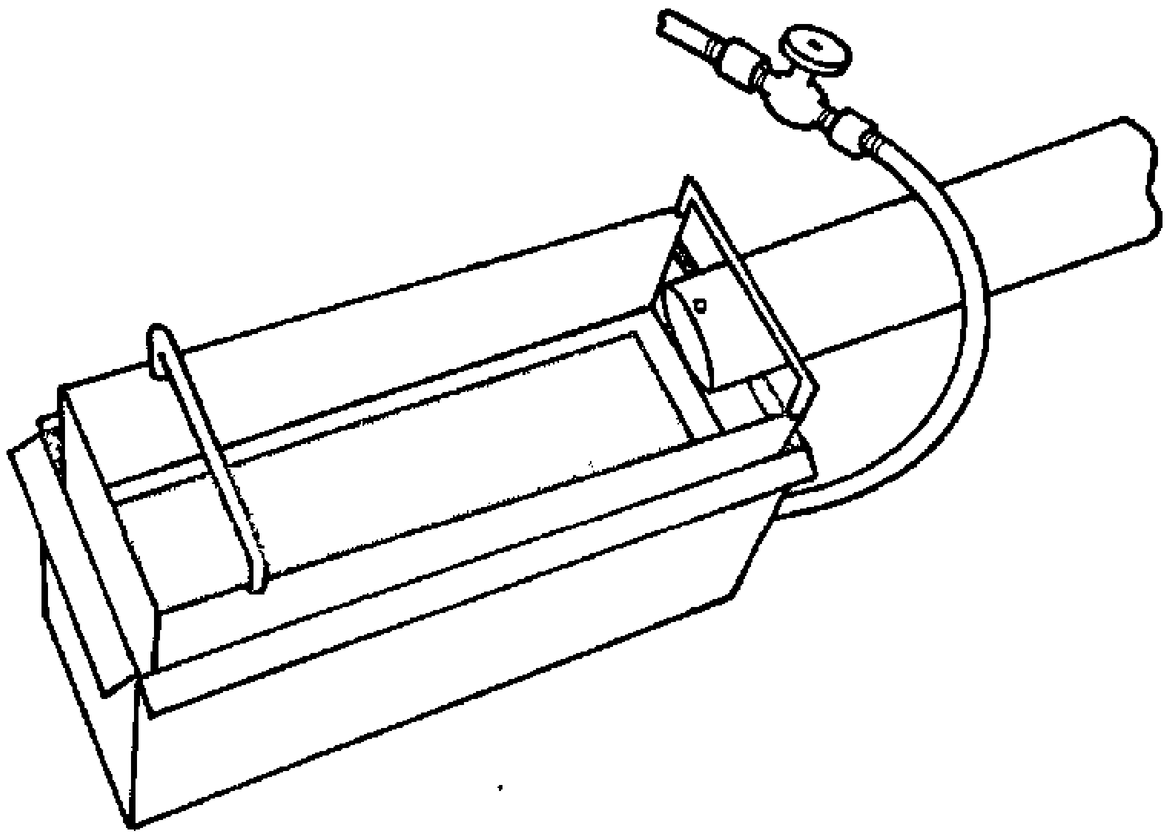

Figure V-4. Exhaust Tube Tip Container.

plant was $80,000 in 1975. In addition, 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.

Handling mercury to be used in filling operations is also an exposure concern. One thermometer manufacturer is currently developing a new mercury addition system to supply mercury to its mercury-filling equipment. The new system will eliminate the need for a worker to transfer mercury from the purification area to the present addition system because both the purification and addition operations will be performed with the same equipment.

The present mercury addition system is being replaced by an aspirator system that will provide a purer quality mercury to the filler. This new system consists of an aspirator jar (with a double-holed stopper at the top and a mercury feed tube at the bottom) and an oxygen and argon injection system. The system will work in the following manner:

- o Mercury is poured into the aspirator jar and the jar is capped with the double-holed stopper.
- o The jar is evacuated through one of the stopper holes.
- o Oxygen is pumped through the second stopper hole and bubbled through the mercury to oxify (purify) it.
- o The oxygen is shut off and the vacuum is released.
- o Argon is injected through the first stopper hole to keep air (with potential contaminants) from coming in contact with the mercury.
- o The mercury stopcock valve is opened, allowing mercury to flow out of the aspirator and into the filler.

A summary of the "Process Substitution and Modification" controls studied is presented in Table V-1.

2. Containment of Mercury Sources

Containment, as a workplace control, is the enclosure of mercury and mercury-containing products and wastes in order to reduce the potential for the release of mercury into the workplace. Many methods of containment are used in the mercury industry. Mercury transfer and addition operations are contained by moving elemental mercury through closed systems using gravity, vacuum, or positive pressure. Particulate mercury is moved in a similar way using pneumatic transfer devices. Mercury filling and mix operations are contained using special dispensing equipment designed to minimize handling, spillage, and waste. These methods are described as follows:

TABLE V-1

Summary of Major Process Substitution and Modification Controls

Controls	Advantages	Disadvantages	Other Applications	Pag
a Substitution for Mercury Electrical Contacts				
1 Roto-ground	- eliminates need for mercury pool	- contact grease may be housekeeping problem	- other electroplating industries	3
2 Collector ring contact	- eliminates need for mercury pool - superior performance to Roto-grounds	- physical limitations of process equipment may prevent the implementation of this control	- other electroplating industries	3
3 Current generator	- eliminates need for mercury pool	- costly to implement	----	3
4 Alternate chlor-alkali cells	- eliminates need for electrolytic mercury cell	- chlorine/caustic production not as cost-effective using most alternative cells	----	-
b Dental Amalgam Handling Modification				
1 Preenclosed dental capsules	- eliminates mercury transfer step in amalgamation process	- may be more expensive than conventional methods - disposable capsules increase mercury waste	----	J
c Particulate Handling Modification				
1 Water-soluble plastic bags	- minimizes worker exposure to particulate generated during chemical mixing	- bag material may contaminate process or product	- could be used for charging reactors in liquid PMA production process	3
d Modification in Mercury Processing				
1 Hydrometallurgical process	- eliminates heating of mercuric sulfide (major vapor emission source)	- involves costly capital investment and increased chemical usage	- could be used to replace retorting and distillation operations	3'
e Modification in Mercury Filling Operations				
1 Mercury pill	- eliminates mercury exposure to air in fill operation - hot mercury vapor does not escape through exhaust tubes - exhaust tube tips do not contain traces of mercury - has resulted in a reduction of mercury vapor concentrations	- mercury exposure may occur in the pill manufacturing area - broken lamp tubes will still emit mercury vapor	- could be used in manufacturing glass mercury switches	41
2 Tube catcher	- quickly removes mercury contaminated parts from area adjacent to worker's breathing zone - traces of mercury are cleared from compression holders by nitrogen blow - contaminated parts are kept under water	- costly to implement	- could be used in manufacturing glass tube mercury switches - could be modified to be used to collect glass tube tips from thermometer finishing operations	41
3 Mercury addition/ purification system	- completely encloses the addition and purification operations, minimizing mercury vaporization - contamination of mercury by room air is eliminated	- needs two gas injection systems and a vacuum system	- applicable in modified form to all mercury filling applications, lamp manufacturers could use this system to purify mercury and fill dosers	44

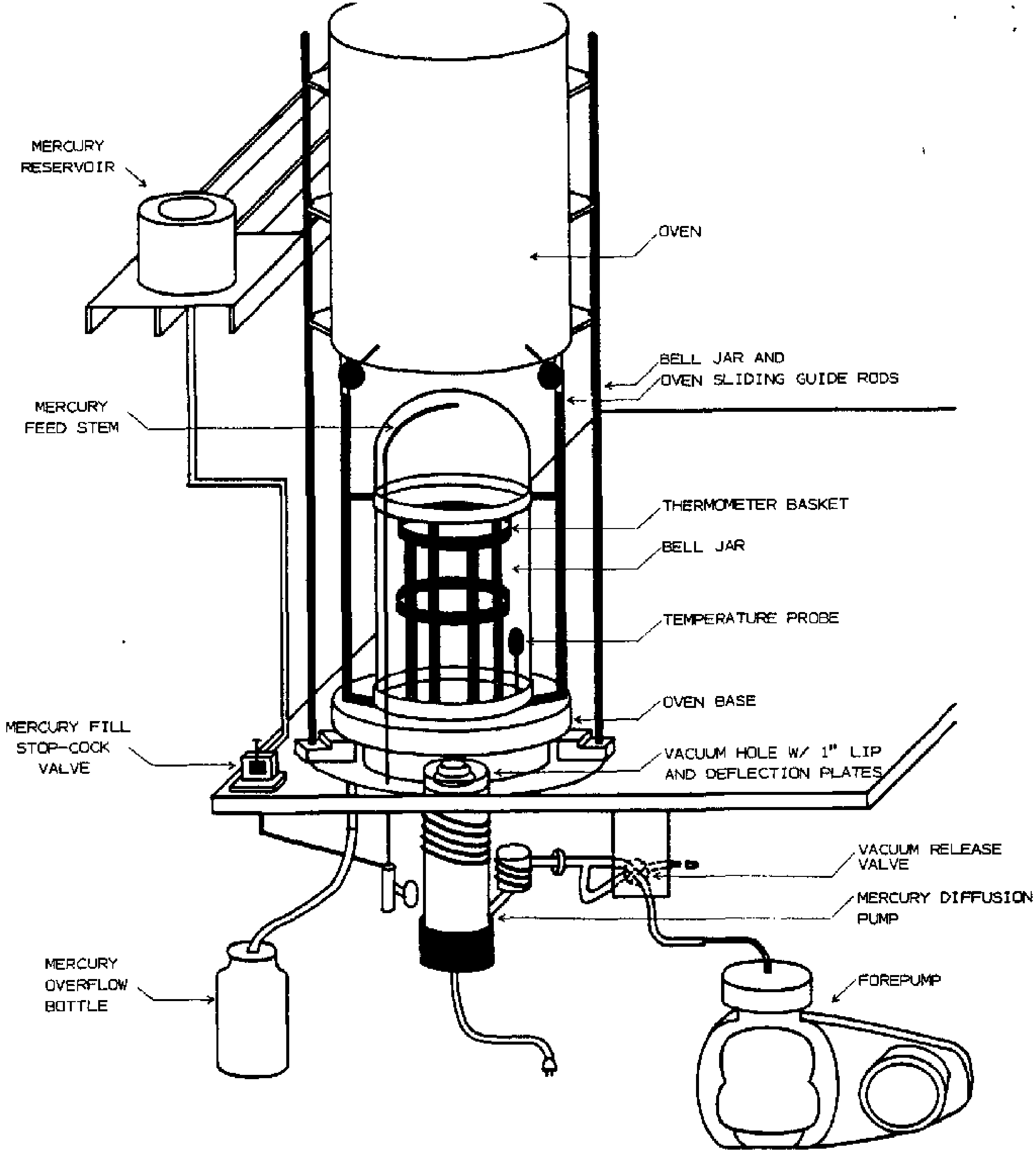

Figure V-5. Schematic Diagram of the Mercury Filler.

a. Enclosed Systems for Liquid Mercury Transfer

Manufacturers using mercury-filling operations have developed many different containment controls. This is particularly true of producers of temperature-sensing instruments. One of the most elaborate containment systems is a vacuum filling device used by one thermometer manufacturer to fill glass tubes. The filler consists of a bell jar, a vacuum system, an oven, and a closed mercury addition system (Figure V-5).

The bell jar rests on an annular-shaped ceramic base set on a bench. By lifting the bell jar, pans of thermometers can be set inside the annular base. The bottom of the pan rests on a set of deflection plates that cover a hole leading to the vacuum system These plates prevent liquid mercury from falling into the vacuum hole. There is also a 1-inch, circular metal lip around the plates to prevent mercury from flowing from the bell jar base into the hole. When the bell jar is lowered, it sets into a seal at its base, which prevents leaks when the vacuum is drawn.

The vacuum is drawn through a series of two pumps consisting of a Cenco HYVAC 7 fore pump (run by a 0.5-hp Dayton motor) and a mercury diffusion pump. The fore pump is a standard vacuum pump that is capable of drawing a vacuum down to 100 mTorr (100 um of mercury). The pump has a mercury trap at the intake. The mercury diffusion pump takes over at 100 mTorr and is capable of drawing a vacuum in the bell jar down to 1 mTorr (1 um).

An oven is used to remove moisture from the glass tubes and to assist in drawing a vacuum. The oven consists of a hollow ceramic cylinder with a stainless steel shell and a heating element. It is lowered over the bell jar and seals against the ceramic base.

The mercury addition system is the major control component in the mercury filler. It is a completely enclosed system that, when coupled with the sealed bell jar, mercury deflection plates, and dual vacuum system, helps to prevent the escape of mercury liquid and vapor into the workplace. Mercury is contained in a covered stainless steel reservoir mounted above the bell jar. One reservoir is used to supply three mercury fillers. Stainless steel tubing connects the reservoir to a stopcock valve mounted below it on the bench. From the stopcock, additional tubing leads down under the bench and up through a mercury feed stem inside the bell jar. By opening the valve, mercury flows through the tubing to the feed stem and into the top of the bell jar where it falls into the pan below in preparation for vacuum filling.

At one mercury switch manufacturing plant surveyed, a mercury filling machine is used that has an enclosed addition system that completely eliminates any manual handling of elemental mercury during the fill operation. This control centers on the use of mercury containers designed by Bethlehem Apparatus Company. These containers (Figure V-6) are constructed 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 connected to

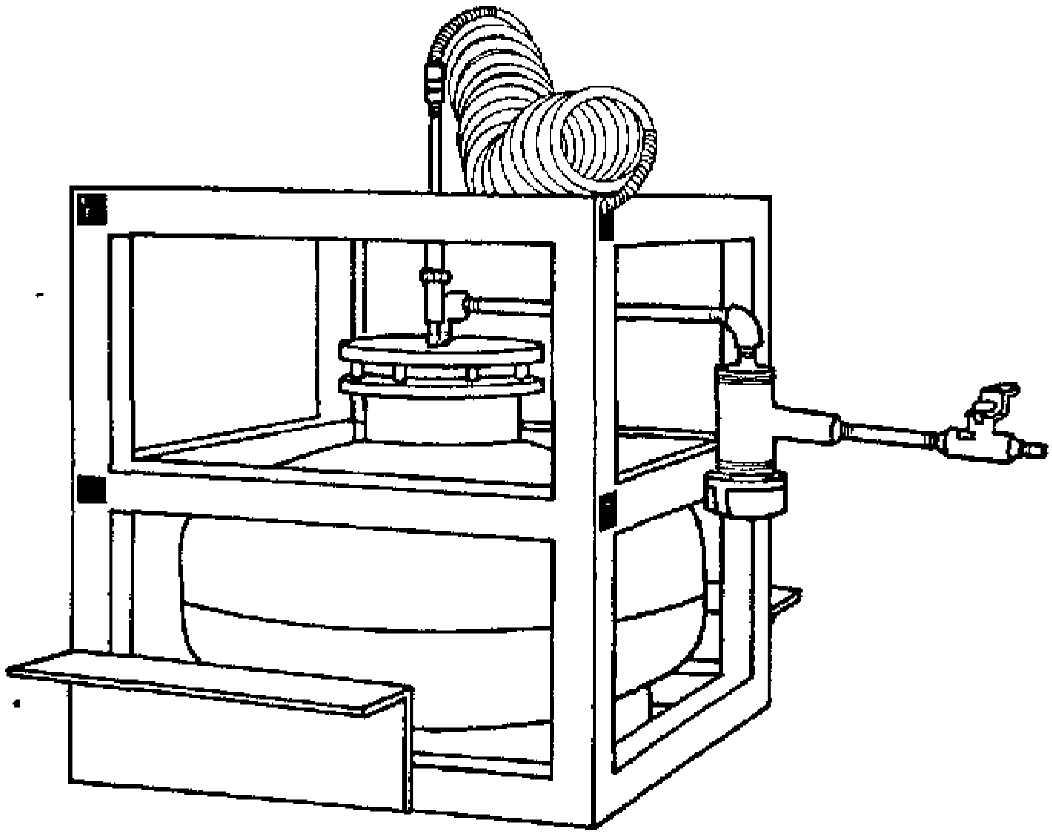

Figure V-6. Mercury Storage Container.

the inlet of the mercury hold tank at the welding machine. Another tube connects the container 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. Transferring mercury from 76-pound flasks to the hold tank has been eliminated, thereby eliminating a potential mercury vapor emission source. This completely contained system could be applicable to most mercury filling operations.

Containment of mercury in process streams is accomplished through the use of effective gaskets and seals. It is important to use materials that will minimize or eliminate leakage normally caused by thermal expansion, contraction, and wear. Single or double mechanical seals should be used on pumps or other moving equipment, depending on the application.

Chlor-alkali facilities are particularly concerned with seals and gaskets because of the extensive piping network and large number of electrolytic cells in the operation. Sealing materials are used throughout the mercury cells to prevent the escape of chlorine gas and mercury vapor. One plant surveyed uses gaskets to seal the seams where the cell covers are clamped to the sides of the cell channels Diaphragm seals are used at the points where the lead-in posts of the anodes penetrate the cell cover. Ethylene-propylene-diene monomer (EPDM) is used in this service. It is resistant to alkalies, oxidizers, and high temperatures.

At the same plant, special sealing materials are used on the decomposer and the mercury sump. The seam between the flanged top of the decomposer vessel and the steel cover bolted to it requires a sealing material that will not fail when subjected to the heat of reaction in the vessel. Asbestos gaskets are used in straight mercury service. Where chlorine is also present, neoprene or Hypalon[R] gaskets must be used. Sealing material is used to seal the connection between the mercury sump and the mercury pump base-plate so that vapor from the hot liquid mercury will not escape into the ambient air. All flanges and valves in the mercury system are similarly sealed.

Another chlor-alkali manufacturer uses continuous, two-ply rubber covers on its mercury cells. The covers are manufactured by B.F. Goodrich and are designed to last as long as the anodes (approximately 18 months). Although there is little possibility of mercury vapor escaping from the cell during normal operation because of the vacuum created by the chlorine gas removal system, the covers provide an effective seal that reduces mercury vapor emission when starting up or shutting down a cell. The copper anode posts are sealed with rubber gasketing material at the points where they penetrate the rubber cover. Plant engineers are currently process testing the use of clear Teflon cell covers. They are more expensive than the rubber covers but are expected to last longer.

The mercury system on each cell has compressed asbestos gaskets at pipe and pump connections. The plant is gradually changing over to nonasbestos materials (mostly Teflon). These gaskets effectively prevent mercury leaks during operation, however, leaks periodically develop during shutdown because of contraction at pipe flanges due to cooling.

b. Enclosed Systems for Particulate Mercury Transfer

Unit operations typically requiring containment control include blending, drying, grinding, sizing, transferring, and packaging.

A combined mercuric oxide grinding and packaging operation at one chemical plant uses a particulate transfer system operated under vacuum. This reduces mercury particulate escaping from flanges and valves and eliminates the need for manually transferring dry mercuric oxide between the grinding and packaging stations. Fine dust generated at the grinder is separated from the oxide product by a cyclone dust separator. The product-size oxide particles are spun to the outside of the cyclone and are channeled through a line to the packaging station. The fine dust falls through the center of the cyclone into a hopper on the bottom. It is emptied periodically into fiber drums lined with plastic bags When emptying, the plastic bag is taped around the bottom of the collection hopper so that the valve is opened the dust is contained in the bag. The discharge from the vacuum pump, after going through another cyclone dust separator, is exhausted to the roof. The collected dust is removed once a week and is reprocessed through the grinder. In a similar operation at another chemical plant, the loading drums are sealed against the packaging equipment. Powdered PMA is packaged in plastic-lined drums underneath the rotary valve and delivery chute on the baghouse particulate separator. The plastic liner is connected to the chute so that the powder will not disperse into the air while a drum is being filled.

Materials handling methods designed to contain mercury particulate are also employed in amalgam mixing operations. One battery manufacturer has reduced mercury vapor concentrations in its amalgamation operation through the use of special material containers designed to complement the enclosed blending operation. The particulate container, or pod, is a covered conical bin with a spring-closed slide gate on the top cover and a handwheel-activated butterfly valve on the bottom (Figure V-7). These pods can be transported on carts with roller bearing supports and can be maneuvered into position above or below mix equipment by a hoist. Material is introduced to the pod through a flanged delivery chute that is inserted through the spring-closed slide gate and attached by fastening quick-release clamps to the flange of the chute. Material is removed from the pod by lifting the pod over its delivery point and opening the butterfly valve. The delivery point is usually a covered hopper that feeds a screw auger. These hoppers have openings in the top that are just large enough to accommodate the nipple below the butterfly valve at the bottom of the cone. The benefits associated with the use of these pods are (1) reduced exposure to amalgam powder because the powder is within a closed system and (2) less manual handling of materials.

c. <u>Containment of Mercury Products and Wastes</u>

The most common containment control for reducing mercury vapor emission is the covering of mercury-containing products, components, and subassemblies as they are completed. At most plants studied, small mercury-containing items such as anodes, cathodes, cells, thermometers, and switches are stored in covered containers for transfer and storage.

Handling mercury-containing wastes is an important aspect of any mercury operation. The waste must be contained to reduce mercury vapor emission, and it must be disposed of properly. Effective waste containment systems remove and contain the waste at its point of generation.

The exhaust tube tip containment systems used by one lamp manufacturer surveyed are good examples of mercury waste containment. The exhaust tube tips discarded during fluorescent lamp manufacturing contain small amounts of mercury. Since the tube tips are hot at the time they are discarded, there is an increased potential for emission of mercury vapor. Two types of tube catching systems are used to reduce the mercury vapor generated. The first type is a vacuum system in which a 4,500-cfm (design specifications) blower draws the tube tips through several 4-inch collection pipes to a cyclone separator. The tubes enter the collection pipe by falling into discharge chutes located on each end of the lamp at the tube sealing station of the lamp manufacturing machine. As the tubes enter the cyclone, they are separated from the airstream and fall into a 55-gallon drum. The exhaust airstream from the blower (mounted on top of the cyclone) flows through a dust

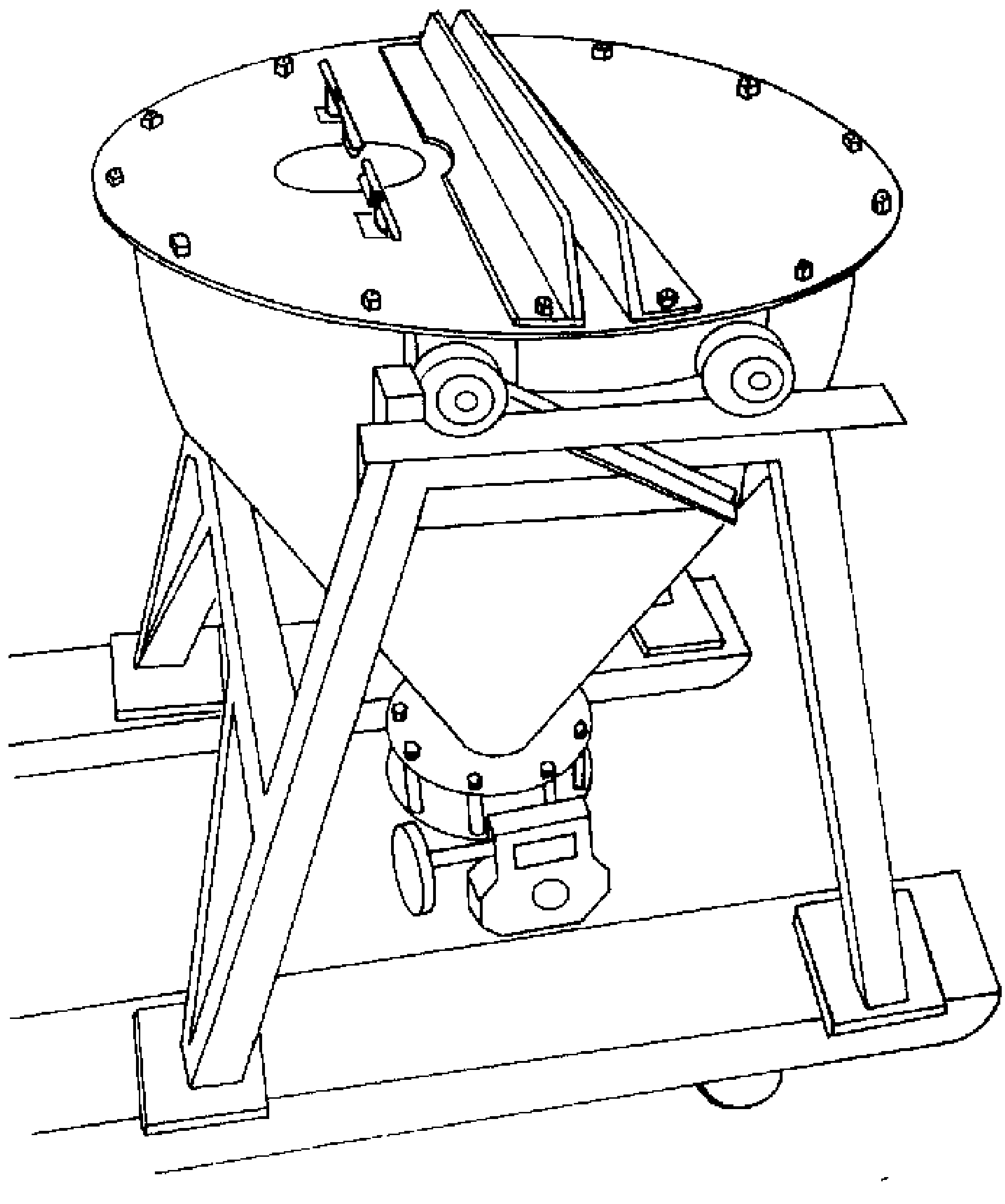

Figure V-7. Material Transfer Container (Pod).

separator before being vented to the roof. The cyclone has a flexible discharge duct that connects to a cover clamped onto the 55-gallon drum. The system is entirely enclosed When the drum is filled to capacity, the cover is unclamped and the drum is transported to a central refuse collection point.

The second type of tube catcher is a gravity system. Exhaust tube tips fall into a discharge that leads to a covered bucket on the floor below. The bucket is connected to its cover by a seal-tight clamp. Buckets are emptied every 2 or 3 days.

d. Containment of Mercury Using Water and Chemical Suppression

When mercury-containing waste is not completely sealed in a drum or other waste container, it should be kept under a level of water (usually 5-6 inches).

Water serves to suppress vaporization of mercury in the waste. Widely applied across all mercury-using industries, water supression is a simple mercury vapor control that is used for the following:

- o scrap amalgam in the dental industry
- o reject materials in the battery industry (anodes, cathodes, chemical mixes, and cells)
- o exhaust tube tips in the fluorescent lamp industry
- o broken thermometers
- o reject and broken mercury switches.

Water may also be an effective control for reducing mercury vapor emission from elemental mercury used as a contact in electrical processes. The inlet and outlet boxes of electrolytic cells are both sources for the potential escape of mercury vapor. At these points, mercury heated in the electrolytic process passes in and out of the cell by flowing through submerged weir-type gates. Maintaining water over the mercury in these boxes helps suppress mercury vaporization. However, as the water is heated due to contact with the hot mercury, mercury vapor may escape more readily. One plant has solved this problem by installing recirculating, chilled water systems, one for the inlet boxes (Figure V-8) and one for the outlet boxes. Each system consists of a surge tank, a 240-gallon-per-minute pump, a chiller unit, and a manifold piping system that circulates water to each cell in parallel. Water from the chiller enters one side of the box, flows over the mercury, and exits through the other side of the box The system supplies 20-30 C (68-86 F) water over the mercury at all times.

In addition to water, other chemicals have been found to suppress mercury vaporization. Mercury vapor emission from the concentrate at a mercury mine was significantly reduced using sodium sulfide (Na_2S) as a mercury vapor suppressant. At the grinder feed in the processing mill, ore from the feed

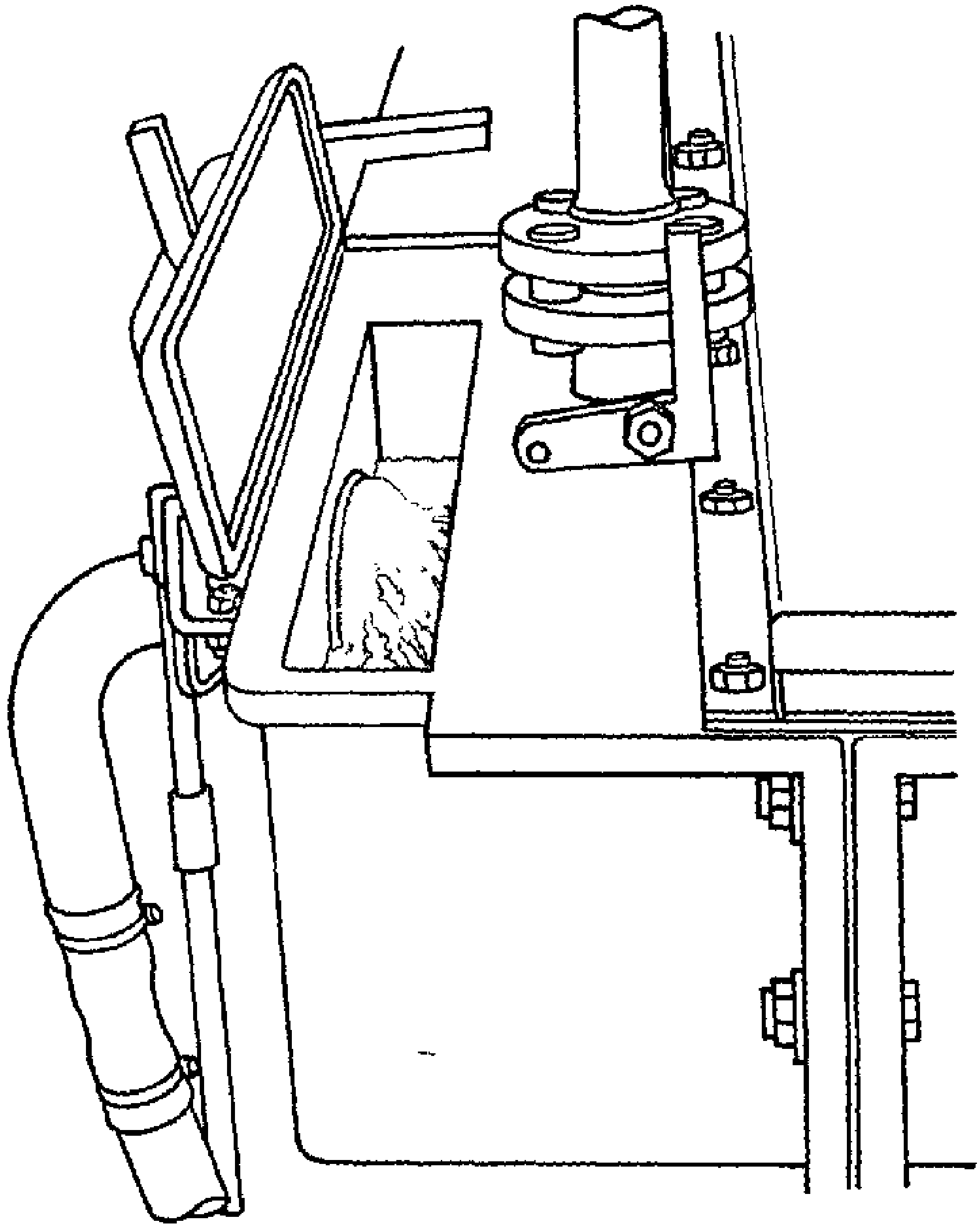

Figure V-9. Inlet Box with Lid Open Showing Waterflow.

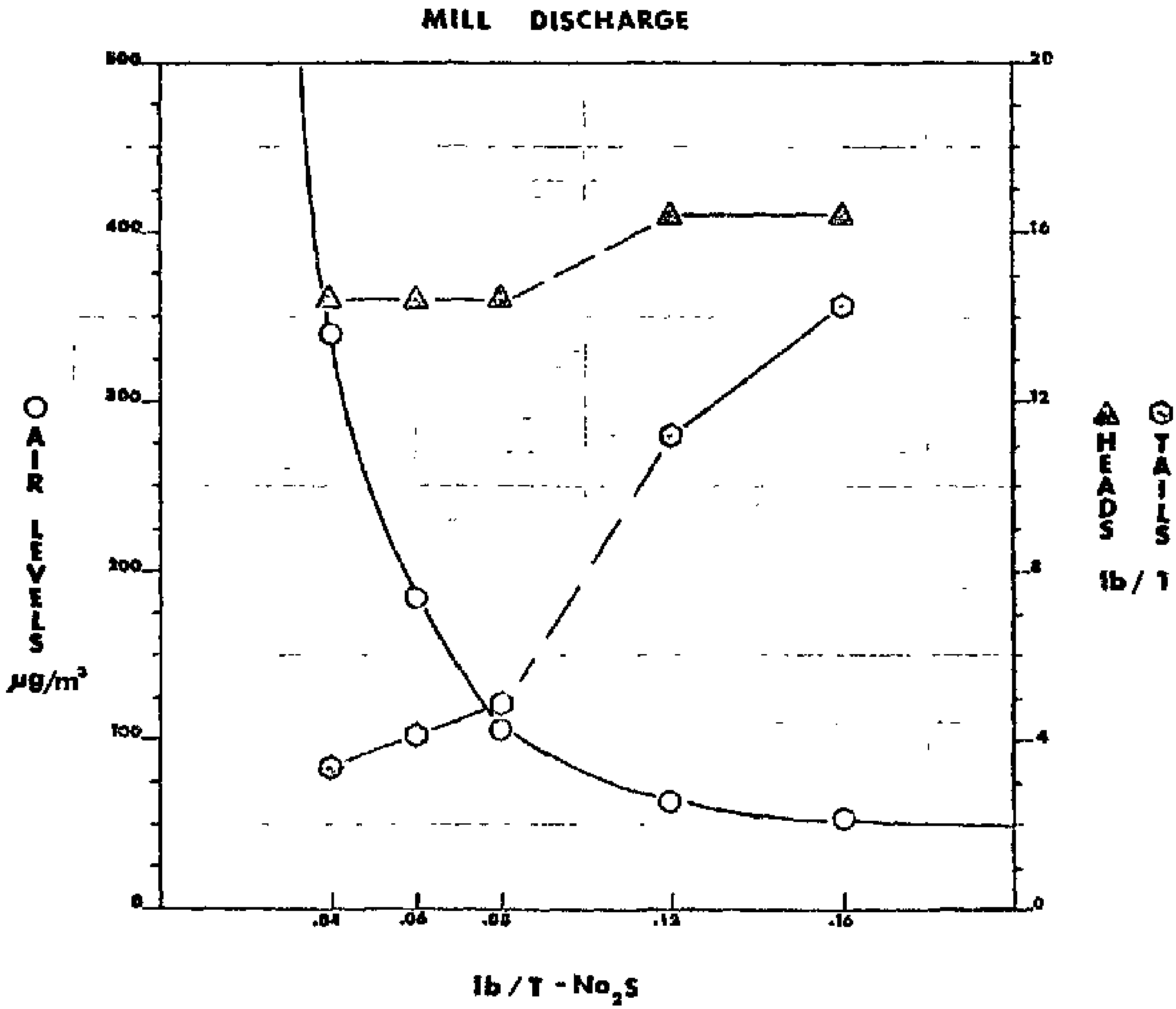

Figure V-9. Mercury Vapor Levels, Heads (Concentrate Production), and Tailing Production as a Function of Na_2S Addition.

Reference. Plant drawing from site visit conveyor combines with oversized milled ore returned from the cyclone separator. Plant representatives have found that the addition of aqueous Na_2S helps to suppress the generation of mercury vapor at this point. Experiments conducted by the safety engineer have shown that mercury vapor concentrations are inversely proportional to the Na_2S addition rate (Figure V-9). The problem, as can be seen on the graph, is that increasing the addition of Na_2S reduces mercuric sulfide flotation and therefore increases the tailings losses. There is a tradeoff between the handling costs of tailings and mercury vapor control, and the plant has found the equilibrium point to be the addition of Na_2S at a rate of 150 cc/ore ton. This corresponds to an addition rate of 0.04 pounds/ore ton.

A commonly used mercury vapor suppressant is HgX[R], manufactured by Acton Associates in Pittston, Pennsylvania. HgX[R] is a polysulfide compound that chemically binds with liquid mercury, minimizing its vaporization. It is used for cleaning work surfaces, equipment, and in mercury spills. A dental clinic is currently investigating the use of sodium thiosulfate solution as a mercury vapor suppressant to cover waste mercury and amalgam. The effectiveness of this control has not yet been determined.

e. Removal of Mercury Spills

In conjunction with HgX[R] usage for cleaning mercury spills, many plants use specially designed spill removal equipment. One fluorescent lamp manufacturer has two cart-mounted mercury vacuum pumps used to pick up mercury spills. The pumps are manufactured by Cenco Megavacs (Central Scientific Company) and operated by 1-hp motors. A rubber hose with an inline mercury trap and a 1/8-inch copper tube tip is used to draw in the mercury. The narrow diameter copper tip is used to increase the suction velocity, thereby facilitating the mercury cleanup. The mercury trap has a tap at the bottom through which the mercury is drained.

Another plant uses two Stokes Model SC2 vacuum pumps mounted on portable carts for cleaning up mercury spills. Suction is drawn through a flexible rubber hose that has an inline covered mercury trap. Plant representatives have been using different filters on the discharge of the pumps to reduce mercury vapor emitted during spill cleanup. It was determined that a series of three AMF CUNO Filters (Model 1M1) were needed to keep mercury vapor emissions from exceeding 0.10 mg/m^3 during pump operation while cleaning up spills. After further experimentation, it was found that one Koby Senior King 60 filter (NLA Products, West Point, Pennsylvania) controls mercury vapor emissions below 0.10 mg/m^3.

One dental clinic uses a portable vacuum pump (Gomco Surgical Mfg.) mounted on a small pushcart to remove spills that cannot be reached by the vacuum system located at the operatory bays. Spilled mercury is drawn through plastic tubing to an inline plastic bottle that acts as a liquid mercury trap. The vacuum pump exhausts through a replaceable fiber filter (not intended to remove mercury vapor). The use of this pump on a mercury spill was found to increase the mercury vapor concentration in the workplace. After vacuuming a spill, mercury collected in the bottle is transferred to a closed container for disposal with other clinic mercury waste.

A portable spill cleanup kit may be used for smaller mercury spills. One kit (manufactured by Science Related Materials) contains a sponge, a suction unit, a 3M 8707 respirator, and mercury-absorbing material. The sponge has a mercury absorbent material on one side. The suction unit is a hand-operated plastic piece with a mercury trap that is capable of creating enough vacuum to draw a small amount of mercury off a work surface. The mercury-absorbent material is spread over the spill area to amalgamate the mercury and suppress vapor emission.

Many facilities handling mercury use a more conventional type of industrial vacuum cleaner that has been specially adapted for mercury use. These vacuum cleaners are mobile, stainless steel, can-style units usually equipped with a 1.5-inch suction hose, vacuum pump, inline mercury trap, and vapor or particulate filter. They typically provide an airflow of approximately 80 cfm and a maximum vacuum of 70 inches of water. The inline mercury trap is used to collect the mercury before it reaches the vacuum pump. The trap is usually a removable plastic container the size of a small can. The filters used are charcoal and/or high-efficiency particulate air (HEPA) filters. Charcoal filters are used to remove mercury vapor from the vacuum pump discharge. HEPA filters are effective in removing mercury particulate (oxide, etc.) from the discharge. Filters must be changed periodically depending on contaminant levels found at the discharge. Manufacturers of vacuum cleaners designed for mercury service include Nilfisk, National Super Service, Mer-Vac, and Dayton.

One plant eliminated the potential for contaminating the workplace (because of mercury vapor breaking through the charcoal filter) by routing the vacuum pump discharge through a flexible hose to an outside vent.

Facilities requiring frequent cleanup of mercury spills and removal of excess mercury from work surfaces generally employ central vacuum systems. One manufacturer of temperature-sensing elements is particularly concerned with removing and containing mercury that is displaced in one of its operations. The plant uses a central vacuum system consisting of a dust separator and a 270-cfm Multi-Stage Centrifugal Turbo Air Exhauster, operating at a vacuum of 5.5 inches of mercury. The exhauster is driven by a 20 hp motor. The system has eight vacuum inlets in the building, each equipped with 2-inch flexible hoses. Each inlet has a cylindrical mercury trap with an internal baffle. The baffle prevents elemental mercury from being drawn into the vacuum system.

f. Sealing Work Surfaces and Floors to Prevent Mercury Penetration

To facilitate mercury removal by vacuuming or cleaning and to prevent mercury penetration, certain materials are used for work surfaces. The materials used are usually smooth, impermeable, and free of cracks and gaps. Permeable surfaces such as wood allow mercury permeation, creating a continuous mercury vapor emission source.

Worktables used by one thermometer manufacturer surveyed have been designed to minimize mercury absorption and spillage. All work surfaces are made of stainless steel to prevent mercury permeation. Tables where workers store thermometers have either half-inch lips around the edges or gutters along the sides to contain the mercury droplets and to prevent them from falling off the table. The gutters have a drain hole through which mercury may be removed. All table legs are caulked at the floor to prevent mercury from collecting under them.

To reduce mercury permeation into cement floors, a 1/4-inch coating of epoxy resin (extended with a fine aggregate) has been applied to the basement floor of the cell room at a chlor-alkali plant. The coating, manufactured by both Conchem or Permachem, is applied by troweling, like cement. Cracks between floor section joints are filled with an epoxy compound containing a finer aggregate. This compound has a higher elasticity than the floor coating and allows for expansion and contraction between floor sections, thus preventing the formation of cracks. The compound is available from the same manufacturers who make the floor coating. Another chlor-alkali plant uses Ceil Cote 682 or 505 to minimize absorption of mercury into cement floors.

The epoxy floors of the Fill Room of a switch manufacturer are dark green to allow for easy detection of liquid mercury. The epoxy coating is also used as a coping against the walls in the room. This creates a 1-inch lip where the floor meets the walls, thereby minimizing seepage of mercury between these two surfaces.

One thermometer manufacturer totally recovered the floor of its manufacturing area to reduce the absorption of mercury into the wood floors. The base of the main floor (11,000 square feet) was cleansed with several applications of HgX^{R}, covered with 1/4-inch plywood, sealed with vinyl epoxy, and covered with vinyl tiles at a cost of $12,190 (1980). The floor of the plant's mercury Fill Room (440 square feet) was covered with several sheets of vinyl that were sealed together to form a single sheet. This was done at a cost of $1,762 (1980).

A summary of the "Containment" controls studied is presented in Table V-2.

3. Ventilated Enclosure

Ventilated enclosures are used to contain and remove mercury vapor and particulate generated at or in process equipment and machinery. A ventilated enclosure should combine process practicality with effective contaminant capture. Exhaust air ducts should be opposite the access points of the enclosure to draw air (and mercury) away from the worker's breathing zone. It is important to have an opening in the unit (such as a port, access point, plastic strip curtain, or small crack) so that the exhauster is able to draw air through the enclosure. If supply air is used in the enclosure in combination with the exhaust air, it must be at a lower flow rate and directed in line with the exhaust stream, otherwise, the supply air will disperse the contaminants.

TABLE V-2

Summary of Major "Containment" Controls

Controls	Advantages	Disadvantages	Other Applications	Page
a Enclosed Systems for Liquid Mercury Transfer				
1 Bell jar mercury filler	- mercury addition is completely enclosed - operation is under negative pressure	- high potential for mercury vapor release when bell jar is raised - vacuum pumps are exhausted inside the fill room	- mercury addition system is applicable to other mercury fillers and mercury bottlers	47
2 Containerized mercury addition system	- eliminates a manual mercury transfer operation (pouring), minimizes mercury exposure to open air	- requires pressurized helium	- applicable to other operations involving mercury filling or bottling	47
b Enclosed Systems for Particulate Mercury Transfer				
1 Grinding/packaging system	- particulate processing is completely enclosed - system operates under vacuum, reducing potential leaks out of the system - particulate "fluff" during packaging is eliminated	-----	- could be applied to other mercury compound production operations to eliminate manual packaging	49
2 Particulate (amalgam) transfer pods	- reduces potential for particulate emission when transferring amalgam in anode processing	- costly to design and implement - periodically requires LEV when discharging the particulate into other equipment	- applicable to other amalgamation operations and to certain mercury compound manufacturing operations	50
c Containment of Mercury Products and Wastes				
1 Exhaust tube tip containment system •	- removes mercury-contaminated exhaust tube tips at their source - waste tips are contained in a covered drum so as not to be exposed to workplace air	- gravity system is not operated under vacuum, it may therefore emit mercury vapor at equipment connections	- could be modified as a central vacuum system and used to collect waste glass in thermometer and mercury switch applications	50
d Containment of Mercury Using Water and Chemical Suppression				
1 Use of water in containers	- inexpensive - reduces vapor emission when kept at reasonably cool temperatures	-----	- applicable to all industries that process elemental mercury and/or generate a mercury-containing waste	52
2 Use of chilled water systems	- reduces temperature of the mercury - prevents exposure of flowing mercury to workplace air	- water in system becomes slightly contaminated with mercury - process leaks must be minimized	- could be used to reduce vaporization from mercury wells in the electroplating industry	52
3 Use of Na_2S in process streams	- proven results in reducing ambient mercury vapor concentrations - easy to add to process stream	- its use may increase the amount of process byproduct produced ("tailings" in the mining industry)	- applicable in all mercury industries for use in cleaning mercury spills	52
4 Use of HgX on work surfaces	- effectively binds with mercury for easy cleaning and removal from work surfaces - commercially available at relatively low cost	-----	- could be used at all elemental mercury-using facilities and some inorganic mercury industries	55

TABLE V-2

Summary of Major "Containment" Controls (Continued)

Controls	Advantages	Disadvantages	Other Applications	Page
e Removal of Mercury Spills				
1 Spill removal pump carts	- inexpensive to design and fabricate - mercury is effectively contained in trap	- vacuum pump discharges are frequently unequipped with filters	- applicable to all industries handling elemental mercury	55
2 Portable spill removal kit	- facilitates the cleanup of smaller spills - inexpensive and convenient	- ineffective in cleaning large spills	- useful for mercury operations conducted at table top, particularly thermometer finishing	55
3 Mercury vacuum pumps	- adequate suction - filtered pump discharge - mercury trap for containment of liquid mercury - available from many manufacturers	- relatively expensive to purchase - filters must be checked and replaced frequently (operation of vacuum may increase workplace mercury vapor concentrations when in use)	- applicable to all industries handling elemental mercury	56
4 Central vacuum systems	- facilitates the removal of mercury at its source - vacuum pump discharge is usually remote from the workplace	- costly to install and operate (pumps are usually running constantly)	- applicable to industries handling elemental mercury to the workplace air	56
f Containment of Mercury on Work Surfaces and Floors				
1 Stainless steel guttered work tables	- impermeable surface prevents mercury seepage into table - liquid mercury can be easily removed - gutters prevent mercury from dropping onto floor and spreading	- stainless steel is expensive, other less expensive impermeable work surfaces would be as effective	- applicable to all industries where elemental mercury or mercury products are handled at a table or bench	57
2 Epoxy coatings	- applied easily and effectively, produces single sheet floor (no cracks for mercury seepage) - dark colors enable mercury droplets to be easily detected	- expensive and time consuming to apply on floor surfaces	- applicable to all mercury-related manufacturing facilities	57
3 Vinyl sheet work surfaces	- relatively inexpensive - impermeable	- cracks in between sheet sections must be sealed effectively or mercury will seep under surface	- applicable to all mercury-related manufacturing facilities	57

a. Ventilated Enclosure of Process Equipment

A ventilated enclosure is used at the mill in a mercury mine to remove mercury vapor and particulate generated by a 6-foot-diameter disc filter at the furnace feed. The enclosure is constructed of fiberglass and fiberglass-coated wood. The exhaust duct is standard PVC piping. These materials are used instead of metal because of the corrosive sulfur dioxide gas present in the gas stream. The enclosure is exhausted by a 3,500-cfm fan located on the roof. This control is important because furnace operations occasionally fluctuate between negative and positive pressure, allowing hot mercury vapor to travel back through the feed screw conveyor and into the filter. This concept of controlling the release of mercury vapor at operations that may experience pressure fluctuations can be applied to mercury stills, retorts, and reactors. The concentrate storage tank at the mill is also enclosed and ventilated to control mercury vapor. The tank is exhausted through PVC piping that leads to the same 3,500-cfm exhaust fan used for the filter hood.

Manufacturing processes that require the use of mercury as an electrical contact use ventilated enclosures for controlling vapor emissions from mercury pools. A sintering operation studied has cabinet-style ventilated enclosures over the mercury cups used in its process. The enclosures have a separate, vertically sliding door for each bottle. The doors are kept closed except when a bar is loaded or unloaded from a bottle. Each set of ventilated enclosures has 12- by 12-inch exhaust air ducts coming off both sides. The ducts combine into a 22- by 22-inch central duct that leads to a 600-cfm roof exhaust fan This system was designed and installed to draw air through the faces of the enclosure for each sintering unit and exhaust the air along with the mercury vapor emitted from the cups. The mercury wells used in a copper plating operation are contained in ventilated enclosures that exhaust to a mercury vapor filter. Each well has a Plexiglas cover with a flexible duct connected to a manifold. There are two manifolds, one for each set of drum plating units of the plant. Each manifold exhausts to a Calgon Vent-sorb filter (described in section on "Mercury Removal from Airstreams" p. 83). The two filters are connected to a common blower that draws the air through the entire system. The blower is a DR 6 Roton blower rated at 100 cfm.

To reduce the potential for mercury vapor escaping from the inlet and outlet boxes on the electrolytic cells at a chlor-alkali plant, the boxes have been designed with ventilated enclosures. Each box has a steel cover over it with access doors for mercury addition and removal. This enclosure has an exhaust air takeoff that leads to an exhaust manifold connected to the other cells. The air is exhausted by a 1,500 cfm compressor located on one side of the cell room. The original system was exhausted through a roof stack. Environmental concerns about emission of mercury vapor into the ambient air prompted the company to install a Pura-Siv^{R} mercury removal system (described in section on "Mercury Removal from Airstreams") similar to the one used to remove mercury from the hydrogen product stream. By removing mercury from the airstream, plant representatives feel that they have also indirectly reduced mercury vapor levels in the workplace because the air exhausted through the stack may have been contaminating the supply air that entered the building.

b. <u>Ventilated Enclosure of Manufacturing Machinery</u>
Ventilated enclosures can provide effective control for mercury emission from manufacturing machinery. Manufacturers of mercury button cells use ventilated enclosures to reduce worker exposure to mercury particulate in grinding, screening, and pelletizing operations.

One button cell manufacturer encloses its presses, slant screens, and granulators in box-shaped (approximately 6 feet high) Plexiglas structures with three or four exhaust takeoffs (Figure V-10). A 50-fpm minimum air velocity is maintained across the enclosures. Two baghouses are used to filter the particulate from the exhaust airstream. Plant management became concerned over increased worker exposure to particulate relating to the use of these enclosures. It was found that the worker access points in the enclosures were situated in positions that had high particulate concentrations. To solve this problem, they redesigned the enclosures so that workers can make adjustments to the units from outside of the enclosure rather than from inside. The sections of the machinery that are now enclosed and ventilated require little or no worker access. The cost of these new enclosures is estimated to be $5,000 per unit (1981).

The same manufacturer stores its completed anodes and cathodes in ventilated enclosures on the cell assembly lines. Each enclosure has an exhaust air takeoff leading to a baghouse.

Another button cell manufacturer uses Plexiglas exhaust structures to enclose its mixing, pelletizing, and consolidating machinery. The mixing of powders is conducted inside a ventilated glove box (Figure V-11). The glove box enables a worker to handle containers of powder and to operate a mixer without risking dermal contact with the mercuric oxide powder. It also allows these operations to be performed inside a completely enclosed hood, minimizing the risk of workers breathing the powder. Enclosures around the machinery that frequently requires human access are equipped with "iris ports." An iris port is a hole in the Plexiglas that has a ring of rubber flaps covering it. When machine access is necessary, the worker slips his arm through the flaps, which become snug around his arm to allow minimal airflow out of the port. Iris ports also allow a small amount of air to be drawn through the port. An iris port is shown in the center of the glove box in Figure V-11.

One manufacturer of temperature-sensing elements has developed unique ventilated enclosures that are directly applicable only to that process, however, the principles of performance may be applied in the construction of enclosures for other industries. The mercury fill station at this facility is an enclosed workbench with a manifold designed to fill 12 capillary-bulb assemblies at one time. The station enclosure is a fixed, three-sided stainless steel hood (Figure V-12) with a cable lift, windowed door at the front (Figure V-13) that is kept closed during the fill process. Air is exhausted through a 6-inch duct on the top of the unit. Outside air is supplied to the enclosure through two 4-inch flexible ducts located adjacent to the base of the door. When the door is in the closed position, a conduit (built into the door) equipped with specially positioned distribution baffles is used to provide a uniform airflow across the face of the station. A stainless steel, sloped tray containing 3 inches of water is mounted below

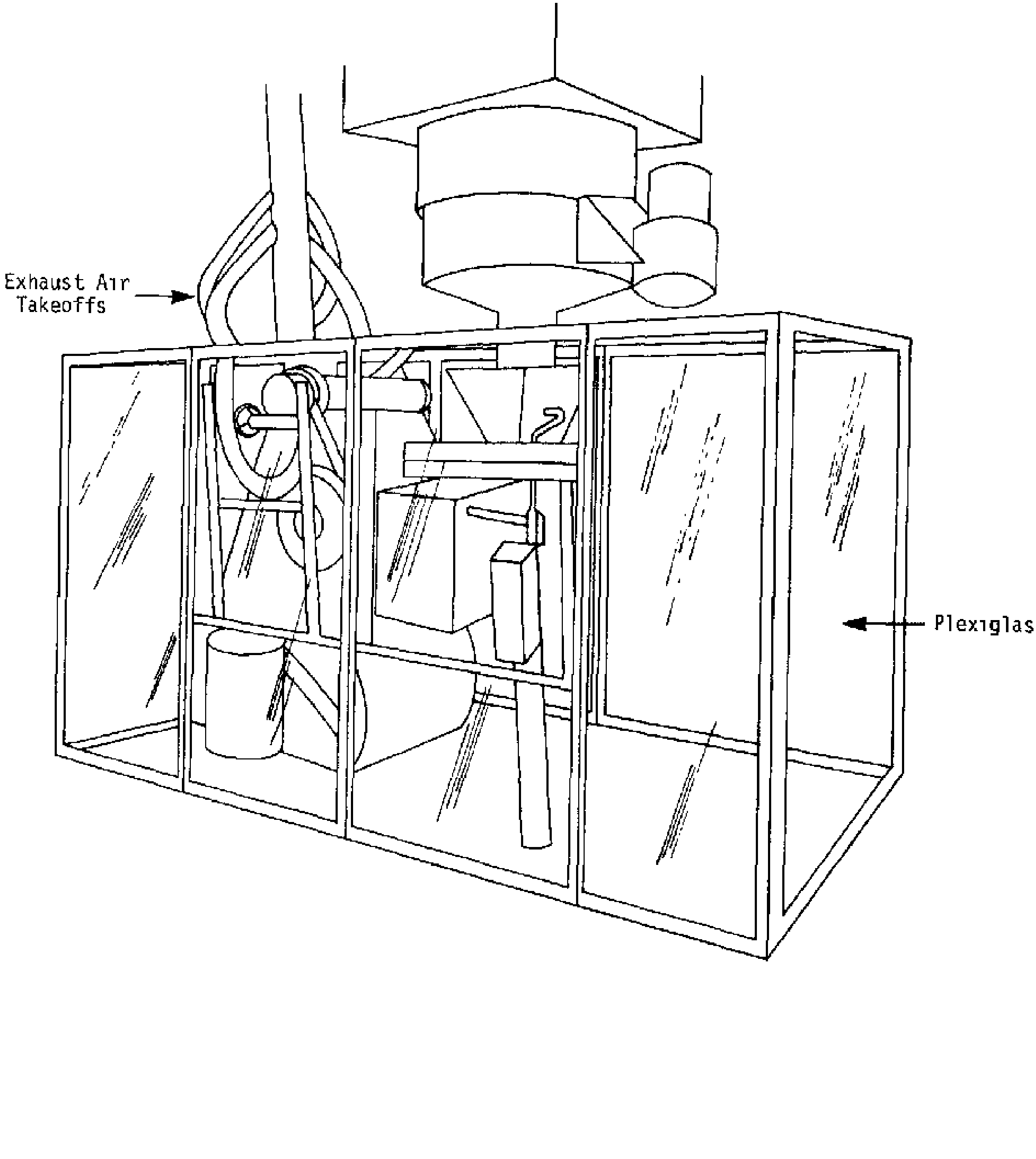

Figure V-10. Plexiglas Machine Enclosure.

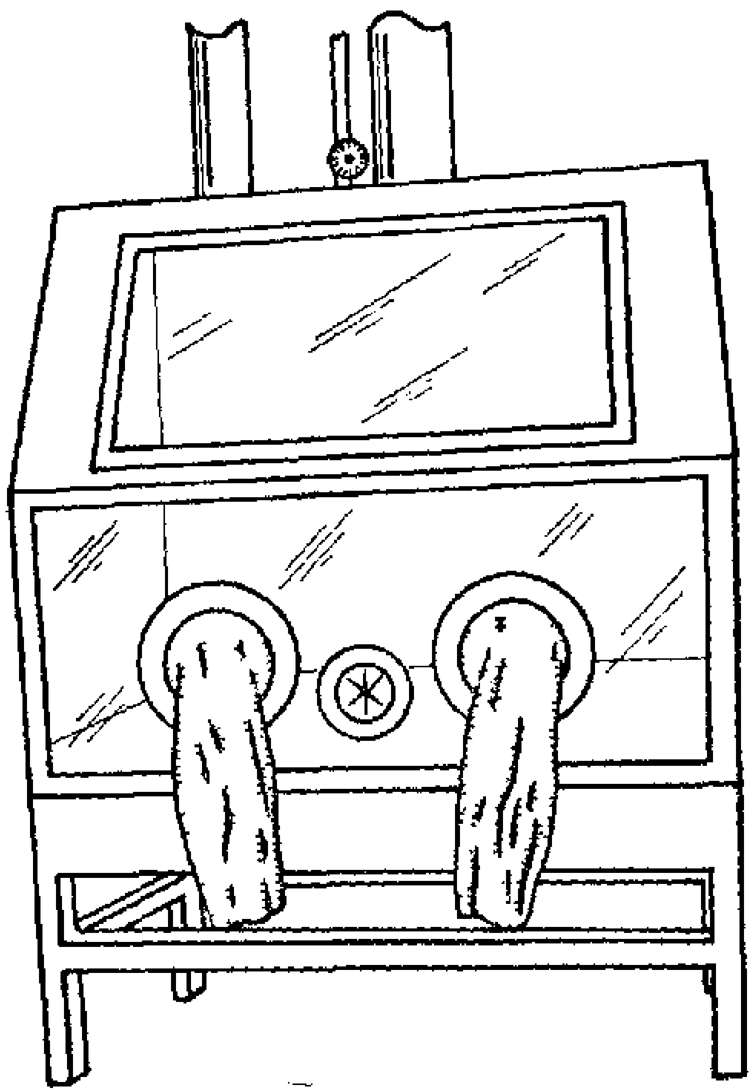

Figure V-11. Glove Box.

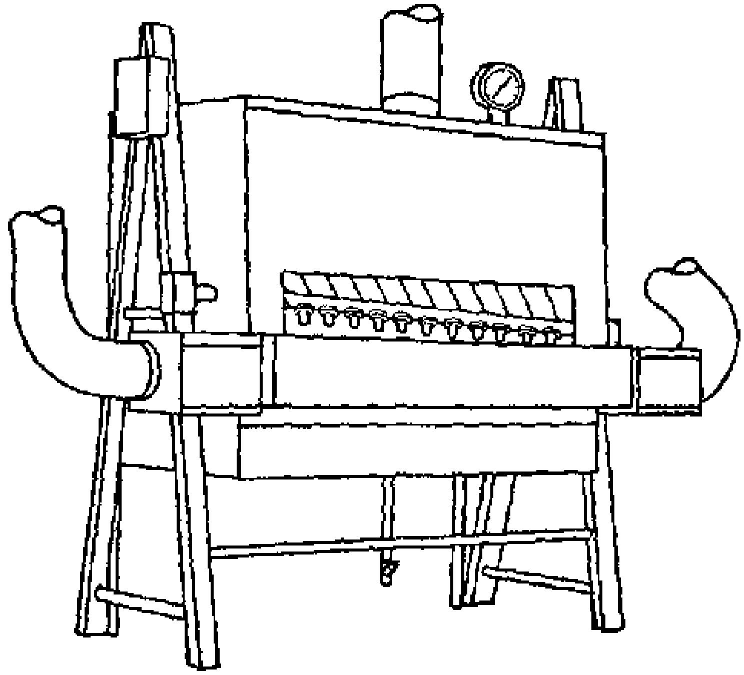

Figure V-12. Mercury Fill Station Hood.

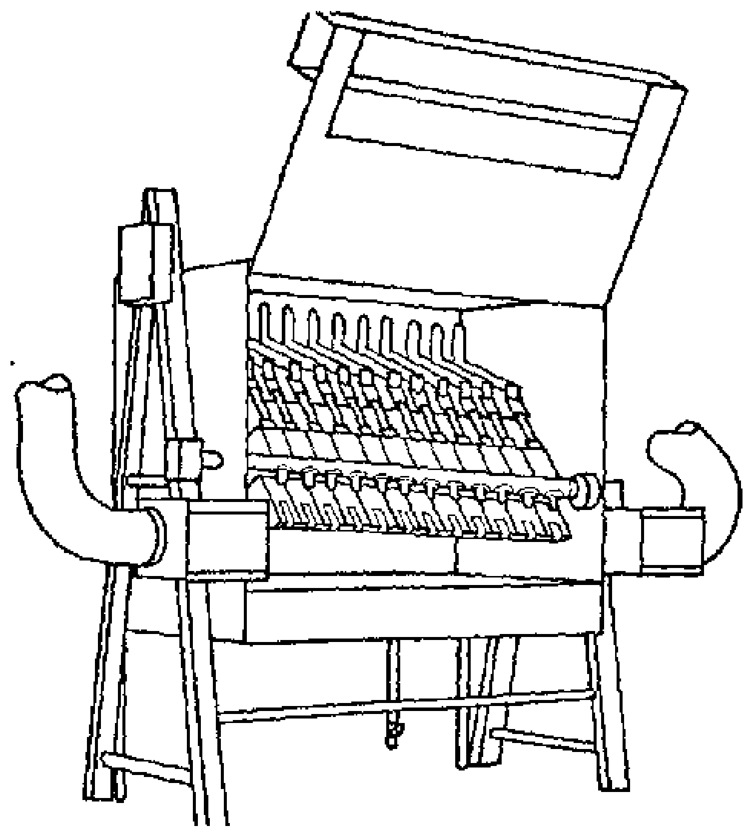

Figure V-13. Mercury Fill Station With Door Opened Showing the Manifold.

the manifold to hold mercury droplets that may leak out during the filling process. The water reduces mercury vapor emitted from the droplets. Mercury is periodically drained from this tray through a trap in the bottom.

A summary of the "Ventilated Enclosure" controls studied is presented in Table V-3.

4. Local Exhaust Ventilation

Local exhaust ventilation is used to control uncontained emission sources so that mercury vapor and particulate are removed from the source quickly and effectively. The two most important requirements for local exhaust ventilation systems are. (1) the exhaust airflow is away from the worker's breathing zone, and (2) the physical design and airflow of the ventilator provide effective capture and removal of the contaminant. The exhaust airflow from the local exhaust ventilation system should be to the exterior of the building or preferably to a mercury vapor/particulate filter system. Different types of local exhaust ventilation systems employed for various mercury operations are presented in this section.

a. Work Station Exhaust Hoods

Industries with mercury-filling operations usually rely heavily on local exhaust ventilation for controlling mercury vapor. This is particularly true of operations performed at workbenches. An exhaust hood used at a calibration station at a thermometer manufacturing facility is a three-sided, stainless steel booth with two 10-inch-diameter wall exhaust fans mounted inside. The booth encloses a workbench containing oil and water baths for calibrating the mercury-filled glass tubes. The booth is 80 inches wide by 48 inches high by 22 inches deep. The face of the unit is slanted and the velocity measured across it was 21 fpm. Total airflow through the unit was calculated to be 330 cfm. The cost of this hood was $1,800 (1977). This three-sided exhaust hood is typical of many local exhaust ventilation systems at mercury work stations except that the face velocity was relatively low

Some exhaust hoods have additional local exhaust ventilation systems mounted inside. An example of this type of hood is found at a work station in a mercury bottle filling operation The station, consisting of two bottle fillers, is enclosed by a three-sided exhaust hood. The roof exhaust fan for the work station is a 1,400-cfm (design) Greenbeck Model CBE1884 situated outside of the building. The fan draws air through a 3- by 70-inch slot at the back of the hood at bench level, and through two gooseneck local exhaust hoods (6- by 6-inch openings) located immediately above each bottle filler. There are two Mylar sheets on the front of the hood that, when drawn down across the face of the hood, increase exhaust air velocity through the remaining open hood space (Figure V-14) The air velocity across the face of the three-sided exhaust hood was measured to be approximately 100 fpm. Measurements of the individual local exhausters inside the hood yielded the following results

- o local exhaust over each bottle filler - approximately 600 fpm (150 cfm each)
- o slot hood - approximately 550 fpm (800 cfm).

TABLE V-3

Summary of Ventilated Enclosure Controls

Controls	Advantages	Disadvantages	Other Applications	Page
a Ventilated Enclosure of Process Equipment				
1 Filter/stock tank enclosures	- draws particulate and vapor through process equipment away from the work-place - removes mercury vapor backflows from the mercury furnace	- large openings in the enclosure around the filter may reduce the controls effectiveness	- could be used to enclose filters for mercuric oxide and liquid PMA production	60
2 Sintering unit enclosures	- totally encloses mercury pools - individual doors at sintering units minimize the open areas in the enclosure	------	- applicable to other mercury pools	60
3 Mercury contact pool enclosures	- totally encloses mercury pools	- vacuum pump is vented indoors, as a safety precaution, it would be better if the vacuum pump discharge was vented outdoors	- applicable for any mercury pool	60
4 Chlor-alkali cell inlet and outlet box enclosures	- totally encloses mercury pools	- airstream treatment for mercury vapor removal may be costly	- applicable for any mercury pool	60
b Ventilated Enclosure of Manufacturing Machinery				
1 Plexiglas enclosures	- contains particulates emitted from machinery - can be constructed to fit tightly over machinery	- limits worker access to equipment - access through enclosure may increase worker exposure	- applicable for mercury switch and battery manufacturing equipment	61
2 Glove box enclosure	- completely encloses operation - provides worker access - equipped with iris ports to provide air intake for vacuum	--------	- would provide effective mercury control at (1) parts repair work stations, (2) mercury doser filling stations, and (3) mercury purification work stations (oxifying)	61
3 Enclosed manifold filling device	- enclosure is closed and ventilated during mercury filling - dilution supply air is provided in front of the worker - view window allows worker to inspect manifold for mercury leaks	- if supply airflow exceeds exhaust airflow, turbulence inside the unit could disperse mercury vapor in the direction of the worker	- though the manifold unit is unique, the ventilated enclosure could be applied to small-scale mercury filling or processing operations	61

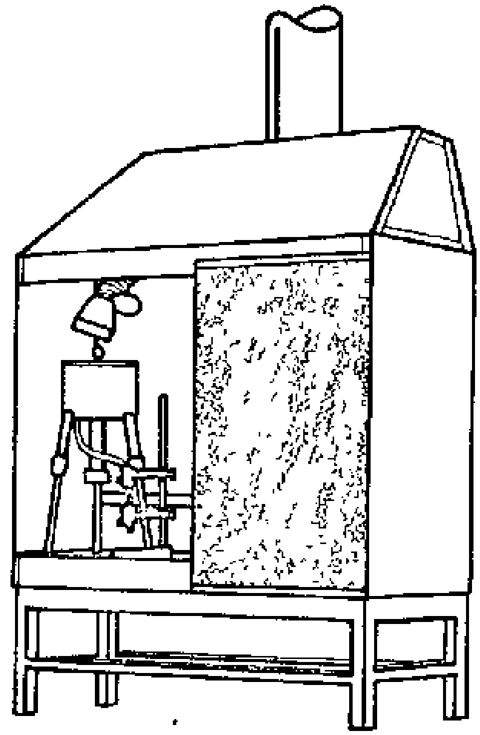

Figure V-14. Mylar Sheet Across the Face of the Exhaust Hood.

Fluorescent lamp manufacturers use workbenches with exhaust hoods for filling mercury dosers (for the exhaust machines), working on mercury-contaminated parts, and purifying mercury through oxification and filtration. The three-sided hood used at the doser filling station at one plant has a vertically sliding Plexiglas door. The door is lowered as much as possible while still allowing enough room for the workers' hands to reach the equipment inside the hood. This increases the air velocity across the face of the hood. Other features at the work station include (1) a stainless steel work surface with a lipped edge to prevent mercury from falling off the bench, (2) a grated section covering a water-filled sink to contain spilled mercury droplets and suppress vaporization, and (3) an air supply vent at the outside of the hood to provide dilution air for the worker.

Smaller operations performed on mercury products at workbenches are frequently controlled through the use of smaller exhaust hoods. Examples of these include slot hoods, canopy hoods, and backdraft rectangular hoods. These controls are typically situated immediately adjacent to the mercury use area.

One thermometer manufacturer uses a workbench local exhaust ventilation system consisting of five bench-mounted, tapered, rectangular exhaust hoods (4- by 10-inch horizontal intake). Each hood is mounted approximately 9 inches off the surface of the workbench. The units are exhausted by a 20-inch-diameter wall fan. Measured airflow through each hood was approximately 50 cfm (180 fpm). Smoke tube testing showed that the capture zone on these units extended approximately 4 inches, not adequate for effective removal of mercury vapor from the workbench. The cost of this local exhaust ventilation system was $1,503 (1977).

b. Equipment Exhausters

Local exhaust ventilation is frequently employed to remove mercury vapor and/or particulate generated at manufacturing equipment. This type of local exhaust ventilation system is usually custom designed to fit specific mercury handling machines and devices. One mercury switch manufacturer uses a specially designed circular slot exhaust hood to draw air over the mercury-containing metal cans riding in carrier cups on the filling and welding machine. The circle is 40 inches in diameter with a 1-inch-high slot around the perimeter. A 16-inch circular exhaust duct extends from the center of the circular slot exhaust to an exhaust network at ceiling level. The average velocity through the slot hood was found to be 1,500 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.

One mercury switch manufacturer uses flat, circular exhaust hoods directly over its filling machines to remove mercury vapor. In addition to this, air is exhausted from the periphery of the filling machine using curved slot hoods. A small, horizontally faced local exhaust ventilation system is situated directly in front of the fill station on the machine. Some machines have plastic strip curtains suspended from the circular exhaust hoods. The strip curtain helps to contain the mercury vapor generated, and it increases the face velocity across the open areas of the curtain where the workers access the machinery. The plant management has found that this control reduces mercury vapor concentrations, and has plans to install plastic curtains on all of the circular exhaust hoods.

Fluorescent lamp manufacturers use exhaust hoods over their mercury filling machinery. These hoods remove heat and mercury vapor generated in the process. One manufacturer uses an exhaust hood that covers the top and part of the sides of the machinery. The exhaust air takeoffs from the hood lead to a 7,500-cfm exhaust fan. Another lamp manufacturer has attempted to remove heat and mercury vapor from the lamp manufacturing equipment by installing commercially available Fyrepel[R] shrouds over the machinery in one of its production areas (Figure V-15). The shrouds are similar to large exhaust ducts leading from above the machines to certain roof exhaust fans. They create a chimney effect that directs the exhaust airflow from the points of mercury vapor and heat generation to the roof exhaust.

Local exhaust ventilation systems are employed at various points in chemical manufacturing processes. One manufacturer of mercuric and mercurous chloride uses an exhaust hood that is situated over the door of the mercuric/mercurous chloride reactor to remove mercury vapor released when the door is opened. The face of the hood is approximately 30 inches wide by 6 inches deep. It leads to a roof exhaust fan and a caustic scrubber for chlorine gas and mercury vapor removal.

The PMA drying, grinding, and packaging operation at one plant has a local exhaust ventilation system consisting of three 12-inch-diameter exhaust air takeoffs. One takeoff is adjacent to the station where the PMA is loaded into drums after drying. The second takeoff is an exhaust hood mounted on the side of the loading hopper for the grinder. The third takeoff is a semicircular slot hood mounted at the edge of the drum loading stand for PMA coming off the grinder (Figure V-16). The ducts from these takeoffs connect

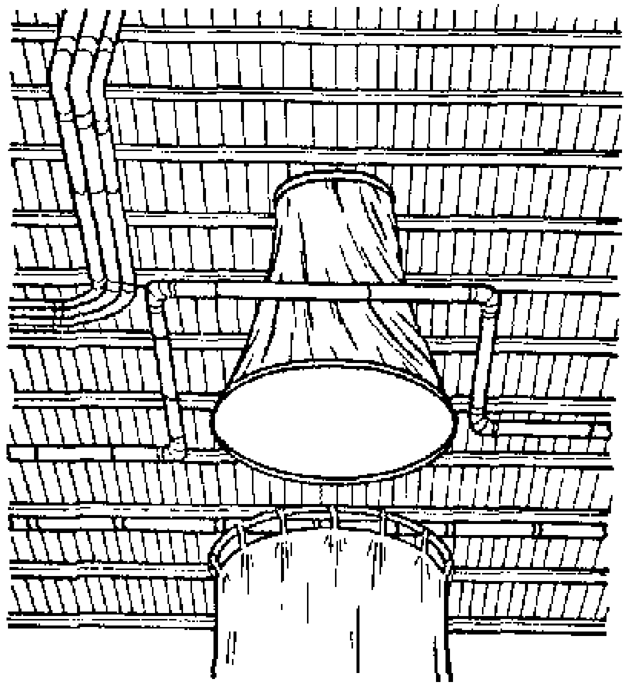

Figure V-15. Shroud Over Exhaust Machine.

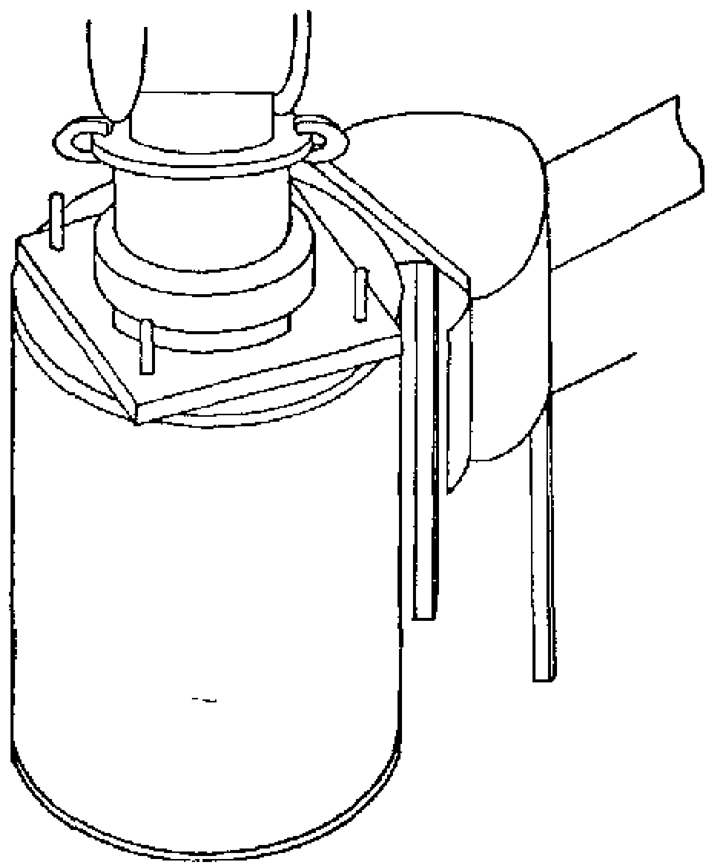

Figure V-16. Exhaust Air Takeoff at Drum Loading Stand.

to a blower that exhausts into a large conical-shaped bag (Figure V-17) mounted in an upper corner of the building. The bag collects the powder dispersed into the air at the three locations previously mentioned.

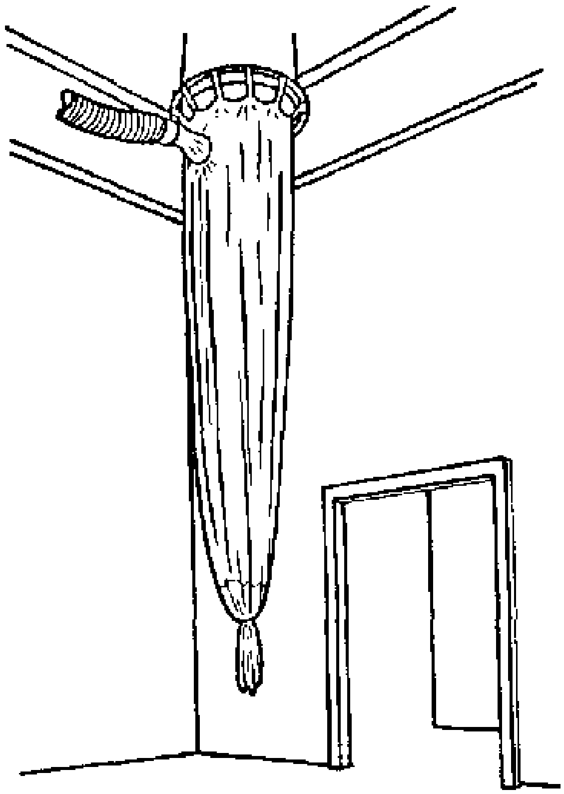

Figure V-17. Filter Bag for Removing PMA from Exhaust Air.

Another PMA manufacturer uses a specially designed, ventilated charger hood for the addition of mercuric oxide to reactor vessels. This control reduces worker exposure to mercury particulate generated when bags of the oxide are opened and emptied into the manhole on the reactor. The charger hood (Figure V-18) is a stainless steel structure with openings for the manhole, an exhaust duct, and a waste disposal bag. The hood is used in the following manner:

- The reactor manhole is opened, vacuum is applied to the reactor, and the hood is put in place over the opening.

- A flexible exhaust duct is connected to an opening on the top of the hood.

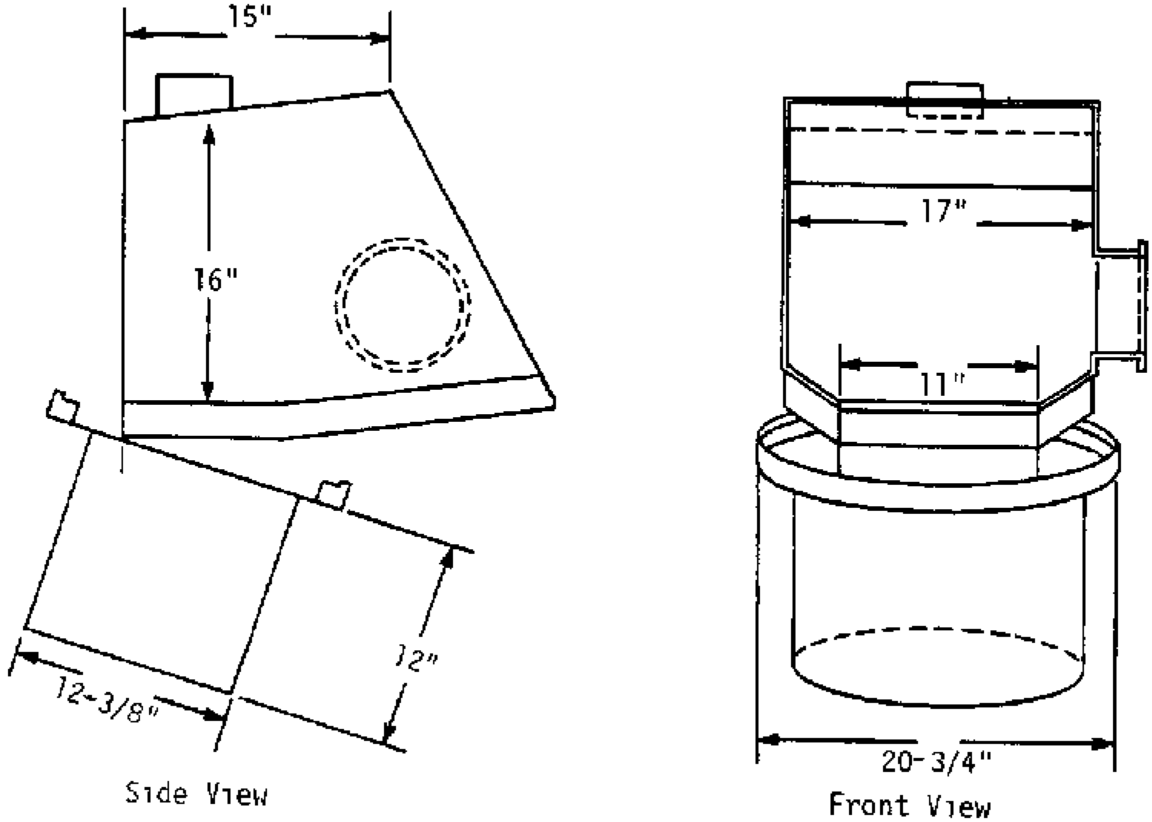

Figure V-18. Mercuric Oxide Charger Hood Design.
Reference: Plant Drawing from site visit

- o A plastic refuse bag is connected to an opening on the side of the hood.
- o The worker opens the plastic liner of the 50-pound mercuric oxide container and empties the bag into the manhole.
- o The empty bag is put into the refuse bag on the side of the hood. The refuse bag is sealed and disposed of in a drum for hazardous waste.
- o The exhaust duct is disconnected, the hood is removed from the opening, the reactor is vented, and the manhole is closed.

The exhaust hood is movable so that it can be used at any reactor being charged with mercuric oxide. The exhaust duct leads to a roof exhaust fan that draws approximately 430 cfm (measured). A HEPA filter is used to remove the particulate mercury from the exhaust airstream.

Dilute PMA powder mixed in a V-blender at the same facility is loaded in drums under a specially designed exhaust ventilation unit. The unit consists of a plastic dust hood (Figure V-19) that is hydraulically lowered over the empty drum before filling. Three flexible exhaust air ducts are attached to the hood. Before loading the drum, a flexible chute is connected from the hood to the blender discharge. This helps to enclose the fill system and reduces powder dispersion. The exhaust air ducts lead to a 16-bag

Mikcro Pul 16S-8-30 baghouse that uses a pneumatically controlled knocker to shake filtered particles into a waste drum. Waste is recycled through the blending process.

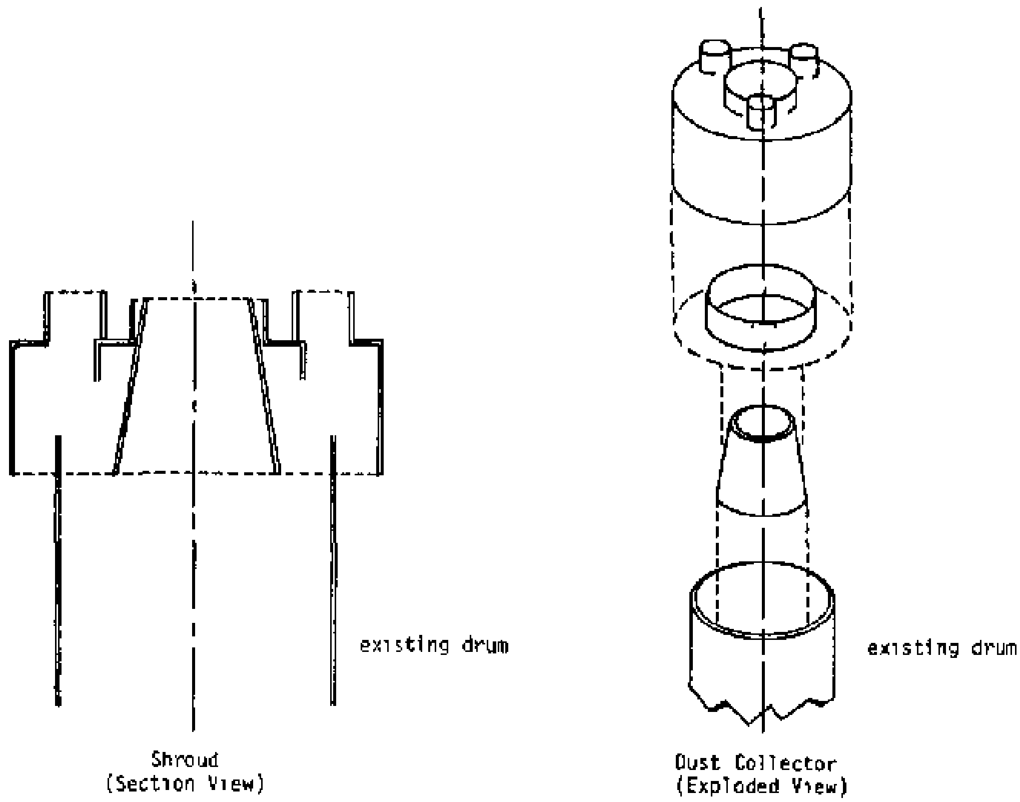

Figure V-19. Schematic Drawing of Drum Loading Hood.

Reference. Plant drawing from site visited.

A filter press used at the plant in the purification of a liquid PMA product has a 2.5- by 5-foot exhaust hood that is lowered over the press while it is operating. The hood has a large baffle inside that creates a 1-inch slot around the periphery of the hood to increase exhaust air velocity. A 12-inch exhaust duct connects the hood to the same exhaust fan used for the mercuric oxide charger hood. The two controls can be isolated so that approximately 530 cfm can be drawn at either hood.

A summary of the "Local Exhaust Ventilation" controls studied is presented in Table V-4.

5. Temperature Control

The vapor pressure of mercury significantly affects the workplace mercury vapor concentration. The temperature of the mercury and/or the workplace air in any mercury-using facility determines the degree of vaporization of mercury.

TABLE V-4

Summary of "Local Exhaust Ventilation" Controls

Controls	Advantages	Disadvantages	Other Applications	Page
a Work Station Exhaust Hoods				
1 Three-sided exhausted work booth	- draws air away from worker's breathing zone	- face velocity may not be sufficient to remove mercury vapor away from the worker fast enough	- applicable for workbenches in any mercury industry (doser filling, mercury purifying, parts repair, etc)	65
2 Exhaust hood with internal LEV	- mercury vapor is exhausted right at the source of generation, improving overall vapor control at the work booth	-----	- applicable where mercury vapor sources in a work booth are localized	65
3 Three-sided exhaust hood with sliding front door	- lowering sliding door enables hood face velocity to be increased, also reduces open space for potential vapor leakage	- door cannot be lowered for all applications	- applicable for workbenches in any mercury industry	67
4 Bench-mounted LEV	- removes mercury vapor at its source when operation is conducted close enough to hood	- the capture of this control was unsatisfactory at distances greater than 4 inches from the exhauster, exhaust fan capacity should be increased	- applicable for workbenches in any mercury industry - particularly applicable to high vapor emission activities (e g , burning-off thermometers)	67
b Equipment Exhausters				
1 Circular slot hood	- has capture velocity sufficient to remove mercury vapor at its source	-----	- also applicable for glass tube mercury switch production	68
2 Machine exhaust hood with plastic strip curtain	- entire machine area is exhausted - plastic curtains reduce mercury vapor diffusion and increase face velocity at point of worker access	- curtains are in strips, allowing some vapor escape	- machinery enclosure applicable to thermometer, switch, and battery manufacturing - plastic curtains applicable for isolating any machine or area	68
3 Exhaust machine hoods	- helps remove heat and mercury vapor generated at machine - also acts as a general room exhauster	- face of the hood is too large to effectively capture all vapor generated at the machine	- applicable for use over open reactors in mercury compound manufacturing operations	68

TABLE V-4

Summary of Local Exhaust Ventilation Controls (Continued)

Controls	Advantages	Disadvantages	Other Applications	Page
b. Equipment Exhausters (Continued)				
4 Fyrepel shrouds	- channels roof exhaust fan intake towards exhaust machine, creating a chimney effect	- shrouds are located far over machinery so that much of the vapor and heat is not removed upon its generation	- applicable for use on all mercury filling machinery where exhaust fans are situated overhead	68
5 Oven door exhaust hood	- reduces hot mercury vapor escaping into workplace when oven door is opened	- if oven door is not cracked open slowly, vapor may disperse before it is captured by the hood	- applicable for retorts and stills	68
6 PMA drying, grinding, and packaging LEV system	- LEV's are located adjacent to the source of emission - baghouse is used for particulate removal	- baghouse is located in work area, bag breakthrough could cause a particulate exposure problem	- applicable to all processing of particulate mercury compounds	68
7 Particulate charger hood	- vacuum in reactor and suction from exhaust fan pull dispersed particulate away from the worker when charging the hood - refuse bag provides for effective disposal of mercury-contaminated plastic bags	- time consuming to set hood into reactor properly - exhaust velocity of observed control was inadequate for effective capture	- applicable for all batch handling of mercury particulate (amalgams and mercury compounds)	70
8 Drum loading hood	- dispersed particulate is captured at its source of emission - particulate is removed from airstream by a baghouse	-----	- applicable for all particulate packaging operations and some particulate transfer operations	71
9 Filter press hood	- slots along outside of hood increase face velocity at the points where vapor/particulate would be emitted into the workplace air - by lowering the hood down on top of the filter, the potential for vapor diffusion from the equipment is decreased	- exhaust air velocity should be greater	- also applicable for exhausting washing/filtering equipment in mercuric oxide manufacturing operations	72

Many facilities handling mercury exposed to the ambient air maintain a workplace temperature of approximately 20 C (68 F). Table V-5 illustrates how a deviation of a few degrees above 20 C results in a significant increase in the vapor pressure of mercury. The table shows that by raising the ambient air temperature from 18 C (64.4 F) to 26 C (78.8 F), the vapor pressure of mercury is doubled. It can also be seen that a temperature increase from 24 C to 26 C results in almost twice the vapor pressure increase as a temperature increase from 16 C to 18 C. Lowering the temperature a few degrees in an environment where a large amount of mercury is used may make the difference between achieving or exceeding the OSHA PEL.

TABLE V-5

Temperature Effect on Mercury Vapor Pressure

Temp (C)	Temp (F)	Saturation Conc. (mg/M^3)	Vapor pressure of Hg (in 10^{-6} mm Hg)
16	60.8	9.40	846
18	64.4	11.15	1009
20	68.0	13.18	1201
22	71.6	15.54	1426
24	75.2	18.31	1691
26	78.8	21.53	2000
28	82.4	25.20	2359
30	86.0	29.49	2777

Mercury switch manufacturers rely heavily on temperature to control mercury vaporization. In one plant surveyed, management places a high priority on maintaining temperatures between 18 and 20 C (64.4 and 68 F) at all times in the mercury Fill Room. There are four thermometers in the room, and if the temperature of any one of them is found to exceed 21 C (69.8 F), the operation is shut down and personnel are evacuated. Air in the room is maintained at this temperature using a General Electric 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 the most effective control used at their plant for the prevention of worker exposure to mercury.

One electroplating plant studied uses temperature control to reduce the vapor generated from the mercury contact wells. The wells were once a major source of mercury vapor contamination because the temperature of mercury in the wells could be as high as 82 C (179.6 F) depending on the equipment and operating conditions. The normal operating range is 26 to 82 C (78.8 to 180 F). Plant efforts were focused on reducing these temperatures by cooling the wells with chilled water. All new wells purchased were constructed with stainless steel water jackets on three sides. Older wells were reworked to accommodate a cooling system by drilling holes through the well bodies to act as channels for the chilled water.

The cooling system consists of a water hold tank, two pumps operating in parallel, a chiller bundle, and a closed loop pipe network that feeds each mercury well and returns the water through a manifold back to the hold tank. The cost of the cooling system was approximately $18,000 in 1980. The system provides a flow of chilled water (4.4-10 C) (39.9-50 F) that maintains mercury temperatures between 15 and 26 C (59 and 78.8 F). Controlling the temperature of mercury to an average of 21 C (69.8 F) rather than at 26-82 C (78.8-180 F) (average 130 F) can reduce the vapor pressure by a factor of 13. This reduces the mercury vapor concentrations, due to vaporization at the wells, to levels that can be controlled using standard exhaust ventilation procedures. A city water header is tied into the system to be used in the event the chiller is inoperative.

A summary of "Temperature" controls studied is presented in Table V-6.

6. Dilution Ventilation

At the plants surveyed, dilution ventilation was the most common engineering control used to reduce workplace mercury vapor and particulate concentrations. Air must be moved through the workplace at a rate sufficient to prevent the buildup of hazardous concentrations of mercury. At the same time, the airflow must be well directed to provide consistent ventilation and minimal dead areas (where little air movement occurs). Unidirectional flow (from one wall to another or from ceiling to floor) helps to achieve this. Older manufacturing facilities frequently have several add-on ventilation systems installed over a period of time, making it difficult to provide unidirectional flow. These systems often require greater ventilation capacity than unidirectional systems to be effective in removing mercury vapor or particulate from the workplace.

Supplied dilution air at any plant using mercury is usually conditioned for three reasons. (1) worker comfort, (2) process requirements, and (3) minimization of mercury vapor concentrations. Conditioning supply air typically involves high operating costs, a point to be seriously considered when evaluating the use of dilution ventilation as a mercury control. For this reason, many facilities employ wholly or partially recirculating air systems with filters to remove mercury vapor and particulate from the workplace. Although filter cost and maintenance are higher with recirculating systems, the overall operating costs are usually lower.

A selection of dilution ventilation systems is presented in this section to provide a general review of ventilation arrangements in use at mercury-using industries. Each design is slightly different in its approach to moving air through the workplace.

TABLE V-6

Summary of "Temperature" Controls

	Controls	Advantages	Disadvantages	Other Applications	Page
1	Workplace temperature controlled below 20 C (68 F)	- mercury vapor pressure is maintained at a level conducive to lower ambient mercury vapor concentrations	- cost of air-conditioning may be high in certain geographical areas	- applicable for all mercury industries	75
2	Temperature monitors	- informs workers and managers of temperatures deviating from center-line that may cause an increase in mercury vaporization	- must be visually monitored frequently to be an effective control	- applicable for all mercury operations conducted in controlled environments	75
3	Mercury pool water jacket cooling system	- historical results show that mercury temperature has been reduced to an average of 21 C (70 F) - the cooling water is isolated from the mercury, minimizing contamination	- system was costly to install in existing equipment	- applicable for cooling mercury pools in sintering and chlor-alkali operations	75

a. Dilution Ventilation Using Air Supply and Exhaust Systems

The mercury Fill Room at one mercury switch manufacturer was designed with a separate ventilation system consisting of a 5,000-cfm (design) air supply system and a 5,500-cfm (design) air exhaust system. The volume of the room is approximately 19,000 cu ft. The 500-cfm difference between air exhausted and air supplied was designed to maintain a negative pressure in the Fill Room, preventing mercury vapor from escaping into adjacent assembly areas. Testing 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 and five floor exhausts. The floor exhausts are retangular ducts that extend from ceiling level to within 5 inches of the floor. The exhaust fan 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 the 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.

Another mercury switch manufacturer currently uses a partial recirculation system but is in the process of changing over to a 100 percent outside air system.

The existing air supply system in the mercury Fill Room at the plant delivers approximately 16,000 cfm, utilizing two 8,000-cfm Lennox air handlers. Each unit has a 25-ton Carrier cooling coil. It is a constant volume, variable temperature system that supplies about 80 percent makeup air to the room. An Economizer control system regulates the air by automatically controlling dampers. This allows for intake of outside air or preconditioned air from another part of the plant. Intake from these two sources is balanced to minimize the temperature adjustment needed. However, plant representatives feel that this system is not working optimally and a new air supply system is being designed to replace the north air handler.

The proposed $150,000 air supply unit is a single 120-ton (1,440,000 Btu/hour) air handler designed to supply 16,000 cfm of outside makeup air at a temperature of 19 C (66 F) Heating capacity for the new unit will be 1,250,000 Btu/hour. The air handler will reduce temperature cycling, which results from the Economizer control on the existing unit's air-conditioner. Four-stage cooling will be accomplished using four 30-ton compressors. Higher energy costs are expected with the new system because only outside air will be used. The existing south air handler will remain operational for use as a backup system whenever the outside air temperature exceeds 37.8 C (100 F).

Fluorescent lamp manufacturers typically have an extensive dilution ventilation system because of the large amount of mercury that is heated in the process. Local exhausting of mercury contaminated air is usually not sufficient to maintain acceptable workplace mercury vapor concentrations.

One lamp manufacturer has an underground duct system for supplying fresh air to ventilators along the side walls of the production floor. This air supply system was built into each of the fluorescent lamp production buildings at the plant to provide the dilution ventilation necessary to control mercury vapor.

An important component of the plant supply air system is the local fresh air supply provided at work stations. A local fresh air supply system was installed in one of the lamp production buildings in 1972 at a cost of $80,000. This system supplies dilution air to work stations that typically have higher than background concentrations of mercury vapor (Figure V-20). Examples of these areas are the tip-off area on the exhaust machines and the loading area at the basing machines. The basing machine area has a potential for elevated mercury vapor concentrations because of its proximity to the exhaust machine (point of mercury addition). The local air supply is designed to reduce the exposure of the operator working at this station by providing cool fresh air at the worker's breathing zone.

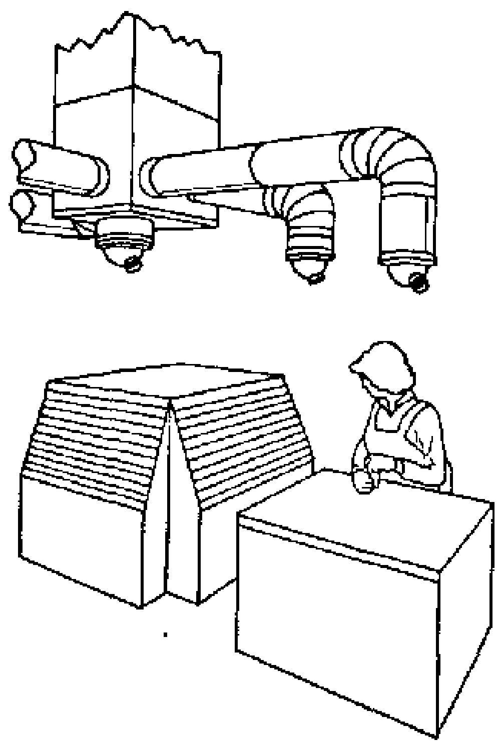

Figure V-20. Local Fresh Air Supply.

An effective dilution ventilation system that employs local fresh air supply and unidirectional airflow across the plant was found at another lamp manufacturing plant. Supply air for the 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. Roof mounted exhaust air fans are located at the opposite end of the building. The general movement of air is in through the south side of this plant and out through the north side.

There are several low-capacity blowers used for local supply air at employee work stations. One such blower provides air for adjustable 2-inch circular supply vents located in front of each worker on one of the manufacturing machines (Figure V-21). Each supply vent provides approximately 78 cfm airflow.

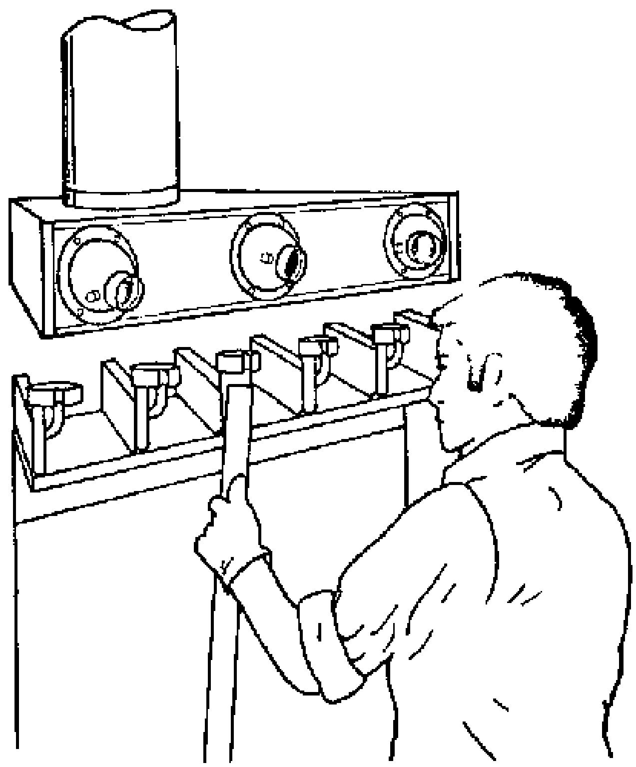

Figure V-21. Adjustable 2-Inch Supply Air Vents.

b. Dilution Ventilation by Draft

Some facilities provide dilution ventilation in the workplace without the use of supply air systems. Drafts created by fans or by process heat are often sufficient to draw dilution air into buildings through louvers, vents, doors, windows, and open wall panels.

The concentrator building at a mercury mine has a dilution ventilation system consisting of seven roof exhaust fans and three wall intake louvers. The exhaust fans, manufactured by Chicago Blowers, are rated at 16,180 cfm each. The wall louvers are Robertson industrial operating louvers, which are located on the first floor of the building. The exhaust fans pull the air through the wall louvers, through the grating between the first and second floors, and out through the roof, thus creating an airflow up past the flotation cells. One potential problem associated with this airflow is that mercury vaporizing from materials on the first floor may be carried up through worker breathing zones on the second floor. Plant representatives believe that the dilution ventilation is not the most effective means of controlling mercury vapor concentrations. Efforts to control mercury are concentrated on the removal of mercury vapor at its source.

The design of many of the mercury cell rooms used in the chlor-alkali industry permits the movement of a large volume of air past the mercury cells. The cell room building at one plant is a double-peaked structure with a large, open basement below the cell level (second floor) and a high ceiling above the cell level. There are vents along the roof and vents and removable wall panels along the walls of the building. Air movement in the cell room is achieved through convection currents resulting from the heat of the mercury cells. The temperature differential between the hot air above the cells and the cooler outside air causes the hot air to rise through the roof vents. Cooler outside air in turn flows in through the wall vents (opened in the winter) or through the removable wall panels (opened in the summer). Air movement between the two floors of the building is achieved through the use of fiberglass grating installed on the walkways of the cell level.

A ventilation study conducted at this facility by the plant engineer in 1975 showed that the average air velocity through the roof vents was 225 fpm. The total open area of the roof vents was 1,180 square feet. The airflow through the building was calculated to be 265,500 cfm. The total air volume of the cell room was 885,000 cu ft.

A summary of the "Dilution Ventilation" controls studied is presented in Table V-7.

7. Isolation

At some facilities, mercury operations associated with mercury vapor concentrations approaching or exceeding the OSHA PEL are isolated from other work areas. This practice facilitates the containment and removal of mercury contaminated air and reduces the potential for the mercury vapor to spread throughout the workplace. Applications of the isolation method include separate rooms with closed doors or separate work areas away from the majority of workers. Isolated mercury handling rooms should be under a negative pressure with respect to adjacent work areas to prevent mercury vapor from diffusing into the other areas.

TABLE V-7

Summary of "Dilution Ventilation" Controls

Controls	Advantages	Disadvantages	Other Applications	Page
a Dilution Ventilation Using Air Supply and Exhaust Systems				
Switch Manufacturer A - Fill Room	- room is under negative pressure - system is operated at 100 percent outside air during production hours in order to prevent recirculation of mercury vapor - system is operated in partial recycle mode during nonproduction hours to minimize energy usage	- high energy consumption during production hours, plant should explore potential of partial air recycle during this time	- applicable to any single-room mercury operation	78
Switch Manufacturer B - Fill Room	- room is under negative pressure - new system expected to supply 15 air changes per hour - south air handler will provide a backup system for warmer weather	- new system is expected to have high energy cost as it will be using only outside air	- applicable to any single-room mercury operation	78
Fluorescent Lamp Manufacturer	- air handling system was designed into the original building - air is supplied at floor level on the walls and exhausted through the center of the ceiling resulting in a one-way airflow - supply air system includes local dilution air at work stations - variable exhaust fan operating schedule conserves energy - building is under negative pressure	-------	- applicable to large-scale manufacturing areas in thermometer and battery manufacturing plants	79
b Dilution Ventilation by Draft				
1. Draft through wall louvers in a mining mill	- lower energy costs than using supply air handlers - one way airflow from first floor outside walls to roof fans	- brings in unconditioned air - airflow could carry mercury vapor and particulate up through worker breathing zones	- applicable to chlor-alkali cell rooms and other large-scale mercury-use areas	81
2 Draft through chlor-alkali cell room	- movement of air is driven by temperature differential rather than by air handlers, saving energy - one-way airflow from wall vents and panels up through roof vents - air changes were calculated to be 16 changes per hour	- incoming air is not conditioned	- applicable only to operations where the heat required to drive the air movement is available	81

Mercury filling operations, with the exception of fluorescent lamp manufacturing, are typically conducted in isolated rooms in production plants. Thermometer filling equipment, in particular, is usually operated in an isolated area because of the quantity of mercury handled and the elevated temperature of some operations. Fluorescent lamp manufacturers use isolated work areas for filling mercury dosers (for exhaust machines) and for performing parts cleaning and maintenance. Mercury chemical production processes that are conducted in different areas of plants are difficult to isolate because of the large doors needed for moving heavy equipment (forklifts, etc.). Several facilities have solved this problem through the use of plastic strip doors at room openings, which allow for easier room-to-room movement while aiding in the isolation of the mercury use area. Mercury distilling operations periodically cause ambient mercury vapor concentrations to exceed the OSHA PEL. For this reason, stills, ovens, furnaces, retorts, and other equipment used for heating mercury are often situated outside of the main plant or are located in separate isolated buildings.

The following are brief descriptions of isolated mercury use areas observed:

- The mercury Fill Room at a thermometer manufacturing plant is isolated from the rest of the manufacturing area. A remote vacuum indicator is located outside of the room so that the operator does not need to enter the Fill Room to check the vacuum being drawn on the filler.

- A thermometer manufacturer has taken steps to separate the mercury use area from the rest of the manufacturing areas by constructing a partial wall using 2- by 4-foot panels. This was constructed in 1977 at a cost of $578. In addition to this, a wall was constructed to separate the mercury Fill Room from the rest of the mercury use area. This was done in 1977 at a cost of $900.

- The mercury use area has been isolated from the rest of the manufacturing area at a mercury switch manufacturing facility because of widespread mercury contamination during the early years of plant operation.

A summary of "Isolation" controls studied is presented in Table V-8.

8. Mercury Removal from Airstreams

Many local exhaust ventilation systems and recirculating ventilation systems are used in conjunction with a mercury removal system to reduce mercury vapor/particulate concentrations in air that is released to the atmosphere or returned to the workplace. The removal of mercury from airstreams aids in meeting environmental and occupational health standards and, if the air is recirculated, reduces the energy costs of conditioning air.

TABLE V-8

Summary of "Isolation" Controls

	Controls	Advantages	Disadvantages	Other Applications	Page
1	Isolated mercury processing rooms	- area with higher potential for mercury exposure is isolated from the rest of the plant	- if pressure in the fill room fluctuates negative to positive, mercury vapor may escape into surrounding work areas	- all thermometer and mercury switch fill rooms, mercury purification, doser filling, and parts repair areas in fluorescent lamp plants, separate processing rooms at battery manufacturing plants	81
2	Plastic strip doors	- separates mercury usage production areas from other areas while allowing easy access for personnel and forklifts	- mercury can escape through the space between the strips	- applicable to all mercury compound manufacturers	83
3	Outdoor processes	- removes high-exposure equipment from the indoor workplace - has natural dilution ventilation	- weather conditions causing stagnant air may increase potential for worker exposure to mercury	- applicable for mercury furnaces, retorts, and stills	83

a. Removal of Mercury from Local Exhaust Airstreams

One chlor-alkali plant surveyed uses a mercury vapor removal system on the exhaust airstream from the ventilated enclosures used to remove mercury vapor generated at the inlet and outlet boxes of the mercury cell. The components of the air treatment system, which include cooling, separation, and adsorption units, are illustrated in Figure V-22. Adsorption of mercury vapor is accomplished using a Pura-Siv^R mercury adsorption unit, manufactured by Union Carbide. It is a dual molecular sieve designed to operate with one sieve (adsorber) in service and the other sieve in regeneration.

During operation, mercury in the airstream is adsorbed in the sieve through a proprietary process. During regeneration, heated 204 C (400 F) "low mercury content" gas is passed back through the sieve, vaporizing the collected mercury and carrying it through a cooler to a Peterson centrifugal separator. The liquid mercury is recovered and reused in the process.

Testing of the unit by both plant engineers and a private contractor showed that effluent mercury concentrations of 0.2 mg/m^3 were achieved with influent concentrations of 9-10 mg/m^3 during a typical 24-hour operating run.

The ventilated enclosures used to remove mercury vapor generated from mercury wells at an electroplating plant are vented through Calgon Vent-sorb filters. The filter housing is a 55-gallon drum with openings for air intake and discharge. The filter media in the Calgon Vent-sorb (approximately 150 pounds in each unit) consists of Pittsburgh Type HGR sulfur-impregnated, activated carbon specially designed for removing mercury from air, hydrogen, and other gases. The HGR contains 13 percent elemental sulfur that is distributed throughout the porous carbon granules. The carbon has a high surface area (5 million square feet per pound) that enhances contact with the airstream. As the mercury vapor in the exhaust stream passes through the filter, it reacts rapidly with the sulfur to form mercuric sulfide.

Care must be taken that the flow of air through each filter does not exceed 50 cfm, since a minimum contact time is required for efficient mercury removal. The filter media is replaced when mercury vapor concentrations at the discharge of the blower exceed 0.1 mg/m^3, as measured with a mercury vapor detector.

b. Removal of Mercury in Recirculating Ventilation Systems

Plants using recirculating dilution ventilation systems generally employ charcoal or particulate filters to remove mercury vapor or particulate from the airstream before returning the air to the workplace. Care must be taken that the filters are replaced when the mercury concentrations at the system discharge begin to rise. Otherwise, contaminated air is returned to the workplace.

The recirculating system for the Cell Assembly Room at one battery manufacturing plant surveyed is designed to remove both mercury vapor and particulate. The system consists of two separate air handling/filtering units,

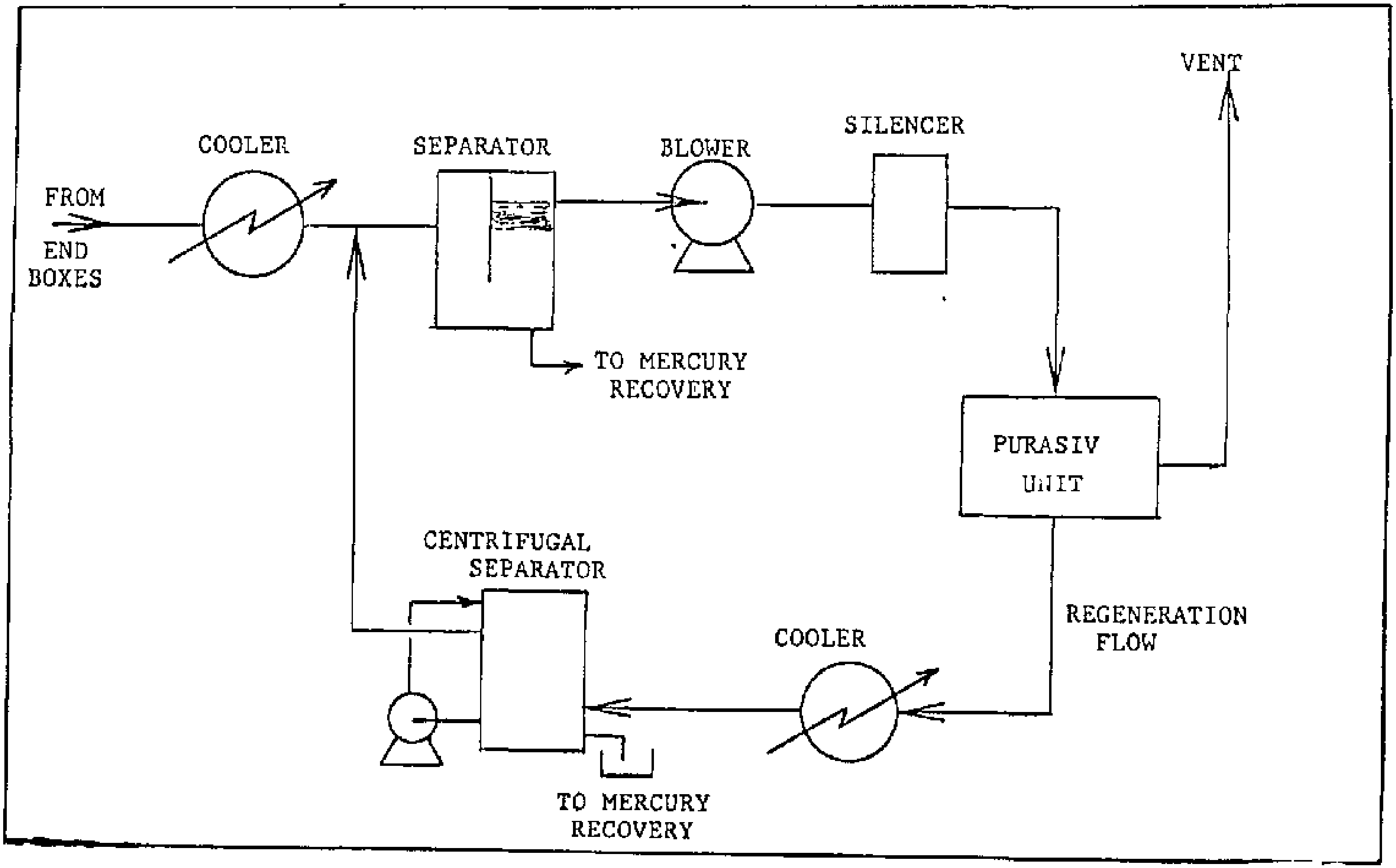

Figure V-22. Air Treatment System for Mercury Removal.

Reference: Diagram from paper presented by A.L. MacMillan at Chlorine Institute's 23rd Plant Manager Seminar, New Orleans, Louisiana, February 6, 1980.

each with one 27-square-foot intake and a network of distributors (Figure V-23). The air handling units are mounted parallel on the roof of the building. They are large "walk-in" units that have been modified to improve mercury vapor removal and reduce filter replacement costs. Each air handler in the original system, installed by Industrial Air, Inc., Greensboro, North Carolina, consisted of the following components:

1. One centrifugal blower

   o manufactured by Eldons Manufacturing Corp., Elgin, Illinois

   o 36.5-inch-diameter wheel

   o operates at 26,000 cfm, 3 inches static pressure, using a 15-hp motor.

2. One set of 35 percent efficient modular fiber filters

   o manufactured by Cambridge Filter Corp., Syracuse, New York

   o 12 filters set into a filter bank measuring 6'2-1/2" x 8'-3/8".

3. One set of 95 percent efficient modular fiber filters (Figure V-24)

   o set into filter bank measuring 6'2-1/2" x 8'-3/8"

   o each filter containing 120 square feet of filter media area.

4. One set of 95 percent efficient charcoal filters

   o manufactured by Barneby-Cheney

   o 144 filter trays set at an incline into an 8- by 6-foot filter rack

   o a total of 33.7 cu ft of filter media in the filter rack

   o approximately $64 per tray

   o each tray consists of iodine-impregnated charcoal pressed between metal screens.

5. One set of cooling coils

6. One set of steam coils

The 35 percent efficient particulate filters were replaced monthly, and the 95 percent efficient particulate filters were replaced yearly. Plant representatives found that the charcoal filters achieved 86 percent efficient

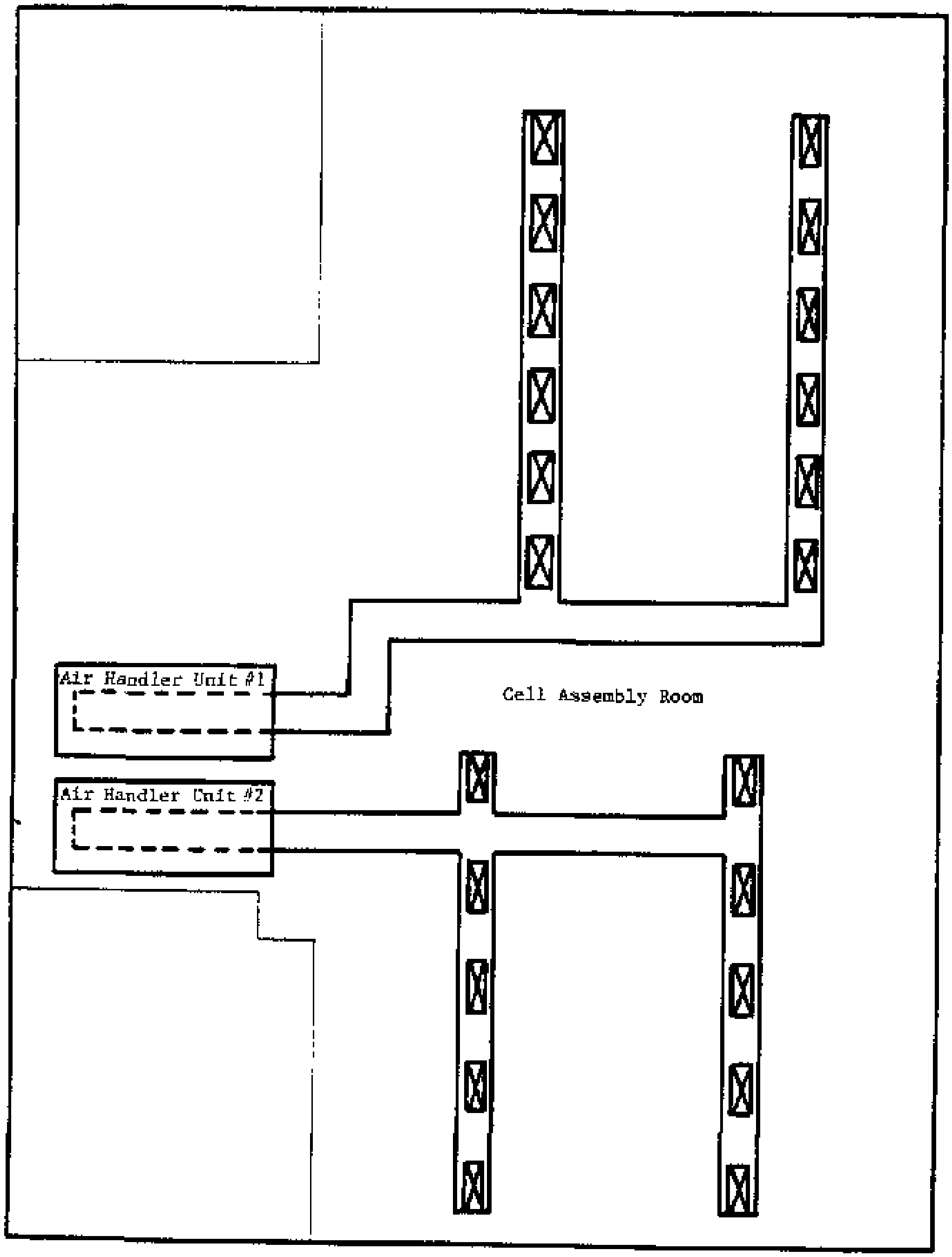

Figure V-23. Schematic of Recirculating Air System.

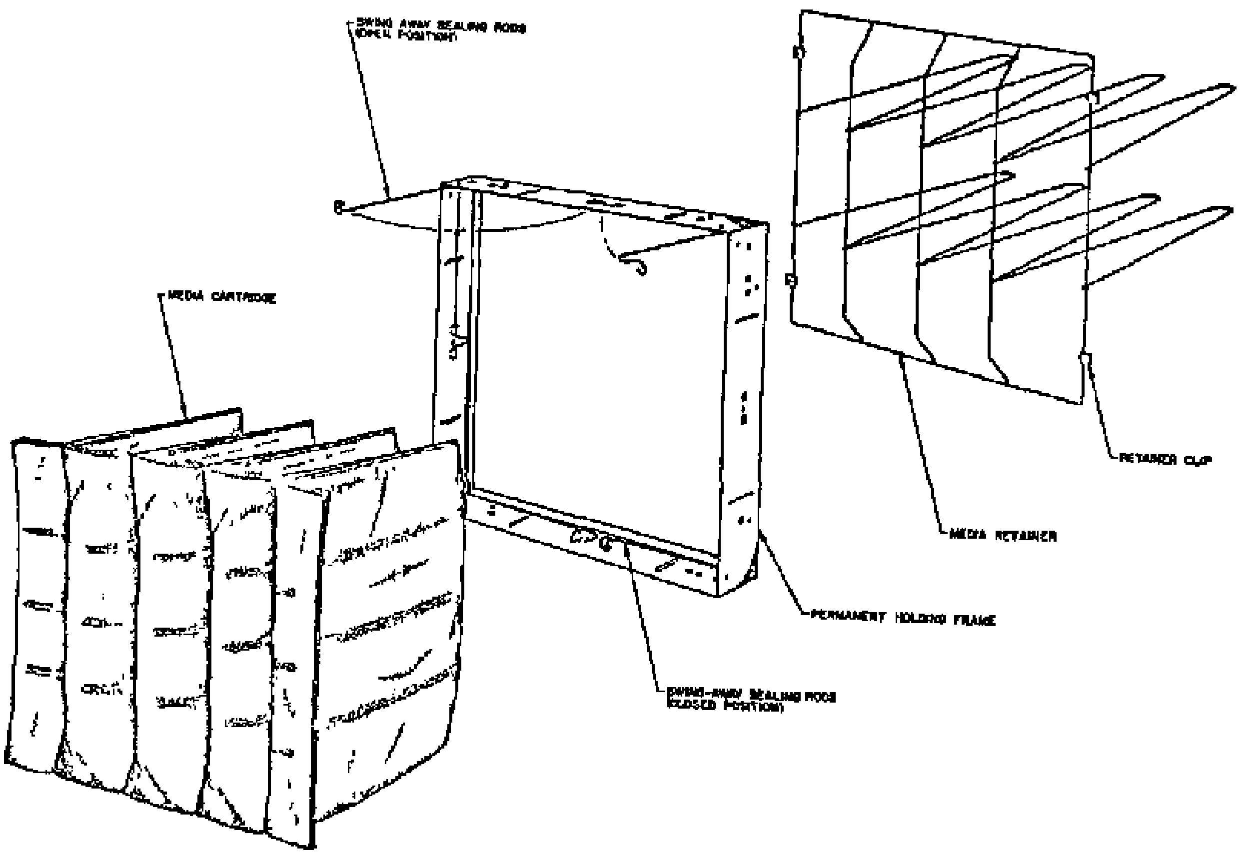

Figure V-24. Fiber Filters for Particulate Removal.

mercury vapor removal when initially installed. When the efficiency fell to 60 percent, based on readings taken with a mercury vapor detector, new filters were ordered. The filter trays were replaced when the efficiency fell to 50 percent (replaced approximately once per year).

In 1982, plant representatives began efforts to reduce filter costs while maintaining reduced mercury vapor concentrations. They installed a second charcoal filter bank to utilize the 50 percent efficient filters rather than discarding them. A new filter bank was installed behind the original one. The 50 percent efficient filters were moved to the front rack and new filters were installed in the back rack. The filter replacement procedure was changed to the following'

- o When total efficiency falls to 60 percent, order new filters.

- o When total efficiency falls to 50 percent, discard front-rack filters and move back-rack filters to front. Install new filters on back rack.

The pressure drop resulting from the addition of another filter bank necessitated an increase in air handler capacity. The layout of the air handler housing prohibited the installation of a larger fan, therefore, the plant installed an additional 26,500-cfm blower in each air handling system. The resulting configuration was two blowers operating in series with the filter banks and conditioning coils situated between them. The original and modified configurations are illustrated in Figure V-25.

The charcoal filter trays are front or side loaded horizontally at a slight angle in the filter rack. The edges of the trays are connected in a continuous zig-zag configuration through the use of compression fittings (Figure V-26). An effective seal is made when the airflow through the unit forces the surface of connecting tray edges against the fitting. Plant representatives stated that clamped connections would provide a more effective seal, but they are not cost-effective.

This recirculating system is also designed with fresh air makeup capabilities. An Economizer controller system is used to open outside air louvers when it is more efficient to condition workplace air with outside air. This louver was closed during most of the site visit.

Ventilation measurements, taken in air handler Unit No. 1 during the survey, showed that the actual airflow achieved using the two fans in series was 38,600 cfm (average of four measurements taken in the plenum between the fans). The airflow measured at the inplant air intake for the air handler was 27,200 cfm. The discrepancy between these two airflows is accounted for by an estimated 6,000-10,000 cfm that was leaking through the "closed" fresh air intake louvers. Therefore, the air handler was actually operating in approximately a 75 percent recirculating mode. The mercury removal efficiency of the air system was determined using a mercury vapor detector at the upstream and downstream sides of the charcoal filter banks. The average mercury vapor concentration upstream of the charcoal filters was 0.030 mg/m^3. The average mercury vapor concentration downstream of the filters was 0.008 mg/m^3. The average removal efficiency for four separate determinations was 73 percent.

Another battery manufacturer recovers the heat of the workplace air without recycling the air itself. Three of the mercury handling rooms at the plant are serviced by two exhaust/supply systems. Each system has an induced draft blower (that draws exhaust air through a baghouse), a heat exchanger, and a charcoal filter. The air is exhausted through a stack. The heat exchanger recovers heat from the exhaust air and uses it to preheat outside supply air drawn by a blower adjacent to the exhaust unit.

Some plants use mercury-filtering air units situated entirely within the workplace to help remove mercury vapor. A mercury distiller and bottler uses a precoat bag filter system to remove mercury vapor from plant air. The system consists of a Torit Model No. 125-50 "dust collection" unit (Figure V-27) manufactured by the Torit Division of the Donaldson Company, St. Paul, Minnesota. The cost of the Torit was $6,735 in 1976. The unit draws plant air from three different rooms. In each room, the air is drawn through a 4- by 10-inch intake duct. The ducts from the three sources connect at a junction box adjacent to the Torit, and the flows combine to pass through the filter unit. The precoat media on the filter bag

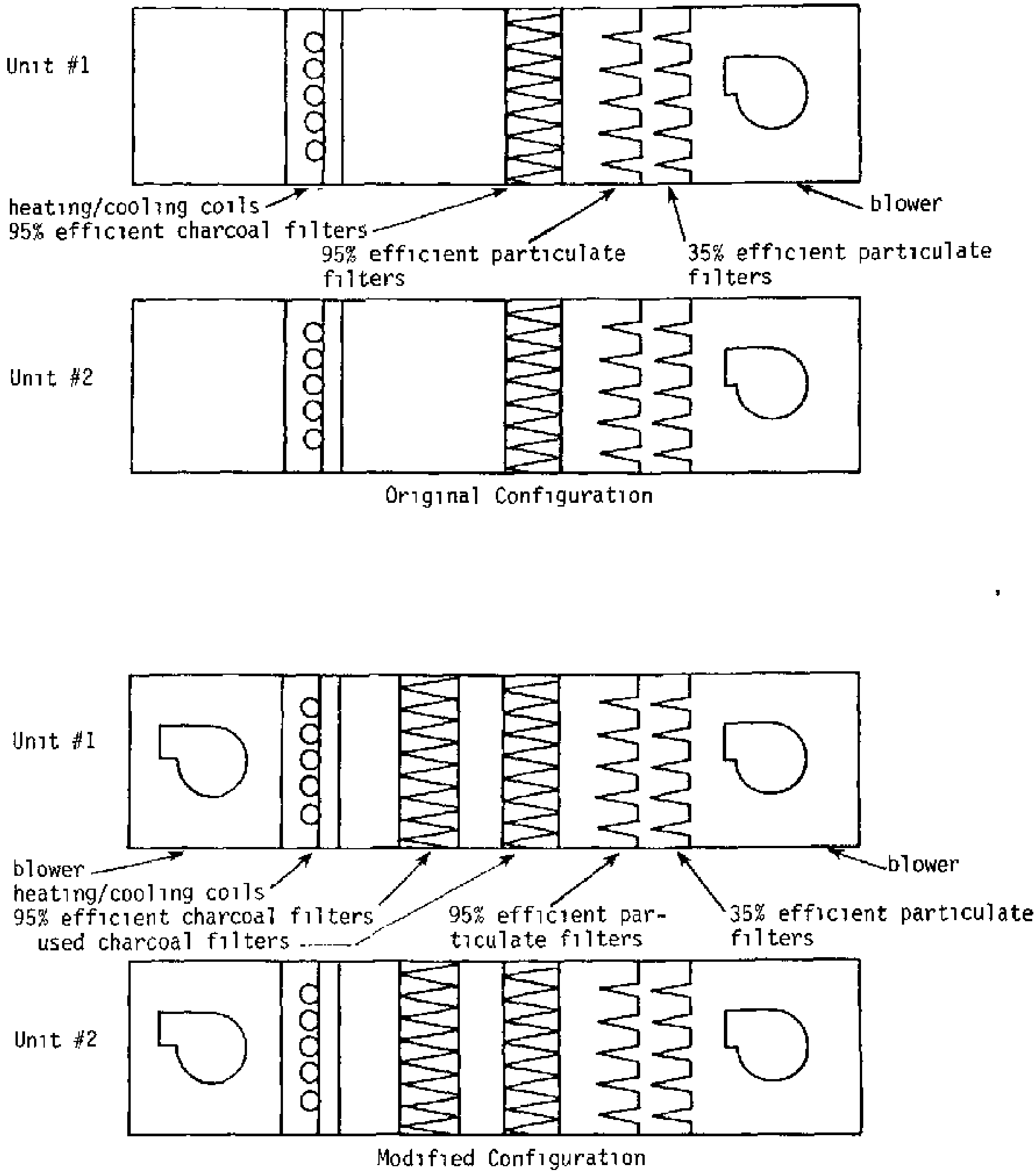

Figure V-25. Original and Modified Air Handler Configurations.

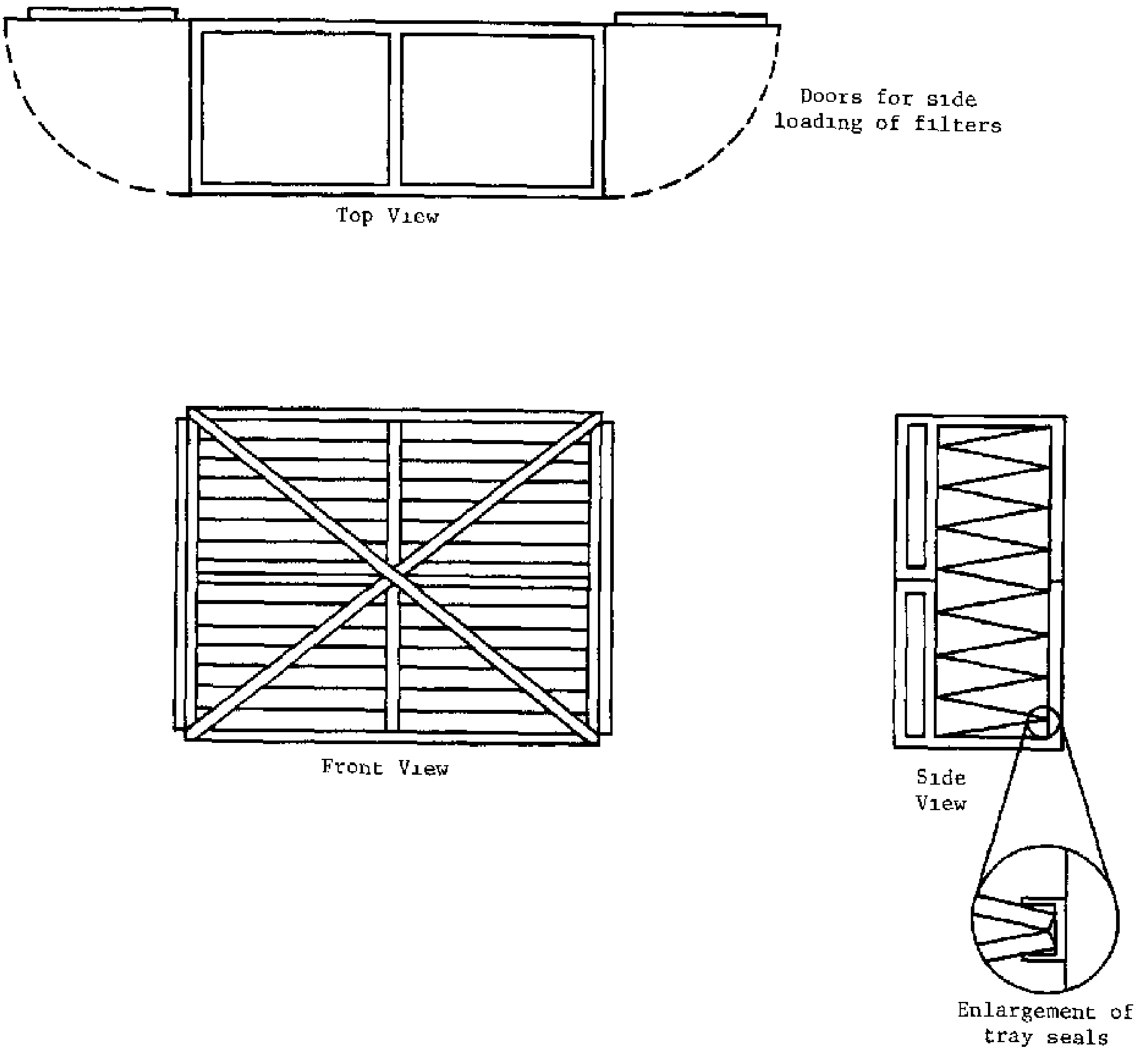

Figure V-26. Charcoal Filter Rack Configuration.

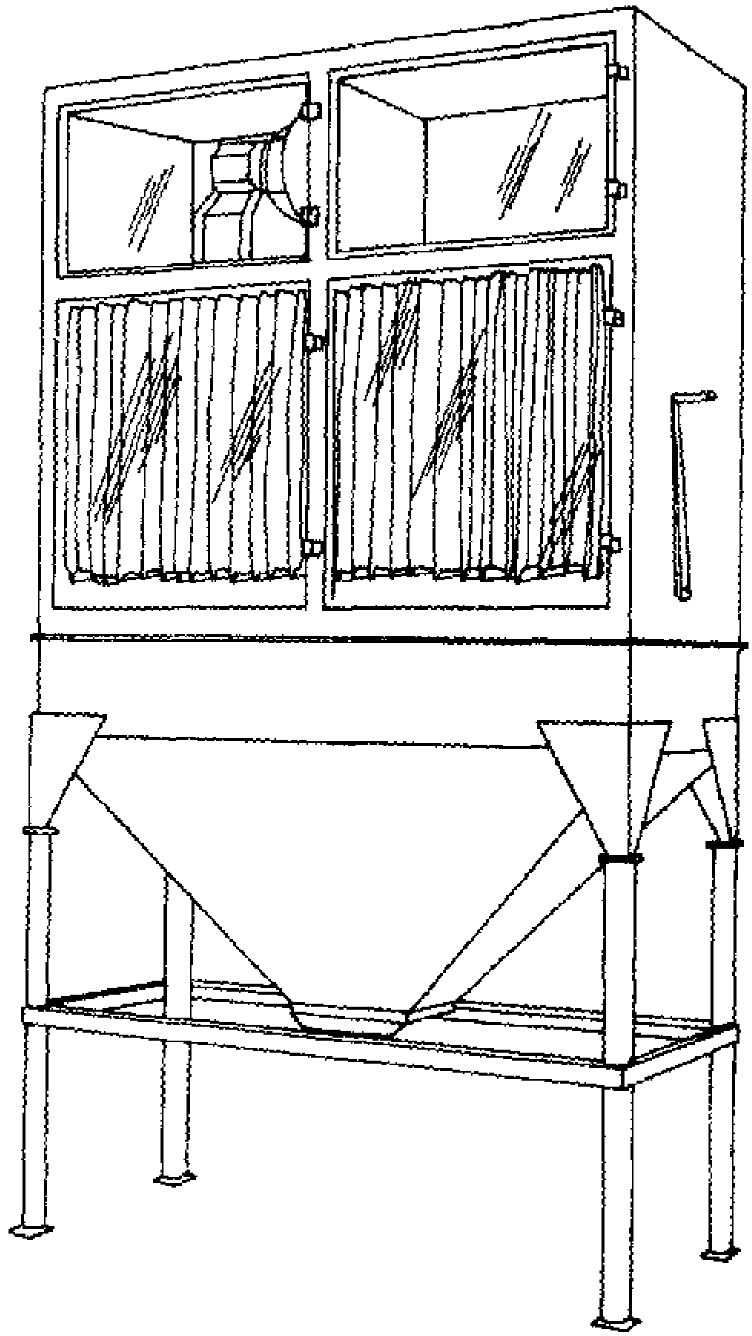

Figure V-27. Torit Dust Collection Unit.

cartridges is manganese dioxide. Manganese dioxide adsorbs the mercury vapor and removes it from the airstream. The mercury vapor concentration in the air from the Torit unit is monitored periodically, and the manganese dioxide is discharged and replaced when the concentration exceeds 0.1 mg/m^3. At present, the manganese dioxide is shaken down and replenished on a weekly basis.

The Torit consists of a chemical charging hopper, a series of filter bags, a blower, a discharge conduit, a shakedown valve, and a shakedown tray. The charging hopper is the junction box where the flows combine from the three exhaust takeoffs. It is a rectangular section of duct with a sheet metal door. To charge the unit with manganese dioxide, the door is opened while the blower is operating and the manganese dioxide is poured in until a pressure drop of 3 inches of water is achieved across the unit. This provides an airflow of approximately 3,000 cfm through the Torit. The pressure drop is determined by reading a pressure gauge on the side of the unit.

The filter section of the Torit consists of 36 cloth filter bags with wire mesh frames. Approximately twice a week, the Torit is shut off and the manganese dioxide is shaken down from the bags into a shakedown tray using a crank on the side of the Torit. The Torit is then started up again and the manganese dioxide is drawn back onto the bags. This practice helps to ensure that an even precoat remains on the filter bags. When the manganese dioxide is being replaced, the used powder is removed from the shakedown tray.

The blower, powered by a 5-hp motor, draws air through the filter bags and into a suction plenum. It exhausts into a discharge plenum mounted above it. The discharge plenum has a 14- by 10-inch opening through which the exhaust air is released to the work area at ceiling level. Manganese dioxide was found at the discharge of the unit. A hole found in one of the filter bags could be contributing to this filter media breakthrough.

The measured airflows from the three exhaust ducts were 780 cfm, 610 cfm, and 1,100 cfm. The total airflow through the Torit is therefore approximately 2,500 cfm. The mercury removal efficiency of the unit was calculated to be 76 percent.

Smaller units designed for removing mercury from workplace air are used for small-scale mercury handling operations. One such unit in use at an electrical standards manufacturer is a recirculating air filter unit manufactured by Barneby-Cheney, Columbus, Ohio. This self-contained unit, situated in the standards lab, consists of a 1,000-cfm, three-speed fan and an activated charcoal filter mounted inside of a casing with approximate dimensions of 1.5 feet by 1.5 feet by 4.5 feet high. The air intake is at floor level and the exhaust is at the top of the unit. The filters are arranged in a series of three. The unit is portable and can be moved to any location in the room. The cost of this unit, purchased in August 1980, was $2,300, including replacement charcoal filters. Information on the mercury vapor removal efficiency of this unit was not available.

A summary of "Mercury Removal from Airstreams" controls is presented in Table V-9.

TABLE V-9

Summary of Mercury Removal from Airstream Controls

Controls	Advantages	Disadvantages	Other Applications	Page
a Removal of Mercury from Local Exhaust/Air Systems				
1 Pura-Siv mercury adsorption unit	- liquid mercury is recoverable - reduces airstream mercury vapor concentrations from 9-10 mg/m^3 to 0 2 mg/m^3	- costly to design and install system - probably overdesigned for use in nonproduct airstream	- could be used to remove mercury from any exhaust airstream containing high mercury vapor concentrations	85
2 Calgon Vent-sorb filter	- compact and easy to install - easy to maintain (change media approximatly once/year) - effluent mercury vapor concentrations were below the OSHA PEL at all filters sampled	- airflow through the unit should not exceed 30 cfm because a minimum contact time is required	- could be used to remove mercury from any exhaust airstream (particularly vacuum pump discharges)	85
b Recirculating Air Systems for the Removal of Mercury from Room Exhaust Airstreams				
1 Recirculating air handling system for particulate and vapor removal	- double charcoal filter system increases filter life, decreasing filter cost - vapor removal efficiency averaged 73 percent - energy costs are reduced because of recycling conditioned air	- 2 blowers operating in series on either side of filters is less efficient than using one larger blower	- applicable for dilution ventilation in any mercury filling industry	85
2 Conditioned air recycling system	- the heat of conditioned air is recycled, reducing fuel cost - mercury-contaminated air is removed from the workplace and filtered - fresh outside air is supplied	- heat exchanging is less efficient than simply recycling the filtered air	- applicable for dilution ventilation in any mercury filling industry	90
3 Torit mercury filter	- recycling of workplace air is less expensive than conditioning the same amount of fresh outside air - the unit is 76 percent efficient in removing mercury vapor from the inlet airstream	- the manganese dioxide is a housekeeping problem and may contribute to worker exposure to mercury particulate	- applicable for use in any small facility or single room operation handling mercury vapor	90
4 Portable mercury vapor adsorption units	- compact and inexpensive to install - easy to maintain - less expensive than providing the same amount of conditioned outside air	- sometimes used in rooms that are too voluminous for the control to be effective	- applicable for use in any small facility or single-room operation handling mercury vapor	94

B. BEHAVIORAL CONTROLS

The physical properties of elemental mercury (liquid state at room temperature, vapor pressure, and ability to cling to skin and clothing) and inorganic mercury compounds (ease of dispersion and high vapor pressure) make it difficult to control worker exposure through engineering controls alone. Most facilities using inorganic mercury have found it necessary to implement a comprehensive control system including behavioral controls and personal protective equipment (discussed in the following section) in order to eliminate exposure or reduce it to acceptable levels. All of the plants surveyed during this study employed behavioral controls to supplement engineering controls.

A summary of the various behavioral controls implemented to reduce worker exposure to mercury is presented in Table V-10.

1. Housekeeping

The housekeeping practices listed in Table V-10 are those used by industry on a routine basis.

a. Mercury Decontaminants

Most industries surveyed used a mercury decontaminant and mercury vapor suppressant cleaning aid as part of their routine housekeeping program. HgX[R] (a proprietary polysulfide compound) was the most commonly used cleaning aid. Other cleaning aids included sodium sulfide and calcium polysulfide. All three compounds are reported to work by binding with elemental mercury and mercury compounds, thereby preventing vaporization and facilitating cleanup. A mixture of equal proportions of powdered zinc and sawdust was used to aid in cleaning mercury spills at one facility studied. A summary of common applications of mercury decontaminants is contained in Table V-11.

b. Vacuum Cleaners

Many plants surveyed relied on the use of specially designed vacuum cleaners for both routine cleanup and cleanup of major spills. These vacuum cleaners are generally modified versions of industrial vacuum cleaners that have been specially adapted for use with mercury.

These vacuum cleaners are mobile, stainless steel can-style units usually equipped with a 1.5-inch-diameter suction hose, vacuum pump, inline mercury trap, and vapor or particulate filter. They typically provide an airflow of approximately 80 cfm and a maximum vacuum of 70 inches of water. The inline mercury trap is used to collect mercury before it reaches the vacuum pump. The trap is usually a small removable plastic container. The vacuum cleaners contain both charcoal filters and high-efficiency particulate air filters. Charcoal filters are used to remove mercury vapor from the vacuum pump discharge. HEPA filters are effective in removing mercury particulate (oxide, etc.) from the discharge airstream. Filters must be changed periodically. Most vacuums have an "hours of service meter" that indicates filter replacement time. Alternatively, the discharge of the vacuum cleaner can be monitored using a mercury vapor detector to determine end of filter life. Mercury vacuum cleaners from four manufacturers were in use at the industries studied. They are Nilfisk, King of Prussia, PA, American Cleaning Equipment, Addison, IL, National Super Service, Toledo, OH, Dayton Electrical Mfg., Chicago, IL.

TABLE V-10

Summary of Behavioral Practices Implemented to Reduce Mercury Exposure

Industry	Process Area/Activity	Housekeeping Practices	Job Rotation or Other Behavioral Controls	Specific Work Practices	Personal Hygiene
BATTERY Button Cell Plant A	Mixing, slugging, and consolidation	- floors cleaned daily using HgX - process machines vacuumed daily with house vacuum		- access limited to essential workers - materials kept in closed containers	- end-of-shift showers & complete clothing char required - rings, watches, and jewelry not permitted
	Assembly lines	- floors washed daily with HgX - floors painted with epoxy paint to reduce absorption			
Button Cell Plant B	Mixing and consolidation	- floors cleaned daily with HgX - machines cleaned daily		- materials kept in closed containers - access limited to essential workers	- disposable clothing changed daily
	Cell assembly	- floors cleaned daily with HgX			
Zinc-Carbon Cell	Mix area				- daily clothing change quired, company suppl clothing
Alkaline Cell	Gel preparation	- floors cleaned daily with HgX	- Gel grinder and gel blender rotate job daily --gelgrinding has high exposure potential - Gel workers spend 2 mo in gel room and 2 mo elsewhere in plant	- transport containers must be taped closed - access limited to 3-4 employees	- daily clothing change quired, company suppl clothing
	Cell assembly	- work stations cleaned daily with soap and water			
FLUORESCENT LAMP Plant A	Lamp filling	- process areas vacuumed daily with mercury vacuum			
	Maintenance	- maintenance areas vacuumed daily with mercury vacuum			- daily clothing change required

TABLE V-10 Summary of Behavioral Practices Implemented to Reduce Mercury Exposure (Continued-b)

Industry	Process Area/Activity	Housekeeping Practices	Job Rotation or Other Behavioral Controls	Specific Work Practices	Personal Hygiene
FLUORESCENT LAMP (Continued)					
Plant B	Lamp filling	- process areas vacuumed daily with mercury vacuum			
	Maintenance	- maintenance areas vacuumed daily with mercury vacuum			
Plant C	Lamp filling	- floors cleaned daily and washed 2 x year with HgX - process area vacuumed with mercury vacuum cleaner daily			- disposable clothing - changed weekly
	Maintenance	- maintenance area vacuumed daily with mercury vacuum		- transfer of mercury conducted over steel trays - parts cleaning station lined with kraft paper to contain mercury--paper is disposed of after repair	- daily clothing change required
ELECTRICAL SWITCH					
Plant A	Fill Room	- floors washed daily with soap and water	- welding operators work every other day at this job		- disposable clothing — replaced every 2 days
Plant B	Fill Room	- floors cleaned 2 x day with HgX		- waste glass must be placed in container under water - full-time janitor on duty during production for cleanup and spill control	- disposable clothing -- replaced weekly
ELECTRICAL PROCESSES					
Chlor-Alkali Plant A	Cell Room	- floors cleaned regularly using hose and water - spills cleaned up using mercury vacuum - floors below cell room coated with epoxy sealant		- access limited to essential personnel	- end-of-shift showers and complete daily clothing change required, company supplies clothing - rings, watches, and jewelry not permitted in process area - hardhats and other safety equipment are washed weekly to remove traces of mercury

TABLE V-10 Summary of Behavioral Practices Implemented to Reduce Mercury Exposure (Continued-c)

Industry	Process Area/Activity	Housekeeping Practices	Job Rotation or Other Behavioral Controls	Specific Work Practices	Personal Hygiene
ELECTRICAL PROCESSES (Continued)					
Chlor-Alkali Plant B	Cell Room	- floors cleaned daily using hose and water - spills cleaned using central vacuum system	- shift rotation in summer months so that work in hottest part of afternoon is minimized	- access limited to essential personnel - spare equipment is used to allow contaminated equipment to cool before performing maintenance	- end-of-shift showers and daily (or more oft[illegible] clothing change requir[illegible] company supplies work clothes - rings, watches, and jewelry not permitted in process area
Metal Sintering	Sintering Area/ Oven Operators	- floors cleaned daily with HgX - equipment cleaned weekly using house vacuum - floors painted with red epoxy (yearly) to minimize absorption of mercury into floor and make drops of mercury more visible		- all materials must be brushed free of mercury before removal from bottle enclosure - maintenance work not permitted until bottle enclosures are vacuumed - access limited to essential personnel - contaminated equipment must be stored in ventilated cabinets - waste materials kept in color-coded drums	- disposable clothing -- replaced weekly - skin abrasions must be kept covered
Copper Plating	Drum Room			- only trained personnel may add mercury to wells	- daily clothing change [re]quired, company suppli[es] work clothes
Electrical Standards	Calibration Areas	- floors routinely cleaned (approx weekly) with HgX		- mercury is handled over plastic trays - amalgamation must be conducted in chemical fume hood	- cloth lab coats -- changed weekly - rings, watches, and jewelry not permitted in mercury areas
TEMPERATURE SENSING					
Thermometer Plant A	Fill Room	- work surfaces cleaned daily with soap and water - floors washed 2 x weekly with HgX - fill room floor and work station vacuumed daily with mercury vacuum		- waste mercury and waste glass must be submerged in water, metal waste containers are available - all thermometer tubes are washed before transfer to assembly	- disposable clothing-- replaced weekly - must change into work shoes upon entering fill rooms and change back upon exiting
	Assembly	- work surfaces cleaned daily with soap and water		- waste glass (broken thermometers) must be kept submerged in water	

TABLE V-10 Summary of Behavioral Practices Implemented to Reduce Mercury Exposure (Continued-d)

Industry	Process Area/Activity	Housekeeping Practices	Job Rotation or Other Behavioral Controls	Specific Work Practices	Personal Hygiene
TEMPERATURE SENSING (Continued)					
Thermometer Plant B	Fill Room	- floors cleaned weekly using HgX - fill unit area vacuumed with mercury vacuum cleaner	- fill room worker is limited to 1 fill operation/day	- access limited to fill room workers - unsealed thermometers must be kept in fill room (isolated area)	- disposable lab coats changed after each fil operation
Thermometer Plant C	Fill Room	- floors and walls painted with epoxy paint - floors vacuumed daily using mercury vacuum cleaners - floors washed 2 x year using HgX	- workers cannot remain in room more than 15 minutes unless respirators are worn, total time limited to 1 hr/day	- access limited to fill room workers - mercury-containing wastes are kept in sealed 55-gallon drums - covered plastic storage bins are used for trasfer of thermometers - plastic bags are placed over hot thermometers to minimize vaporization	- beards and long hair n permitted
	Assembly	- floors and walls painted with epoxy paint to minimize absorption - work stations vacuumed daily using mercury vacuum cleaner - floors washed weekly using soap and water		- covered plastic storage bins used for transfer of thermometers - waste glass kept in sealed 55-gallon drum - tube stems are filled using syringe to minimize dermal contact	
Thermal Sensor Plant D	Assembly	- floors washed daily with HgX - floors near work stations vacuumed daily using standard industrial vacuum - floors painted 1 x yr with urethane-based paint to minimize mercury absorption - major equipment washdown every 6 mo	- seal and fill workers spend 3 months at this "high exposure" job and 3 months elsewhere in plant		- beards and long hair n permitted
MERCURY CHEMICAL PRODUCTION					
Distillation	Bottling/Packaging Room	- floor cleaned weekly using HgX - work areas vacuumed daily using house vacuum system		- bottling operation must be conducted over stainless steel tray - packaged mercury in bottles must be kept on tray filled with water	- disposable lab coats--replaced weekly

TABLE V-10 Summary of Behavioral Practices Implemented to Reduce Mercury Exposure (Continued-e)

Industry	Process Area/Activity	Housekeeping Practices	Job Rotation or Other Behavioral Controls	Specific Work Practices	Personal Hygiene
MERCURY CHEMICAL PRODUCTION (Continued)					
Cinnabar Processing	Concentration and Furnace Areas	- floors washed monthly using sodium sulfide followed by high pressure water spray		- flotation cells and concentrate sumps must be washed down if an unscheduled plant shutdown exceeds 24 hr	- end-of-shift showers daily change of work clothes required, co supplies work clothe - boots must be washed workers exit concent tion/furnace complex boot wash stations a provided
Mercury Compounds Plant A (inorganic mercurial salts)	Process Rooms	- process area floors cleaned using a liquid mixture of polysulfide followed by hose and water washing			- disposable coveralls replaced every 3 days - end of day showers re quired for workers i and HgO areas
Plant B (inorganic mercurial salts)	Process Rooms	- process area floors cleaned weekly using an industrial floor cleaner - floors washed down daily with hose and water			- daily change of work clothes required, co supplies clothing
DENTAL					
Clinic A	Operatory Area		- waste amalgam submerged in water, container available for this purpose		
Clinic B	Operatory Area		- one trained person fills all mercury dispensers - waste mercury and amalgam is placed in screw top bottles		

TABLE V-11

Summary of Mercury Decontaminant Applications

Decontaminant	Form of Mercury: Hg	HgO	PMA	Mercuric Sulfide	Hg-Zn Amalgam
HgX^R	*	*	*	–	*
Na_2S	*	–	–	*	–
Calcium polysulfide	*	*	*	–	–
Zinc/sawdust	*	–	–	–	–

* = observed in use.

– = not observed in use.

Most of the plants surveyed had spill cleanup procedures in the event of accidental spills of both elemental and particulate forms of mercury. The procedures are similar at most plants. Major elements of all cleanup procedures used by plants are·

- o The area around a spill is immediately vacuumed using a mercury vacuum cleaner.
- o The area is inspected for traces of mercury, a flashlight is often used to illuminate elemental mercury.
- o A mercury decontaminant (described in Table V-11) is applied and the area is mopped and/or hosed down with water.
- o A mercury vapor detector may be used to monitor the area to determine if mercury vapor concentrations in the spill area are higher than normal. Spill cleanup procedures may be repeated based on monitoring results.

c. Painting Floors

In 7 of the 24 plants surveyed, floors were painted regularly (usually yearly) with dark-colored paint to aid in the detection of mercury drops and/or an epoxy/urethane sealant to minimize mercury penetration. Plant representatives report fewer housekeeping problems and lower mercury vapor concentrations following the application of floor coatings.

2. Job Rotation

Job rotation is a commonly practiced worker exposure control in mercury-using industries. It is practiced both as a routine preventive measure, in activities where worker exposure cannot be reduced through engineering or other behavioral controls, and as a corrective measure when employees' biological monitoring levels show unacceptably high concentrations of mercury. Corrective job rotation is discussed in the Biological/Medical Monitoring section, p. 112.

a. Preventive Job Rotation

Preventive job rotation is usually practiced in work areas that have a potentially high mercury vapor concentration. In the Fill Room of one mercury switch manufacturer, the welding machine operators alternate jobs so that only every other day is spent at the welding machine. In the filling area of a thermometer manufacturing plant, workers practice a rotating schedule in which 3 months are spent at a potentially high-exposure job (e.g., mercury filling) and 3 months are spent in another area of the plant. Reliance on job rotation as a preventive measure has the disadvantage of spreading worker exposure over a wider employee population.

b. Work Shift Change

At one chlor-alkali facility surveyed, plant representatives found that worker exposure to mercury vapor could be reduced (based on biological monitoring levels) by altering work hours so that work during the hottest part of the day could be avoided. During the summer season, and particularly during midday, the average mercury vapor concentration in the cell room was at its highest. Normal first-shift hours at the plant were from 7.30 a.m. to 4·00 p.m. During the hottest months of summer, the first-shift hours were changed so that workers started at 5:00 a.m. and finished at 2.00 p.m., when the second shift started.

3. Work Practices

The principal objectives of work practices used at most of the mercury-using plants studied were to minimize the emission of mercury vapor and particulate, and to contain liquid mercury.

A common work practice is submerging mercury, and mercury-containing products and wastes, in containers of water. The water prevents direct vaporization of mercury to the atmosphere This practice is particularly valuable in industries that generate mercury-contaminated waste such as the thermometer industry (waste glass), switch industry (defective switches and parts), and the dental industry (waste amalgam).

Transfer, packaging, and bottling operations are frequently conducted over steel or plastic trays having raised edges to contain stray drops or spills.

At one chlor-alkali plant visited, spare equipment was used during maintenance activities to avoid working on hot process equipment. Mercury recycle pumps typically operate at a temperature in excess of 80 C (176 F).

Work procedures for maintenance activities at one fluorescent lamp plant required that kraft paper be spread out at equipment repair work stations to collect mercury and oil that may contain mercury. The paper was treated as hazardous waste and sent to an appropriate landfill.

4. Personal Hygiene Practices

The personal hygiene practices listed in Table V-10 do not include the general practices commonly used at to most mercury-using industries surveyed. These practices are summarized as follows.

- o Employees are encouraged to wash their hands often. Washing is mandatory before eating or smoking. Washing with soap is required because liquid mercury and some mercury components are difficult to remove from the skin.

- o Smoking, eating, or drinking are not permitted in or near process areas.

- o Tobacco or food products are not allowed in process areas due to potential contamination problems. Tobacco and food products can absorb mercury, whether in liquid or vapor state, and serve as a source of mercury intake.

The primary objective of the personal hygiene requirements of the mercury industries surveyed was to minimize employees' microenvironmental exposure. The most rigid personal hygiene requirements in effect were noted in the following industries: battery manufacturing, chlor-alkali processing, cinnabar processing, and mercury compound manufacturing. In these industries, both end-of-shift showers and daily changes of clothing or the use of disposable clothing were mandatory to minimize mircroenvironmental exposure, in addition to general personal hygiene practices.

5. Education and Training

All of the mercury-using industries studied instituted some form of employee education and training program specific for mercury control. Most plants had informal training sessions for new employees. Several plants developed employee handbooks for this purpose. The objectives of the education and training programs are to·

- o teach employee awareness of potential health hazards associated with the use of mercury.

- o teach employees the housekeeping practices, work practices, and personal hygiene practices needed to minimize exposure.

Several audiovisual education tools are currently being used by mercury-using industries as part of their employee orientation programs and periodic refresher training sessions.

- A slide show package with sound track is used by one thermometer manufacturer. The package details potential health hazards and the importance of the microenvironment with regard to use of elemental mercury.

- A 30-minute film is used at a battery manufacturing plant. The film details the physical properties of elemental mercury and the work practices used in the battery industry.

C. PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

Personal protective equipment was used at most of the plants surveyed. A summary of personal protective equipment used is presented in Table V-12. Of primary concern at most of the facilities was protection against inhalation of mercury vapor and particulate, and dermal or clothing contact with mercury.

1. Respirators

Currently there are no respirators approved by NIOSH for protection against inorganic mercury. However, respirators are widely used in mercury-using industries for nonroutine operations where control of mercury through engineering or other methods is not feasible. Certain mercury-using industries rely on respirators as a primary control method because the desired plant-wide workplace concentrations of mercury cannot be achieved. At the plants surveyed, the processes in which the use of respirators was most relied on for worker protection were the particulate handling operations of battery manufacturers and mercury chemical producers, and the distilling operations of mercury processors. A description of commonly used respirators follows.

a. Respirator Descriptions

Specific for Mercury Vapor

3M 8707 Disposable Mercury Vapor Respirator (3M Company, St. Paul, MN)
A half-mask, air-purifying respirator containing iodine-impregnated charcoal as the adsorption medium.

MSA Mersorb Respirator (Mine Safety Appliances Co., Pittsburgh, PA)
A half-facepiece (Comfo-II model) dual cartridge, air-purifying respirator containing (1) Mersorb[R] (a proprietary sorbent) as the primary adsorption medium, and (2) a color indicator that changes from orange to dark brown when the filter medium has adsorbed a specified amount of mercury vapor.

Other Respirators

Norton Highly Toxic Particulates Filter Respirator (Norton Safety Products, Cranston RI)
A half-facepiece, dual cartridge, air-purifying respirator approved for respiratory protection against dusts, fumes, and mists having a TWA concentration less than 0.05 mg/m^3 (NIOSH approval No. TC-21C-152).

TABLE V-12

Summary of Personal Protective Equipment Used

Industry	Location and/or Activity	Primary Mercury Exposure Concern	Personal Protective Equipment and Clothing Used
BATTERY			
Button Cell Plant A	Mixing, Slugging, and Consolidation Areas	inhalation of mercury vapor and particulate, dermal contact with HgO	- disposable respirator - complete set of company-supplied clothing--changed daily - work shoes/boots - cloth work gloves
	Cell Assembly Area	dermal contact while handling cells	- finger cots (latex finger coverings)
Button Cell Plant B	Mixing Consolidating Room	inhalation of mercury vapor and particulate, dermal exposure	- toxic particulate filter respirators - disposable clothing - gloves--5-mil, vinyl - barrier cream--applied to hands
Zinc-Carbon	Adding mercuric cloride to mixture	inhalation of particulate, dermal contact with mercuric chloride	- toxic particulate filter respirator - cloth work gloves - cloth coveralls--changed daily
Alkaline Cell	Preparation of anode gel during mixing operation	inhalation of mercury vapor, dermal contact with liquid mercury and amalgam	- positive-pressure, air-line respirators - plastic face shields - rubber gloves - plastic arm coverings - plastic aprons - cloth coveralls--changed daily
FLUORESCENT LAMP			
Plant A	Filling doser reservoir and routine maintenance	inhalation of mercury vapor, dermal contact with liquid mercury	- disposable mercury vapor respirator - cloth gloves
Plant B	Filling doser reservoir and routine doser maintenance	inhalation of mercury vapor, dermal contact with liquid mercury	- reusable half-mask mercury vapor respirator - disposable clothing--changed daily - barrier cream--applied to hands
Plant C	Filling doser reservoir and routine maintenance	inhalation of mercury vapor, dermal contact with liquid mercury	- reusable half-mask mercury vapor respirator - cloth work gloves

TABLE V-12

Summary of Personal Protective Equiment Used (Continued-b)

Industry	Location and/or Activity	Primary Mercury Exposure Concern	Personal Protective Equipment & Clothing Used
ELECTRICAL SWITCH			
Plant A	Fill Room	inhalation of mercury vapor, dermal contact with liquid mercury when handling switches	- disposable latex gloves - disposable work clothes - work shoes--that cannot be worn home
Plant B	Fill Room	inhalation of mercury vapor, dermal contact with liquid mercury when handling switches	- disposable latex gloves - disposable work clothes - disposable respirator--for welder operator only - work shoes--that cannot be worn home
ELECTRICAL PROCESSES			
Chlor-Alkali	Cell Room/general operations	contact with liquid mercury	- cloth uniforms--changed daily - rubber boots--changed & cleaned weekly - cloth or rubber gloves
	Cell Room/maintenance	contact with liquid mercury, inhalation of mercury vapor	- cloth uniforms changed daily - rubber boots--changed & cleaned weekly - cloth or rubber gloves - disposable respirators--when working on open cells
Metal Sintering	Sintering Area/ treating oven operators handling metal contaminated with mercury	dermal contact with liquid mercury	- disposable smocks--changed weekly
	Sintering Area/ cleaning of treating ovens	inhalation of mercury vapor	- air-line respirator
Zinc Plating	Drum Room/mercury addition to wells	inhalation of mercury vapor, dermal contact with liquid mercury	- disposable respirator - cloth uniforms--changed daily - rubber gloves
Electrical Standards	Calibration Room	occasional contact with elemental mercury	- cloth lab coats--changed weekly - disposable latex surgical gloves
TEMPERATURE SENSING			
Thermometer Plant A	Tube Fabricating Room/ filling and sealing	dermal contact with elemental mercury, inhalation of mercury vapor	- cloth smocks--changed daily - disposable hair bonnets - disposable gloves - air-line respirator--during sealing process

TABLE V-12

Summary of Personal Protective Equiment Used (Continued-c)

Industry	Location and/or Activity	Primary Mercury Exposure Concern	Personal Protective Equipment & Clothing Used
TEMPERATURE SENSING (Continued)			
Thermometer Plant B	Fill Room/thermometer filling only	dermal contact with elemental mercury, inhalation of mercury vapor	- disposable respirators - disposable gloves - disposable smocks--disposed of after each fill - work shoes--that cannot be worn home
Thermometer Plant C	Fill Room/thermometer filling only	inhalation of mercury vapor	- disposable mercury vapor respirators--used when worker is required to remain in fill room more than 15 min on a single occasion or 1 hr/day
Thermal Sensor	Instrument assembly	dermal contact with liquid mercury	- rubber aprons
MERCURY CHEMICAL			
Distillation	Distillation operations	inhalation of mercury vapor and contact with liquid mercury	- disposable mercury vapor respirator - disposable laboratory coat - vinyl-coated cloth gloves - work shoes--that cannot be worn away from plant
Cinnabar Processing	Concentrator and Furnace Areas	inhalation of mercury vapor, dermal contact with mercury and mercuric sulfide	- reusable half-facepiece mercury vapor respirators - rubber boots--cleaned daily - rubber gloves--changed daily - cloth coveralls--changed daily
Mercury Compound Plant A	Process Rooms	inhalation of particulate mercury compounds and mercury vapor, dermal contact with mercury compounds	- full-facepiece, air-purifying respirator for mercury vapor and particulate - disposable mercury vapor respirator - disposable coveralls - work boots
Mercury Compound Plant B	Blending, Mixing, and Reacting Rooms	inhalation of particulate mercury and mercury vapor, dermal contact with mercury compounds	- reusable respirators worn during blending and bagging operations - air-line respirators worn when cleaning baghouses and dryers - cloth uniforms - gloves (latex or nitrile) used when handling mercury compounds
DENTAL	Operatory Areas	none	-none

A summary of the different types of respirators worn in mercury-using industries is presented in Table V-13.

TABLE V-13

Summary of Respirators

Type of Respirator	Advantage	Disadvantage
Disposable Mercury Vapor Respirator	Cleaning is not needed	More costly than reusable respirators Generally do not provide an air tight seal around the face causing leakage
Reusable Mercury Vapor Respirator	Can be individually fit for each employee	Must be cleaned daily or more often due to contamination problems
Toxic Particulate Filter Respirator	Can be individually fit for each employee	Must be cleaned daily or more often due to contamination problems

b. Respirator Applications

In the depolarizer and slugger rooms of one mercury button cell manufacturer surveyed, disposable respirators are worn on a full-time basis. The processes in both rooms generate both particulate mercury (HgO) and mercury vapor. The plant has so far been unable to control the workplace concentrations of mercury (combined particulate and vapor) to below the OSHA PEL.

In the mercuric oxide bagging operation at the same facility, a Scott supplied-air, pressure-demand, full-facepiece respirator is required. Plant representatives feel that adequate control of particulate mercuric oxide in bagging operations is not feasible with the current local exhaust ventilation system because the material is so readily aerosolized. The plant will eventually eliminate the operation and replace it with an enclosed system. Until then, the use of the respirator is considered to be necessary to control worker exposure to within the allowable limits.

In the gel preparation (mercury-zinc amalgamation) room of an alkaline cell manufacturer surveyed workers wear positive-pressure, continuous mode, airline respirators (Wilson Products). These respirators are used to protect against mercury vapor generated from gel handling operations. This operation is typically associated with TWA concentrations of mercury vapor in excess of the OSHA PEL.

In the concentrator and furnace areas of a cinnabar processing plant, MSA Mersorb Respirators (Comfo-II, half-facepiece, dual chemical cartridge) are used by all employees. This respirator has a color indicator on the cartridge that changes from orange to brown when the filter media has absorbed a specified amount of mercury vapor (before breakthrough occurs). One advantage of the respirator is that a worker can easily monitor the color indicator on another worker's respirator. In areas of the plant where workplace concentrations of mercury vapor consistently exceed the MSHA and OSHA PEL, the cartridges generally last several weeks before needing to be replaced. This facility has relied on respirators since startup in 1975. Plant representatives report that the respirator use is effective in minimizing worker exposure to mercury based on biological monitoring results. The average urine-mercury concentrations for operators at this facility was approximately 0.10 mg/L with a high of 0.175 mg/L in 1981. Maintenance workers generally have lower biological monitoring results.

At a mercury compound production plant, respirators are worn in all areas where mercury or mercury compounds are produced. Pulmosan Type CMH, No. 10792 full-facepiece, air-purifying, cartridge respirators with hood are worn by workers when handling PMA and HgO. These respirators are intended to protect against mercury vapor, which plant representatives have determined to be present in association with PMA and HgO production. They may also be effective in reducing exposure to PMA and HgO particulate.

2. Other Protective Equipment

Protective clothing, to minimize worker contact with inorganic mercury, was utilized in all of the industries studied except for the dental industry. The most commonly used protective clothing included the following:

- Disposable uniforms or lab coats. Most of the disposable garments in use during this study were made of Tyvek[R] (DuPont, Wilmington, DE), which is a lightweight, spill-resistant, synthetic fabric.
- Cloth work clothes that are changed daily. Work uniforms at one chlor-alkali plant were made of 65 percent polyester and 35 percent cotton, a blend that plant representatives have determined through testing to be highly resistant to mercury penetration and absorption.
- Disposable gloves (various manufacturers). The gloves were made of various materials and thicknesses depending on the job application. Surgeon's gloves (5-mil latex) were used extensively at electrical switch, electrical standards, and thermometer manufacturers. The gloves were usually disposed of and replaced several times per day.

D. MONITORING CONTROL EFFECTIVENESS

1. Workplace Air Monitoring

All but 4 of the 24 plants visited conducted routine air monitoring to determine the airborne concentration of mercury. The most common sampling and analytical methods employed by industry are described below:

a. Mercury Vapor Monitoring

Direct Reading Instruments

Commonly used instruments and sampling methods are described below:

- Bacharach MV-2:
  Principle of Operation - ultraviolet light at a specified wavelength is absorbed by mercury vapor. Absorption occurs in proportion to sampled concentrations.

  Sensitivity. minimum detectable concentration is 0.01 mg/m^3.

  Interferences· organic solvents.

- Jerome 401 Mercury Vapor Detector:
  Principle of Operation - absorption of mercury vapor on a gold film, thereby increasing its resistance. Resistance is proportional to mass of mercury present in sampled air.

  Sensitivity. minimum detectable concentration is 0.002 mg/m^3.

  Interferences. none reported.

  This instrument can also be used as a continuous monitor.

Time-Weighted Average Sampling

Passive Dosimeters. Passive dosimeters or badges are available from several manufacturers including 3M Company and SKC Corporation. The badges contain a solid sorbent that adsorbs mercury vapor at a known rate proportional to ambient concentrations. These badges can be worn by employees or set out in an area during a full shift. The badges must be sent to the manufacturer for analysis.

Solid Sorbent Tubes: Solid sorbent tubes for the collection of mercury vapor are available from various manufacturers including Mine Safety Appliances (MSA) (Pittsburgh, PA), SKC Corporation (Eighty Four, PA) and Anatole Sipin Co., Inc. (New York, NY). The sorbent tubes consist of a proprietary solid sorbent medium (such as Hopcalite^R or Hydrar^R) mounted in a glass tube. Samples are obtained using calibrated personal sampling pumps to draw air through the sorbent tube. Samples obtained in this manner require analyses in a laboratory. The standard analytical method involves dissolving the media in a mixture of nitric and hydrochloric acids. Analyses are completed using flameless atomic absorption (Rathje and Marcero 1976).

A collection tube containing a gold coil as the collection medium is available for TWA sampling (from Jerome Instrument Corporation). This system requires the use of a sampling pump. An advantage of this system is that onsite analysis can be conducted using the Jerome 401 Mercury Vapor Detector.

b. Particulate Mercury Monitoring

Because mercury vapor is often present in association with particulate inorganic compounds of mercury, a sampling method capable of collecting both forms should be used to determine the total inorganic mercury present. The sampling and analytical method widely used is a variation of NIOSH P&CAM 175 (NIOSH 1975). Particulate mercury is collected on a glass fiber filter (available from Whatman Laboratory Products) or a mixed cellulose ester acetate filter mounted in a cassette filter holder.

The filter cassette is located in front of the mercury vapor solid sorbent tube. Air is drawn through the sampling train using a calibrated personal sampling pump. The filter is analyzed to determine the amount of particulate mercury present, and the sorbent tubes are analyzed to determine the amount of mercury vapor.

2. Biological/Medical Monitoring

Biological monitoring programs were in effect at all of the industries studied except for the dental industry. At many plants, biological monitoring was under the direction of an occupational health physician and was part of a medical program designed to monitor and control worker exposure to mercury.

The program consists of periodic analyses of workers' urine or blood (or both) to determine the concentration of mercury. The results of analyses are compared with. (1) recommended biological threshold limits (TABLES 14 and 15) or arbitrary threshold limits (set by plant representatives) and/or (2) previous biological monitoring results or results of coworkers to determine if biological concentrations are increasing or decreasing. A note of caution should be mentioned, that is urine analysis for mercury often shows poor correlation between urinary mercury and signs and symptoms.

When a worker's biological concentration exceeds the "allowable limit," set by the plant, or increases significantly over previous sample concentrations, a plant representative usually examines that worker's job activities, work practices, and use of personal protective equipment to determine the cause of the elevated concentration. At the same time, the worker may be removed from his/her present position to an area of the facility with less potential for exposure to mercury. The worker is usually reinstated when his/her biological concentration falls below the threshold limit.

TABLE V-14

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.

TABLE V-15

Mercury Exposure Limits for the State of California

Urine-Mercury Concentration (mg/L)	Condition
0.10-0.20	Warning level
0.21-0.30	Hazardous level, remove from further exposure
0.31 and Above	Significant exposure

Urinalyses were the basis of the monitoring programs at 20 of the 24 plants studied that used biological monitoring, blood analyses were relied on at the other four plants. Urinalyses were preferred over blood analyses by most plant representatives because sample collection was easier. At most of these plants, single voiding samples were collected rather than 24-hour composite samples. Although 24-hour composite samples were thought to be a better indicator of exposure, the problems associated with the collection of these samples made this method of sampling impractical.

The biological threshold limit at which workers were removed from their positions varied considerably among the plants visited. The urine-mercury limits ranged from 0.05 to 0.50 milligrams per liter (mg/L). At most plants, the limit was 0.30 mg/L or lower. The "concern limit" for repeating urinalyses ranged from 0.025 to 0.30 mg/L. At plants where blood analyses were the basis of biological monitoring, the mercury concentration at which workers were removed from their jobs was 10 ug/100 ml of blood.

Although biological monitoring programs are designed to monitor worker exposure and workplace control effectiveness, several mercury-using industries have reported an additional benefit of the program. By making employees aware of their results in the periodic sampling (urine or blood concentrations of mercury), they become more aware of activities that result in elevated biological samples and usually take corrective action on their own to reduce exposure.

VI. CONCLUSIONS

GENERAL COMMENTS

1. The control of worker exposure to mercury at the facilities studied was the result of an integrated control approach that included engineering controls, behavioral controls, personal protection, and monitoring programs applied as necessary. The combined control approach was used in every facility studied, with the exception of dental clinics.

2. Good housekeeping, sound work practices, and use of smooth, impermeable materials on floors and work surfaces are sometimes sufficient controls to maintain worker exposure to mercury below the allowable limit. This is particularly true of operations involving the use of small amounts of mercury at or below normal room temperature such as dental facilities and standards manufacturers.

3. NIOSH or plant reported area and personal mercury air samples taken during this study were generally above the OSHA PEL of 0.1 mg/m^3 in the following processes/industries:

   - button cell cathode production (particulate) and anode gel preparation in battery manufacturing (vapor)
   - furnace and concentrator areas in cinnabar processing (vapor)
   - spray drying and reactor/drumming areas of a PMA manufacturer (vapor).

   For these operations the full-time use of respirators was required to minimize exposures until appropriate control measures could be effected.

4. NIOSH area and personal mercury air samples taken during this study were generally above the NIOSH recommended level of 0.05 mg/m^3 but below the OSHA PEL of 0.1 mg/m^3 in the following processes/industries.

   - button cell cathode production- slugging (vapor) in a battery plant
   - conventional mercury addition process (vapor) of a fluorescent lamp manufacturer
   - fill room (vapor), next to the fill units, in one thermometer plant
   - spray drying operator (vapor) of a PMA manufacturer

5. Area and personal samples which were taken during this study, other than those reported in #3 and #4, were below the NIOSH recommended level of 0.05 mg/m^3.

SPECIFIC CONTROLS

1. The use of the mercury "pill' in the fluorescent lamp manufacturing process results in lower workplace mercury vapor concentrations and eliminates routine mercury "doser" maintenance that is associated with direct contact with liquid mercury.

2. Ventilated work stations can control mercury vapor emission during elevated temperature operations (e.g., "burning off" and sealing thermometers).

3. Collector ring contacts or similar electrical contact devices can eliminate the need for mercury electrical contacts in certain electroplating processes. These devices, if applied to other electroplating operations, could reduce the number of workers exposed to mercury.

4. Preenclosed dental capsules are probably more convenient in dental operating procedures, however, their effectiveness in reducing mercury vapor concentrations was not demonstrated in this study.

5. Water-soluble plastic bags containing mercury compounds, used for charging batch chemical mixing operations, may have value in reducing or eliminating worker exposure. However, problems associated with shipping (e.g., accidental contact with water in transit or storage) may require additional protective packaging.

6. Enclosed liquid mercury addition/transfer systems driven by air pressure have been shown to work well in several facilities. These systems can be applied in modified form to almost all mercury-manufacturing industries, thus eliminating manual handling steps.

7. Liquid mercury can be effectively contained at work stations/benches having the following characteristics:

   - Work surface made of stainless steel

   - Stainless steel drainage troughs along the front of the work surface. The troughs should be sloped so that mercury can drain to a collection bottle. A lip along the other sides of the surface prevents mercury from spilling onto the floor.

   - Alternately, if work activities permit, a worktable made of stainless steel having a screened or grated surface over a sloped sink is effective. The sink should be sloped to allow mercury to drain into a collection bottle. A level of water should be maintained in the sink to further minimize mercury vaporization.

   Examples of effective work stations are shown in Figures VI-1 and VI-2.

8. Floors that are sealed with epoxy coating, vinyl sheets, or other impermeable coverings are highly effective in minimizing housekeeping problems and facilitating cleanup of mercury spills.

9. The Plexiglas-ventilated machine enclosures seen at particulate-generating processes were not effective in controlling particulate concentrations to within allowable limits even though ventilation capacity was increased. Insufficient control is caused by repeated worker access to the machine while opening the enclosure to make adjustments, etc. The solution to this problem is in locating important access/adjustment points outside the enclosure.

10. Temperature control was probably the most effective engineering control for reducing general workplace air concentrations of mercury vapor. Applying temperature controls in many instances may make it possible to relax or eliminate other more costly controls, as long as spills are prevented.

11. Pura-Siv^R mercury adsorption units effectively remove mercury from exhaust airstreams. This type of unit is beneficial for mercury removal service in high-mercury-content (approximately 10 mg/m^3) airstreams.

12. The Torit mercury filter unit was found to be approximately 75 percent efficient in removing mercury in a recirculation system. However, the housekeeping problems associated with the use of this unit makes its application impractical.

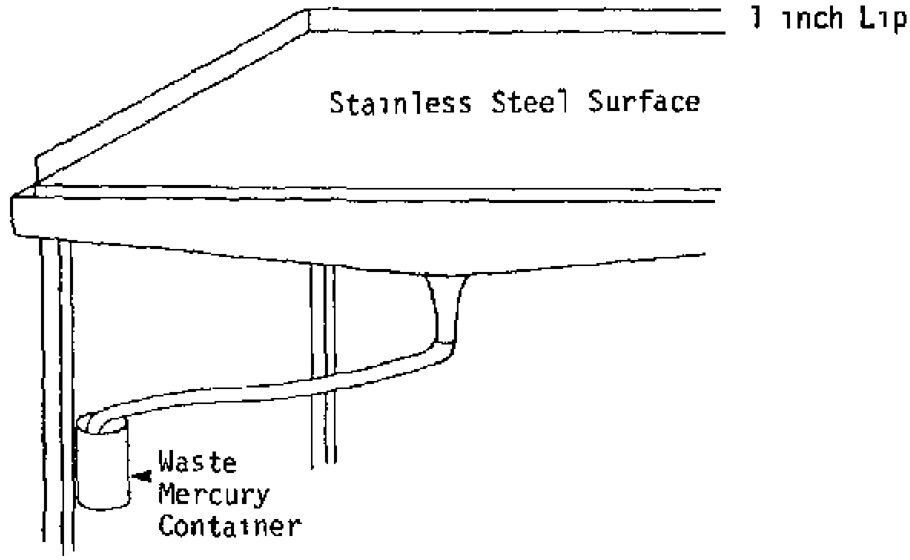

Figure VI-1 Work Station with Drainage Trough

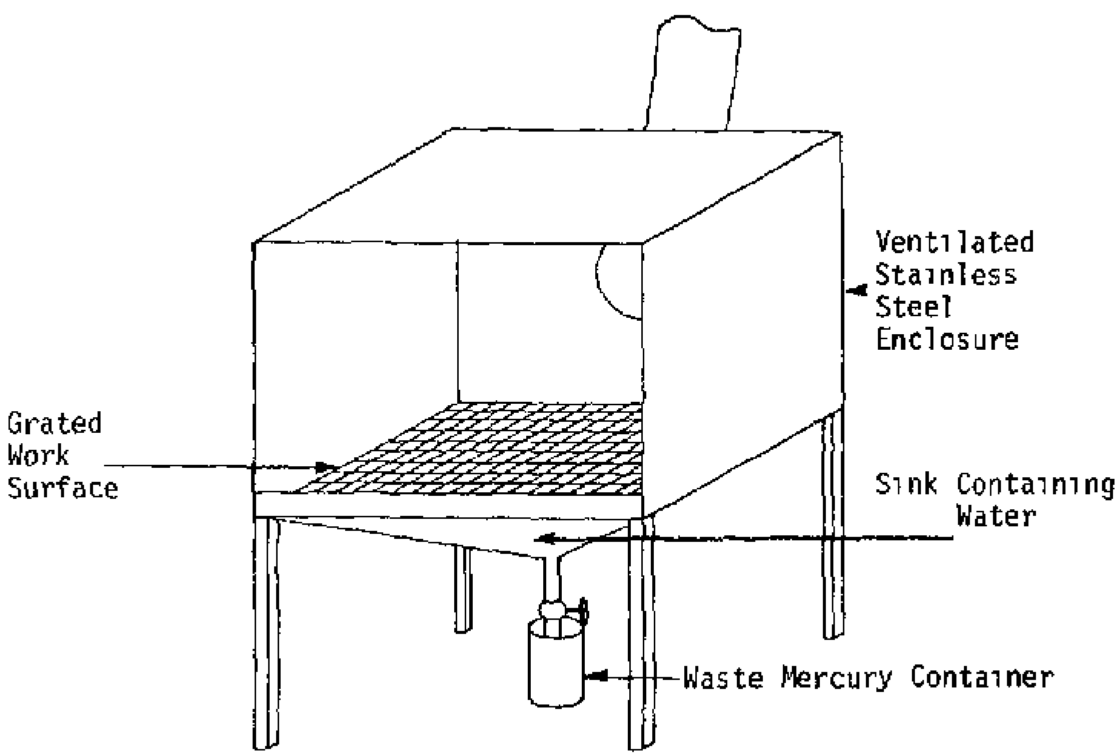

Figure VI-2. Ventilated Work Station with Grated Surface

VII. RECOMMENDATIONS

1. Mercury should be purchased in containers sized for particular process needs, these containers should adapt readily to enclosed addition systems. Currently, most industries using mercury are buying 76-pound flasks and manually transferring mercury to the system.

2. Investigation into designing completely enclosed methods of mercury particulate transfer should continue. Inadequacies in all of the solids materials handling systems were observed at the facilities studied.

3. Vacuum cleaners equipped with mercury traps and carbon filters should be used both for routine cleaning and for cleanup of spills. Use of conventional vacuum cleaners results in high mercury vapor concentrations.

4. Plant air recirculation systems are effective in removing mercury and can be cost effective depending on geographical location. If these systems are to be used, a filter/air handler inspection program should be instituted to determine if the system is performing optimally. The program should include monitoring filter effectiveness, determining airflow characteristics, and determining the quality of the reintroduced air.

5. The use of preenclosed dental capsules is recommended, although they did not result in a detectable lowering of mercury vapor concentrations in the dental facilities studied. However, they eliminate a mercury handling step and the associated potential for accidental spills.

6. The "mercury pill" addition system observed at a fluorescent lamp plant should be used at other fluorescent lamp manufacturing facilities, the system should be further modified so that it can be used in the mercury switch manufacturing industry.

7. Workers who are involved in mercury particulate handling operations should continue to wear respirators until effective control methods have been developed. A study to develop control methods is recommended.

8. Workers should continue to wear respirators when involved with distilling operations or other operations where elemental mercury is handled at temperatures above room temperature and local exhaust is impractical. New air exhaust systems should be designed and/or installed to eliminate worker exposure and dependence on respirators.

9. Mercury decontamination cleaning aids should be routinely used in general plant housekeeping programs and in the cleanup of spills. The use of mercury decontaminants may not be necessary if stringent housekeeping measures using conventional industrial cleaners are instituted.

10. Daily clothing changes or disposable clothing should be required for all workers who routinely contact mercury. Disposable clothing has the advantage of eliminating laundering of contaminated clothing but requires proper disposal.

11. Because mercury is difficult to remove from the skin, washing hands thoroughly before breaks and at the end of shifts should be mandatory.

12. Disposable gloves should be worn whenever possible for workers who handle mercury or mercury-containing items.

13. Although job rotation on a routine basis can reduce an employee's exposure to mercury to allowable limits, it has the disadvantage of spreading mercury exposures over a wide population. Consequently, job rotation should be used only as an interim measure until other control methods are applied to reduce exposures to acceptable levels.

14. Biological monitoring should be conducted for all exposed workers. Evaluation of group biological monitoring results provides more information on the extent of exposure and effectiveness of controls than do individual evaluations.

15. Care should be taken that job-related decisions on mercury control are based on sound data. No less than two determinations should be made, and these should be no less than 48 hours apart. The final decision should be made by a physician after examining the worker. Exposure or health effects cannot be determined by the laboratory results alone. Individuals can experience very different health effects at the same biological mercury levels. An effective monitoring program must integrate medical determinations into its decisionmaking process so that actions are taken based on all of the available information.

16. Workplace area and personal monitoring should be conducted to determine employee exposure and control effectiveness. Although the currently available direct reading instruments for the measurement of mercury vapor are sensitive and accurate, TWA breathing zone determinations are a more reliable indicator of worker exposure.

17. At many of the facilities visited ventilation systems were designed on a "number of air changes per hour" basis. This is inadequate for areas where mercury is used. Monitoring programs should be instituted at these locations to measure area and personal mercury concentrations on a regular basis, because of the potential for localized high exposures.

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APPENDIX
SAMPLING AND EVALUATION METHODS

This appendix presents the methods for air sampling and analysis used during this study to measure workplace concentrations of mercury, as well as the methods of engineering evaluation used to determine the effectiveness of control measures.

A. AIR SAMPLING AND ANALYSES

Air samples were collected to determine the airborne concentrations of mercury.

1. TWA Samples

a. Personal sampling -- Personal air sampling was conducted to evaluate the exposure of a worker to airborne mercury from various sources. Where respiratory protection was used, samples were collected outside of the respirator. The results of these samples were compared with the allowable limit to determine the effectiveness of the control measures used. Sample periods usually included a full shift.

b. Area sampling -- Area sampling was conducted to determine the effectiveness of the controls used to reduce ambient concentrations of mercury in the workplace. Samples were collected at fixed locations. Sample time varied but usually lasted the duration of the shift.

Both personal and area mercury vapor concentrations were obtained using personal monitoring pumps (MSA Model C-200) to draw air through Hopcalite solid sorbent tubes. 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 (soap-bubble meter). Analyses of samples were conducted using flameless atomic absorption (Rathje and Marcero 1976).

Particulate mercury samples were obtained using a high-flow personal sampling pump (MSA Model S or G) to draw air through glass microfiber filters (Whatman Laboratory Products) mounted in 37-mm cassettes. The flow rates, set at 2.0 liters of air per minute, were determined both before and after sampling using a buret. Analyses of samples for total mercury were conducted using flameless atomic absorption.

2. Grab Samples

A direct reading instrument that provides an instantaneous measurement of mercury vapor was used to determine area and breathing zone concentrations. A Jerome Model 401 Mercury Vapor Detector, with a sensitivity of 0.001 mg/m^3 and a range of 0.001-0.50 mg/m^3, was used to collect grab samples.

B. AIRFLOW MEASUREMENTS

The effectiveness of local exhaust ventilation (LEV) systems and dilution ventilation systems was determined in part by the measurement of air velocities to calculate airflows. Face velocities at exhaust or supply openings were measured using a velometer (Alnor Series 6000 or thermoanemometer). Duct velocities were determined using a Pitot tube and inclined manometer. The contaminant capture range of some LEV systems was measured using a smoke generation tube.