FINAL REPORT

MERCURY CONTROL TECHNOLOGY ASSESSMENT STUDY

Oak-Mitsui Corporation
Hoosick Falls, New York

In-depth Survey Report
for the Site Visit of
February 17-18, 1982

Contract No. 210-81-7107

June 18, 1982

Submitted to

Alfred A Amendola, Project Officer
National Institute for Occupational
Safety and Health
Division of Physical Sciences and Engineering
4676 Columbia Parkway
Cincinnati, Ohio 45226

Submitted by

Donato R Telesca, Manager
Engineering Department
Dynamac Corporation
Enviro Control Division
11140 Rockville Pike
Rockville, Maryland 20852

REPORT NO
ECTB 109-24b

DISCLAIMER

Mention of company name or product in this report does not constitute endorsement by the National Institute for Occupational Safety and Health.

FOREWORD

A Control Technology Assessment (CTA) team consisting of members of Dynamac Corporation, Enviro Control Division, met with representatives of Oak-Mitsui Corporation in Hoosick Falls, New York, on February 17 and 18, 1982, to conduct an indepth survey on the techniques used to control worker exposure to mercury. Participants in the survey were

Dynamac Corporation

- Donato Telesca, Manager, Engineering Department
- Robert Reisdorf, Industrial Hygienist
- David D'Orlando, Environmental Engineer

Oak-Mitsui Corporation

- Anthony Butkas, Manufacturing Manager/Director of Safety
- William Hall, Quality Control Manager
- Joseph Rizzo, Vice President/General Manager
- Dion Finnegan, Process Engineer
- William Morgan, Project Engineer
- Susan Taber, Quality Control Technician
- Louis Schneider, Manufacturing Manager

The indepth CTA survey was completed in 2 days. The study included personal and area air sampling and detailed inspections of mercury controls.

CONTENTS

INTRODUCTION

CONTRACT BACKGROUND

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

JUSTIFICATION FOR SURVEY

The Oak-Mitsui Plant was selected for an indepth survey because of the containment and control of mercury used as an electrical contact. The plant has addressed a former mercury problem by continuously implementing engineering controls and work practices specifically designed to reduce worker exposure to mercury.

SUMMARY OF INFORMATION OBTAINED

An opening conference was held during which the objectives of the program were discussed with plant representatives. A tour of the copper foil manufacturing operation was made and information on mercury controls was obtained from the safety director and plant engineers. Area and personal monitoring was conducted in the process areas. Historical information on control implementation and urine-mercury levels was obtained.

PLANT DESCRIPTION

Oak-Mitsui, a division of Oak Products, Inc., located in Hoosick Falls, New York, manufactures copper foil for use in the production of printed circuit boards. The company began production in 1976, when it occupied an old foundry and converted it into a manufacturing facility. The facility occupies approximately 60,000 square feet and consists of production rooms, quality control laboratories, and office space. The production buildings are constructed of brick and have wooden ceilings and concrete floors. Major renovations and process changes implemented for improved mercury control were cooling jackets for mercury wells, local exhaust for mercury wells, and substitution of rotary contact devices for some mercury wells. A major mercury cleanup involving vacuuming and decontamination was conducted from August to October of 1980 following corporate awareness of a mercury exposure problem.

The plant operates two 12-hour shifts per day, 7 days a week. There are 160 people employed at this facility, 16 of whom work in areas where there is a potential for exposure to mercury.

PROCESS DESCRIPTION

High purity copper foil used for laminate in printed circuit boards is produced in an electrodeposition process at this facility. The production process (Figure 1) begins with the dissolving of scrap copper in a copper sulfate solution. The solution is pumped to a storage tank and on to a head tank where it is combined with additives to aid in forming specified copper grain structures. From the head tank, 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 slowly, the copper plates out on the drum surface as a continuous foil. The 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 and is stored in preparation for special treatment.

The rotation of the cathode drum necessitates the use of a rotating electrical contact between the buslines and the drum. The contact is established by using elemental mercury as a continuous contact between the rotating copper shaft of the drum and the electrical connections. A pool of mercury, termed a "mercury well," is situated at one end of the rotating drum shaft. Attached to the shaft is a series of copper discs that rotate through the mercury pool so that constant contact is maintained with the mercury (Figure 2).

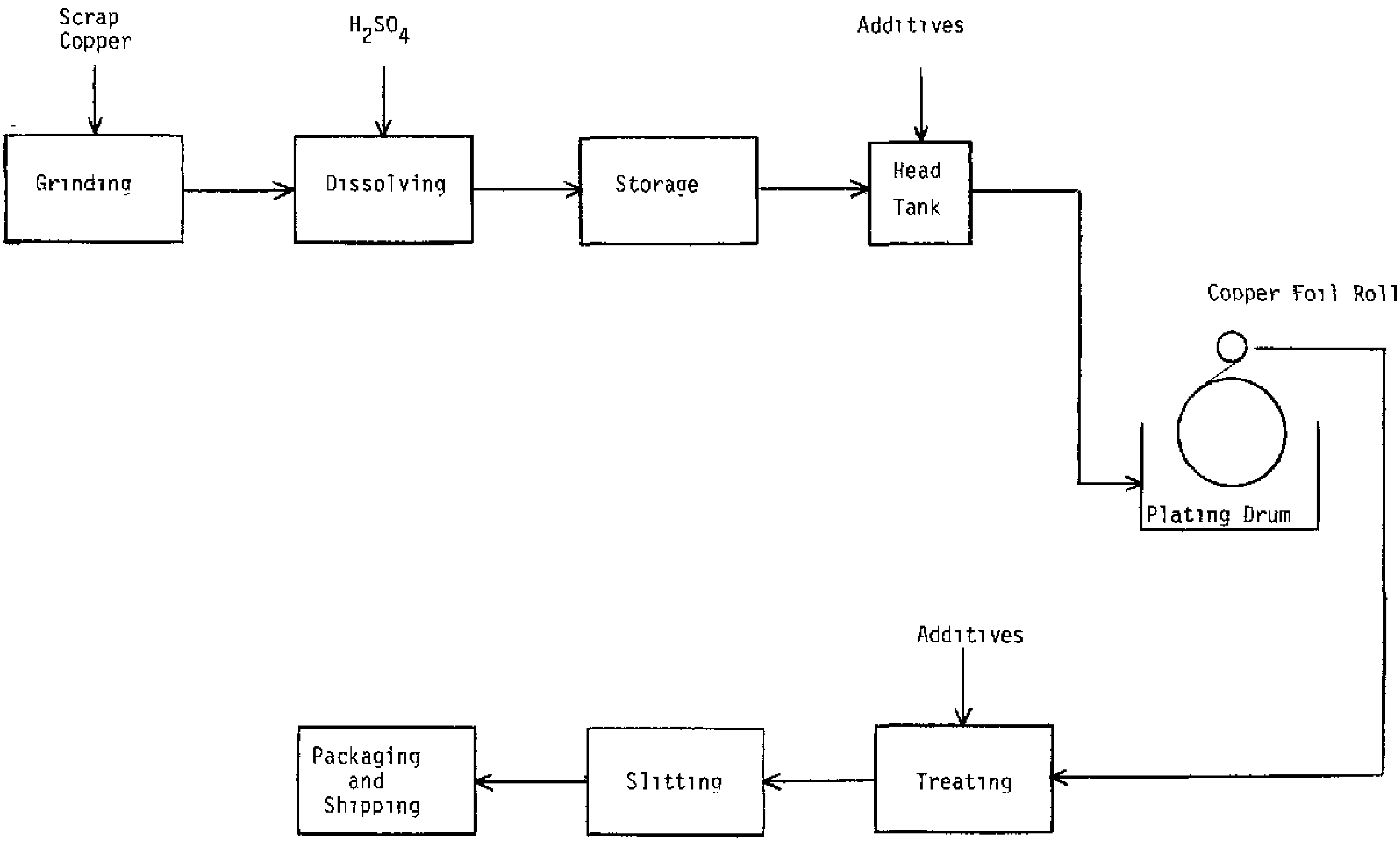

Figure 1 Copper Foil Manufacturing Process Flow Diagram

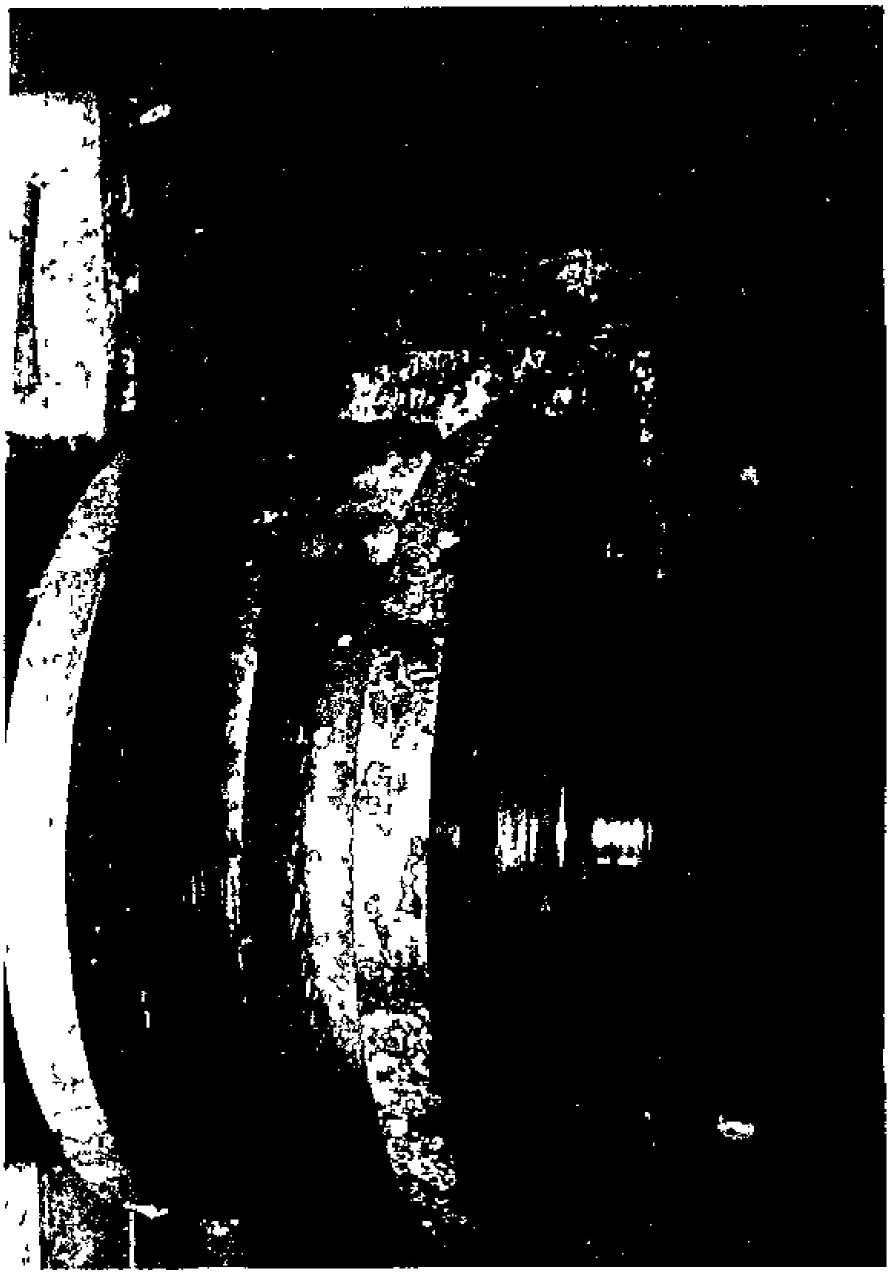

Figure 2 Copper Discs in the Mercury Pool

The drum side of the copper foil sheet is smooth textured for optimal electrical and mechanical performance. The opposite side is rough textured so that it may be surface treated for improved lamination qualities. This treatment involves depositing additional free copper on the rough surface of the foil and then stainproofing it. The process is proprietary and is conducted on specially designed treating machines.

The treating process involves charging the copper foil with an electrical current by establishing a potential across the solid copper rollers used to move the foil through the machine. To pass a current through the roller, a continuous electrical contact similar to the mercury wells on the drum shafts is needed at each end of the rotating roller shaft. The plant used mercury wells until 1980 to establish continuous contact between electrical buslines and the shaft. Presently, mechanical rotating contact devices are used for electrical contact. The amount of current needed for treating applications is significantly lower than that needed for plating.

After the rolls of copper foil are treated, they are annealed to increase flex strength. The foil is then slit to the proper width, wrapped, weighed, covered, and shipped. Residual foil is recycled to the grinder with the scrap copper wire.

Mercury in the contact wells must periodically be cleaned and replenished. Approximately once a month, small quantities of mercury (less than 150 pounds) are removed from the wells, filtered through gauze cloth, and passed through 20 percent nitric acid solution to remove impurities. The mercury is then returned to the wells. The filter unit is a 4-inch polyvinyl chloride column with a drain line on the bottom to remove the purified mercury that settles below the acid level. The gauze pad is disposed of as hazardous waste.

MERCURY CONTROL TECHNIQUES

PROCESS SUBSTITUTION

Rotary Contact Devices

Plant representatives determined that the mercury wells that are used as continuous contacts for rotating shafts in the "treating" process were the single source that contributed most significantly 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 2000 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 employed at the facility. One type is the TWECO Roto-ground (Figure 3), a heavy-duty rotary grounding device typically used in welding applications. It consists of an annular shaped head and a shaft (both are made of copper) that fits around the rotating shaft and has 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 presently use a graphite-containing grease that provides the same conductance while reducing housekeeping problems typically associated with the copper grease. The Roto-ground can be used in series of one to three heads on each end of the rotating shaft, depending on the range of electrical current desired. The total cost of substituting Roto-grounds for mercury wells was reported to be approximately $9,000.

The other type of rotary contact device used is a Japanese-manufactured NR series collector ring contact (Figure 4). The contact is made of a series of SAE 40 bronze rings that fit over the rotating shaft. The number of

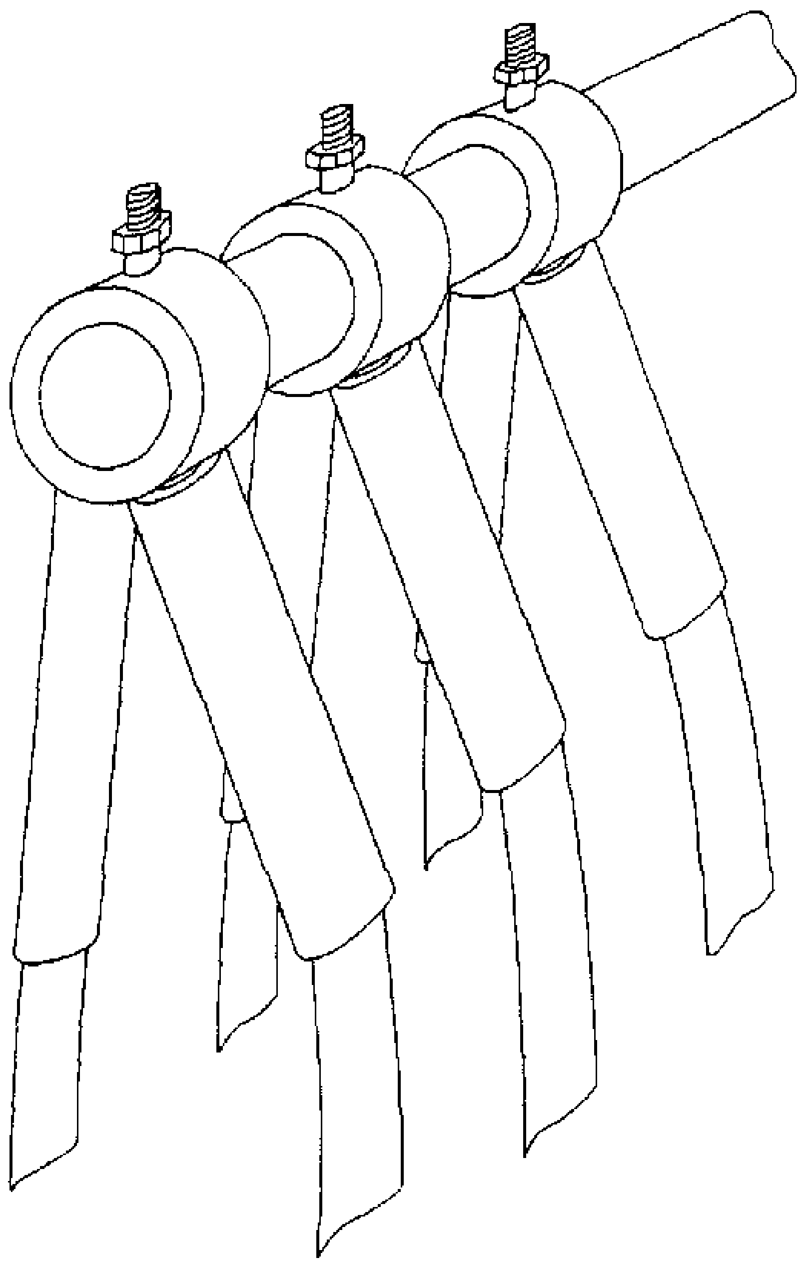

Figure 3 TWECO Roto-grounds Mounted on a Rotating Shaft.

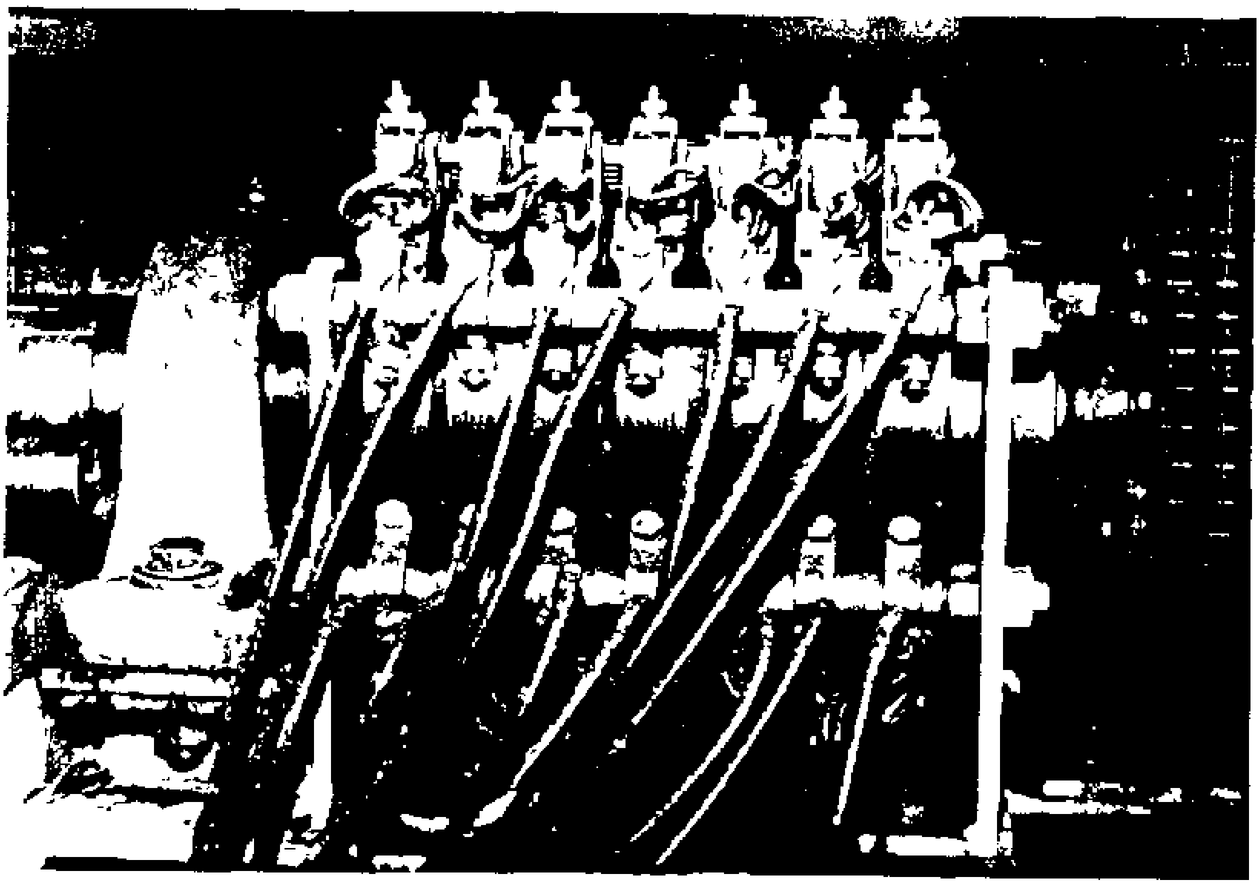

Figure 4. Japanese-Manufactured Collector Ring Contact.

internally mounted metal brushes for continuous contact with the shaft. The plant has found that this rotary grounding device performs superior to the Roto-ground, but it is not possible to fit all treating machines with the NR series contacts due to physical limitations. Plant engineers are currently evaluating another series of all-purpose collector rings with copper alloy brushes (Figure 5). These units are manufactured in the United States by Industrial Electric Reels.

TEMPERATURE CONTROL

The plant has found that rotating contact devices capable of handling higher current loads at acceptable efficiences are not currently available commercially. Therefore, mercury wells must still be used for continuous contact with the rotating shaft of the plating drum. The mercury wells were a major source of mercury vapor contamination because the temperature of mercury in the wells could be as high as 82 C (180 F) depending on the equipment and operating conditions. The normal operating range is 27-82 C (80-180 F). As mercury readily vaporizes at higher temperatures, plant efforts were focused on reducing these temperatures. This was accomplished 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 body 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 is approximately $18,000. A city water header is tied into the system to be used in the event that the chiller is inoperative. The system provides a flow of 1 gallon per minute of chilled water 4.4-10 C (40-50 F) that maintains mercury temperatures between 15 and 26 C (60 and 80 F).

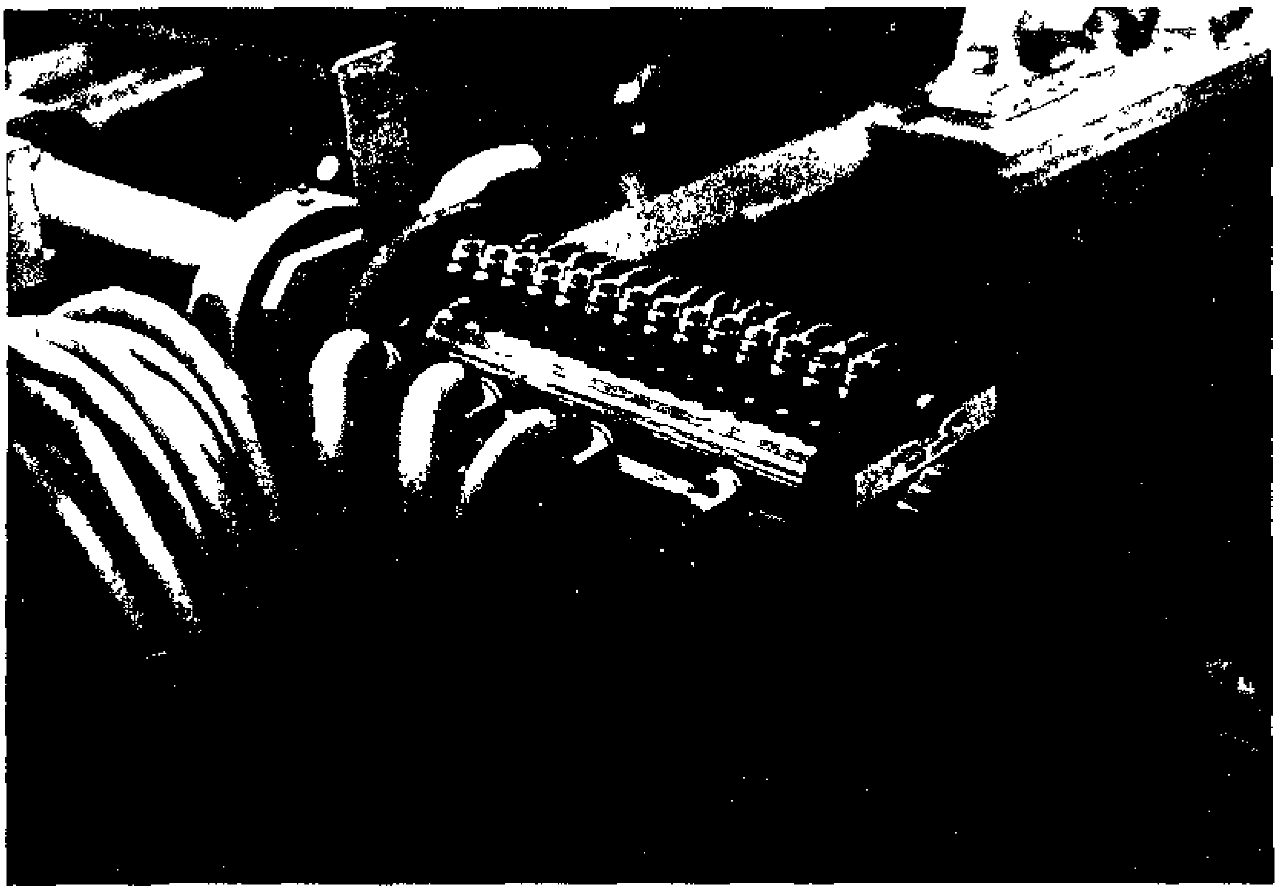

Figure 5. U.S.-Manufactured Collector Ring.

Controlling the temperature of mercury to an average of 21 C (70 F) rather than at 27-82 C (80 F to 180 F) can reduce the vapor pressure by a factor of 13. This reduces the resulting mercury vapor concentration (due to vaporization at the wells) to levels that may be controlled through standard exhaust ventilation procedures.

LOCAL EXHAUST VENTILATION

The mercury wells on the plating drum units are enclosed and ventilated by a specially designed local exhaust system. The purpose of the mercury vapor ventilation system is to draw air from the mercury wells and then into a mercury filter. Each well has a Plexiglas cover with a flexible duct connected to a manifold (Figure 6). There are two manifolds, one for each side of the drum plating units. The manifolds exhaust into a Calgon Vent-sorb filter (Figure 7). 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 cubic feet per minute (cfm). The filter media in the Calgon Vent-sorb (approximately 150 pounds in each unit) consists of Pittsburgh Type HGR, a 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), which enhances the medium 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 so 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 the Jerome Mercury Vapor Detector). The units have been on-line for a year, and replacement of the HGR has not yet been necessary.

The cost of the exhaust ventilation system (and also the mercury well cooling jackets) was reported to be approximately $50,000.

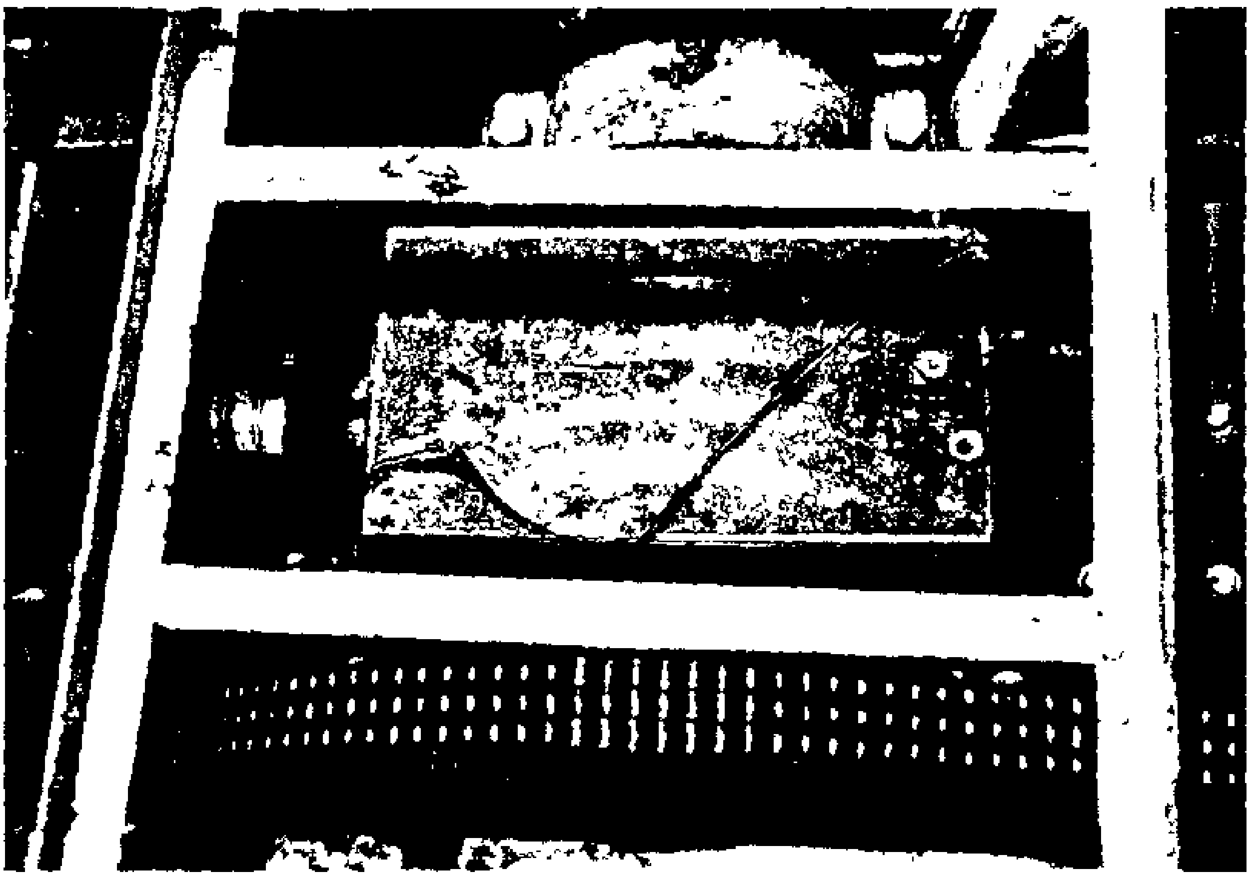

Figure 6. Ventilated Enclosure over Mercury Well.

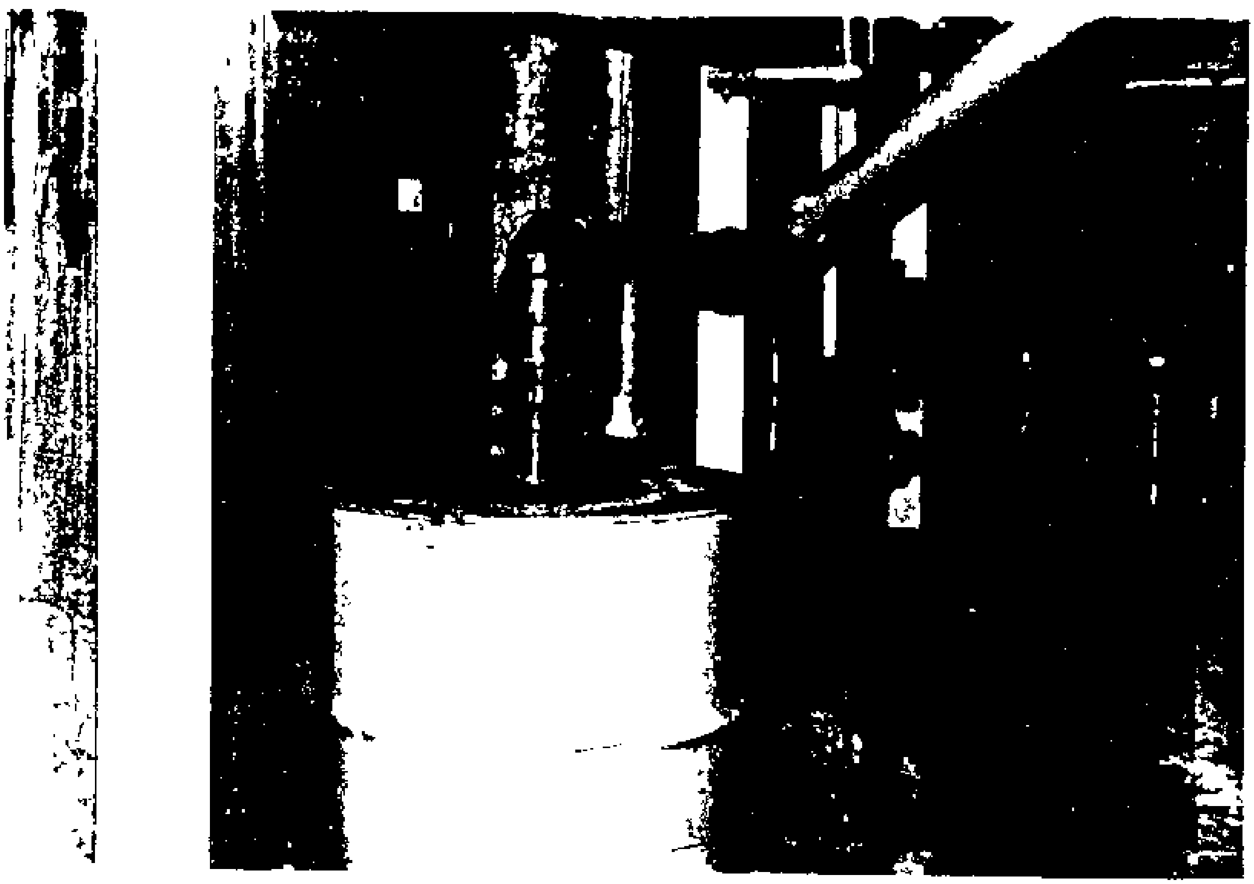

Figure 7. Calgon Vent-sorb Filter

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment for control of exposure to mercury is not used at this facility on a plantwide basis. Plant representatives feel that the engineering controls recently implemented adequately control exposure to mercury liquid and vapor. Certain activities may have a high potential for exposure to mercury. These activities include: mercury addition, emergency spill cleanup procedures, and temperature checking by the drum operators, during which the mercury well enclosures are opened. For these activities, workers wear rubber gloves and a respirator (3M #8707, air-purifying, half-face, disposable repirator containing iodine-impregnated charcoal as the primary adsorption medium). In addition, all operators wear cloth uniforms that are changed daily.

WORK PRACTICES

Of the production operators, only the drum operators are considered to have a high potential for exposure to mercury. Other operators have little or no opportunity to contact mercury or to be near open mercury. Mercury handling procedures are summarized below.

- Only trained personnel may handle mercury.
- Personal protective equipment must be worn.
- Smoking is not allowed during the mercury handling process, smoking is allowed in most areas of the plant except in the vicinity of the drums.
- Hands must be washed thoroughly after handling mercury.

The above procedures must also be followed in the cleanup of accidental spills of mercury. Spills are cleaned up using a vacuum cleaner equipped with a charcoal filter for the removal of mercury vapor.

Specialized housekeeping procedures designed to control mercury are not used at this facility. Plant representatives have found general housekeeping procedures (routine cleaning of floors and walkways with soap and water) to be sufficient in controlling worker exposure to mercury. HgX[R], a mercury vapor suppressant, was used at this facility previously as part of the housekeeping program; however, plant representatives feel that its use did not result in an apparent lowering of mercury vapor concentrations.

MONITORING PROGRAMS

Biological Monitoring

Drum operators are monitored periodically (usually monthly) to determine the concentrations of mercury in their urine. Treater operators and maintenance workers, who have less potential for exposure, are monitored on an occasional basis (several times per year). Twelve-hour (full-shift) composite urine samples are collected. Analyses are conducted at an outside laboratory.

The urine-mercury level at which action (removal from job or other administrative control) would be taken is 100 micrograms per liter (ug/L). This level has been set by the plant's consulting physician. Current biological monitoring records show that all workers have urine-mercury concentrations well below 100 ug/L. Generally, workers' urine-mercury concentrations have been steadily decreasing since mid-1980, when the engineering controls were introduced.

Air Monitoring

Periodic air monitoring is conducted using a direct reading instrument (Jerome Mercury Vapor Detector). A review of plant air monitoring shows a significant reduction in mercury vapor concentrations throughout the facility between August 1980 (when controls were first implemented) and the time of this survey. Selected plant monitoring data are presented in Table 1.

Personal monitoring to determine the time-weighted average (TWA) exposure of drum operators and treater operators to mercury vapor is conducted on a weekly basis. Monitoring is conducted using the Jerome Gold Coil Mercury Vapor Dosimeter connected to sampling pumps. The results of this monitoring also show a steady decline in worker exposure since engineering controls were instituted. Selected data collected by plant representatives are presented in Table 2.

TABLE 1

Results of Area Monitoring
(Summary of Plant Monitoring Data)

	Average Concentration (mg/m^3)		
Location	8/80 (8)*	1/81 (9)	1/82 (3)
Drum 1	0.08	0.04	0.013
Drum 4	0.21	0.03	0.016
Drum 7	0.20	0.04	0.014
Drum 10	0.14	0.03	0.015
Drum 13	0.19	0.04	0.022
Drum 16	0.06	0.05	0.019
Treater	0.19	0.02	0.003

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

TABLE 2

Results of Personal Monitoring
(Summary of Plant Monitoring Data)

	Drum Operator Concentration (mg/m^3)		Treater Operator Concentration (mg/m^3)	
Date	Range	Average	Range	Average
7/80	0.059-0.070	0.065 (3)*	0.076-0.189	0.116 (3)*
8/80	0.019-0.058	0.039 (4)	0.092-0.292	0.182 (5)
2/81	0.038-0.072	0.060 (3)	0.018-0.030	0.022 (3)
9/81	0.025-0.029	0.026 (4)	0.006-0.011	0.007 (3)
1/82	0.011-0.021	0.016 (4)	0.003-0.013	0.007 (4)

*Numbers in parentheses indicate number of samples taken at each worker's breathing zone.

SURVEY DATA

Personal and area samples for mercury vapor were collected during the site visit using sampling pumps and Hopcalite as the adsorption medium. For personal samples, the Hopcalite tube was attached to the collar of the employee. The flow rates, set at 75 ml of air per minute, were determined using a buret (soapbubble meter) both before and after sampling. Analysis of samples was done by flameless atomic absorption. Sample results are presented in Table 3.

TABLE 3

Results of Personal and Area Monitoring (2/18/82)

Employee/Location	Full-Shift TWA Concentration (mg/m^3)
Drum Operator A	0.024
Drum Operator B	0.026
Area Sample - Drum 6 (near Mercury well)	0.022
Area Sample - Drum 15 (near Mercury well)	0.005
Area Sample - Treater Room	0.018

Results are in close agreement with plant personal and area monitoring sample results. (Note that plant samples are collected using dosimeters and are analyzed on the Jerome Mercury Vapor Detector by the plant quality control technician.) The highest TWA personal exposure measured during the survey was 0.026 mg/m^3. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for mercury vapor is 0.1 mg/m^3 (as a TWA). Area sample results were similar to personal sample results.

CONCLUSIONS

Based on sampling results and review of historical data, it is apparent that Oak-Mitsui has achieved and is maintaining mercury vapor levels below the OSHA PEL of 0.1 mg/m^3 (as a TWA). Workplace concentration of mercury vapor approached and at times exceeded the OSHA PEL before controls were applied. Recent plant data indicate personal exposure in the range of 0.003-0.021 mg/m^3. These levels have been achieved through a four-phase approach consisting of a full-scale mercury cleanup, a substitution for mercury wherever possible, temperature control for mercury, and enclosure and ventilation of mercury point sources.

This was one of the few facilities studied that did not rely on dilution ventilation for mercury control. This is because the mercury sources are easier to contain in this type of manufacturing operation than they are in many others. There are numerous advantages to not having to install dilution ventilation systems to reduce mercury vapor levels. The most important advantage is the cost savings for installation and conditioning air. On cold days, this plant is able to shut down its air supply system with no negative impact on mercury vapor levels.

The use of the mechanical rotary contact devices, in addition to reducing workplace concentrations of mercury vapor, has also significantly reduced mercury usage, resulting in a cost benefit. However, the application of the control is limited to those industries that use mercury as a means of production rather than as a raw material for production.

Temperature control and vented enclosures are applicable to many mercury-using industries and are currently widely used for this purpose.