United States
Environmental Protection
Agency

Research and Development

Risk Reduction
Engineering Laboratory
Cincinnati, OH 45268

EPA/600/S-92/050 October 1992

EPA

ENVIRONMENTAL RESEARCH BRIEF

Waste Reduction Activities and Options for a Manufacturer of Systems to Produce Semiconductors

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Abstract

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a facility that manufactures systems for vapor deposition of organometallic compounds or metals used in the production of semiconductors. As part of the manufacturing process it is necessary to test the systems using the materials actually used in semiconductor production. Test deposition of materials containing arsenic, indium, or gallium, among others, result in much of the waste stream. A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included changes in degreasing procedures and modifications to filtering systems. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

Introduction

The environmental issues facing industry today have expanded considerably beyond traditional concerns. Wastewater, air emissions, potential soil and groundwater contamination, solid waste disposal, and employee health and safety have become increasingly important concerns. The management and disposal of hazardous substances, including both process-related wastes and residues from waste treatment, receive significant attention because of regulation and economics.

As environmental issues have become more complex, the strategies for waste management and control have become more systematic and integrated. The positive role of waste minimization and pollution prevention within industrial operations at each stage of product life is recognized throughout the world. An ideal goal is to manufacture products while generating the least amount of waste possible.

The Hazardous Waste Advisement Program (HWAP) of the Division of Hazardous Waste Management, New Jersey Department of Environmental Protection and Energy, NJDEPE, is pursuing the goals of waste minimization awareness and program implementation in the state. HWAP, with the help of an EPA grant from the Risk Reduction Engineering Laboratory, conducted an Assessment of Reduction and Recycling Opportunities for Hazardous Waste (ARROW) project. ARROW was designed to assess waste minimization potential across a broad range of New Jersey industries. The project targeted 30 sites to perform waste minimization assessments following the approach outlined in EPA's *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003). Under contract to NJDEPE, the Hazardous Substance Management Research Center at the New Jersey Institute of Technology (NJIT) assisted in conducting the assessments. This research brief presents an assessment of the manufacturing of systems for vapor deposition of organometallic compounds or metals used in the production of semiconductors (1 of the 30 assessments performed) and provides recommendations for waste minimization options resulting from the assessment.

Methodology of Assessments

The assessment process was coordinated by a team of technical staff from NJIT with experience in process operations, basic chemistry, and environmental concerns and needs. Because the EPA waste minimization manual is designed to be

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primarily applied by the inhouse staff of the facility, the degree of involvement of the NJIT team varied according to the ease with which the facility staff could apply the manual. In some cases, NJIT's role was to provide advice. In others, NJIT conducted essentially the entire evaluation.

The goal of the project was to encourage participation in the assessment process by management and staff at the facility. To do this, the participants were encouraged to proceed through the organizational steps outlined in the manual. These steps can be summarized as follows:

- Obtaining corporate commitment to a waste minimization initiative
- Organizing a task force or similar group to carry out the assessment
- Developing a policy statement regarding waste minimization for issuance by corporate management
- Establishing tentative waste reduction goals to be achieved by the program
- Identifying waste-generating sites and processes
- Conducting a detailed site inspection
- Developing a list of options which may lead to the waste reduction goal
- Formally analyzing the feasibility of the various options
- Measuring the effectiveness of the options and continuing the assessment.

Not every facility was able to follow these steps as presented. In each case, however, the identification of waste-generating sites and processes, detailed site inspections, and development of options was carried out. Frequently, it was necessary for a high degree of involvement by NJIT to accomplish these steps. Two common reasons for needing outside participation were a shortage of technical staff within the company and a need to develop an agenda for technical action before corporate commitment and policy statements could be obtained.

It was not a goal of the ARROW project to participate in the feasibility analysis or implementation steps. However, NJIT offered to provide advice for feasibility analysis if requested.

In each case, the NJIT team made several site visits to the facility. Initially, visits were made to explain the EPA manual and to encourage the facility through the organizational stages. If delays and complications developed, the team offered assistance in the technical review, inspections, and option development.

No sampling or laboratory analysis was undertaken as part of these assessments.

Facility Background

The facility is a manufacturer of a vapor deposition system used in the production of semiconductors. The facility manufactures the units and then tests them under simulated semiconductor production conditions using the actual chemical materials which are deposited on silicon wafers in large-scale production. This testing produces the bulk of the waste which is generated at the facility.

The facility is located in a suburban area and employs about 100 people. The demanding quality standards of the semiconductor manufacturing field are reflected in this facility and in the care which goes into the manufacture of each of its units.

Manufacturing Processes

The facility produces the vapor deposition units by assembling several components which are produced outside the facility. Stainless steel tubing is used in the units for structural strength and to minimize interference with the deposition process which might occur with other materials. The facility carries out cutting and forming operations on the tubing and generates some metal working fluid wastes as a result. The tubing is also etched with nitric and hydrofluoric acid and degreased with a chlorofluorocarbon in an ultrasonic bath.

The completed units are tested under simulated semiconductor wafer manufacturing conditions involving vapor deposition on silicon wafers of materials containing arsenic, gallium, phosphorus, mercury, indium and other elements used in semiconductor production. The vapors which are not deposited on the test wafers are captured in stainless steel traps. The majority of the waste streams from this part of the operation result from the procedures to clean the traps for reuse. The cleaning steps involve vacuuming with special "clean room" filters and then washing with solutions which are somewhat specific for the material trapped in the filter. The washing solutions include caustic, hydrofluoric acid, ammonium hydroxide, hydrogen peroxide, nitric acid, and sulfuric acid. The washings may contain small amounts of chromium, molybdenum, gallium, indium, arsenic, and phosphorus.

Existing Waste Management Activities

The company generates relatively small quantities of waste. The challenge from a waste management perspective is that while the total amount is small, the waste stream is composed of several different types of waste which should be segregated and managed separately. This raises costs and limits some of the options for pollution prevention.

From the production portion of the operation, the degreasing step using chlorofluorocarbon in an ultrasonic bath produces no specific waste stream. On the other hand, the facility purchases two drums of the solvent annually, indicating that evaporative losses do occur. The solvent was chosen because it is an effective cleaner and leaves no residue on the parts. The facility is looking for an effective substitute. In addition, the etching of stainless steel tubing generates about 2 drums per year of mixed acid. The metal working fluid waste stream also generates about 2 drums per year of material. Both streams are sent offsite for disposal.

The testing and evaluation component of the operation generates additional waste streams. The vapor retention and recovery system for the test setups include both stainless steel filters and activated carbon traps. Efforts are made to clean and reuse the steel filters. The carbon traps are sent offsite for disposal. About 60 lb/yr of this material is generated.

The steel filters are first vacuumed to recover loose materials and then are washed with different solutions, depending upon the material entrained in the filter. This process uses about 0.5 gal of each solution for each cleaning. Each year about 4 drums of ammonium hydroxide/hydrogen peroxide solution, 2 drums of sulfuric acid, and 4 drums of sodium hydroxide are generated. These materials are sent offsite for disposal.

In addition, other waste streams include about 2 drums of mixed solvents such as acetone and methanol used for the cleaning and processing of the test wafers and about 2 drums of plant scrap solid wastes including gloves and wipes used for cleaning the test units are shipped for disposal as hazardous wastes.

Waste Minimization Opportunities

The type of waste currently generated by the facility, the source of the waste, the quantity of the waste and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization recommended for the facility. The type of waste, the minimization opportunity, the possible waste reduction and associated savings, and the implementation cost along with the payback time are given in the table. The quantities of waste currently generated at the facility and possible waste reduction depend on the level of activity of the facility. All values should be considered in that context.

It should be noted that the economic savings of the minimization opportunity, in most cases, results from the need for less raw material and from reduced present and future costs associated with waste treatment and disposal. It should also be noted that the savings given for each opportunity reflect the savings achievable when implementing each waste minimization opportunity independently and do not reflect duplication of savings that would result when the opportunities are implemented in a package.

The cost savings are calculated both in terms of avoided costs of waste disposal and recovery of the value of raw material used again. Also, no equipment depreciation is factored into the calculations.

This type of facility represents a unique challenge to identification of pollution prevention options. The facility has control over the manufacturing steps and suggestions about modifications of that can be considered. The facility has little control over the use its customers will make of their units. Because the facility must test the units under realistic operating conditions, the employees must simulate the production processes of their customers. Therefore, they have very limited control over the types and quantities of the materials they use in the tests. They do have some control over the procedures used to capture and handle the waste streams from the tests. This situation is made more complex by the fact that the chemicals used for the test raise concern about worker safety because of potential health effects.

Regulatory Implications

There are no significant regulatory issues which would impede implementation of pollution prevention initiatives at this facility. Tightened regulatory scrutiny on the use and manufacture of chlorofluorocarbons can be expected to accelerate the change to a substitute degreaser. Air quality regulations and technology advancement may change the operations of semiconductor manufacturers which will in turn cause modification of the testing procedures at this facility.

This Research Brief summarizes a part of the work done under cooperative Agreement No. CR-815165 by the New Jersey Institute of Technology under the sponsorship of the New Jersey Department of Environmental Protection and Energy and the U.S. Environmental Protection Agency. The EPA Project Officer was Mary Ann Curran. She can be reached at:

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* Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Table 1. *Summary of Current Waste Generation*

Waste Generated	*Source of Waste*	*Annual Quantity Generated*	*Annual Waste Management Costs*
Chlorofluorocarbon	*Evaporative loss from degreasing tank*	*110 gal*	*$ 3600 (raw material cost)*
Mixed Acid	*Etching of stainless steel tubing drawing operation*	*110 gal*	*400*
Water Soluble Oils	*Metal working lubricant and coolant*	*110 gal*	*750*
Spent Carbon	*Carbon filters*	*60 lb*	*200*
Cleaning Solutions	*Washings of stainless steel filters*	*1100 gal*	*2000*
Mixed Solvents	*Processing of test wafers*	*110 gal*	*400*
Solid Wastes	*Plant scraps, gloves, and wipes*	*110 gal*	*650*

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Table 2. Summary of Recommended Waste Minimization Opportunities

Waste Stream Reduced	Minimization Opportunity	Annual Waste Reduction		Net Annual Savings	Implementation Cost	Payback Years *
		Quantity	Percent			
Chlorofluorocarbon	Change to aqueous-based solution for degreasing. Because ultrasonic tank is already available, such a change should be facilitated.	110 gal	100	$ 3,600 (It will be necessary to purchase an alternative cleaning solvent, and an aqueous waste stream can be expected.)	0	immed
Cleaning Solutions	Stop cleaning filters for reuse. More waste is generated by the cleaning process than if the filters were directly disposed of.	1100 gal	100	2000 (It will be necessary to purchase more filters and to pay for disposal of this waste stream. The actual cost savings will depend on the cost of the filters. We can estimate about a $1000 savings.)	0	immed
Scrap Waste	Consider how to reuse gloves and how to clean using fewer wipes.	11 gal	10	40	0	immed

* Savings result from reduced raw material and treatment and disposal costs when implementing each minimization opportunity independently.

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