This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates (Cambridge, MA), and Booz-Allen & Hamilton, Inc. (McLean, VA). This publication may be **purchased** from the Superintendent of Documents, U.S. Government Printing Office. A listing of available Sector Notebooks and document numbers is included on the following page.

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Electronic versions of all Sector Notebooks are available free of charge at the following web address: **www.epa.gov/oeca/sector**. Direct technical questions to the "Feedback" button at the bottom of the web page.

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EPA Office of Compliance Sector Notebook Project

PROFILE OF THE ELECTRONICS AND COMPUTER INDUSTRY

September 1995

Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
401 M St., SW (MC 2221-A)
Washington, DC 20460

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EPA/310-R-95-004.	Inorganic Chemical Industry*	Walter DeRieux	564-7067
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EPA/310-R-95-006.	Lumber and Wood Products Industry	Seth Heminway	564-7017
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EPA/310-R-95-009.	Motor Vehicle Assembly Industry	Anthony Raia	564-6045
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EPA/310-R-95-017.	Stone, Clay, Glass, and Concrete Industry	Scott Throwe	564-7013
EPA/310-R-95-018.	Transportation Equipment Cleaning Ind.	Virginia Lathrop	564-7057
EPA/310-R-97-001.	Air Transportation Industry	Virginia Lathrop	564-7057
EPA/310-R-97-002.	Ground Transportation Industry	Virginia Lathrop	564-7057
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EPA/310-R-98-008.	Local Government Operations	John Dombrowski	564-7036

*Spanish translations available.

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ELECTRONICS AND COMPUTER INDUSTRY
(SIC 36)
LIST OF ACRONYMS

AFS -	AIRS Facility Subsystem (CAA database)
AIRS -	Aerometric Information Retrieval System (CAA database)
BIFs -	Boilers and Industrial Furnaces (RCRA)
BOD -	Biochemical Oxygen Demand
CAA -	Clean Air Act
CAAA -	Clean Air Act Amendments of 1990
CERCLA -	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS -	CERCLA Information System
CFCs -	Chlorofluorocarbons
CO -	Carbon Monoxide
COD	Chemical Oxygen Demand
CSI -	Common Sense Initiative
CWA -	Clean Water Act
D&B -	Dun and Bradstreet Marketing Index
ELP -	Environmental Leadership Program
EPA -	United States Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
FIFRA -	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS -	Facility Indexing System
HAPs -	Hazardous Air Pollutants (CAA)
HSDB -	Hazardous Substances Data Bank
IDEA -	Integrated Data for Enforcement Analysis
LDR -	Land Disposal Restrictions (RCRA)
LEPCs -	Local Emergency Planning Committees
MACT -	Maximum Achievable Control Technology (CAA)
MCLGs -	Maximum Contaminant Level Goals
MCLs -	Maximum Contaminant Levels
MEK -	Methyl Ethyl Ketone
MSDSs -	Material Safety Data Sheets
NAAQS -	National Ambient Air Quality Standards (CAA)
NAFTA -	North American Free Trade Agreement
NCDB -	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP -	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC -	National Enforcement Investigation Center
NESHAP -	National Emission Standards for Hazardous Air Pollutants
NO_2 -	Nitrogen Dioxide
NOV -	Notice of Violation

ELECTRONICS AND COMPUTER INDUSTRY
(SIC 36)
LIST OF ACRONYMS (CONT'D)

NO_X - Nitrogen Oxide
NPDES - National Pollution Discharge Elimination System (CWA)
NPL - National Priorities List
NRC - National Response Center
NSPS - New Source Performance Standards (CAA)
OAR - Office of Air and Radiation
OECA - Office of Enforcement and Compliance Assurance
OPA - Oil Pollution Act
OPPTS - Office of Prevention, Pesticides, and Toxic Substances
OSHA - Occupational Safety and Health Administration
OSW - Office of Solid Waste
OSWER - Office of Solid Waste and Emergency Response
OW - Office of Water
P2 - Pollution Prevention
PCS - Permit Compliance System (CWA Database)
POTW - Publicly Owned Treatments Works
RCRA - Resource Conservation and Recovery Act
RCRIS - RCRA Information System
SARA - Superfund Amendments and Reauthorization Act
SDWA - Safe Drinking Water Act
SEPs - Supplementary Environmental Projects
SERCs - State Emergency Response Commissions
SIC - Standard Industrial Classification
SO_2 - Sulfur Dioxide
TOC - Total Organic Carbon
TRI - Toxic Release Inventory
TRIS - Toxic Release Inventory System
TCRIS - Toxic Chemical Release Inventory System
TSCA - Toxic Substances Control Act
TSS - Total Suspended Solids
UIC - Underground Injection Control (SDWA)
UST - Underground Storage Tanks (RCRA)
VOCs - Volatile Organic Compounds

ELECTRONICS AND COMPUTER INDUSTRY (SIC 36)

I. Introduction to the Sector Notebook Project

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water, and land pollution are an inevitable and logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education / outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water, and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial "sector-based” approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, States, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community, and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate, and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene Bulletin Board or the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing these data systems. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the existing notebooks reflect an approximation of the relative national occurrence of facility types that occur within each sector. In many instances, industries within specific geographic regions or States may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages State and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested States may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with State and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume.

If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE ELECTRONICS/COMPUTER INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the Electronics/Computer industry. The type of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of sales.

II.A. Introduction, Background, and Scope of the Notebook

The electronics/computer industry is classified by the U.S. Bureau of Census as SIC code 36. SIC 36 includes manufacturers of electrical distribution equipment, household appliances, communication equipment, electrical industrial apparatus, radio and television receiving equipment, electronic components and accessories, electrical wiring and lighting equipment, and other electrical equipment and supplies. The electronics/computer industry is comprised of five major sectors: telecommunications, computers, industrial electronics, consumer electronics, and semiconductors. Many segments of the electronics/computer industry are interdependent and share common manufacturing processes.

The Department of Commerce provides the following three-digit breakout for industries in SIC 36:

- SIC 361 - Transformers
- SIC 362 - Motors/Generators
- SIC 363 - Household Appliances
- SIC 364 - Electrical Wiring and Lighting Equipment
- SIC 365 - Household Audio and Video Equipment and Audio Recordings
- SIC 366 - Communication Equipment
- SIC 367 - Printed Wiring Boards (also commonly called Printed Circuit Boards), Semiconductors, Integrated Circuits, and Cathode Ray Tubes
- SIC 369 - Storage Batteries, Primary Batteries (wet and dry).

In 1988, the U.S. Bureau of Census reclassified some of the manufacturing of computer parts, such as semiconductors, printed wiring boards, and integrated microcircuits, and included them with the component industries in SIC code 36. For the purpose of this profile, computer equipment (SIC 35) and the electronics/computer industry (SIC 36) have been combined because of the overlapping industry segments. Currently there is no SIC code for electronic assemblies manufactured by the electronic manufacturing services industry (EMSI), otherwise known as contract assemblies. Electronic assemblies are sometimes classified under SIC 3679 as indicated by the Institute for Interconnecting and Packaging Electronic Circuits (IPC).

Due to the vast size of the electronics and computer industries, this profile will focus on the distinct equipment and products that raise environmental concerns.

II.B. Characterization of the Electronics/Computer Industry

The electronics/computer industry produces a variety of products such as batteries, televisions, computer chips/components, and household appliances. During the manufacture of many of these products, chemicals are released into the environment. This profile will focus on three products:

SIC 3674 - Semiconductors and Related Devices
SIC 3672 - Printed Wiring Boards (PWBs)
SIC 3671 - Cathode Ray Tubes (CRTs).

The profile focuses on semiconductors and not integrated circuits because integrated circuits are used to produce semiconductors and most electronic devices manufactured today are multiple devices/circuit chips. Semiconductors, although accounting for only a small portion of total industry sales, are crucial to all electronic products and to the U.S. economy and pose numerous environmental concerns. PWBs and CRTs also raise environmental concerns from their manufacturing processes.

The following sections describe the size and geographic distribution, product characterization, and economic trends of the electronics/computer industry and specifically semiconductors, PWBs, and CRTs. The information provided in the following sections was compiled from a variety of sources including the Bureau of Census, documents developed by The World Bank, U.S. International Trade Commission, and the U.S. Department of Commerce.

II.B.1. Industry Size and Geographic Distribution

Variation in facility counts occur across data sources due to many factors, including reporting and definitional differences. This document does not attempt to reconcile these differences, but rather reports the data as they are maintained by each source.

Size Distribution

The U.S. has the largest electronics (including computer) workforce in the world, although Japan, the Republic of Korea, and other Asian nations are experiencing rapid growth in their electronics workforces. The size of the U.S. domestic electronics workforce for SIC 36 was estimated to be 2.39 million in 1991, while the number of worldwide employees was estimated to be four million. In addition, the electronics/computer industry is estimated to provide four million additional jobs to people who support and service U.S. electronics firms. The electronics/computer industry provides more jobs than any other manufacturing sector in the U.S., three times as many jobs as automotive manufacturing, and nine times more than the steel industry. The electronics/computer industry has not, however, experienced growth in domestic employment for the past two and one-half years. In fact, since 1989, the industry has lost 210,000 jobs.

IPC states that this stagnation in job growth is caused primarily by two factors: increased productivity and increased competition by foreign manufacturers that may have fewer government regulations. IPC also notes that the U.S. electronic manufacturing services industry or contract assembly industry is one of the fastest growing industries in the country, employing over 150,000 people.

The following exhibit lists the segments of the industry highlighted in this profile, as well as the number of facilities with fewer than and greater than 20 employees. Just under 50 percent of semiconductor and PWB manufacturing facilities have greater than 20 employees.

Exhibit 1
Facility Size Distribution of Electronics/Computer Industry

SIC Code	Number of Facilities with <20 Employees	Number of Facilities with > 20 Employees	Percentage of Facilities with > 20 Employees
3674 Semiconductors and Related Devices	484	439	48%
3672 Printed Wiring Boards	734	591	45%
3671 Cathode Ray Tubes	120	69	37%

***Source:* Based on 1992 Bureau of the Census data, Preliminary Report Industry Series.**

Exhibit 2 lists the top ten electronics/computer industry companies worldwide according to a 1992 addition of *Electronic News*. The companies are listed in descending order of electronic sales during the latest available four quarters in 1992. Many of these top ten companies are not from the United States. However, a representative from the Electronic Industries Association (EIA) noted that many of these international companies have manufacturing facilities in the United States. Corporations that are among the top 25 in terms of electronic sales include AT&T, General Motors, Xerox, Apple Computer, Hewlett Packard, Motorola, and General Electric.

Exhibit 2
Top 10 Worldwide Electronics/Computer Industry Companies

Company Name	1992 Electronic Sales in Millions of Dollars
IBM	$53,600
Matsushita Electric	$48,668
Toshiba	$29,232
NEC	$28,375
Fujitsu	$25,879
Philips	$25,747
Hitachi	$25,107
Siemens	$24,550
Sony	$22,959
Alcatel Alsthom	$20,892

***Source:* Based on 1992 Electronic News.**

Geographic Distribution

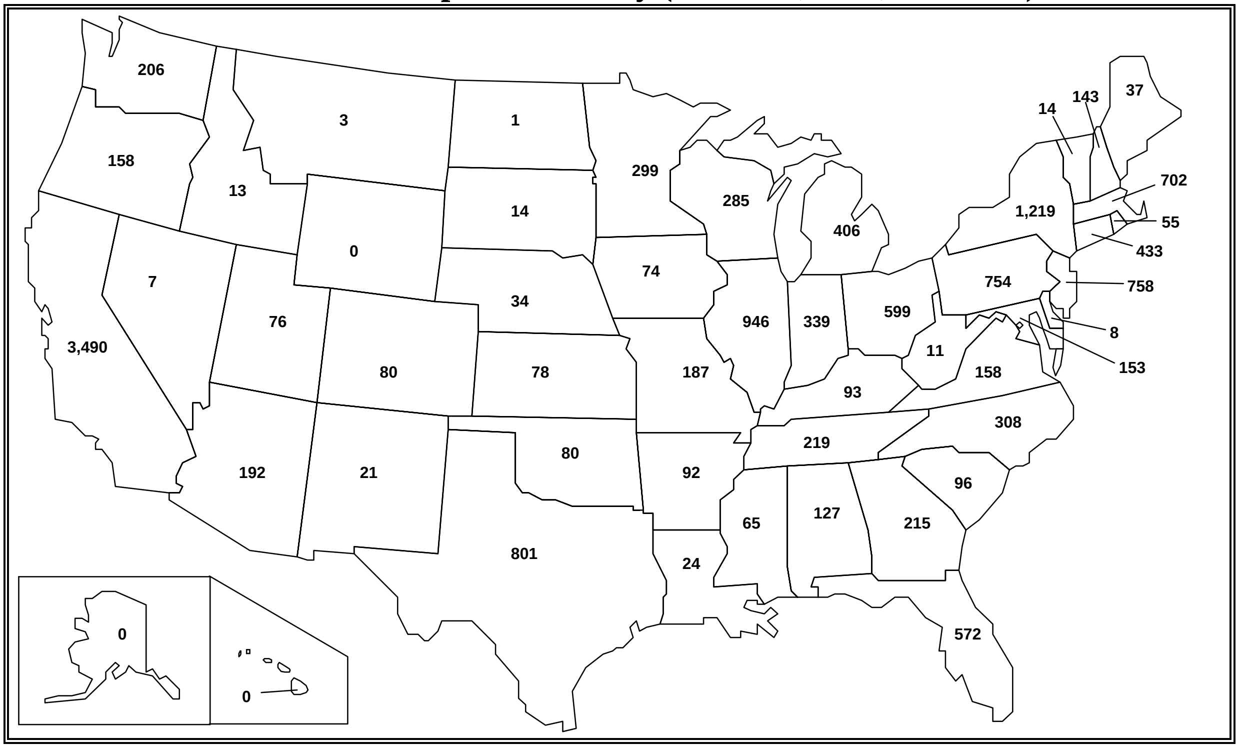
Exhibit 3 displays the number of electronics/computer industry facilities in each State for SIC 3671, 3672, and 3674. As seen in Exhibit 4, approximately 38 percent (3,689) of the facilities in the electronics/computer industry are located in EPA Region IX[1]. Region V has approximately 13 percent of the electronics/computer industry facilities. Across the U.S., approximately 60 percent of the facilities in the electronics/computer industry are located in six States: California (34 percent), Texas (6.5 percent), Massachusetts (6.4 percent), New York (4.5 percent), Illinois (4.4 percent), and Pennsylvania (4 percent).

The U.S. semiconductor industry is concentrated in California, New York, and Texas, specifically to be near primary users, transportation routes, utility and telecommunication infrastructures, and engineering experts. Texas, Oregon, and Colorado also received a large portion of capital investments by semiconductors producers during 1986-1992. Manufacturers have selected these States because of low tax rates, land values, and energy prices.

California has the largest concentration of industry workers, accounting for almost one-third of the semiconductor industry's employment. Texas, Arizona, New York, and Massachusetts also have high employment in the semiconductor industry. The majority of PWB manufacturers are located in Texas, California, Illinois, New York, Minnesota, and Massachusetts. According to Dun & Bradstreet, approximately 51 manufacturers produce cathode ray tubes (CRTs) in the U.S.; most of them are located in Illinois, Indiana, Ohio, Kentucky, Pennsylvania, and California (1994).

[1]EPA Regions include the following States: I (CT, MA, ME, RI, NH, VT); II (NJ, NY, PR, VI); III (DC, DE, MD, PA, VA, WV); IV (AL, FL, GA, KY, MS, NC, SC, TN); V (IL, IN, MI, MN, OH, WI); VI (AR, LA, NM, OK, TX); VII (IA, KS, MO, NE); VIII (CO, MT, ND, SD, UT, WY); IX (AZ, CA, HI, NV, Pacific Trust Territories); X (AK, ID, OR, WA).

Exhibit 3
Geographic Distribution of and Number of Companies in the Electronics/Computer Industry (SIC 3671, 3672, and 3674)



Source: Based on 1992 Bureau of the Census data.

Exhibit 4
Percentage of Companies in the Electronics/Computer Industry (SIC 3671, 3672, and 3674) by Region

Region I:	10.8%	Region VI:	7.2%
Region II:	8.0%	Region VII:	1.4%
Region III:	6.0%	Region VIII:	3.4%
Region IV:	7.6%	Region IX:	37.6%
Region V:	13.1%	Region X:	4.8%

II.B.2. Product Characterization

Semiconductors

Although semiconductors account for only a small portion of electronics/computer industry sales, this product is crucial to all electronic products and to the U.S. economy. Semiconductors can serve one of two purposes: they act as a conductor, by guiding or moving an electrical current; or as an insulator, by preventing the passage of heat or electricity. Semiconductors are used in computers, consumer electronic products, telecommunication equipment, industrial machinery, transportation equipment, and military hardware. Typical functions of semiconductors in these products include information processing, display purposes, power handling, data storage, signal conditioning, and conversion between light and electrical energy sources. According to EPA's Design for the Environment (DfE) initiative, computers are the principal end use of semiconductors, constituting 40 percent of the market in 1992.

Printed Wiring Boards

Computers are also the major U.S. market for PWBs, with communications being the second largest application market. The Institute for Interconnecting and Packaging Electronic Circuits (IPC) indicates that nearly 39 percent of printed wiring boards produced in 1993 were used by the computer market, while 22 percent were used by the communication industry. PWBs and assemblies are used in many electronic products such as electronic toys, radios, television sets, electrical wiring in cars, guided-missile and airborne electronic equipment, computers, biotechnology, medical devices, digital imaging technology, and industrial control equipment.

Cathode Ray Tubes

According to EPA's Common Sense Initiative (CSI) subcommittee, the CRT industry produces tube glass, color picture tubes and single phosphor tubes, television sets, and computer displays. Currently, nearly all projection television tube and computer display manufacturers and the majority of CRT glass manufacturers are located outside the United States. Therefore, this CRT industry profile focuses on the production of color picture tubes, single phosphor tubes, and rebuilt tubes (collectively called CRTs and categorized under SIC 3671). These products are the video display component of televisions, computer displays, military and commercial radar, and other display devices.

II.B.3. Economic Trends

For the past two decades, worldwide production of electronics (including computers) has grown faster than any other industrial sector. The American Electronics Association (AEA) estimates that domestic sales of U.S. electronics companies increased from $127 billion to $306 billion during the period from 1980 to 1990. According to the U.S. Department of Commerce, the value of shipments (sale of computer products and services) in the computer industry declined during the 1990-1991 recession, but has experienced growth since then. The value of shipments increased two percent in 1993 to $8.3 billion and is expected to increase another two percent in 1994, to $8.48 billion. U.S. exports of the electronics/computer industry have increased at an average rate of 18 percent since 1977.

EIA indicates that the U.S. electronics/computer industry has experienced a 13 percent growth in production in 1994. Japan now holds the largest share of global consumer electronics production; 49 percent in 1990. Although the U.S. produced a little over 10 percent of global consumer electronics equipment, it is one of the two largest consumers of such products, with purchases totaling $33 billion in 1990.

Semiconductors

The U.S. semiconductor industry has experienced growth since 1992. The U.S. global market share of semiconductors, semiconductor processing equipment, and computer systems fell between 1980 to 1991. Japanese firms gained most of the market share lost by U.S. firms. Although the U.S. continues to be the world's largest consumer of electronics products, as a result of Japan's growth in consumer electronics production, Japan is now the world's largest consumer of semiconductors. The U.S. is the second largest market in the world for semiconductors, with consumption at $17.4 billion in 1990. The five largest U.S. producers are Motorola, Intel, Texas Instruments, National Semiconductor, and Advanced Micro Devices. According to the Department of Commerce, the value of shipments of U.S. semiconductors is estimated to be $37.6 billion in 1993 and is expected to grow 12 percent in 1994 to over $42.1 billion.

Printed Wiring Boards/Electronic Assemblies

Japan and the U.S. now have equal market shares, 27 percent each. IPC notes that the U.S. was the largest PWB market in the world with a value of approximately $5.5 billion in 1993. According to the Department of Commerce, the value of printed wiring board shipments produced in the U.S. was $6.75 billion in 1993 and is expected to grow by three percent, to $6.95 billion, in 1994. According to IPC, the U.S. electronic manufacturing services industry or contract assemblies industry generates over $9 billion in revenue.

Cathode Ray Tubes

According to 1994 U.S. Industrial Outlook data, the total value of CRT shipments was $3 billion in 1993 and is expected to increase six percent to $3.2 billion in 1994. The total value of CRT shipments is expected to increase more than 3.5 percent per year due to a projected rising demand for television sets and computer displays.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the electronics/computer industry, including the materials and equipment used, and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the processes. This section also describes the potential fate (air, water, land) of these waste products.

III.A. Industrial Processes in the Electronics/Computer Industry

The products discussed in this section, semiconductors, printed wiring boards (PWBs), and cathode ray tubes (CRTs), pose significant environmental concerns during the manufacturing processes and/or comprise a large portion of the electronics/computer industry. This section will describe and distinguish these products as well as the steps followed to manufacture them. This discussion also includes an explanation of the wastes generated during the manufacturing processes.

III.A.1. Semiconductor Manufacturing

Semiconductors are made of a solid crystalline material, usually silicone, formed into a simple diode or many integrated circuits. A simple diode is an individual circuit that performs a single function affecting the flow of electrical current. Integrated circuits combine two or more diodes. Up to several thousand integrated circuits can be formed on the wafer, although 200-300 integrated circuits are usually formed. The area on the wafer occupied by integrated circuits is called a chip or die.

Information in this section is from a variety of sources including the following: U.S. EPA's DfE initiative, U.S. EPA Common Sense Initiative (CSI), California Department of Toxic Substances Control, McGraw Hill Encyclopedia of Science and Technology, *Integrated Circuits, Making the Miracle Chip, Microchip Fabrication*: *A Practical Guide to Semiconductor Processing*, and Microelectronics and Computer Technology Corporation (MCC). The semiconductor manufacturing process is complex and may require that several of the steps be repeated to complete the process. To simplify this discussion, the process has been broken down into five steps:

- Design
- Crystal processing
- Wafer fabrication
- Final layering and cleaning
- Assembly.

The primary reason that semiconductors fail is contamination, particularly the presence of any microscopic residue (including chemicals or dust) on the surface of the base material or circuit path. Therefore, a clean environment is essential to the manufacture of semiconductors. Cleaning operations precede and follow many of the manufacturing process steps. Wet processing, during which semiconductor devices are repeatedly dipped, immersed, or sprayed with solutions, is commonly used to minimize the risk of contamination.

Step One: Design

As with any manufacturing process, the need for a particular type of product must be identified and process specifications must be developed to address that need. In the case of semiconductors, the circuit is designed using computer modeling techniques. Computer simulation is used to develop and test layouts of the circuit path. Then, patterning "masks," which are like stencils, are fabricated, manufacturing equipment is selected, and operating conditions are set. All of these steps occur prior to actually producing a semiconductor.

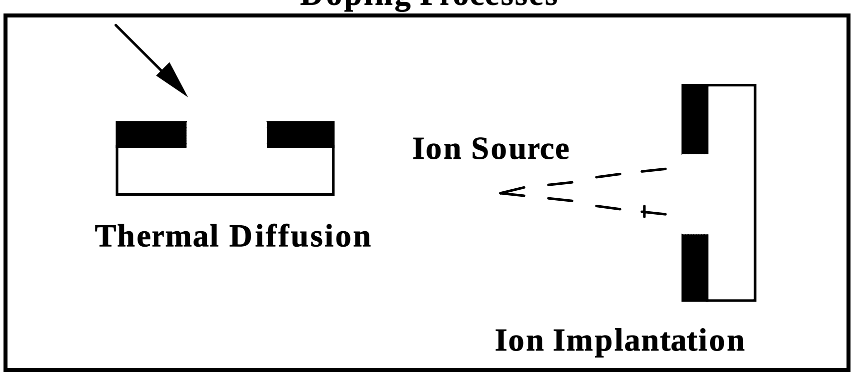
Step Two: Crystal Processing

Wafers, which consist of thin sheets of crystalline material, are the starting point of semiconductor production. Silicon, in the form of ingots, is the primary crystalline material used in the production of 99 percent of all semiconductors. Silicon crystals are actually "grown" using controlled techniques to ensure a uniform crystalline structure. Because crystals of pure silicon are poor electrical conductors, controlled amounts of chemical impurities or **dopants** are added during the development of silicon ingots to enhance their semiconducting properties. Dopants are typically applied using **diffusion** or **ion implantation** processes (See Exhibit 5). Dopants eventually form the circuits that carry the flow of current.

- Diffusion is a chemical process which exposes the regions of the silicon surface to vapors of the metal additive (dopant) while maintaining high temperatures. The process ends when the additives (represented by the arrow in Exhibit 5) migrate to the proper depth and reach the appropriate concentration in the silicon wafer.

- Ion implantation is a process that allows for greater control of the location and concentration of dopants added to the wafer. Metal dopants are ionized and accelerated to a high speed. As shown in Exhibit 5, the ions penetrate the silicon surface and leave a distribution of the dopant.

Exhibit 5
Doping Processes



Source: Based on 1990 Microchip Fabrication: A Practical Guide to Semiconductor Processing.

Either doping process can be used in semiconductor manufacturing. Antimony, arsenic, phosphorus, and boron compounds are the dopant materials most commonly used for silicon-based semiconductors. Other dopants include aluminum, gallium, gold, beryllium, germanium, magnesium, silicon, tin, and tellurium. Wastes including antimony, arsenic, phosphorus, and boron may be generated in the wastewater as a result of ion implantation or diffusion. Excess dopant gases, contaminated carrier gases, and out-gassed dopant gases from semiconductor materials may also be generated.

Most semiconductor manufacturers obtain single crystal silicon ingots from other firms. Ingots are sliced into round wafers approximately 0.76 mm (0.03 inches) thick and then **rinsed**. The wafers are further prepared by mechanical or chemical means. A wafer's surface may be **mechanically ground**, **smoothed**, and **polished**, as well as **chemically etched** so that the surface is smooth and free of oxides and contaminants. Chemical etching removes organic contaminants using cleaning solvents and removes damaged surfaces using acid solutions. Chemical etching is usually followed by a **deionized water rinse** and **drying** with compressed air or nitrogen. In some cases, bare silicon wafers are cleaned using ultrasound techniques, which involve potassium chromate or other mildly alkaline solutions.

Etching is a method of cutting into, or imprinting on, the surface of a material. Several etching processes can be used on semiconductors, as well as integrated circuits and printed wiring boards. Wet etching uses acid solutions to cut patterns into the metal. Dry etching involves reactive gases and is rapidly becoming the method of choice for high resolution. Dry etching processes use various halogenated or nonhalogenated gaseous compounds.

In the semiconductor industry, dry plasma etching, reactive ion etching, and ion milling processes are being developed to overcome the limitations of wet chemical etching. Dry plasma etching, the most advanced technique, allows for etching of fine lines and features without the loss of definition. This process forms a plasma above the surface to be etched by combining large amounts of energy with low pressure gases. The gases usually contain halogens.

Materials used during the wet etching process may include acids (sulfuric, phosphoric, hydrogen peroxide, nitric, hydrofluoric, and hydrochloric), ethylene glycol, hydroxide solutions, and solutions of ammonium, ferric, or potassium compounds. Materials used during the dry etching process may include chlorine, hydrogen bromide, carbon tetrafluoride, sulfur hexafluoride, trifluoromethane, fluorine, fluorocarbons, carbon tetrachloride, boron trichloride, hydrogen, oxygen, helium, and argon. Typical solvents and cleaning agents include acetone, deionized water, xylene, glycol ethers, and isopropyl alcohol. The most commonly used cleaning solution in semiconductor manufacturing includes a combination of hydrogen peroxide and sulfuric acid.

Acid fumes and organic solvent vapors may be released during cleaning, etching, resist drying, developing, and resist stripping operations. Hydrogen chloride vapors may also be released during the etching process.

Step Three: Wafer Fabrication

Wafers are usually fabricated in batches of 25 to 40. Wafer preparation begins with an **oxidation** step.

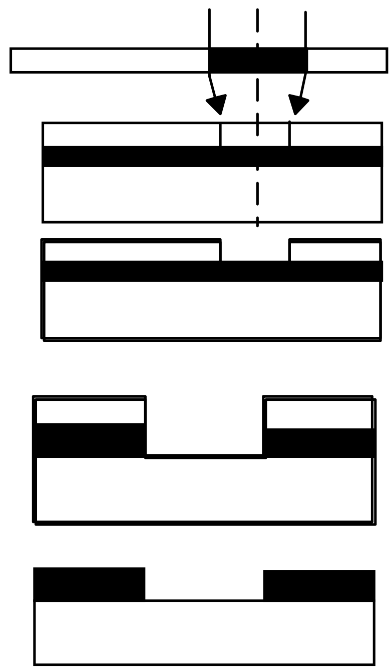
- Oxidation is a process in which a film of silicon dioxide is formed on the exterior surface of the silicon wafer. Thermal oxidation takes place in a tube furnace with controlled, high temperatures and a controlled atmosphere. Oxidation is a reaction between the silicon wafer surface and an oxidant gas such as oxygen or steam. This process may be needed as a preliminary step before diffusion or ion implantation (doping). This layer protects the wafer during further processing. Following oxidation, the wafer surface is thoroughly cleaned and dried.

Materials used during oxidation, include silicon dioxide, acids (hydrofluoric), and solvents. Materials such as oxygen, hydrogen chloride, nitrogen, trichloroethane, and trichloroethylene may also be used. Wastes that may be generated from this process include: organic solvent vapors from cleaning gases; rinsewaters with organic solvents from cleaning operations; spent solvents (including F003); and spent acids and solvents in the wastewater.

Next, patterns are imprinted onto the substrate using **photolithography** (also referred to as lithography) and **etching** processes. Photolithography is the most crucial step in semiconductor manufacturing because it sets a device's dimensions; incorrect patterns affect the electrical functions of the semiconductor.

- Photolithography is a process similar to photoprocessing techniques and other etching processes in that a pattern is imprinted. The silicon wafer is coated uniformly with a thin film of resist. A glass plate or mask is created with the circuit pattern, and the pattern is imprinted in one of several ways. One type of optical photolithography is the projection of x-rays through a special mask close to the silicon slice. Another type of optical photolithography, one that does not need a mask, is electron-beam direct patterning, which uses a controllable electron beam and an electron sensitive resist. Once the pattern is developed, some areas of the wafer are clear and the rest are covered with resist (See Exhibit 6).

Exhibit 6
Photolithography Process

Process Step	Purpose	Cross Section
1. Alignment and exposure	Precise alignment of mask to wafer and exposure to U.V. light. Negative resist is polymerized.	
2. Development	Removal of unpolymerized resist.	
3. Etch	Selective removal of top surface layer.	
4. Photoresist Removal	Cleaning of photoresist from the wafer's surface.	
5. Final Inspection	Inspection of wafer for correctness of image transfer from photoresist to top layer.	

Source: Based on 1990 Microchip Fabrication: A Practical Guide to Semiconductor Processing.

Two types of photoresists can be used during semiconductor production:

- Positive photoresists are chemicals that are made more soluble, with regard to a solvent (i.e., developer), after exposure to radiation. During development, the developer removes the resist that was exposed to radiation.

- Negative photoresists are chemicals that polymerize and stabilize upon exposure to radiation. During development, the developer removes the resist that was protected from radiation.

After photolithography, chemical **developers** are used to remove unnecessary coatings or resist material that remains on the substrate. Development can be conducted by liquid methods (dip, manual immersion, or spray coating) or dry methods (plasma). The wafer is then **etched** in an acid solution to remove selected portions of the oxide layer to create depressions or patterns. The patterns are areas in which dopants will be applied. The wafer is **rinsed**, typically by immersing in a stripping solution to remove unwanted photoresist, and then dried. See Exhibit 7 for a list of materials used during the photolithography process.

Exhibit 7
Chemicals Used in Photolithography for Semiconductors

Photoresists	Developer	Solvents and Cleaning Agents
Positive:	**Positive:**	Deionized water
Ortho-diazoketone	Sodium hydroxide	Detergent
Polymethacrylate	Potassium hydroxide	Isopropyl alcohol
Polyfluoroalkylmethacrylate	Silicates	Acetone
Polyalkylaldehyde	Ethylene glycol	Ethanol
Polycyanoethylacrylate	Ethanolamine	Hydrofluoric acid
Polymethylmethacrylate	Isopropyl alcohol	Sulfuric acid
Poly (hexafluorobutylmeth-acrylate)	Phosphates	Hydrogen peroxide
	Tetramethyl-ammonium hydroxide	Hydrochloric acid
		Nitric acid
Negative:	Alkyl amine	Chromic acid
Isoprene	Ethyl acetate	Ammonium hydroxide
Ethyl acrylate	Methyl isobutyl ketone	Hexamethyldisilazane
Glycidylmetharcylate		Xylene
Copolymer-ethylacrylate	**Negative:**	Cellosolve acetate
	Xylene	n-Butyl acetate
	Aliphatic Hydrocarbons	Ethylbenzene
	N-Butyl acetate	Chlorofluorocarbons
	Cellosolve acetate	Chlorotoluene
	Isopropyl alcohol	Glycol ethers
	Stoddard solvent	
	Glycol ethers	

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Semiconductor Industry: Preliminary Draft.

During the next step, **dopants** are applied to the patterned wafer surface typically using diffusion or ion implantation. See Step two for a list of materials used and wastes generated during the doping process.

Additional layers of silicon may also be applied to the wafer using **deposition** techniques, typically epitaxial growth or chemical vapor deposition.

- Epitaxyl allows the growth of another layer of silicon on top of the wafer. A silicon layer is grown using high temperatures and dopant compounds. This top layer of silicon is where the final device will be formed. Not all semiconductors need this layer.

- Chemical vapor deposition deposits a thin coating on materials by a chemical process. Vapor deposition is a low pressure process that combines appropriate gases in a reactant chamber at elevated temperatures to produce a uniform film thickness.

Materials that may be used during deposition include silane, silicon tetrachloride, ammonia, nitrous oxide, tungsten hexafluoride, arsine, phosphine, diborane, nitrogen, and hydrogen.

Wastes that may be generated from these processes include: acid fumes from etching operations; organic solvent vapors from cleaning resist drying, developing, and resist stripping; hydrogen chloride vapors from etching; rinsewaters containing acids and organic solvents from cleaning, developing, etching, and resist stripping processes; rinsewaters from aqueous developing systems; spent etchant solutions; spent solvents (including F003) and spent acid baths.

Many products require that steps two through three be repeated several times in order to create the specified structure.

Step Four: Final Layering and Cleaning

Once the wafer is patterned, the wafer surface is coated with thin layers of metal by a process called **metallization**. These metal layers perform circuit functions within the finished semiconductor. External connections to the silicon wafer are provided by evaporation of thin metal films onto areas of the semiconductor chip surface in a vacuum. Almost every metal can be used to make this electrical connection to the silicon; aluminum, platinum, titanium, nickel/chromium, silver, copper, tungsten, gold, germanium, and tantalum are most common. Argon gas is also used in some operations. **Sputtering** and **high vacuum evaporation** are two types of metallization.

- Sputtering (also called partial vacuum evaporation) is a physical, rather than chemical process. This process occurs in a vacuum chamber which contains a target (solid slab of the film material) and the wafers. Argon gas is introduced in the chamber and ionized to a positive charge. The positively charged argon atoms accelerate toward and strike the target, dislodging the target atoms. The dislodged atoms are deposited onto the wafer surface. A uniform thickness of the coating is produced over the silicon slice.

- High vacuum evaporation is a process that uses an electron beam, a ceramic bar heated by thermal resistance, or a wire heated by electrical resistance. This method coats the surface of the wafer with metal.

Photolithography and etching are also used to remove any unnecessary metal using chlorinated solvents or acid solutions. Wastes generated include: acid fumes and organic solvent vapors from cleaning, etching, resist drying, developing, and resist stripping; liquid organic waste; aqueous metals; and wastewaters contaminated with spent cleaning solutions.

In the next step, **passivation** is used to apply a final layer of oxide over the wafer surface to provide a protective seal over the circuit. This coating protects the semiconductor from exterior influences and may range in thickness from a single layer of silicon dioxide to a relatively thick deposit of special glass. It also insulates the chip from unwanted contact with other external metal contacts. Materials used to form the passivation layer are silicon dioxide or silicon nitride.

After all layers have been applied to the wafer, the wafer is typically **rinsed** in deionized water. The back of the wafer is then mechanically ground (also called **lapping** or **backgrinding**) to remove unnecessary material. A film of gold may be applied to the back of the wafer by an evaporation process to aid the connection of leads to the bonding pads during a later process step.

Testing with alcohol compounds is conducted to ensure that each chip is performing the operation for which it was designed. Chips that do not meet specifications are marked with an ink droplet for discard during assembly operations. The wafer is cleaned again after testing, using solvents such as deionized water, isopropyl alcohol, acetone, and methanol.

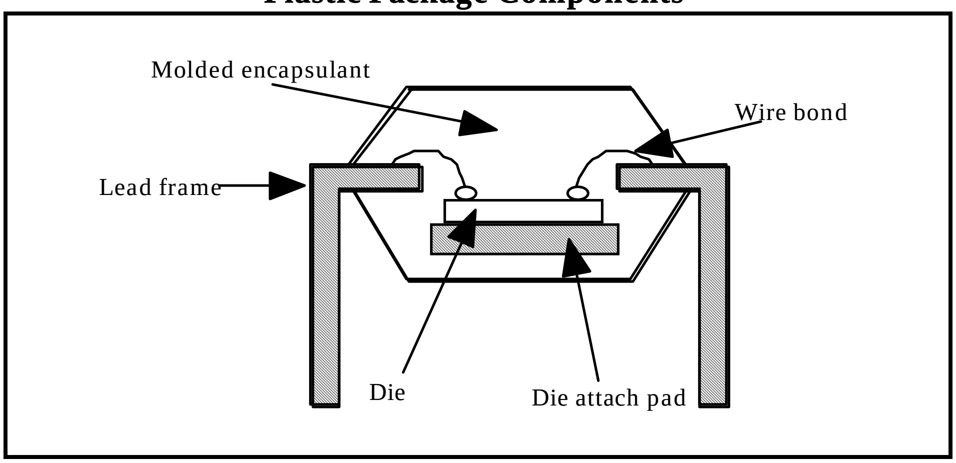
Wastes generated from these processes include: spent solvents and acids in the wastewater and rinsewater from cleaning, developing, etching, resist stripping, and rinsing processes; acid fumes and organic solvent vapors from cleaning, rinsing, resist drying, developing, and resist stripping; spent silicon dioxide or nitride; hydrogen chloride vapors from etching; rinsewaters from aqueous developing systems; spent etchant solutions; spent acid baths; and spent solvents.

Step Five: Assembly

Semiconductors are assembled by mounting chips onto a metal frame, connecting the chips to metal strips (leads), and enclosing the device to protect against mechanical shock and the external environment. There are many types of packaging; such as plastic or ceramic. Plastic packages comprised more than 90 percent of the market in 1990.

Each package contains five parts: the die (e.g., chip), the lead frame of the package, the die-attach pad, the wire bond, and the molded encapsulant (i.e., plastic housing) (See Exhibit 8). This section describes how plastic packages are assembled. All semiconductor packages whether plastic or ceramic share the same basic parts and are assembled using the same general processes.

Exhibit 8
Plastic Package Components



Source: Based on 1993 Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics Industry.

The lead frame consists of a rectangular-shaped metal frame connected to metal strips or leads. The leads connect the chip to the electronic product. Plastic package lead frames are fabricated from sheets of metal, either copper or alloy 42, that is either **punched** or **etched**. The lead frame and leads provide the connections for the electronic components.

- The punching process consists of an array of small mechanical punches that remove sections of the metal sheet until the lead frame is complete. The leads are cleaned with water-based cleaning systems. In the past, manufacturers used chlorinated fluorocarbons (CFCs) or other solvents to remove cutting fluids. The lead frame is coated with a layer of photoresist, exposed, and developed. The manufacturer etches the lead frame, removes the photoresist, and cleans the lead frame again with water based cleaning systems.

- If the lead frames are etched, the process is similar to that used during PWB manufacturing. Acids or metal chlorides are usually used during etching. Sometimes ammonia is used to stabilize the metal chloride. The photoresist contains solvents (such as trichloroethylene or TCE) that are baked out and generate VOC emissions. Developers that are typically used include either an amine or metal hydroxide. Once the photoresist is removed, it is cleaned with solvents such as a mild hydrochloric acid (HCL) solution or with a brightener that contains sulfuric acid.

Wastes generated during punching or etching may include: spent organic vapors generated from cleaning, resist drying, developing, and resist stripping; spent cleaning solutions; rinsewaters contaminated with organic solvents; and spent aqueous developing solutions. Scrap copper or alloy 42 may be recycled during the punching process.

The chip is then **attached** to an "attach pad," with a substance such as an epoxy material (thermoset plastic). Once mounted, the chips are inspected. The chip parts are bonded to the leads of the package with tiny gold or aluminum wires. A package may have between 2 and 48 wire bonds. The assembly is cleaned and inspected again. The combined components are then placed into a **molding press**, which encases the chip, wire bonds, and portions of the leads in plastic. The plastic-molding compound used in the press contains primarily fused silica. After the molding compound cures and cools around the package, the package is heated again to ensure that the plastic is completely cured. Excess material is removed using a chemical or mechanical **deflash** process. M-Pyrol is one organic solvent used during the deflash process. The final steps in package fabrication include **trimming** and **forming** the leads.

Waste generated during these steps includes excess epoxy/thermoset plastic; antimony trioxide (from the molding process); and spent organic solvents. Excess gold or aluminum from trimming processes can be reclaimed and reused.

Final computer tests are conducted to evaluate whether the product meets specifications. Even though the chips are produced using the same process, some may work better (e.g., faster) than others. As a result, packages are separated into low- and high-quality circuits. Often, low-quality circuits can still be sold. Final process steps include marking the circuits with a product brand. The finished product is then packaged, labeled, and shipped according to customer specifications.

III.A.2. Printed Wiring Board Manufacturing

Printed wiring boards (PWBs) are the physical structures on which electronic components such as semiconductors and capacitors are mounted. The combination of PWBs and electronic components is an electronic assembly or printed wiring assembly (PWA). According to Microelectronics and Computer Technology Corporation's (MCC) *Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics and Computer Industry*, PWB manufacturing is the most chemical intensive process in the building of a computer workstation.

PWBs are subdivided into single-sided, double-sided, multilayer, and flexible boards. Multilayer boards are manufactured similarly to single and double-sided boards, except that conducting circuits are etched on both the external and internal layers. Multilayer boards allow for increased complexity and density. PWBs are produced using three methods: additive, subtractive, or semi-additive technology. The subtractive process accounts for a significant majority, perhaps 80 percent, of PWB manufacturing.

The conventional subtractive manufacturing process begins with a board, consisting of epoxy resin and fiberglass, onto which patterns are imaged. In most operations, conducting material, usually copper, is bonded onto the substrate surface to form copper-clad laminate. After drilling holes through the laminate and making those holes conductive, unwanted copper is etched off, leaving copper patterns. The patterns on the board form the electric circuits that conduct electricity. Multilayer boards typically use metals such as platinum, palladium, and copper to form electric circuits. Specialized PWBs may use nickel, silver, or gold.

<u>Additive</u> technology is used less often than substractive technology because it is a more difficult and costly production process. This capital-intensive technology is used primarily for small interconnection components used in multi-chip devices. The production process begins with a base plate upon which a dielectric material is deposited. An interconnecting layer of copper is plated onto the dielectric layer which connects the layers of dielectric material and copper. Copper posts are plated-up and another layer of dielectric material is deposited exposing the posts. The next interconnect layer is plated and makes contact with the posts. Layers of dielectric material, copper, and copper posts are added to complete the interconnect. A lithographic process, similar to the one used in semiconductor manufacturing, diminishes the spaces and widths of the PWB.

This section provides a simplified discussion of the steps commonly performed during conventional subtractive manufacturing. The actual steps and materials used by a PWB manufacturer vary depending on customer requirements and the product being manufactured. The information provided in this section comes from various sources, including documents developed by MCC, IPC, EPA's Center for Environmental Research Information, EPA's DfE Program, California Department of Toxic Substances, EPA's CSI, and EPA's Office of Research and Development. PWB manufacturing can be grouped into five steps:

- Board preparation
- Application of conductive coatings (plating)
- Soldering
- Fabrication
- Assembly.

Step One: Board Preparation

Board preparation begins with a **lamination** process. Two-side etched copper dielectric boards (consisting usually of fiberglass and epoxy resin) are separated by an insulating layer and laminated or bonded together, usually by heat and pressure. Photographic tools are used to transfer the circuit pattern to the PWB, and computer control programs are used to control the drilling, routing, and testing equipment. Preparing the copper-clad board involves **drilling** holes to establish an electrical path between the layers and to mount components. The boards are then mechanically **cleaned** to remove drilling wastes (i.e., fine particulate contaminants, such as copper). Vapor degreasing, abrasive cleaning, chemical cleaning with alkaline solutions, acid dips, and water rinses are techniques used to clean the boards and prepare them for the next process, **electroless plating**. See Exhibit 9 for a list of materials used during lamination, drilling, and cleaning processes.

Exhibit 9
Chemicals Used in Lamination, Drilling, and Cleaning

Lamination	Drilling	Cleaning
Epoxies	Sulfuric Acid Potassium Permanganate Ammonium bifluoride Oxygen Fluorocarbon gas	Acetone 1,1,1-Trichloroethane Silica (and other abrasives) Sulfuric acid Ammonium hydroxide Hydrochloric acid

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

Wastes generated include: airborne particulates, acid fumes, and organic vapors from cleaning, surface preparation, and drilling; spent acid and alkaline solutions; spent developing solutions, spent etchants, and waste rinsewaters in the wastewater; and scrap board materials and sludges from wastewater treatment. Drilling and routing dust (copper, aluminum, and gold) are collected and recycled.

Step Two: Electroless Plating

The first process in this step is to prepare the surfaces of the drilled holes. The holes are prepared by an etchback process to remove smeared epoxy resin and other contaminants using one of the following: sulfuric or hydrochloric acid; potassium permanganate; or carbon tetrafluoride, oxygen and nitrogen. The holes are then coated with a material such as copper or graphite carbon, by a chemical process called **electroless plating.**

Electroless plating coats a uniform conducting layer of copper or other material on the entire surface including the barrels of the holes of the prepared board without outside power sources. According to *Printed Circuit Board Basics,* this coating of copper is not thick enough to carry an electrical current, but provides a base upon which additional copper can be deposited electrolytically. According to DfE, copper is the industry standard, but many are switching to direct metallization processes. Chemical deposition is the technique used to coat the board. After the electroless plating, the boards are dried to prevent the board from oxidation (e.g., rusting). The board may also be cleaned to prepare for a following electroplating processing. See Exhibit 12 for a list of materials used. Waste generated include: spent electroless copper baths; spent catalyst solutions; spent acid solutions; waste rinsewaters; and sludges from wastewater treatment.

Step Three: Imaging

During imaging, circuit patterns are transferred onto the boards through **photolithography** or a **stencil printing** process. Photoresist (i.e., a light sensitive chemical) is applied to the board in areas where the circuit pattern will not be set. The board is exposed to a radiation source and **developed** to remove the unwanted areas of the resist layer. Stencil printing uses a printing process, such as silk screening, to apply a protective film that forms the circuit pattern.

After photolithography, the boards are subjected to a light **etching** process, typically using ammoniacal etchants, to remove rust inhibitor (applied by the company that produced the material from which the board is made) or other metals (usually copper). After the stencil printing process, the protective film is dried, and the exposed copper is etched away. Sulfuric acid and hydrogen peroxide are common etchants used during imaging. After plating or etching, the photoresist is removed with an photoresist stripper.

See Exhibits 10 and 11 for a list of materials used during photolithography and etching processes. Wastes generated during the cleaning and etching processes include: RCRA listed F001, F002, F003, F004, and F005 depending on the concentration of the spent solvents and the mixture of spent halogenated and non-halogenated solvents; spent resist material; and wastewater containing metals (copper). Other wastes generated include organic vapors and acid fumes, spent developing solutions, spent resist material, spent etchant, spend acid solutions, and sludges from waste water treatment.

Exhibit 10
Chemicals Used in Photolithography for Printed Wiring Boards

Resists	Photopolymer Developers	Photopolymer Strippers
Mylar Vinyl Photoresists	Isopropyl alcohol Potassium bicarbonate Sodium bicarbonate 1,1,1-Trichloroethane Amines Glycol ethers	Sodium hydroxide Potassium hydroxide Methylene chloride

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

Exhibit 11
Materials Used During Etching

Ammonia Ammonium chloride Ammonium hydroxide Ammonium persulfate Ammonium sulfate Boric acid Carbon tetrafluoride Chlorine	Cupric chloride Hydrochloric acid Hydrofluoric acid Hydrogen peroxide Lead	Nickel Nickel chloride Nickel sulfamate Nitrate Nitric acid Nitrogen Orthophosphate Oxygen Peptone	Permanganates Sodium citrate Sodium hydroxide Stannous chloride Sulfuric acid Tin

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

Step Four: Electroplating

Electroplating is a process in which a metal is deposited on a substrate through electrochemical reactions. Electroplating is required to build up the thickness and strength of the conducting layers to provide reliable electrical conductivity between inner layers or from one side of the PWB to the other. Electroplating can also protect against corrosion, wear, or erosion. This process involves immersing the article to be coated/plated into a bath containing acids, bases, or salts. The industry standard for this process is copper, although many are switching to direct metallization techniques according to DfE.

The **electroplating** process for PWBs usually begins with the copper laminate which is coated with a plating resist (**photolithography**), by stenciling, leaving the area exposed to form the circuit pattern. The resist prevents the conductive material from adhering to other areas of the board and forms the circuit pattern.

The PWB plating process typically uses as copper and tin-lead as plating materials, although silver, nickel, or gold can be used. Copper in a plating bath solution is deposited to a sufficient thickness, and a solvent or aqueous solution is applied to remove the plating resist. The copper coating forms interconnections between the layers and provides electrical contact for electronic parts mounted or assembled on the PWB surface. PWB manufacturers then typically electroplate a tin or tin-lead solder on the board to protect the circuit pattern during the following etching or stripping processes. An acid etch solution (ammoniacal, peroxide solutions, sodium persulfate, cupric chloride, or ferric chloride) removes the exposed copper foil, leaving the thicker copper plating to form the circuit pattern. Ammoniacal and cupric chloride are the primary etchants used by PWB manufacturers. Fluoroboric acid is used in the tin-lead plating process to keep the metals dissolved in the solution and to ensure a consistent deposition of the tin-lead alloy onto the circuit board.

After the plating bath, the board is **rinsed** with water, scrubbed, and then dried to remove the copper, spray etch solutions, and other materials. Rinsing ends the chemical reactions during plating and prevents contamination or dragout from being released in the next bath or rinse water (dragout is the plating solution that sticks to parts after taken out of the plating bath). Dragout can occur in any bath step, not just in one plating bath. The tin-lead layer is generally removed and the panel is electrically tested for discontinuities in the electrical pathway and shorts. See Exhibit 12 for a list of materials used during the electroplating process.

Exhibit 12
Materials Used in Copper and Tin-Lead Electro- and Electroless Plating Processes

Type of Plating	Electroplating Chemicals	Electroless Chemicals
Copper	Copper pyrophosphate Orthophosphate Pyrophosphate Nitrates Ammonia Acid copper Copper sulfate Sulfuric acid	Hydrochloric acid Palladium chloride Stannous chloride Metallic tin pellets Sodium hydroxide Copper sulfate Formaldehyde
Tin-Lead	Tin-Lead Fluoroboric acid Boric acid Peptone	Tin chloride Sodium hypophosphite Sodium citrate

Source: Based on EPA DfE 1993: Industry Profile and Description of Chemical Use for the Printed Wiring Board Industry: Preliminary Draft.

The primary RCRA hazardous wastes generated during plating include: photoresist skins, F006 sludge from plating wastewater treatment, D008, F007, and F008 from plating and etching; spent acid solutions, waste rinsewaters, spent developing solutions, spent etchant, and spent plating baths in the wastewater; organic vapors from spent developing solution and spent resist removal solution; and acid and ammonia fumes. According to IPC, photoresist skins or the stripped resist material are exempt from categorical F006 classification if the skins stripping is separate from electroplating and if the boards are rinsed and dried.

Step Five: Soldering Coating

Solder coating is used to add solder to PWB copper component before component assembly. Fabricators use several methods of solder coating, but all of them involve dipping the panel into molten solder. The solder, an alloy consisting of 60 percent tin and 40 percent lead, coats the pads and holes not covered by solder mask. The excess solder is removed with a blast of hot oil or hot air. However, the hot oil or hot air does not remove the solder that has formed a chemical (intermetallic) bond with the copper. The removal of the excess solder is called "solder leveling." The most common process is hot-air leveling. According to *Printed Circuit Board Basics: Quick and Easy*

Guide, final solder coating thicknesses of 50 to 1,200 microinches can be achieved with most solder-leveling processes. Solder is only applied to desired areas so there is no metal or “objectionable fluid” discharged to the wastestream, according to MCC. MCC considers it to be the most environmental friendly solder application method.

Step Six: Electrical and Mechanical Testing

A cross section is cut from a sample panel from each lot using a grinding process called **routing,** and the plated holes are examined with a photomicrograph. Individual circuit boards are cut out of panels that pass quality control. Routing generates dust which may contain copper, lead, or other metals plated to the panel, but the dust is recycled. Electrical tests, dimensional and visual inspections, and quality audits are performed to ensure compliance with customer requirements. Finally, the finished PWBs are packaged, labeled, and shipped to the customer which in most cases is the original equipment manufacturer (OEM) or contract electronic assembly company.

Step Seven: Printed Wiring Board Assembly and Soldering

After the PWBs are manufactured, the electrical components are attached during **assembly**. Adhesives are applied to the boards, and then the components are attached and soldered to the boards. Components are attached to the PWB by a process called **soldering**. There are several different kinds of soldering processes, including wave, dip, and drag. In wave soldering, the PWA is passed over the crest of a wave of molten solder, thereby permanently attaching the components to the board. A type of chemical known as "flux" is used before soldering to facilitate the production of the solder connection. Not only does flux clean the surface and remove oxidized material, it prevents oxidation from occurring during the solder process. After the solder has been applied, flux residue may be removed from the board. According to a leading PWB manufacturer, deionized water instead of CFCs (such as Freon 113) and trichloroethane (TCA), are now used to remove flux. Although the residue may not affect the PWB's performance, it may lower the board's cosmetic quality. After soldering, the board may be cleaned and dried. Many assemblies, however, are looking at no-clean soldering operations.

The wastes generated during assembly include: solder dross, post-solder scrap boards, filters, gloves, rags, and spent gaseous or semi-gaseous solvents from cleaning processes. The wastes that may be generated during soldering, flux application, and cleaning include:

organic vapors and CFCs (although CFC usage will be eliminated by 1996); copper, lead, spent solvents, and spent deionized water into the wastewater; solder dross; and wastewater treatment sludge. Solder dross is primarily oxidized solder skin that forms on any molten solder exposed to oxygen and can be recycled off-site.

III.A.3. Cathode Ray Tube Manufacturing

Cathode Ray Tubes (CRTs) have four major components: the glass panel (faceplate), shadow mask (aperture), electron gun (mount), and glass funnel. The glass funnel protects the electron gun and forms the back end of the CRT. In response to electrical signals, the electron gun emits electrons that excite the screen. The shadow mask forms a pattern on the screen. The shadow mask itself is a steel panel with a mask pattern applied through one of several kinds of photolithography.

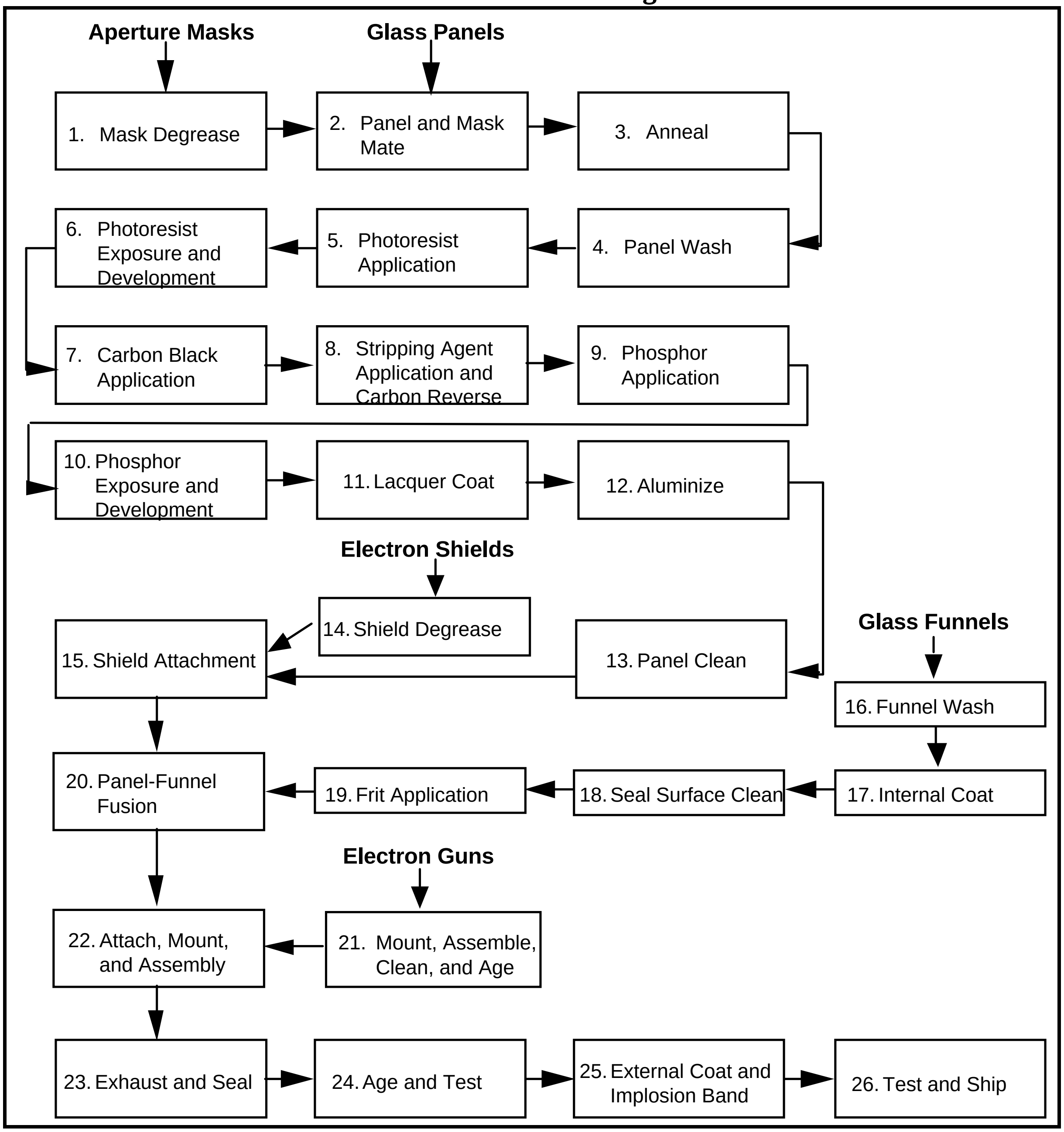
This section summarizes the manufacturing process for color CRTs. Information used to describe CRT manufacturing comes from a variety of sources such as MCC, EPA's Common Sense Initiative (CSI), Corporate Environmental Engineering, and EPA's Effluent Guideline Division. For this discussion, the process is grouped into six steps:

- Preparation of the glass panel and shadow mask
- Application of the coating to the glass panel interior
- Installation of the electron shield
- Preparation of the funnel and joining to the glass panel/shadow mask assembly
- Installation of the electron gun
- Finishing.

Color CRTs

Exhibit 13 presents the steps for manufacturing a color CRT. The names of the operations may vary by manufacturer, but the basic processing sequence is identical in all color CRT manufacturing facilities. Lead in CRT display components and end-of-life concerns have been the most significant environmental issues in CRT manufacturing.

Exhibit 13
Color CRT Manufacturing Process



Source: Based on 1995 EPA Common Sense Initiative (CSI) documents.

Step One: Preparation of the Panel and Shadow Mask

The shadow mask is constructed from a thin layer of aluminum steel (referred to as a flat mask) which is etched with many small slits or holes, and a metal frame that supports the flat mask. The shadow mask serves as a template for preparing a pattern on the glass panel surface. Shadow masks are commonly manufactured overseas and shipped to CRT manufacturers in the United States. The shadow mask is then **molded** to match the contour of the glass panel's interior surface and "blackened" in an oven to provide corrosion resistance. Finally, the shadow mask is **welded** to a blackened metal frame, usually steel, that provides support. Degreasing solvents and caustics are frequently used for **cleaning** the shadow mask assembly and production equipment. Oils are used for lubricating the press and other production equipment.

The front end glass panel is purchased from a glass manufacturer and shipped to the CRT manufacturer. Metal "pins," provided as part of the glass panel, are attached to the inside of the glass to serve as connection points for the shadow mask.

The shadow mask is carefully positioned inside the glass panel. Steel springs are then placed over the pins in the glass panel and attached to "hook-plates" or "clips" located on the mask assembly frame. With the glass panel and shadow mask assembly positions fixed in relation to each other, the springs are **welded** to the hook-plates. The glass panel and mask must remain as a matched pair through the remaining processes. The glass panel and shadow mask preparation operation frequently uses organic solvents or caustic cleaners for degreasing, oil for equipment maintenance, and oxidizers, such as hydrogen peroxide, for cleaning reclaimed masks.

Wastes generated during this step include spent solvents in the wastewater, vapors from solvent degreasing tanks, and waste glass from breakage.

Step Two: Application of Coating to Panel Interior

For the panel-mask to create images, a special coating is applied to the interior surface through a process called screening. Screening, the most complex part of the manufacturing process, is comparable to a photographic development process.

The screening operation begins with a **panel wash**. The mask is removed and the glass panel is washed to remove dust, oil, grease, and other contamination. The glass panel wash commonly uses acids and caustics followed by deionized water rinses for cleaning the glass.

The glass panel undergoes the **carbon stripe** process, which uses organic photoresist, chromate, deionized water, dilute acids and oxidizers, carbon slurry with binding agents, and surfactants to produce the black and clear striped pattern called the "black matrix." The clear areas will eventually be filled with color-producing phosphors. The glass panels are coated with a photoresist, which contains chromate (a toxic heavy metal compound) as a catalyzer. The panel is spun to even out the photoresist and then dried.

The shadow mask is re-inserted in the glass panel and a series of exposures are made on the panel surface using ultraviolet (UV) light in a **photolithography** process. The light passes through the mask openings to imprint the mask pattern on the photoresist. The mask also shadows the areas of the photoresist that will not be exposed. When UV light contacts the photoresist, polymerization occurs, and the exposed areas become less soluble in water than the non-exposed areas.

After the exposure, the shadow mask is removed and the glass panel is sprayed with water to remove the non-polymerized material. The imprinted pattern of exposed photoresist remains on the glass panel. The glass panel is then coated and developed again. The resulting image is essentially a "negative image" of the original photoresist exposure pattern.

During the **phosphor stripe** process, three phosphor colors (green, blue, and red) are used to make a color CRT and are applied using the same steps as the carbon stripe process. The phosphor stripe process uses various chemicals, including phosphor slurries containing metals (such as zinc compounds) and organic photoresists, chromate, deionized water, dilute oxidizers, and surfactants. The phosphor materials that are spun off the panels and removed in the developers are recovered and reclaimed either onsite or by a phosphor vendor. The reclaiming process involves the use of acids and caustics, chelating agents, and surfactants.

Two **coatings** are then added to the glass panel, which now has the black matrix and the three phosphor colors on it: lacquer (a wax-like layer) to smooth and seal the inside surface of the screen, and aluminum to enhance brightness. The panel is then ready to be joined to the back end of the CRT, known as the funnel. In preparation for joining, the panel edges must be **cleaned** to remove all traces of contaminants. A clean edge is critical to ensuring a good panel-to-seal connection in the finished CRT. The shadow mask and glass panel are reattached. Chemicals used in these processes include organic solvents and alcohol, caustics, silica-based coatings, aluminum, acids, ammonia, and deionized water. The material removed in the cleaning process is sent to a smelter to recover metals and sulfites.

Wastes generated during this step include: vapors from the lacquer area; wastewater containing deionized water, acids, oxidizers, carbon slurry, surfactants, chromate, phosphor solutions, chelating agents, caustics, organic solvents, alcohol, silica-based coatings, ammonia, zinc, and aluminum; process cooling waters, liquid wastes from precipitation, washing, filtration, and scrubber blowdown; lacquer wastes from spun off and over-sprayed lacquer; and lacquer remaining in lacquer containers.

Step Three: Installation of the Electron Shield

Most CRT manufacturers employ an internal **electron shield** to prevent stray electrons from reaching outside the screen area. Computer monitor CRTs often use external shielding, which is installed on the outside of the CRT's glass bulb. Before installation, the shields are cleaned with degreasing solvents or caustic cleaners. The internal-type electron shield is made of thin aluminum and is typically **welded** to the shadow mask assembly before the panel and shadow mask are connected with the funnel. Metal (steel) springs are also **welded** to the mask frame at this time. The springs provide an electrical connection between the mask and the funnel interior surface. Wastes generated from these processes include electron shield degrease wastewaters and metals from the welding.

Step Four: Preparation of the Funnel and Joining to Panel-Mask Assembly

The back end of the CRT (funnel) is purchased from a glass vendor and washed prior to use. The funnel is made of high lead content glass and the resulting wash water contains elevated lead levels. After the funnel is **washed**, the interior surface is **coated** with a black graphite coating which is a good electrical conductor and a non-reflective coating. The seal edge of the funnel is **cleaned** to facilitate bonding with the panel, and **frit** or **solder** glass is applied in a bead along the entire surface of the seal edge. The frit, approximately 70 percent lead, has the consistency of toothpaste or caulking. The viscosity of the frit is controlled by the addition of organic solvents. The frit serves as an adhesive to join the panel-mask assembly to the funnel.

After the frit is applied, the panel-mask assembly is connected to the funnel, and the whole glass package is placed in a positioning clamp to hold the two parts in place. The connected panel-mask and funnel assembly is then exposed to high temperatures in an oven to fuse the frit joint between the panel and funnel at the seal edges. The frit forms a strong bond between the two pieces of glass. During the **frit-seal fusion** process, the organic chemicals from the screening operation and in the frit are "burned out" of the CRT. The organic materials must "burn" cleanly to minimize any remaining residue. Wastes generated include wastewaters contaminated with spent black graphic, lead, and chemicals associated with the funnel wash, frit application, and seal surface cleaning. Wastes generated include frit contaminated clothing, instruments and utensil used to prepare the frit, unusable frit glass, and waste glass from breakage.

Step Five: Installation of the Electron Gun

Each CRT contains three guns: one dedicated to each of the phosphor colors used in the screen (red, green, and blue). To produce an electron gun, several metal components are **assembled** and loaded onto spindles to align the various elements. Glass parts are placed into fixture blocks and **heated**. When the glass reaches the proper temperature, the metal parts are embedded in the glass. The combination of metal parts and glass make up the gun. The guns are **cleaned** with organic solvents or caustic cleaners before they are mounted in the neck of the CRT funnel. Materials commonly found in the gun assemblies include metals, high lead glass stem (for electrical connection feed-through and exhaust purposes), ribbon connectors, and other manufacturer-specific parts.

The gun assembly is then inserted in the neck of the CRT funnel. The gun is aligned and the CRT funnel neck is **fused** to the gun by rotating the parts in front of open flame burners. An additional component is **welded** to the gun assembly to allow for removal of gases from the electron gun in subsequent steps. Wastes generated from this step include waste glass from breakage and wastewaters contaminated with spent organic solvents and caustic cleaners from mount cleaning.

Step Six: Finishing

The CRT "bulb" is still open to the atmosphere after the gun mount is sealed in the neck of the funnel. To complete the tube, the gases are removed by applying a vacuum to the bulb. Organic solvents are used to clean and maintain the vacuum pumps.

The bulb is "aged" by an electronic treatment applied to the gun or mount. The CRT is then coated with an external carbon black paint, and a metal band is placed around the outside of the panel with adhesives for implosion protection and safety. The band also provides mounting brackets for installing the CRT. The finished tube is tested in a high voltage testing station, and the CRT tested thoroughly to ensure that it meets all specifications before shipment. Each tube is packaged prior to shipment to the customer. Wastes generated from finishing processes include spent solvents and VOC emissions.

In some cases where the bulb face needs a special application, such as reference lines for an oscilloscope, a separate panel and funnel are used. A photoresist and mask are used to apply the reference lines on the panel. The single phosphor is applied in the same way as for a one-piece bulb, using a settling solution that contains potassium silicate and, usually, an electrolyte.

Tube Salvage

Cathode ray tubes may or may not be salvaged. Picture tube salvage operations reclaim spent or rejected picture tubes and return them to production. Salvage operation processes include a panel-funnel acid defrit, acid cleaning of panels and funnels (i.e., nitric acid), and cleaning of the shadow mask. These reclaimed components are returned to the process for reuse or are returned to the glass manufacturer for recycling. A product with knocks, scratches, chips, etc., is repaired. New necks are spliced onto funnels. Electron guns are usually discarded. Glass that cannot be used because of serious defects is recycled back to a glass plant directly or is sent off-site for cleaning and segregation before going to a glass plant.

CRT technology is a mature and efficient process; however, the use of a new technology called Flat Panel Displays (FPD) is becoming more common. FPDs offer certain environmental advantages over CRTs because of the tenfold reduction in glass used and substantial power savings. Existing performance deficiencies, such as poorer screen brightness and substantially higher prices, are limiting the widespread incorporation of FPDs into electronics products.

III.B. Raw Materials Inputs and Pollution Outputs

Outputs from the electronics and computer industry manufacturing processes affect the land, air, and water. Exhibits 14-16 describe the wastes generated during each manufacturing process.

Exhibit 14
Semiconductor Pollution Outputs

Process	Air Emissions	Process Wastes (Liquids/Waste Waters)	Other Wastes (Solids/RCRA)
Crystal Preparation	Acid fumes, VOCs, dopant gases	Spent deionized water, spent solvents, spent alkaline cleaning solutions, spent acids, spent resist material	Silicon,
Wafer Fabrication	VOCs and dopant gases	Spent solvents, spent acids, aqueous metals, spent etchant solution, and spent aqueous developing solutions.	F003
Final Layering and Cleaning	Acid fumes and VOCs	Spent deionized water, spent solvents, spent acids, spent etchants, spent aqueous developing solutions, spent cleaning solutions, aqueous metals, and D007 (chromium).	Spent solvents
Assembly	VOCs	Spent cleaning solutions, spent solvents, aqueous developing solutions, and P & U wastes.	Spent epoxy material and spent solvents

Exhibit 15
Printed Wiring Board Pollution Outputs

Process	Air Emissions	Process Wastes (Liquids/Waste Waters)	Other Wastes (Solids/RCRA)
Board Preparation	Particulates, acid fumes, and VOCs	Spent acids and spent alkaline solutions	Sludge and scrap board material
Electroless Plating		Spent electroless copper baths, spent catalyst solutions, spent acid solutions	Waste rinse water and sludges from waste water treatment
Imaging	Organic vapors and acid fumes	Spent developing solutions, spent resist material, spent etchants, spent acid solutions, and aqueous metals	F001-5, depending on concentration and mixture of solvents. Sludges from waste water treatment
Electroplating	Acid fumes, ammonia fumes, and VOCs	D008 (lead), D002, D003, spent etchants, spent acid solutions, spent developing solutions, spent plating baths	F006, F007, and F008

Exhibit 15 (cont'd)
Printed Wiring Board Pollution Outputs

Process	Air Emissions	Process Wastes (Liquids/Waste Water)	Other Wastes (Solids/RCRA)
Solder Coating	VOCs and CFCs		
PWB Assembly And Soldering	VOCs and CFCs	Metals (nickel, silver, and copper), D008 (lead), flux residue, spent deionized water, spent solvents	Solder dross, scrap boards, filters, gloves, rags, waste water treatment sludge

Exhibit 16
Cathode Ray Tubes Pollution Outputs

Process	Air Emissions	Process Wastes (Liquid/Waste Waters)	Other Wastes (Solids/RCRA)
Preparation of the Panel and Shadow Mask	Solvent vapors	Spent solvents	Glass (lead) from breakage
Application of Coating to Panel Interior	Vapors from lacquer area	Spent photoresists, deionized water, acids, oxidizers, carbon slurry, surfactants, chromate, phosphor solutions, chelating agents, caustics, solvents, alcohol, coatings, ammonia, aluminum, and process cooling waters	Lacquer wastes
Installation of Electron Shield		Electron shield degrease and metals	
Preparation of Funnel and Joining to Panel-Mask Assembly		Funnel wash, seal surface cleaning, and frit application wastewaters	Frit contaminated clothing, instruments, utensils, unusable frit glass (lead), glass (lead) from break-age
Installation of Electron Gun		Spent solvents and caustic cleaners	Glass from breakage
Finishing	VOCs	Spent solvents	

III.C. Management of Chemicals in Wastestream

The Pollution Prevention Act of 1990 (EPA) requires facilities to report information about the management of TRI chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1992-1995 and are meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

While the quantities reported for 1992 and 1993 are estimates of quantities already managed, the quantities reported for 1994 and 1995 are projections only. The EPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Exhibit 17 shows that the electronics/computer industry managed about 122 million pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 1993 (column B). Column C reveals that of this production-related waste, 44 percent was either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases by the total quantity of production-related waste. In other words, about 81 percent of the industry's TRI wastes were managed on-site through recycling, energy recovery, or treatment as shown in columns D, E and F, respectively. The majority of waste that is released or transferred off-site can be divided into portions that are recycled off-site, recovered for energy off-site, or treated off-site as shown in columns G, H, and I, respectively. The remaining portion of the production-related wastes (6.7 percent), shown in column J, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed off-site.

Exhibit 17
Source Reduction and Recycling Activity for SIC 36

A	B	C	D	E	F	G	H	I	J
	Production Related Waste Volume		**On-Site**			**Off-Site**			**Remaining Releases and Disposal**
Year	**(10^6 lbs.)**	% Reported as Released and Transferred	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	
1992	121	49%	8.27%	0.41%	70.75%	3.21%	3.96%	4.83%	8.52%
1993	122	44%	9.38%	0.20%	72.12%	3.41%	3.77%	4.41%	6.70%
1994	121	—	7.63%	0.13%	74.99%	4.33%	3.88%	3.58%	5.44%
1995	129	—	8.87%	0.59%	74.45%	4.61%	3.65%	3.04%	4.78%

IV. CHEMICAL RELEASE AND TRANSFER PROFILE

This section is designed to provide background information on the pollutant releases that are reported by this industry. The best source of comparative pollutant release information is the Toxic Release Inventory System (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act (EPCRA), TRI includes self-reported facility release and transfer data for over 600 toxic chemicals. Facilities within SIC Codes 20-39 (manufacturing industries) that have more than 10 employees, and that are above weight-based reporting thresholds are required to report TRI on-site releases and off-site transfers. The information presented within the sector notebooks is derived from the most recently available (1993) TRI reporting year (which then included 316 chemicals), and focuses primarily on the on-site releases reported by each sector. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries.

Although this sector notebook does not present historical information regarding TRI chemical releases over time, please note that in general, toxic chemical releases have been declining. In fact, according to the 1993 Toxic Release Inventory Data Book, reported releases dropped by 42.7 percent between 1988 and 1993. Although on-site releases have decreased, the total amount of reported toxic waste has not declined because the amount of toxic chemicals transferred off-site has increased. Transfers have increased from 3.7 billion pounds in 1991 to 4.7 billion pounds in 1993. Better management practices have led to increases in off-site transfers of toxic chemicals for recycling. More detailed information can be obtained from EPA's annual Toxics Release Inventory Public Data Release book (which is available through the EPCRA Hotline at 1-800-535-0202), or directly from the Toxic Release Inventory System database (for user support call 202-260-1531).

Wherever possible, the sector notebooks present TRI data as the primary indicator of chemical release within each industrial category. TRI data provide the type, amount, and media receptor of each chemical released or transferred. When other sources of pollutant release data have been obtained, these data have been included to augment the TRI information.

TRI Data Limitations

The reader should keep in mind the following limitations regarding TRI data. Within some sectors, the majority of facilities are not subject to TRI reporting because they are not considered manufacturing industries, or because they are below TRI reporting thresholds. Examples are the mining, dry cleaning, printing, and transportation equipment cleaning sectors. For these sectors, release information from other sources has been included.

The reader should also be aware that TRI "pounds released" data presented within the notebooks is not equivalent to a "risk" ranking for each industry. Weighting each pound of release equally does not factor in the relative toxicity of each chemical that is released. The Agency is in the process of developing an approach to assign toxicological weightings to each chemical released so that one can differentiate between pollutants with significant differences in toxicity. As a preliminary indicator of the environmental impact of the industry's most commonly released chemicals, the notebook briefly summarizes the toxicological properties of the top five chemicals (by weight) reported by each industry.

Definitions Associated With Section IV Data Tables

General Definitions

SIC Code -- the Standard Industrial Classification (SIC) is a statistical classification standard used for all establishment-based Federal economic statistics. The SIC codes facilitate comparisons between facility and industry data.

TRI Facilities -- are manufacturing facilities that have 10 or more full-time employees and are above established chemical throughput thresholds. Manufacturing facilities are defined as facilities in Standard Industrial Classification primary codes 20-39. Facilities must submit estimates for all chemicals that are on the EPA's defined list and are above throughput thresholds.

Data Table Column Heading Definitions

The following definitions are based upon standard definitions developed by EPA's Toxic Release Inventory Program. The categories below represent the possible pollutant destinations that can be reported.

RELEASES -- are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) -- Include all air emissions from industry activity. Point emissions occur through confined air streams as found in stacks, ducts, or pipes. Fugitive emissions include losses from equipment leaks, or evaporative losses from impoundments, spills, or leaks.

Releases to Water (Surface Water Discharges) - encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Any estimates for stormwater runoff and non-point losses must also be included.

Releases to Land -- includes disposal of waste to on-site landfills, waste that is land treated or incorporated into soil, surface impoundments, spills, leaks, or waste piles. These activities must occur within the facility's boundaries for inclusion in this category.

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal.

TRANSFERS -- is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting under TRI. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment.

Transfers to POTWs -- are wastewaters transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or landfilled within the sludge.

Transfers to Recycling -- are sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Energy Recovery -- are wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to Treatment -- are wastes moved off-site for either neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal -- are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

IV.A. EPA Toxic Release Inventory for the Electronics/Computer Industry

The follow section provides TRI data for the semiconductor, printed wiring board (PWB) and cathode ray tube (CRT) industries. The manufacture of these products results in the release of similar substances, including solvents, acids, and heavy metals. The commonly released solvents include acetone, xylene, and methanol. Commonly released acids include sulfuric, hydrochloric, and nitric. A significant amount of ammonia is also released by the electronics/computer industry.

IV.A.1. TRI Data for Semiconductor Industry

The following exhibits present TRI data pertaining to semiconductor manufacturing. Exhibit 18 presents the top ten facilities in terms of TRI releases. Many of these companies are also among the top companies in terms of sales. Exhibit 19 presents the top TRI releasing facilities for all of electronics and other electric facilities. Exhibit 20 displays the number of TRI-reporting semiconductor manufacturing facilities per State. As expected, California and Texas contain the largest number of semiconductor manufacturing facilities.

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases. The top reporting facilities for this sector are listed below. Facilities that have reported only the SIC codes covered under this notebook appear on the first list. The second list contains additional facilities that have reported the SIC code covered within this report, and one or more SIC codes that are not within the scope of this notebook. Therefore, the second list includes facilities that conduct multiple operations — some that are under the scope of this notebook, and some that are not. Currently, the facility-level data do not allow pollutant releases to be broken apart by industrial process.

Exhibit 18
Top 10 TRI Releasing Semiconductor Manufacturing Facilities (SIC 3674)

Rank	Total TRI Releases in Pounds	Facility Name	City	State
1	225,840	Micron Semiconductor Inc.	Boise	ID
2	203,120	Motorola Inc.	Mesa	AZ
3	159,465	Intel Corp.	Hillsboro	OR
4	142,256	Texas Instruments Inc.	Dallas	TX
5	138,950	AT&T Microelectronics	Reading	PA
6	134,208	Intel Corp.	Rio Rancho	NM
7	112,250	Advanced Micro Devices Inc.	Austin	TX
8	82,854	IBM Corp. E. Fishkill Facility	Hopewell Junction	NY
9	81,719	Dallas Semiconductor Corp.	Dallas	TX
10	80,545	Sgs-Thomson Microelectronics Inc.	Carrollton	TX

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 19
Top 10 TRI Releasing Electronics/Computer Industry Facilities

SIC Codes	Total TRI Releases in Pounds	Facility Name	City	State
3671	861,508	Zenith Electronics Corp. Rauland Div.	Melrose Park	IL
3671	378,105	Philips Display Components Co.	Ottawa	OH
3469, 3674, 3089, 3694	297,150	Delco Electronics Corp. Bypass	Kokomo	IN
3672, 3471	274,950	Photocircuits Corp.	Glen Cove	NY
3671	257,954	Toshiba Display Devices Inc.	Horseheads	NY
3672	255,395	IBM Corp.	Endicott	NY
3674	225,840	Micron Semiconductor Inc.	Boise	ID
3674	203,120	Motorola Inc.	Mesa	AZ
3672	193,720	Hadco Corp. Owego Div.	Owego	NY
3674	159,465	Intel Corp.	Hillsboro	OR

Source: US EPA, Toxics Release Inventory Database, 1993.

Note: Being included on this list does not mean that the release is associated with non-compliance with environmental laws.

Exhibit 20
TRI Reporting Semiconductor Manufacturing Facilities (SIC 3674) by State

State	Number of Facilities	State	Number of Facilities
AZ	9	OR	7
CA	56	PA	7
CO	4	PR	1
FL	2	RI	1
ID	3	SC	1
MA	9	TX	20
MD	2	UT	3
ME	1	VT	1
MN	4	WA	1
MO	1	WI	1
NC	2		
NH	2		
NM	2		
NY	6		
OH	4		

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibits 21 and 22 show the chemical releases and transfers for the semiconductor industry. Sulfuric acid and hydrochloric acid, two of the most commonly-released chemicals, are used during etching and cleaning processes. Solvents such as acetone, glycol ethers, xylene, and Freon 113 are used during photolithography and cleaning processes. 1,1,1-trichloroethane is used during oxidation and ammonia is used during photolithography and cleaning. A significant amount of methyl ethyl ketone is released during the degreasing and cleaning processes. Most of these solvents are released into the air. Facilities with zero releases of certain chemicals are reported here because transfers of the chemical may have been reported.

Exhibit 21
Releases for Semiconductor Manufacturing Facilities (SIC 3674) in TRI, by Number of Facilities (Releases Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Under-ground Injection	Land Disposal	Total Releases	Average Releases per Facility
Sulfuric Acid	125	13644	88209	17	250	139	102259	818
Hydrochloric Acid	78	8262	69429	3	0	10	77704	996
Hydrogen Fluoride	71	4940	55479	9902	0	5	70326	991
Phosphoric Acid	69	4039	25674	0	0	5	29718	431
Nitric Acid	57	5403	47628	23	0	5	53059	931
Acetone	53	121794	890290	1460	659	5	1014208	19136
Ammonia	42	42770	101717	42082	17805	8600	212974	5071
Glycol Ethers	27	41317	212900	500	0	82000	336717	12471
Xylene (Mixed Isomers)	25	9952	252661	0	139	0	262752	10510
Ethylene Glycol	16	1688	9316	1600	0	0	12604	788
Methanol	16	31049	135566	0	129	0	166744	10422
Freon 113	10	41211	73335	0	0	0	114546	11455
1,1,1-Trichloroethane	8	1691	82366	0	1	0	84058	10507
Methyl Ethyl Ketone	6	1332	128250	0	0	5	129587	21598
Tetrachloroethylene	4	514	55034	1	0	0	55549	13887
Ammonium Nitrate (Solution)	3	0	0	0	0	0	0	0
Ammonium Sulfate (Solution)	3	250	0	0	0	0	250	83
Lead	3	0	0	0	0	0	0	0
Phenol	3	50	2745	0	0	0	2795	932
Toluene	3	25170	33580	0	0	0	58750	19583
Trichloroethylene	3	14009	21896	0	0	0	35905	11968
Copper	2	0	0	12	0	0	12	6
Ethylbenzene	2	175	1300	0	0	0	1475	738
Methyl Isobutyl Ketone	2	750	9325	0	0	0	10075	5038
1,2-Dichlorobenzene	2	200	49234	0	0	0	49434	24717
1,2,4-Trichlorobenzene	2	0	6519	0	0	0	6519	3260
Antimony Compounds	1	18	5	1	0	0	24	24
Chlorine Dioxide	1	5	5	0	0	0	10	10
Cobalt Compounds	1	5	2	0	0	0	7	7
Isopropyl Alcohol (Manufacturing)	1	0	0	0	0	0	0	0
Lead Compounds	1	0	0	0	0	0	0	0
N-Butyl Alcohol	1	21	84	0	0	0	105	105
Nickel Compounds	1	0	0	0	0	0	0	0
Nitrilotriacetic Acid	1	5	5	0	0	0	10	10
P-Xylene	1	0	430	0	0	0	430	430
Totals	-------	370,264	2,352,984	55,601	18,983	90,774	2,888,606	-------

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 22
Transfers for Semiconductor Manufacturing Facilities (SIC 3674) in TRI, by Number of Facilities (Transfers Reported in Pounds/Year)

Chemical Name	# Reporting Chemical	POTW Discharges	Disposal	Recycling	Treatment	Energy Recovery	Total Transfers	Average Transfer per Facility
Sulfuric Acid	125	147449	500380	1039071	169372	0	1856272	14850
Hydrochloric Acid	78	236415	29599	21664	84745	5	372428	4775
Hydrogen Fluoride	71	11733	198630	525	151929	0	362817	5110
Phosphoric Acid	69	1103	269124	200000	33594	0	503821	7302
Nitric Acid	57	56177	99817	20910	62904	0	239808	4207
Acetone	53	104090	1582	136987	116610	1075656	1442137	27210
Ammonia	42	944298	52771	650	10806	0	1008525	24013
Glycol Ethers	27	30889	3345	139100	56330	1049440	1279104	47374
Xylene (Mixed Isomers)	25	3891	824	31304	127501	728688	892208	35688
Ethylene Glycol	16	458412	2027	15194	623	102016	578272	36142
Methanol	16	14474	0	27715	64502	716413	823104	51444
Freon 113	10	25	592	36937	2435	5660	45649	4565
1,1,1-Trichloroethane	8	263	5	75267	18264	8000	101799	12725
Methyl Ethyl Ketone	6	869	750	0	2105	276109	279833	46639
Tetrachloroethylene	4	0	0	10215	59628	53000	122843	30711
Ammonium Nitrate (Solution)	3	224302	0	0	0	0	224302	74767
Ammonium Sulfate (Solution)	3	1488462	0	122000	0	0	1610462	536821
Lead	3	0	1500	59125	13961	0	74586	24862
Phenol	3	2331	0	0	27	94679	97037	32346
Toluene	3	0	0	0	17000	5970	22970	7657
Trichloroethylene	3	0	0	59736	0	0	59736	19912
Copper	2	0	18	0	166	0	184	92
Ethylbenzene	2	0	146	0	190	16800	17136	8568
Methyl Isobutyl Ketone	2	0	0	0	9300	12190	21490	10745
1,2-Dichlorobenzene	2	10	0	0	2157	93600	95767	47884
1,2,4-Trichlorobenzene	2	1413	0	0	32273	0	33686	16843
Antimony Compounds	1	0	18100	0	0	0	18100	18100
Chlorine Dioxide	1	0	0	0	0	0	0	0
Cobalt Compounds	1	0	3780	0	0	0	3780	3780
Isopropyl Alcohol (Manufacturing)	1	5	0	10165	0	0	10170	10170
Lead Compounds	1	0	6630	0	0	0	6630	6630
N-Butyl Alcohol	1	10430	0	0	0	1433	11863	11863
Nickel Compounds	1	381	0	3574	0	0	3955	3955
Nitrilotriacetic Acid	1	0	0	0	0	0	0	0
P-Xylene	1	0	0	0	10380	0	10380	10380
Zinc Compounds	1	0	267300	0	0	0	267300	267300
Totals	-------	3,737,422	1,456,920	2,010,139	1,046,802	4,239,659	12,498,154	-------

Source: US EPA, Toxics Release Inventory Database, 1993.

IV.A.2. TRI Data for Printed Wiring Board Industry

The following exhibits present TRI data pertaining to PWB manufacturing. Exhibit 23 presents the top ten TRI-reporting PWB manufacturing facilities in terms of TRI releases. IBM is one of these companies which is also among the top ten electronics sales generating companies. Exhibit 24 displays the number of TRI-reporting facilities per State. California has the largest number of PWB manufacturing facilities.

Exhibit 23
Top 10 TRI Releasing Printed Wiring Board Manufacturing Facilities (SIC 3672)

Rank	Total TRI Releases in Pounds	Facility Name	City	State
1	255,395	IBM Corp.	Endicott	NY
2	193,720	Hadco Corp. Oswego Div.	Oswego	NY
3	127,283	Continental Circuits Corp.	Phoenix	AZ
4	120,864	Thomson Consumer Electronics Inc.	Dunmore	PA
5	96,191	Hadco Corp.	Derry	NH
6	79,250	QLP Laminates Inc.	Anaheim	CA
7	74,653	Synthane-Taylor	La Verne	CA
8	68,456	Circuit-Wise Inc.	North Haven	CT
9	67,050	American Matsushita Electronics Corp.	Troy	OH
10	65,088	Pec Viktron	Orlando	FL

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 24
TRI Reporting Printed Wiring Board Manufacturing Facilities (SIC 3672) by State

State	Number of Facilities	State	Number of Facilities
AZ	9	NJ	3
CA	82	NY	8
CO	3	OH	7
CT	7	OK	1
FL	11	OR	6
GA	2	PA	5
IA	2	PR	4
IL	18	SC	2
IN	3	SD	1
KS	1	TX	8
MA	9	UT	4
MD	1	VA	3
MI	1	VT	1
MN	14	WA	6
MO	4	WI	4
NC	1		
NH	9		

Source: US EPA, Toxics Release Inventory Database, 1993.

As seen in Exhibits 25 and 26, the top releases of acids from PWB facilities include sulfuric acid, hydrochloric acid, and nitric acid, all of which are used during cleaning, electroless plating and electroplating operations. Hydrochloric acid is also used during etching. The acids are primarily released to the air or recycled. Glycol ethers are released during image application and cleaning; most of the releases are emitted into the air. Freon 113 is used primarily for flux removal and is released into the air. Nearly all Freon 113 transfers are recycled. Acetone, a solvent used to clean the board before imaging, is released primarily into the air. Ammonium sulfate solution is used during electroplating, imaging, and etching processes and is released to the water or transferred to POTWs. Metals such as lead and copper are commonly used during electroplating, etching, and soldering (i.e., lead) processes. These metals and their compounds are primarily recycled.

Exhibit 25
Releases for Printed Wiring Board Manufacturing Facilities (SIC 3672) in TRI, by Number of Facilities (Releases Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Under-ground Injection	Land Disposal	Total Releases	Average Release per Facility
Sulfuric Acid	208	25640	98477	0	0	250	124367	598
Ammonia	117	80332	480081	28029	0	0	588442	5029
Copper	89	1345	1860	27	0	8500	11732	132
Copper Compounds	73	6830	7532	1831	0	9739	25932	355
Hydrochloric Acid	70	13268	40342	32189	0	27	85826	1226
Nitric Acid	59	7572	12750	0	0	0	20322	344
Glycol Ethers	25	82099	132118	23057	0	0	237274	9491
Formaldehyde	22	3225	14912	255	0	0	18392	836
Chlorine	16	1545	5992	50	0	0	7587	474
Lead	12	250	750	5	0	3500	4505	375
Acetone	10	117974	70711	0	0	0	188685	18869
Freon 113	9	83258	37550	0	0	0	120808	13423
Lead Compounds	7	760	1260	252	0	0	2272	325
Ammonium Sulfate (Solution)	6	0	0	100000	0	0	100000	16667
Methyl Ethyl Ketone	6	13770	25023	0	0	0	38793	6466
Phosphoric Acid	6	510	505	0	0	0	1015	169
Methanol	5	62978	7394	0	0	0	70372	14074
Dichloromethane	4	51269	125288	5	0	0	176562	44141
1,1,1-Trichloroethane	3	24930	8310	0	0	0	33240	11080
2-Methoxyethanol	3	5000	40960	0	0	0	45960	15320
Hydrogen Fluoride	2	0	250	0	0	0	250	125
Nickel	2	0	0	0	0	0	0	0
Toluene	2	29425	14125	0	0	0	43550	21775
Zinc Compounds	2	750	0	0	0	0	750	375
Ammonium Nitrate (Solution)	1	0	0	0	0	0	0	0
Barium Compounds	1	250	0	0	0	0	250	250
Ethylbenzene	1	250	2600	0	0	0	2850	2850
Ethylene Glycol	1	600	1200	0	0	0	1800	1800

Exhibit 25 (cont'd)
Releases for Printed Wiring Board Manufacturing Facilities (SIC 3672) in TRI, by Number of Facilities (Releases Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Under-ground Injection	Land Disposal	Total Releases	Average Releases per Facility
Isopropyl Alcohol (Manufacturing)	1	0	0	0	0	0	0	0
Methylenebis (Phenylisocyanate)	1	0	0	0	0	0	0	0
Phenol	1	750	750	250	0	0	1750	1750
Silver	1	0	0	.	0	0	0	0
Tetrachloroethylene	1	12900	22300	0	0	0	35200	35200
Trichloroethylene	1	14920	26000	0	0	0	40920	40920
Xylene (Mixed Isomers)	1	1000	16560	0	0	0	17560	17560
1,2-Dichlorobenzene	1	1800	2130	0	0	0	3930	3930
Totals	-------	**645,200**	**1,197,730**	**185,950**	**0**	**22,016**	**2,050,896**	-------

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 26
Transfers for Printed Wiring Board Manufacturing Facilities (SIC 3672) in TRI, by Number of Facilities (Transfers Reported in Pounds/Year)

Chemical Name	# Reporting Chemical	POTW Discharges	Disposal	Recycling	Treatment	Energy Recovery	Total Transfers	Average Transfers per Facility
Sulfuric Acid	208	34596	15558	85488	456242	28400	620284	2982
Ammonia	117	412348	2513	6102550	212950	0	6730361	57524
Copper	89	18527	77880	5159806	104791	0	5361004	60236
Copper Compounds	73	31441	101998	7949551	263240	0	8346230	114332
Hydrochloric Acid	70	1317	750	1056064	1453601	3100	2514832	35926
Nitric Acid	59	265	8500	169722	202665	0	381152	6460
Glycol Ethers	25	475285	1350	6974	240182	21792	745583	29823
Formaldehyde	22	64501	0	0	2500	0	67001	3046
Chlorine	16	655	0	94152	111000	0	205807	12863
Lead	12	1025	13297	268496	4231	40	287089	23924
Acetone	10	2100	45	3000	1600	188153	194898	19490
Freon 113	9	250	0	77460	1700	5	79415	8824
Lead Compounds	7	1559	14454	92233	5125	0	113371	16196
Ammonium Sulfate (Solution)	6	338933	0	0	0	0	338933	56489
Methyl Ethyl Ketone	6	0	250	0	750	397048	398048	66341
Phosphoric Acid	6	250	0	0	460	0	710	118
Methanol	5	41902	170	0	10746	0	52818	10564
Dichloromethane	4	253	0	71940	2526	38970	113689	28422
1,1,1-Trichloroethane	3	0	0	115750	1410	8180	125340	41780
2-Methoxyethanol	3	0	0	0	0	12250	12250	4083
Hydrogen Fluoride	2	0	0	0	5600	0	5600	2800
Nickel	2	251	0	381	0	0	632	316
Toluene	2	8905	0	0	0	121600	130505	65253
Zinc Compounds	2	4334	10876	0	1087	0	16297	8149
Ammonium Nitrate (Solution)	1	73000	0	0	0	0	73000	73000
Barium Compounds	1	0	500	0	0	0	500	500

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 26 (cont'd)
Transfers for Printed Wiring Board Manufacturing Facilities (SIC 3672) in TRI, by Number of Facilities (Transfers Reported in pounds/year)

Chemical Name	# Reporting Chemical	POTW Discharges	Disposal	Recycling	Treatment	Energy Recovery	Total Transfers	Average Transfer per Facility
Ethylbenzene	1	0	5	0	500	117430	117935	117935
Ethylene Glycol	1	9300	230	0	0	0	9530	9530
Isopropyl Alcohol (Manufacturing)	1	0	3900	0	5460	0	9360	9360
Methylenebis (Phenylisocyanate)	1	0	0	0	16800	0	16800	16800
Phenol	1	0	0	0	10340	22870	33210	33210
Silver	1	0	0	3	0	0	3	3
Tetrachloroethylene	1	0	0	0	1091590	49020	1140610	1140610
Trichloroethylene	1	0	0	0	61600	0	61600	61600
Xylene (Mixed Isomers)	1	0	250	0	2360	559310	561920	561920
1,2-Dichlorobenzene	1	0	0	0	0	109810	109810	109810
Totals	**-------**	**1,524,043**	**252,526**	**21,253,570**	**4,271,056**	**1,677,978**	**28,976,127**	**-------**

Source: US EPA, Toxics Release Inventory Database, 1993.

IV.A.3. TRI Data for Cathode Ray Tube Industry

Exhibits 27 present the top ten TRI-reporting CRT manufacturers in terms of releases, and Exhibit 28 presents the number of TRI reporting CRT manufacturing facilities by State. It is not surprising that few facilities are reported in TRI because most manufacturing occurs outside the United States. Exhibits 29 and 30 show TRI releases and transfers per chemical. As expected, a significant amount of lead (used during the frit sealing process) is released, much of which is transferred off-site for disposal and recycling. Zinc compounds are used during the phosphor stripe process and are transferred for recycling. Nitric acid, which is used during tube salvaging, is released into the air. Freon 113 is used as a cleaning agent during panel shadow mask preparation and is also released into the air. Solvents (i.e., acetone, methyl ethyl ketone, toluene, and methanol) are used for cleaning and degreasing and are released primarily into the air or transferred for recycling.

Exhibit 27
Top 10 TRI Releasing Cathode Ray Tube Manufacturing Facilities (SIC 3671)

Rank	Total TRI Releases in Pounds	Facility Name	City	State
1	861,508	Zenith Electronics Corp., Rauland Div.	Melrose Park	IL
2	378,105	Philips Display Components Co.	Ottawa	OH
3	257,954	Toshiba Display Devices Inc.	Horseheads	NY
4	78,756	Varian X-Ray Tube Prods.	Salt Lake City	UT
5	47,000	Richardson Electronics Ltd.	Lafox	IL
6	43,055	Thomson Consumer Electronics	Marion	IN
7	42,323	Varian Assoc. Inc. Power Grid Tube Prods.	San Carlos	CA
8	24,901	Clinton Electronics Corp.	Loves Park	IL
9	21,613	Hitachi Electronic Devices USA Inc.	Greenville	SC
10	6,250	ITT Corp., ITT Electron Technology Div.	Easton	PA

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 28
TRI Reporting Cathode Ray Tube Manufacturing Facilities (SIC 3671) by State

State	Number of Facilities
CA	1
IL	4
IN	2
KY	1
MA	1
NY	1
OH	1
PA	2
RI	1
SC	1
UT	1

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 29
Releases for Cathode Ray Tube Manufacturing Facilities (SIC 3671) in TRI, by Number of Facilities (Releases Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	Fugitive Air	Point Air	Water Discharges	Under-ground Injection	Land Disposal	Total Releases	Average Releases per Facility
Hydrochloric Acid	9	359	589	0	0	0	948	105
Acetone	8	121559	102405	0	0	0	223964	27996
Nitric Acid	8	2767	77073	0	0	0	79840	9980
Lead Compounds	7	99	2637	435	0	0	3171	453
Sulfuric Acid	7	1580	152	0	0	0	1732	247
Methanol	6	41906	35307	1550	0	0	78763	13127
Trichloroethylene	6	151543	393048	0	0	0	544591	90765
Barium Compounds	5	6	5	476	0	0	487	97
Hydrogen Fluoride	5	1760	4175	0	0	0	5935	1187
Toluene	5	38856	480286	1681	0	0	520823	104165
Zinc Compounds	4	205	5017	164	0	0	5386	1347
Copper	3	10	255	65	0	0	330	110
Ammonia	2	1069	8411	3103	0	0	12583	6292
Arsenic Compounds	2	0	0	2	0	0	2	1
Freon 113	2	34718	5227	0	0	0	39945	19973
Methyl Ethyl Ketone	2	72778	54045	0	0	0	126823	63412
1,1,1-Trichloroethane	2	1484	35983	5	0	0	37472	18736
Chromium Compounds	1	0	0	146	0	0	146	146
Copper Compounds	1	10	200	5	0	0	215	215
Methyl Isobutyl Ketone	1	139	13777	0	0	01	13916	13916
Methylenebis (Phenylisocyanate)	1	0	0	0	0	0	0	0
Nickel	1	5	5	0	0	0	10	10
Nickel Compounds	1	0	0	50	0	0	50	50
Tetrachloroethylene	1	0	0	0	0	0	0	0
Xylene (Mixed Isomers)	1	70	70418	0	0	0	70488	70488
Totals	-------	**470,923**	**1,289,015**	**7,682**	**0**	**1**	**1,767,620**	-------

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 30
Transfers for Cathode Ray Tube Manufacturing Facilities (SIC 3671) in TRI, by Number of Facilities (Transfers Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	POTW Discharges	Disposal	Recycling	Treatment	Energy Recovery	Total Transfers	Average Transfers per Facility
Hydrochloric Acid	9	250	0	0	250	0	500	56
Acetone	8	173	0	21712	60	38674	60619	7577
Nitric Acid	8	0	0	0	333274	0	333274	41659
Lead Compounds	7	1175	1924617	487010	137506	0	2550308	364330
Sulfuric Acid	7	0	0	250	20639	0	20889	2984
Methanol	6	202029	0	64240	5000	5820	277089	46182
Trichloroethylene	6	250	0	151155	150000	0	301405	50234
Barium Compounds	5	255	295228	138785	1850	0	436118	87224
Hydrogen Fluoride	5	39347	0	0	215536	0	254883	50977
Toluene	5	81	0	626179	277	106983	733520	146704
Zinc Compounds	4	1397	56654	212504	59710	0	330265	82566
Copper	3	61	279	80492	0	0	80832	26944
Ammonia	2	0	0	0	0	0	0	0
Arsenic Compounds	2	0	7388	7579	0	0	14967	7484
Freon 113	2	0	0	7170	0	0	7170	3585

Source: US EPA, Toxics Release Inventory Database, 1993.

Exhibit 30 (cont'd)
Transfers for Cathode Ray Tube Manufacturing Facilities (SIC 3671) in TRI, by Number of Facilities (Transfers Reported in Pounds/Year)

Chemical Name	# Facilities Reporting Chemical	POTW Discharges	Disposal	Recycling	Treatment	Energy Recovery	Total Transfers	Average Transfers per Facility
Methyl Ethyl Ketone	2	0	0	0	0	15549	15549	7775
1,1,1-Trichloroethane	2	7	0	10845	0	0	10852	5426
Chromium Compounds	1	0	162	2	0	0	164	164
Copper Compounds	1	45	0	68700	0	0	68745	68745
Methyl Isobutyl Ketone	1	0	0	0	0	1722	1722	1722
Methylenebis (Phenylisocyanate)	1	0	4192	0	0	0	4192	4192
Nickel	1	63	0	24146	0	0	24209	24209
Nickel Compounds	1	0	36	40260	0	0	40296	40296
Tetrachloroethylene	1	0	0	0	20600	0	20600	20600
Xylene (Mixed Isomers)	1	0	0	0	0	0	0	0
Totals	-------	245,133	2,288,556	1,941,029	944,702	168,748	5,588,168	-------

Source: US EPA, Toxics Release Inventory Database, 1993.

IV.B. Summary of Selected Chemicals Released

The following is a synopsis of current scientific toxicity and fate information for the top chemicals (by weight) that facilities within this sector self-reported as released to the environment based upon 1993 TRI data. Because this section is based upon self-reported release data, it does not attempt to provide information on management practices employed by the sector to reduce the release of these chemicals. Information regarding pollutant release reductions over time may be available from EPA's TRI and 33/50 programs, or directly from the industrial trade associations that are listed in Section IX of this document. Since these descriptions are cursory, please consult the sources referenced below for a more detailed description of both the chemicals described in this section, and the chemicals that appear on the full list of TRI chemicals appearing in Section IV.A.

The brief descriptions provided below were taken from the *1993 Toxics Release Inventory Public Data Release* (EPA, 1994), the Hazardous Substances Data Bank (HSDB), and the Integrated Risk Information System (IRIS), both accessed via TOXNET[2]. The information contained below is based upon exposure assumptions that have been conducted using standard scientific procedures. The effects listed below must be taken in context of these exposure assumptions that are more fully explained within the full chemical profiles in HSDB.

The following chemicals are those released in the greatest quantity by the electronics/computer manufacturing industry:

Acetone
Ammonia
Dichloromethane
Freon 113
Glycol Ethers
Methanol
Methyl Ethyl Ketone
Sulfuric Acid
Toluene
Trichloroethylene
Xylene

[2] TOXNET is a computer system run by the National Library of Medicine that includes a number of toxicological databases managed by EPA, National Cancer Institute, and the National Institute for Occupational Safety and Health. For more information on TOXNET, contact the TOXNET help line at 1-800-231-3766. Databases included in TOXNET are: CCRIS (Chemical Carcinogenesis Research Information System), DART (Developmental and Reproductive Toxicity Database), DBIR (Directory of Biotechnology Information Resources), EMICBACK (Environmental Mutagen Information Center Backfile), GENE-TOX (Genetic Toxicology), HSDB (Hazardous Substances Data Bank), IRIS (Integrated Risk Information System), RTECS (Registry of Toxic Effects of Chemical Substances), and TRI (Toxic Chemical Release Inventory). HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure potential, exposure standards and regulations, monitoring and analysis methods, and additional references.

Acetone

Toxicity. Acetone is irritating to the eyes, nose, and throat. Symptoms of exposure to large quantities of acetone may include headache, unsteadiness, confusion, lassitude, drowsiness, vomiting, and respiratory depression.

Reactions of acetone (see environmental fate) in the lower atmosphere contribute to the formation of ground-level ozone. Ozone (a major component of urban smog) can affect the respiratory system, especially in sensitive individuals such as asthmatics or allergy sufferers.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. If released into water, acetone will be degraded by microorganisms or will evaporate into the atmosphere. Degradation by microorganisms will be the primary removal mechanism.

Acetone is highly volatile, and once it reaches the troposphere (lower atmosphere), it will react with other gases, contributing to the formation of ground-level ozone and other air pollutants. EPA is reevaluating acetone's reactivity in the lower atmosphere to determine whether this contribution is significant.

Physical Properties. Acetone is a volatile and flammable organic chemical.

Note: Acetone was removed from the list of TRI chemicals on June 16, 1995 (60 FR 31643) and will not be reported for 1994 or subsequent years.

Freon 113 (Trichlorotrifluoroethane)

Toxicity. No adverse human health effects are expected from ambient exposure to Freon 113. Inhalation of high concentrations of Freon 113 causes some deterioration of psychomotor performance (loss of ability to concentrate and a mild lethargy), and an irregular heartbeat. Chronic exposure to Freon 113 caused reversible weakness, pain, and tingling in the legs of one occupationally-exposed woman. There is some evidence of a higher incidence of coronary heart disease among hospital personnel and refrigerant mechanics exposed to fluorocarbons. Exposure to high concentrations of Freon 113 may cause eye and throat irritation.

Fluorocarbons are, however, considerably less toxic than the process materials used in their manufacture (e.g., chlorine). In addition, under certain conditions, fluorocarbon vapors may decompose on contact with flames or hot surfaces, creating the potential hazard of inhalation of toxic decomposition products.

Populations at increased risk from exposure to Freon 113 include people with existing skin disorders, and people with a history of cardiac arrhythmias.

The most significant toxic effect associated with Freon 113 is its role as a potent ozone-depleter. Stratospheric ozone depletion causes an increase in the levels of ultraviolet solar radiation reaching the earth's surface, which in turn is linked to increased incidence of skin cancers, immune system suppression, cataracts, and disruptions in terrestrial and aquatic ecosystems. In addition, increased UV-B radiation is expected to increase photochemical smog, aggravating related health problems in urban and industrialized areas.

<u>Carcinogenicity</u>. There is currently no evidence to suggest that this chemical is carcinogenic.

<u>Environmental Fate</u>. All of the Freon 113 produced is eventually lost as air emissions and builds up in the atmosphere. If released on land, Freon 113 will leach into the ground and volatilize from the soil surface. No degradative processes are known to occur in the soil. Freon 113 is not very water soluble and is removed rapidly from water via volatilization. Chemical hydrolysis, bioaccumulation and adsorption to sediments are not significant fate processes in water.

Freon 113 is extremely stable in the lower atmosphere and will disperse over the globe and diffuse slowly into the stratosphere where it will be lost by photolysis. In this process, chlorine atoms are released that attack ozone.

Glycol Ethers

Due to data limitations, data on diethylene glycol (glycol ether) are used to represent all glycol ethers.

<u>Toxicity</u>. Diethylene glycol is only a hazard to human health if concentrated vapors are generated through heating or vigorous agitation or if appreciable skin contact or ingestion occurs over an

extended period of time. Under normal occupational and ambient exposures, diethylene glycol is low in oral toxicity, is not irritating to the eyes or skin, is not readily absorbed through the skin, and has a low vapor pressure so that toxic concentrations of the vapor can not occur in the air at room temperatures.

At high levels of exposure, diethylene glycol causes central nervous depression and liver and kidney damage. Symptoms of moderate 0 diethylene glycol poisoning include nausea, vomiting, headache, diarrhea, abdominal pain, and damage to the pulmonary and cardiovascular systems. Sulfanilamide in diethylene glycol was once used therapeutically against bacterial infection; it was withdrawn from the market after causing over 100 deaths from acute kidney failure.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Diethylene glycol is a water-soluble, volatile organic chemical. It may enter the environment in liquid form via petrochemical plant effluents or as an unburned gas from combustion sources. Diethylene glycol typically does not occur in sufficient concentrations to pose a hazard to human health.

Methanol

Toxicity. Methanol is readily absorbed from the gastrointestinal tract and the respiratory tract, and is toxic to humans in moderate to high doses. In the body, methanol is converted into formaldehyde and formic acid. Methanol is excreted as formic acid. Observed toxic effects at high dose levels generally include central nervous system damage and blindness. Long-term exposure to high levels of methanol via inhalation cause liver and blood damage in animals.

Ecologically, methanol is expected to have low toxicity to aquatic organisms. Concentrations lethal to half the organisms of a test population are expected to exceed 1 mg methanol per liter water. Methanol is not likely to persist in water or to bioaccumulate in aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Liquid methanol is likely to evaporate when left exposed. Methanol reacts in air to produce formaldehyde which contributes to the formation of air pollutants. In the atmosphere it can react with other atmospheric chemicals or be washed out by rain. Methanol is readily degraded by microorganisms in soils and surface waters.

Physical Properties. Methanol is highly flammable.

Methylene Chloride (Dichloromethane)

Toxicity. Short-term exposure to dichloromethane (DCM) is associated with central nervous system effects, including headache, giddiness, stupor, irritability, and numbness and tingling in the limbs. More severe neurological effects are reported from longer-term exposure, apparently due to increased carbon monoxide in the blood from the break down of DCM. Contact with DCM causes irritation of the eyes, skin, and respiratory tract.

Occupational exposure to DCM has also been linked to increased incidence of spontaneous abortions in women. Acute damage to the eyes and upper respiratory tract, unconsciousness, and death were reported in workers exposed to high concentrations of DCM. Phosgene (a degradation product of DCM) poisoning has been reported to occur in several cases where DCM was used in the presence of an open fire.

Populations at special risk from exposure to DCM include obese people (due to accumulation of DCM in fat), and people with impaired cardiovascular systems.

Carcinogenicity. DCM is a probable human carcinogen via both oral and inhalation exposure, based on inadequate human data and sufficient evidence in animals.

Environmental Fate. When spilled on land, DCM is rapidly lost from the soil surface through volatilization. The remainder leaches through the subsoil into the groundwater.

Biodegradation is possible in natural waters but will probably be very slow compared with evaporation. Little is known about bioconcentration in aquatic organisms or adsorption to sediments but these are not likely to be significant processes. Hydrolysis is not an important process under normal environmental conditions.

DCM released into the atmosphere degrades via contact with other gases with a half-life of several months. A small fraction of the chemical diffuses to the stratosphere where it rapidly degrades through exposure to ultraviolet radiation and contact with chlorine ions. Being a moderately soluble chemical, DCM is expected to partially return to earth in rain.

Methyl Ethyl Ketone

Toxicity. Breathing moderate amounts of methyl ethyl ketone (MEK) for short periods of time can cause adverse effects on the nervous system ranging from headaches, dizziness, nausea, and numbness in the fingers and toes to unconsciousness. Its vapors are irritating to the skin, eyes, nose, and throat and can damage the eyes. Repeated exposure to moderate to high amounts may cause liver and kidney effects.

Carcinogenicity. No agreement exists over the carcinogenicity of MEK. One source believes MEK is a possible carcinogen in humans based on limited animal evidence. Other sources believe that there is insufficient evidence to make any statements about possible carcinogenicity.

Environmental Fate. Most of the MEK released to the environment will end up in the atmosphere. MEK can contribute to the formation of air pollutants in the lower atmosphere. It can be degraded by microorganisms living in water and soil.

Physical Properties. Methyl ethyl ketone is a flammable liquid.

Sulfuric Acid

Toxicity. Concentrated sulfuric acid is corrosive. In its aerosol form, sulfuric acid has been implicated in causing and exacerbating a variety of respiratory ailments.

Ecologically, accidental releases of solution forms of sulfuric acid may adversely affect aquatic life by inducing a transient lowering of the pH (i.e., increasing the acidity) of surface waters. In addition, sulfuric acid in its aerosol form is also a component of acid rain. Acid rain can cause serious damage to crops and forests.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Releases of sulfuric acid to surface waters and soils will be neutralized to an extent due to the buffering capacities of both systems. The extent of these reactions will depend on the characteristics of the specific environment.

In the atmosphere, aerosol forms of sulfuric acid contribute to acid rain. These aerosol forms can travel large distances from the point of release before the acid is deposited on land and surface waters in the form of rain.

Toluene

Toxicity. Inhalation or ingestion of toluene can cause headaches, confusion, weakness, and memory loss. Toluene may also affect the way the kidneys and liver function.

Reactions of toluene (see environmental fate) in the atmosphere contribute to the formation of ozone in the lower atmosphere. Ozone can affect the respiratory system, especially in sensitive individuals such as asthma or allergy sufferers.

Some studies have shown that unborn animals were harmed when high levels of toluene were inhaled by their mothers, although the same effects were not seen when the mothers were fed large quantities of toluene. Note that these results may reflect similar difficulties in humans.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. The majority of releases of toluene to land and water will evaporate. Toluene may also be degraded by microorganisms. Once volatilized, toluene in the lower atmosphere will react with other atmospheric components contributing to the formation of ground-level ozone and other air pollutants.

Physical Properties. Toluene is a volatile organic chemical.

Trichloroethylene

Toxicity. Trichloroethylene was once used as an anesthetic, though its use caused several fatalities due to liver failure. Short term inhalation exposure to high levels of trichloroethylene may cause rapid coma followed by eventual death from liver, kidney, or heart failure. Short-term exposure to lower concentrations of trichloroethylene causes eye, skin, and respiratory tract irritation. Ingestion causes a burning sensation in the mouth, nausea, vomiting and abdominal pain. Delayed effects from short-term trichloroethylene poisoning include liver and kidney lesions, reversible nerve degeneration, and psychic disturbances. Long-term exposure can produce headache, dizziness, weight loss, nerve damage, heart damage, nausea, fatigue, insomnia, visual impairment, mood perturbation, sexual problems, dermatitis, and rarely jaundice. Degradation products of trichloroethylene (particularly phosgene) may cause rapid death due to respiratory collapse.

Carcinogenicity. Trichloroethylene is a probable human carcinogen via both oral and inhalation exposure, based on limited human evidence and sufficient animal evidence.

Environmental Fate. Trichloroethylene breaks down slowly in water in the presence of sunlight and bioconcentrates moderately in aquatic organisms. The main removal of trichloroethylene from water is via rapid evaporation.

Trichloroethylene does not photodegrade in the atmosphere, though it breaks down quickly under smog conditions, forming other pollutants such as phosgene, dichloroacetyl chloride, and formyl chloride. In addition, trichloroethylene vapors may be decomposed to toxic levels of phosgene in the presence of an intense heat source such as an open arc welder.

When spilled on the land, trichloroethylene rapidly volatilizes from surface soils. The remaining chemical leaches through the soil to groundwater.

Xylene (Mixed Isomers)

Toxicity. Xylenes are rapidly absorbed into the body after inhalation, ingestion, or skin contact. Short-term exposure of humans to high levels of xylenes can cause irritation of the skin, eyes, nose, and throat, difficulty in breathing, impaired lung function, impaired memory, and possible changes in the liver and kidneys. Both short- and long-term exposure to high concentrations can cause effects such as headaches, dizziness, confusion, and lack of muscle coordination. Reactions of xylenes (see environmental fate) in the atmosphere contribute to the formation of ozone in the lower atmosphere. Ozone can affect the respiratory system, especially in sensitive individuals such as asthma or allergy sufferers.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. The majority of releases to land and water will quickly evaporate, although some degradation by microorganisms will occur.

Xylenes are moderately mobile in soils and may leach into groundwater, where they may persist for several years.

Xylenes are volatile organic chemicals. As such, xylenes in the lower atmosphere will react with other atmospheric components, contributing to the formation of ground-level ozone and other air pollutants.

IV.C. Other Data Sources

The Aerometric Information Retrieval System (AIRS) contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. With the exception of volatile organic compounds (VOCs), there is little overlap with the TRI chemicals reported above. Exhibit 31 summarizes annual releases of carbon monoxide (CO), nitrogen dioxide (NO_2), particulate matter of 10 microns or less (PM10), total particulates (PT), sulfur dioxide (SO_2), and volatile organic compounds (VOCs).

Exhibit 31
Pollutant Releases (Short Tons/Years)

Industry	CO	NO_2	PM_{10}	PT	SO_2	VOC
U.S. Total	97,208,000	23,402,000	45,489,000	7,836,000	21,888,000	23,312,000
Metal Mining	5,391	28,583	39,359	140,052	84,222	1,283
Nonmetal Mining	4,525	28,804	59,305	167,948	24,129	1,736
Lumber and Wood Products	123,756	42,658	14,135	63,761	9,149	41,423
Wood Furniture and Fixtures	2,069	2,981	2,165	3,178	1,606	59,426
Pulp and Paper	624,291	394,448	35,579	113,571	341,002	96,875
Printing	8,463	4,915	399	1,031	1,728	101,537
Inorganic Chemicals	166,147	108,575	4,107	39,082	182,189	52,091
Organic Chemicals	146,947	236,826	26,493	44,860	132,459	201,888
Petroleum Refining	419,311	380,641	18,787	36,877	648,153	309,058
Rubber and Misc. Plastic Products	2,090	11,914	2,407	5,355	29,364	140,741
Stone, Clay, Glass, and Concrete	58,043	338,482	74,623	171,853	339,216	30,262
Iron and Steel	1,518,642	138,985	42,368	83,017	238,268	82,292
Nonferrous Metals	448,758	55,658	20,074	22,490	373,007	27,375
Fabricated Metals	3,851	16,424	1,185	3,136	4,019	102,186
Electronics/ Computer	**367**	**1,129**	**207**	**293**	**453**	**4,854**
Motor Vehicles, Bodies, Parts, and Accessories	35,303	23,725	2,406	12,853	25,462	101,275
Dry Cleaning	101	179	3	28	152	7,310

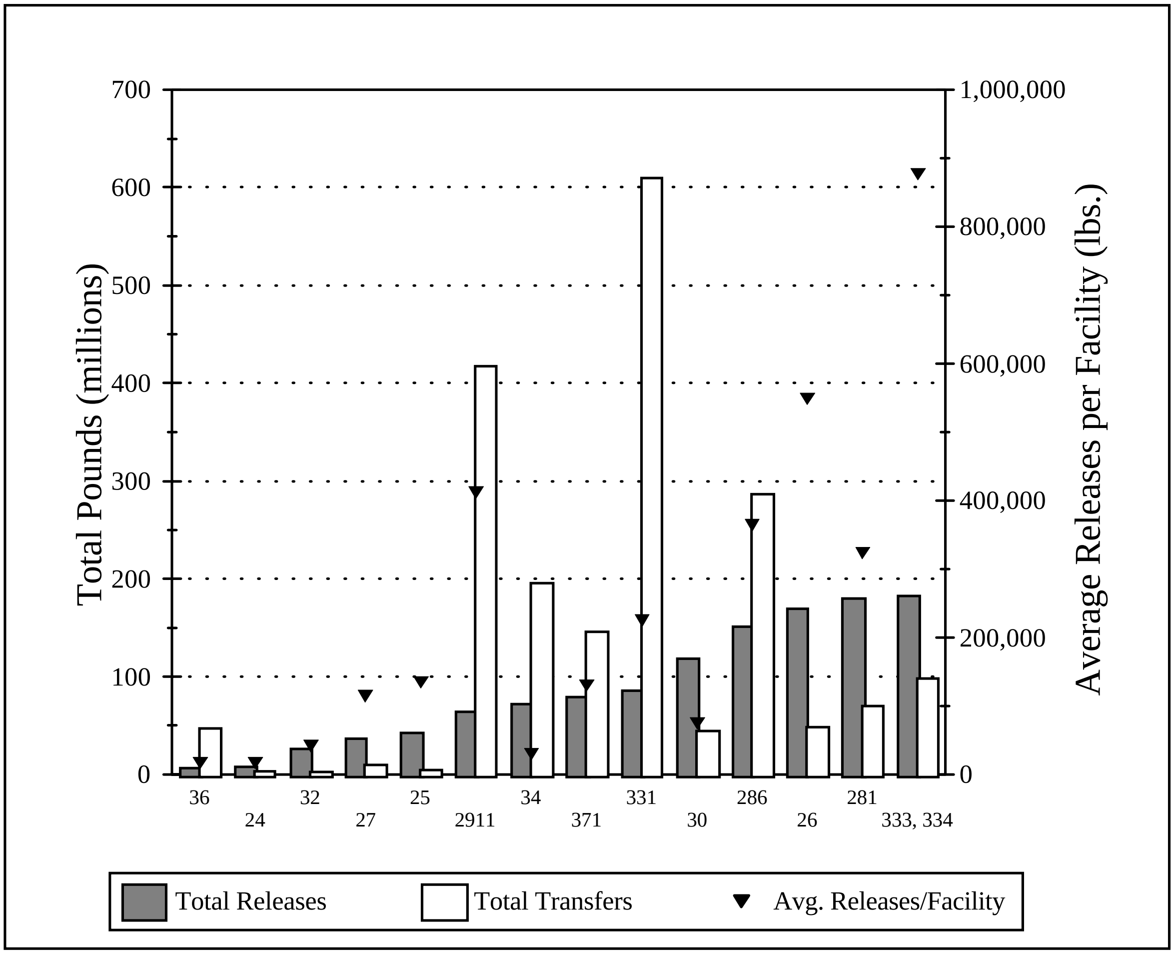
Source: U.S. EPA Office of Air and Radiation, AIRS Database, May 1995.

IV.D. Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers within each sector profiled under this project. Please note that the following table does not contain releases and transfers for industrial categories that are not included in this project, and thus cannot be used to draw conclusions regarding the total release and transfer amounts that are reported to TRI. Similar information is available within the annual TRI Public Data Release book.

Exhibit 32 is a graphical representation of a summary of the 1993 TRI data for the electronics/computer industry and the other sectors profiled in separate notebooks. The bar graph presents the total TRI releases and total transfers on the left axis and the triangle points show the average releases per facility on the right axis. Industry sectors are presented in the order of increasing total TRI releases. The graph is based on the data shown in Exhibit 33 and is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors. The reader should note, however, that differences in the proportion of facilities captured by TRI exist between industry sectors. This can be a factor of poor SIC matching and relative differences in the number of facilities reporting to TRI from the various sectors. In the case of electronics/computer industry, the 1993 TRI data presented here covers 406 facilities. These facilities listed SIC 36 Electronics/Computer Industry as a primary SIC code.

Exhibit 32-bar graph
Summary of 1993 TRI Data: Releases and Transfers by Industry



SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
36	Electronic Equipment and Components	2911	Petroleum Refining	286	Organic Chemical Mfg.
24	Lumber and Wood Products	34	Fabricated Metals	26	Pulp and Paper
32	Stone, Clay, and Concrete	371	Motor Vehicles, Bodies, Parts, and Accessories	281	Inorganic Chemical Mfg.
27	Printing	331	Iron and Steel	333,334	Nonferrous Metals
25	Wood Furniture and Fixtures	30	Rubber and Misc. Plastics		

Exhibit 33-Comparative TRI Table
Toxic Release Inventory Data for Selected Industries

Industry Sector	SIC Range	# TRI Facilities	Releases		Transfers		Total Releases + Transfers (10^6 pounds)	Average Release+ Transfers per Facility (pounds)
			Total Releases (10^6 pounds)	Average Releases per Facility (pounds)	1993 Total (10^6 pounds)	Average Transfers per Facility (pounds)		
Stone, Clay, and Concrete	32	634	26.6	41,895	2.2	3,500	28.2	46,000
Lumber and Wood Products	24	491	8.4	17,036	3.5	7,228	11.9	24,000
Furniture and Fixtures	25	313	42.2	134,883	4.2	13,455	46.4	148,000
Printing	2711-2789	318	36.5	115,000	10.2	732,000	46.7	147,000
Electronics/Computers	36	406	6.7	16,520	47.1	115,917	53.7	133,000
Rubber and Misc. Plastics	30	1,579	118.4	74,986	45.0	28,537	163.4	104,000
Motor Vehicle, Bodies, Parts and Accessories	371	609	79.3	130,158	145.5	238,938	224.8	369,000
Pulp and paper	2611-2631	309	169.7	549,000	48.4	157,080	218.1	706,000
Inorganic Chem. Mfg.	2812-2819	555	179.6	324,000	70.0	126,000	249.7	450,000
Petroleum Refining	2911	156	64.3	412,000	417.5	2,676,000	481.9	3,088,000
Fabricated Metals	34	2,363	72.0	30,476	195.7	82,802	267.7	123,000
Iron and Steel	3312-3313 3321-3325	381	85.8	225,000	609.5	1,600,000	695.3	1,825,000
Nonferrous Metals	**333, 334**	**208**	**182.5**	**877,269**	**98.2**	**472,335**	**280.7**	**1,349,000**
Organic Chemical Mfg.	2861-2869	417	151.6	364,000	286.7	688,000	438.4	1,052,000
Metal Mining	10	Industry sector not subject to TRI reporting						
Nonmetal Mining	14	Industry sector not subject to TRI reporting						
Dry Cleaning	7215, 7216, 7218	Industry sector not subject to TRI reporting						

Source: U.S. EPA, Toxics Release Inventory Database, 1993.

V. POLLUTION PREVENTION OPPORTUNITIES

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimizing environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitution of toxic chemicals. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the electronics/computer industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. When possible, this section provides information from real activities that can, or are being implemented by this sector -- including a discussion of associated costs, time frames, and expected rates of return. This section provides summary information from activities that may be, or are being implemented by this sector. When possible, information is provided that gives the context in which the techniques can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects, air, land, and water pollutant releases.

Pollution prevention (sometimes referred to as source reduction) is the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. Pollution prevention includes practices that reduce the use of hazardous materials, energy, water or other resources, and practices that protect natural resources through conservation or more efficient use.

EPA is promoting pollution prevention because it is often the most cost-effective option to reduce pollution and the environmental and health risks associated with pollution. Pollution prevention is often cost effective because it may reduce raw material losses; reduce reliance on expensive "end-of-pipe" treatment technologies and disposal practices; conserve energy, water, chemicals, and other inputs; and reduce the potential liability associated with waste generation. Pollution prevention is environmentally desirable for these very same reasons: pollution itself is reduced at the source while resources are conserved.

V.A. Identification of Pollution Prevention Activities in Use

The electronics and computer industries have participated in many pollution prevention projects and have been the focus of many case studies. Pollution prevention techniques and processes used by these industries can be grouped into four general categories:

- Process or equipment modification
- Raw material substitution or elimination
- Waste segregation / separation / preparation
- Recycling.

Each of these categories is briefly discussed below. Refer to Section V.B. for a list of specific pollution prevention techniques and associated costs, savings, and other information.

Process or equipment modification is used to reduce the amount of waste generated. For example, manufacturers can change equipment or processes to: enhance water conservation by installation of countercurrent rinsing systems; reduce alkaline and acid concentration in tanks by installing a pH controller; and reduce drag-out by decreasing the withdrawal rate of parts from plating tanks.

Raw material substitution or elimination is the replacement of existing raw materials with other materials that produce less waste, or a non-toxic waste. Examples include substituting non-cyanide solution for a sodium cyanide solution in copper plating baths and replacing hexavalent chromium with trivalent chrome plating system.

Waste segregation/separation/preparation involves avoiding the mixture of different types of wastes and avoiding the mixture of hazardous wastes with non-hazardous wastes. This makes the recovery of hazardous wastes easier by minimizing the number of different hazardous constituents in a given waste stream. Also, it prevents the contamination of non-hazardous wastes. A specific example is segregation of wastewater sludge by metal contaminants.

Recycling is the use or reuse of a waste as an ingredient or feedstock in the production process on-site. Examples of recycling include:

recovering copper during the etching processes, recovering lead and tin from printed wiring boards, and installing a closed-loop recycling system to reuse freon (which is being phased-out) and reduce/reuse water consumption.

V.B. Pollution Prevention Techniques for the Electronics/Computer Industry

This section provides examples of pollution prevention techniques used in the electronics/computer industry. Much of the information provided in this section is from the following EPA offices/programs: the Common Sense Initiative (CSI), EPA's DfE Program, the Pollution Prevention Information Center, the Office of Environmental Engineering and Technology Demonstration, the Office of Pollution Prevention, and Office of Research and Development. Other sources include the Oregon Department of Environmental Quality and the California Department of Toxic Substances and Control. Where available, cost information is provided. However, source documents did not always provide cost information.

V.B.1. Examples of Source Reduction and Recycling Options for Electroplating Operations

Technique - Process or Equipment Modification

Option 1 - Modify rinsing methods to control drag-out by:
- Increasing bath temperature
- Decreasing withdrawal rate of parts from plating bath
- Increasing drip time over solution tanks; racking parts to avoid cupping solution within part cavities
- Shaking, vibrating, or passing the parts through an air knife, angling drain boards between tanks
- Using wetting agents to decrease surface tension in tank.

Contact: Braun Intertec Environmental, Inc., and MN Office of Waste Management (612) 649-5750.

Option 2 - Utilize water conservation methods including:
- Flow restrictors on flowing rinses
- Counter current rinsing systems
- Fog or spray rinsing
- Reactive rinsing
- Purified or softened water
- Dead rinses
- Conductivity controllers
- Agitation to assure adequate rinsing and homogeneity in rinse tank
- Flow control valves.

Contact: Braun Intertec Environmental, Inc., and MN Office of Waste Management (612) 649-5750.

Option 3 - Implement counter flow rinsing and cascade rinsing systems to conserve consumption of water. **Costs and Savings:** Costs: $75,000 to upgrade existing equipment and purchasing new and used equipment. Waste Savings/Reduction: reduce water use and wastewater treatment costs. **Contact:** Eastside Plating and OR Department of Environmental Quality (800) 452-4011**.**

Option 4 - Use drip bars to reduce drag-out. **Costs and Savings:** Capital Investment: $100/tank. Savings: $600/year. **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 5 - Use drain boards between tanks to reduce generations of drag-out. **Costs and Savings:** Capital Investment: $25/tank. Savings: $450/year . **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 6 - Install racking to reduce generations of drag-out. **Costs and Savings:** Capital Investment: zero dollars. Operating Costs: minimal. Savings: $600/year. **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 7 - Employ drag out recovery tanks to reduce generations of drag-out. **Costs and Savings:** Capital Investment: $500/tank. Savings: $4,700/year. **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 8 - Install counter-current rinsing operation to reduce water consumption. **Costs and Savings:** Capital Investment: $1,800-2,300. No direct costs. Savings: $1,350/year. Waste Savings/Reductions: reduce water use by 90-99%. **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 9 - Redesign rinse tank to reduce water conservation. **Costs and Savings:** Capital Investment: $100. No direct costs. Savings: $750/year. **Contact:** NC Department of Natural Resources & Community Development, Gary Hunt (919) 733-7015.

Option 10 - Increase parts drainage time to reduce drag-out. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 11 - Regenerate plating bath by activated carbon filtration to remove built up organic contaminants. **Costs and Savings:** Capital Investment: $9,192. Costs: $7,973/year. Savings: $122,420/year. Waste Savings/Reduction: 10,800 gallons/year. Reduce volume of plating baths disposed and requirements for virgin chemicals. **Contact:** EPA Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, Harry Freeman.

Option 12 - Install pH controller to reduce the alkaline and acid concentrations in tanks. **Contact:** Securus, Inc., DBA Hubbard Enterprises.

Option 13 - Install atmospheric evaporator to reduce metal concentrations. **Contact:** Securus, Inc., DBA Hubbard Enterprises.

Option 14 - Install process (e.g., CALFRAN) to reduce pressure to vaporize water at cooler temperatures and recycle water by condensing the vapors in another container, thus concentrating and precipitating solutes out. **Costs and Savings:** Waste Savings/Reduction: reduce volume and quantity of aqueous waste solutions by recovering pure water. **Contact**: CALFRAN International, Inc., (413) 525-4957.

Option 15- Use reactive rinsing and multiple drag-out baths. **Costs and Savings:** Savings: Reduce cost of treating spent process baths and rinsewaters. Waste Savings/Reduction: increase lifetime of process baths and reduce the quantity or rinsewater requiring treatment. **Contact:** SAIC, Edward R. Saltzberg.

Option 16 - Improve control of water level in rinse tanks, improve sludge separation, and enhance recycling of supernatant to the process by aerating the sludge. **Costs and Savings:** Savings: $2,000/year. Waste Savings/Reduction: reduce sludge generation by 32%. **Contact:** NJ Hazardous Waste Facilities Siting Commission, Hazardous Waste Source Reduction and Recycling Task Force.

Option 17 - Install system (e.g., Low Solids Fluxer) that applies flux to printed wiring boards, leaving little residue and eliminates the need for cleaning CFCs. **Costs and Savings:** Waste Savings/Reduction: reduce CFC emissions over 50%. **Contact:** AT&T Bell Laboratories, Princeton, NJ.

Option 18 - Install ion exchange system to reduce generation of drag-out. **Costs and Savings:** Savings: $1,900/year. Capital Investment: $78,000. Operating Costs: $3,200/year. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 19 - Employ reverse osmosis system to reduce generation of drag-out. **Costs and Savings:** Savings: $40,000/year. Capital Investment: $62,000. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 20 - Use electrolytic metal recovery to reduce generation of drag-out. **Costs and Savings:** Capital Investment: $1,000. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 21- Utilize electrodialysis to reduce generation of drag-out. **Costs and Savings:** Capital Investment: $50,000. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 22 - Implement evaporative recovery to reduce generation of drag-out. **Costs and Savings:** Capital Investment: $2,500. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 23- Implement the electrodialysis reversal process for metal salts in wastewater. **Costs and Savings**: Savings: $40,100/year in operating costs. **Contact:** Ionics, Inc., Separations Technology Division.

Technique - Raw Material Substitution

Option 1 - Substitute cyanide plating solutions with alkaline zinc, acid zinc, acid sulfate copper, pyrophosphate copper, alkaline copper, copper fluoborate, electroless nickel, ammonium silver, halide silver, methanesulfonate-potassium iodide silver, amino or thio complex silver, no free cyanide silver, cadmium chloride, cadmium sulfate, cadmium fluoborate, cadmium perchlorate, gold sulfite, and cobalt harden gold. **Contact:** Braun Intertec Environmental, Inc. and MN Office of Waste Management (612) 649-5750.

Option 2 - Substitute sodium bisulfite and sulfuric acid for ferrous sulfate in order to oxidize chromic acid wastes, and substitute gaseous chlorine for liquid chlorine in order to reduce cyanide reduction. **Costs and Savings:** Savings: $300,000/year. Waste Savings/Reduction: reduces feedstock by 50%. **Contact:** Eastside Plating and OR Department of Environmental Quality (800) 452-4011.

Option 3 - Replace hexavalent chromium with trivalent chromium plating systems. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 4 - Replace cyanide with non-cyanide baths. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 5 - Replace conventional chelating agents such as tartarates, phosphates, EDTA, and ammonia with sodium sulfides and iron sulfates in removing metal from rinse water which reduces the amount of waste generated from precipitation of metals from aqueous wastestreams. **Costs and Savings:** Costs: $178,830/year. Savings: $382,995/year. Waste Savings/Reduction: 496 tons of sludge/year. **Contact:** Tyndall Air Force Base, FL, Charles Carpenter (904) 283-2942; EG & G, Dan Sucia, Penny Wilcoff, & John Beller (208) 526-1149.

Option 6 - Replace methylene chloride, 1,1,1-trichloroethane, and perchloroethylene (solvent-based photochemical coatings) with aqueous base coating of 1% sodium carbonate. **Costs and Savings:** Waste Savings/Reduction: reduce solvent use by 60 tons/year. **Contact:** American Etching and Manufacturing, Pacoima, CA.

Option 7 - Replace methanol with nonflammable alkaline cleaners. **Costs and Savings:** Waste Savings/Reduction: eliminate 32 tons/year of flammable methyl alcohol. **Contact:** American Etching and Manufacturing, Pacoima, CA.

Option 8 - Substitute a non-cyanide for a sodium cyanide solution used in copper plating baths. **Costs and Savings:** Waste Savings/Reduction: reduce 7,630 pounds/year. **Contact:** Highland Plating Company, Los Angeles, CA.

Technique - Recycling

Option 1 - Send drag-out waste to another company for waste exchange. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 2 - Reuse rinse water. **Costs and Savings:** Savings: $1,500/year. Capital Investment: $340/tank. No direct costs. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 3- Reuse drag-out waste back into process tank. **Contact:** NC Department of Natural Resources & Community Development; Pollution Prevention Pays Program Gary Hunt (919) 733-7015.

Option 4- Recover process chemicals with fog rinsing parts over plating bath. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 5 - Evaporate and concentrate rinse baths for recycling. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 6 - Use ion exchange and electrowinning, reverse osmosis, and thermal bonding when possible. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 7 - Use sludge slagging techniques to extract and recycle metals. **Costs and Savings:** Capital Investment: $80,000 for 80 tons/year and $400,000 for 1,000 tons/year. Operating Costs: $18,000 per year for an 80 ton facility. Waste Savings/Reduction: reduces volume of waste by 94%. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 8 - Use hydrometallurgical processes to extract metals from sludge. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 9- Convert sludge to smelter feed. **Contact:** City of Los Angeles Hazardous and Toxic Material Project; Board of Public Works (213) 237-1209.

Option 10 - Remove and recover lead and tin from boards by electrolysis or chemical precipitation. **Contact:** Control Data Corporation and MN Office of Waste Management (612) 649-5750.

Option 11 - Install a closed loop batch treatment system for rinsewater to reduce water use and waste volume. **Costs and Savings:** Savings: $58,460/year. Capital Investment: $210,000. Waste Savings/Reduction: 40,000 gallons/year (40%). **Contact:** Pioneer Metal Finishing, Inc., Harry Desoi (609) 694-0400.

Option 12 - Install an electrolytic cell which recovers 92 percent of dissolved copper in drag-out rinses and atmospheric evaporator to recover 95 percent of chromatic acid drag-out, and recycle it into chromic acid etch line. **Contact:** Digital Equipment Corporation and Lancy International Consulting Firm, William McLay (412) 452-9360.

Option 13- Oxidize cyanide and remove metallic copper to reduce metal concentrations. **Contact:** Securus, Inc., DBA Hubbard Enterprises.

V.B.2. Examples of Source Reduction and Recycling Options for Etching Operations

Technique - Raw Material Substitution

Option 1 - Substitute sodium persulfate etchant (acid etch solution) with hydrogen peroxide/ sulfuric acid. **Contact**: ADC Products and MnTAP (612) 625-4949.

Technique - Recycling

Option 1 - Recover copper by electrolytic processes. **Contact**: ADC Products and MnTAP (612) 625-4949.

V.B.3. Examples of Source Reduction and Recycling Options for Semiconductor Manufacturing

Technique - Process or Equipment Modification

Option 1 - Install a system (e.g., the CALFRAN process) to reduce pressure to vaporize water at cooler temperatures, recycle water by condensing the vapors in another container, and concentrate and precipitate solutes. **Costs and Savings**: Waste Savings/Reduction: reduce volume and quantity of aqueous waste solutions by recovering pure water. **Contact**: CALFRAN International, Inc. Springfield, MA 01101, Val Partyka (413) 525-4957.

Option 2 - Reduce chrome waste generation by :

- Installing a rain cover over on outdoor tanks to reduce chrome waste
- Treating on-site with caustics and sodium bisulfite to reduce chrome VI liquid to chrome III sludge
- Repairing water leaks in process rinse tank to reduce chrome waste.

Costs and Savings: Capital Investment: $30,000 for the rain cover, pipe repairs, and on-site treatment system. Waste Savings/Reduction: Savings: $15,000/year in disposal costs, and reduce 95% of chrome wastes from 6,000 gallons to two or three drums generated per quarter. **Contact**: Wacker Siltronic Corporation and University of MN (612) 625-4949.

Technique - Raw Material Substitution

Option 1 - Replace chlorinated solvent baths with a non-hazardous product to reduce, and later, eliminate use of chlorinated solvents. **Costs and Savings**: Waste Savings/Reduction: reduce chlorinated solvent use by 93%, and then completely eliminate the use of the chemical. **Contact**: Wacker Siltronic Corporation and University of MN (612) 625-4949.

Technique - Recycling

Option 1 - Convert an open-top still into a closed loop system to recycle Freon 113. **Costs and Savings**: Costs: $20,000. Waste Savings/Reduction: $57,000/year in disposal and feedstock costs, and reduce waste volume by 85%. **Contact**: Wacker Siltronic Corporation and University of MN (612) 625-4949.

Option 2 - Use Athens system to reprocess sulfuric acid generated during wafer fabrication operations. The acid is heated to boil off water and other impurities, purified through distillation, and pumped back into wet stations to continue wafer processing. Costs and savings: Annual savings/Reductions: $2.9 million from not purchasing sulfuric acid and 28% reduction in sulfuric acid generated in 1993. Contact: Intel or Alameda Instruments, Inc. and Athens Corporation (manufacturers of this type of equipment).

V.B.4. Examples of Source Reduction and Recycling Options for Printed Wiring Board Manufacturing

V.B.4.a. General Operations

Technique - Process or Equipment Modification

Option 1 - Modify sludge pretreatment processes by:
- Adding flow control valves
- Installing metal recovery equipment
- Adding of deionization system

Costs and Savings: Costs: lower chemical treatment costs. Waste Savings/Reduction: $90,000 in disposal costs. **Contact**: Unisys Corporation and MnTAP (612) 625-4949.

Option 2 - Redesign board during board assembly. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Option 3 - Install a system (e.g., CALFRAN process) to reduce pressure to vaporize water at cooler temperatures, recycle water by condensing the vapors in another container, concentrate and precipitate solutes. **Costs and Savings**: Waste Savings/Reduction: reduce volume and quantity of aqueous waste solutions by recovering pure water. **Contact**: CALFRAN International, Inc. Springfield, MA 01101, Val Partyka (413) 525-4957.

Option 4 - Alternatives to wet chemical processes include:
- Mechanical cleaning as an alternative to chemical methods;
- Process efficiency improvements for applying photopolymers, printing, and developing;
- Alternative processes for connecting the PWB layers together; and
- Alternatives to lead-based soldering involving the use of lasers, reactive gases, or ultrasonics.

Contact: EPA CSI.

Technique - Raw Material Substitution

Option 1 - Substitute semiaqueous or aqueous photoresist for TCA and methylene chloride during board manufacturing. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Option 2 - Substitute no-clean fluxes for CFC 113 and TCA during board assembly. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Option 3 - Substitute aqueous clean fluxes for CFC 113 and TCA during board assembly. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Option 4 - Substitute semi-aqueous cleaning materials for CFC 113 and TCA during board assembly. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Option 5 - Substitute other solvents for CFC 113 and TCA during board assembly. **Contact**: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

Technique - Waste Segregation/Separation/Preparation

Option 1 - Segregate wastewater sludge to prepare for metal recovery. **Contact**: Unisys Corporation and MnTAP (612) 625-4949.

Technique - Recycling

Option 1 - Remove and recover lead and tin from boards by electrolysis-chemical precipitation. **Contact**: Control Data Corporation and MN Office of Waste Management (612) 649-5750.

V.B.4.b. Cleaning Operations

Technique - Process or Equipment Modification

Option 1 - Install a system (e.g., Low Solids Fluxer {LSF}) which applies flux to printed wiring boards, leaves little residue, and eliminates the need for cleaning with CFCs. **Costs and Savings**: Waste Savings/Reduction: reduce CFC emissions over 50%. **Contact**: AT&T Bell Laboratories, Princeton, NJ.

Technique - Raw Material Substitution

Option 1 - Substitute for CFC 113 used in defluxing with:
- Fully aqueous system using water soluble fluxes
- Aqueous system using saponifiers to remove rosin based fluxes
- Semi-aqueous system using terpenes as a solvent
- Hydrogenated CFCs with chlorinated solvents

Contact: Medtronic Inc. and MN Technical Assistance Program (MnTAP) (612) 627-4848 Maria Scheller.

Option 2 - Substitute CFC 113 used in hand cleaning boards with:
- Blend of HCFC and methanol dispensed from a trigger-grip device that limits the amount of solvent lost to the atmosphere

Contact: Medtronic Inc. and MN Technical Assistance Program (MnTAP) (612) 627-4848 Maria Scheller.

V.B.4.c. Electroplating Operations

Technique - Raw Material Substitution

Option 1 - During tin-lead electroplating process, substitute fluoboric acid with:
- Organic sulfonic acid (OSA) plating
- Acid tin sulfate plating which eliminates lead use
- Hot air leveling
- Conductive, solderable polymer solutions

Contact: Capsule Environmental Engineering Inc. and MN Office of Waste Management (612) 649-5750.

V.B.5. Examples of Source Reduction and Recycling Options for Cathode Ray Tube Manufacturing

Technique - Process or Equipment Modification

Option 1- Reduce building of contamination in bath solutions by increasing process efficiency (e.g., implement ion exchange technology). **Contact:** EPA CSI.

Technique - Raw Material Substitution

Option 1 - Replace lacquer in panel preparation with a wax-like material similar to floor wax. It provides the necessary coating without a high VOC content. One potential drawback, however, is the use of ammonia. **Contact:** EPA CSI.

Option 2 - Replace Freon as a cleaning agent for removing particulate contaminants from panel mask frames with air blow cleaning and an aqueous wash (nearly all CRT manufacturers have implemented this change). **Contact:** EPA CSI.

Option 3 - Identify less hazardous cleaning chemicals, such as isopropyl alcohol, as alternatives to acetone or chlorinated solvents in maintenance and cleanup processes. **Contact:** EPA CSI.

Option 4 - Find substitutes for chromium-based photoresists. **Contact:** EPA CSI.

Option 5 - Identify alternatives to the lead-based frit used in sealing the funnel with the panel mask. **Contact:** EPA CSI.

Technique - Recycling

Option 1 - Regenerate acids for glass cleaning and frit removal in waste glass recovery operations using existing technologies and equipment. **Contact:** EPA CSI.

Option 2 - Reclaim and reuse photoresists from one of the panel preparation processes. **Contact:** EPA CSI.

Option 3 - Recover soluble lead generated during the waste glass recovery operation by ion exchange resins. Reuse in lead smelting operations. **Contact:** EPA CSI.

Option 4 - Improve phosphor solution recovery and recycling efficiencies to further reduce discharge of metals to the environment. **Contact:** EPA CSI.

Option 5- Reduce or recover the following:
- Chrome wastes
- Cleaning materials (hydrofluoric acids)
- EP effluent
- Furnaces slag
- Cullet dust
- Fugitive dust
- Refractory brick wastes
- Alcohols

Contact: EPA CSI.

V.C. Pollution Prevention Case Studies

The electronics/computer industry is actively involved in pollution prevention activities, especially for products such as semiconductors and printed wiring boards. Pollution prevention techniques are available and have been implemented successfully for processes such as cleaning, etching, electroplating, and wastewater treatment.

California's *Assessment of the Semiconductor Industry Source Reduction Planning Efforts* provides additional information and case studies on pollution prevention techniques. Eastside Plating, Unisys Corporation, and Wacker Siltronic Corporation are examples of companies with successful pollution prevention programs. The pollution prevention activities employed in these three case studies provided each company with significant savings.

Eastside Plating, Portland, Oregon's oldest and largest electroplating facility, demonstrated that complying with environmental laws and implementing pollution prevention activities is cost effective. Eastside used three major pollution prevention techniques: water conservation, material substitution, and machinery automation and upgrade.

The first activity addressed the challenge of diminishing the use of water. Ninety percent of water required for electroplating is used during the rinsing process (to clean the wafer, end chemical reactions, and prevent contaminants from being released into the next bath). Eastside modified the rinsing process by installing two systems that conserve water: counter flow and cascade rinsing systems. Counter flow rinsing recycles and reuses water throughout a multiple tank system, reducing significantly the volume of water required. Fresh water is only introduced in the last tank of the system. Cascade rinsing also reduces the volume of water required. This system uses one tank with a center divider which allows the water to spill into the other side. During cascade rinsing, the tank is filled and drained slowly and continuously in order to reduce water consumption. Overflow from one tank can be used as the water supply for another compatible rinsing system.

Eastside also reduced chromium and cyanide wastes through material substitution. The reducing agent for chromic acid wastes was changed from ferrous sulfate to bisulfite and sulfuric acid, which reduced the volume of sludge produced. Cyanide wastes are reduced more efficiently with gaseous instead of liquid chlorine.

Finally, three major waste treatment components were upgraded or automated: the cyanide oxidation tank, chromium reduction tank, and the acid/alkali neutralization tank. The goal of automating and upgrading this equipment was to increase efficiency, separate tank flow, and eliminate contamination of acid/alkali neutralization tank. Automated metering equipment was installed and reduced the expensive caustic chemicals required to treat acid wastes by 50 percent. The cyanide and chromic acid oxidation tanks were redesigned as gravity flow systems to equalize flow rate and to eliminate the risks associated with plumbing failure. To prevent cross contamination of the tanks, the plumbing was segregated.

Other important steps taken by Eastside Plating to enhance pollution prevention included collaborating with suppliers on modifications to reaction and neutralization tanks, working with regulators to solve problems, and providing employee education.

The new rinsing systems, materials substitution, and upgrade/ automation of equipment cost Eastside $75,000. Overall, Eastside implemented changes to the operation which has saved the company more than $300,000 annually. In addition, pollution prevention and waste minimization has resulted in a cleaner facility, increased productivity, and a better product.

Unisys is a manufacturer of both large and small computers. In 1986, Unisys implemented pollution prevention/waste minimization techniques associated with the automated copper plating process in its printed circuit board manufacturing plant in Roseville, Minnesota. Unisys worked with Minnesota Technical Assistance Program (MnTAP) to reduce the two to three drums of wastewater treatment sludge produced each day.

MnTAP recommended several changes in the pretreatment process such as: segregation of the wastestreams; addition of flow control valves; installation of metal recovery equipment; and addition of a deionization system. Wastestream segregation involved changing the plumbing to separate the wastestreams containing metal contaminants. Another modification reduced overall water usage through the installation of flow control valves. Metal recovery techniques, such as ion exchange and electrolytic metal recovery, reclaim copper from metal-bearing wastestreams. The deionization systems allow the pretreatment process to operate more efficiently. Ion exchange and electrolytic recovery is enhanced by deionization by removing hard water ions in the process and rinse tanks. The modifications ensure environmental compliance, lower treatment chemical costs, and reduce sludge disposal costs by an estimated $90,000 per year. In addition, the pollution prevention and waste minimization changes have allowed Unisys to expand its plating line.

Wacker Siltronic Corporation, a semiconductor manufacturer, successfully implemented pollution prevention and waste minimization techniques similar to those employed by Unisys and

Eastside. In order to maintain cleanliness in silicon wafer production, Wacker made extensive use of chloride solvent baths. Once the disposal of chlorinated solvent wastes at a Oregon hazardous waste facility was prohibited by Federal regulations, Wacker sought to recycle the solvents. However, the potential liability associated with transporting thousands of gallons of solvents to a recycling facility led Wacker to seek other alternatives. A six month pilot project was first implemented to decrease chlorinated solvent use which resulted in the elimination of 93 percent of Wacker's chlorinated solvent waste. Ultimately, Wacker eliminated completely the use of chlorinated solvents through replacement with non-hazardous cleaning products.

Wacker used to generate 2000 gallons of chrome VI waste each month, which needed to be sent off-site for disposal. Reduction of chrome waste to two to three drums each quarter involved three techniques: installation of a rain cover over the outdoor tanks; on-site treatment of chrome VI waste using caustics and sodium bisulfite; and repairing water leaks in the process rinse tank. The rain cover cost $7,000, but reduced the volume of waste shipments by 25 percent. The new treatment of the chrome VI liquid reduced it to a less hazardous chrome III sludge which can be dried and sent off-site for disposal. Repair of small leaks in the rinse tanks resulted in a 50 percent reduction of wastes. The cover, pipe repairs, and on-site treatment system cost $30,000 and led to a 95 percent reduction of chrome waste as well as annual savings of $15,000. The initial costs were recovered within three years.

A final pollution prevention waste minimization technique involved recycling Freon 113. An open-top still was converted into a closed-loop system at a cost of $20,000. The conversion reduced the volume of Freon waste by 85 percent and saves the company $57,000 each year. Overall, Wacker states that pollution prevention and waste minimization has resulted in annual savings of $300,000.

VI. SUMMARY OF FEDERAL STATUTES AND REGULATIONS

This section discusses the Federal statutes and regulations that may apply to this sector. The purpose of this section is to highlight, and briefly describe the applicable Federal requirements, and to provide citations for more detailed information. The three following sections are included.

- Section IV.A contains a general overview of major statutes
- Section IV.B contains a list of regulations specific to this industry
- Section IV.C contains a list of pending and proposed regulations

The descriptions within Section IV are intended solely for general information. Depending upon the nature or scope of the activities at a particular facility, these summaries may or may not necessarily describe all applicable environmental requirements. Moreover, they do not constitute formal interpretations or clarifications of the statutes and regulations. For further information, readers should consult the Code of Federal Regulations (CFR) and other State or local regulatory agencies. EPA Hotline contacts are also provided for each major statute.

VI.A. General Description of Major Statutes

Resource Conservation And Recovery Act

The Resource Conservation And Recovery Act (RCRA) of 1976 which amended the Solid Waste Disposal Act, addresses solid (Subtitle D) and hazardous (Subtitle C) waste management activities. The Hazardous and Solid Waste Amendments (HSWA) of 1984 strengthened RCRA's waste management provisions and added Subtitle I, which governs underground storage tanks (USTs).

Regulations promulgated pursuant to Subtitle C of RCRA (40 CFR Parts 260-299) establish a "cradle-to-grave" system governing hazardous waste from the point of generation to disposal. RCRA hazardous wastes include the specific materials listed in the regulations (commercial chemical products, designated with the code "P" or "U"; hazardous wastes from specific industries/sources, designated with the code "K"; or hazardous wastes from non-specific sources, designated with the code "F") or materials which exhibit a hazardous waste characteristic (ignitibility, corrosivity, reactivity, or toxicity and designated with the code "D").

Regulated entities that generate hazardous waste are subject to waste accumulation, manifesting, and recordkeeping standards. Facilities that treat, store, or dispose of hazardous waste must obtain a permit, either from EPA or from a State agency which EPA has authorized to implement the permitting program. Subtitle C permits contain general facility standards such as contingency plans, emergency procedures, recordkeeping and reporting requirements, financial assurance mechanisms, and unit-specific standards. RCRA also contains provisions (40 CFR Part 264 Subpart S and §264.10) for conducting corrective actions which govern the cleanup of releases of hazardous waste or constituents from solid waste management units at RCRA-regulated facilities.

Although RCRA is a Federal statute, many States implement the RCRA program. Currently, EPA has delegated its authority to implement various provisions of RCRA to 46 of the 50 States.

Most RCRA requirements are not industry specific but apply to any company that transports, treats, stores, or disposes of hazardous waste. Here are some important RCRA regulatory requirements:

- **Identification of Solid and Hazardous Wastes** (40 CFR Part 261) lays out the procedure every generator should follow to determine whether the material created is considered a hazardous waste, solid waste, or is exempted from regulation.
- **Standards for Generators of Hazardous Waste** (40 CFR Part 262) establishes the responsibilities of hazardous waste generators including obtaining an ID number, preparing a manifest, ensuring proper packaging and labeling, meeting standards for waste accumulation units, and recordkeeping and reporting requirements. Generators can accumulate hazardous waste for up to 90 days (or 180 days depending on the amount of waste generated) without obtaining a permit.
- **Land Disposal Restrictions** (LDRs) are regulations prohibiting the disposal of hazardous waste on land without prior treatment. Under the LDRs (40 CFR 268), materials must meet land disposal restriction (LDR) treatment standards prior to placement in a RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment). Wastes

subject to the LDRs include solvents, electroplating wastes, heavy metals, and acids. Generators of waste subject to the LDRs must provide notification of such to the designated TSD facility to ensure proper treatment prior to disposal.

- **Used Oil Management Standards** (40 CFR 279) impose management requirements affecting the storage, transportation, burning, processing, and re-refining of the used oil. For parties that merely generate used oil, regulations establish storage standards. For a party considered a used oil marketer (one who generates and sells off-specification used oil directly to a used oil burner), additional tracking and paperwork requirements must be satisfied.

- **Tanks and Containers** used to store hazardous waste with a high volatile organic concentration must meet emission standards under RCRA. Regulations (40 CFR Part 264-265, Subpart CC) require generators to test the waste to determine the concentration of the waste, to satisfy tank and container emissions standards, and to inspect and monitor regulated units. These regulations apply to all facilities who store such waste, including generators operating under the 90-day accumulation rule.

- **Underground Storage Tanks** (USTs) containing petroleum and hazardous substance are regulated under Subtitle I of RCRA. Subtitle I regulations (40 CFR Part 280) contain tank design and release detection requirements, as well as financial responsibility and corrective action standards for USTs. The UST program also establishes increasingly stringent standards, including upgrade requirements for existing tanks, that must be met by 1998.

- **Boilers and Industrial Furnaces** (BIFs) that use or burn fuel containing hazardous waste must comply with strict design and operating standards. BIF regulations (40 CFR Part 266, Subpart H) address unit design, provide performance standards, require emissions monitoring, and restrict the type of waste that may be burned.

EPA's RCRA/Superfund/UST Hotline, at (800) 424-9346, responds to questions and distributes guidance regarding all RCRA regulations. The RCRA Hotline operates weekdays from 8:30 a.m. to 7:30 p.m., EST, excluding Federal holidays.

Comprehensive Environmental Response, Compensation, And Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a 1980 law commonly known as Superfund, authorizes EPA to respond to releases, or threatened releases, of hazardous substances that may endanger public health, welfare, or the environment. CERCLA also enables EPA to force parties responsible for environmental contamination to clean it up or to reimburse the Superfund for response costs incurred by EPA. The Superfund Amendments and Reauthorization Act (SARA) of 1986 revised various sections of CERCLA, extended the taxing authority for the Superfund, and created a free-standing law, SARA Title III, also known as the Emergency Planning and Community Right-to-Know Act (EPCRA).

The CERCLA **hazardous substance release reporting regulations** (40 CFR Part 302) direct the person in charge of a facility to report to the National Response Center (NRC) any environmental release of a hazardous substance which exceeds a reportable quantity. Reportable quantities are defined and listed in 40 CFR 302.4. A release report may trigger a response by EPA, or by one or more Federal or State emergency response authorities.

EPA implements **hazardous substance responses** according to procedures outlined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300). The NCP includes provisions for permanent cleanups, known as remedial actions, and other cleanups referred to as "removals." EPA generally takes remedial actions only at sites on the National Priorities List (NPL), which currently includes approximately 1300 sites. Both EPA and States can act at other sites; however, EPA provides responsible parties the opportunity to conduct removal and remedial actions and encourages community involvement throughout the Superfund response process.

EPA's RCRA/Superfund/UST Hotline, at (800) 424-9346, answers questions and references guidance pertaining to the Superfund program. The CERCLA Hotline operates weekdays from 8:30 a.m. to 7:30 p.m., EST, excluding Federal holidays.

Emergency Planning And Community Right-To-Know Act

The Superfund Amendments and Reauthorization Act (SARA) of 1986 created the Emergency Planning and Community Right-to-Know Act (EPCRA, also known as SARA Title III), a statute designed to improve community access to information about chemical hazards and to facilitate the development of chemical emergency response plans by State and local governments. EPCRA required the establishment of State emergency response commissions (SERCs), responsible for coordinating certain emergency response activities and for appointing local emergency planning committees (LEPCs).

EPCRA and the EPCRA regulations (40 CFR Parts 350-372) establish four types of reporting obligations for facilities which store or manage specified chemicals:

- **EPCRA §302** requires facilities to notify the SERC and LEPC of the presence of any "extremely hazardous substance" (the list of such substances is in 40 CFR Part 355, Appendices A and B) if it has such substance in excess of the substance's threshold planning quantity, and directs the facility to appoint an emergency response coordinator.

- **EPCRA §304** requires the facility to notify the SERC and the LEPC in the event of a release exceeding the reportable quantity of a CERCLA hazardous substance or an EPCRA extremely hazardous substance.

- **EPCRA §§311 and 312** require a facility at which a hazardous chemical, as defined by the Occupational Safety and Health Act, is present in an amount exceeding a specified threshold to submit to the SERC, LEPC, and local fire department material safety data sheets (MSDSs) or lists of MSDSs and hazardous chemical inventory forms (also known as Tier I and II forms). This information helps the local government respond in the event of a spill or release of the chemical.

- **EPCRA §313** requires manufacturing facilities included in SIC codes 20 through 39, which have ten or more employees, and which manufacture, process, or use specified chemicals in amounts greater than threshold quantities, to submit an annual toxic chemical release report. This report, commonly known as the Form R, covers releases and transfers of toxic chemicals to various facilities and environmental media, and allows EPA to compile the national Toxic Release Inventory (TRI) database.

All information submitted pursuant to EPCRA regulations is publicly accessible, unless protected by a trade secret claim.

EPA's EPCRA Hotline, at (800) 535-0202, answers questions and distributes guidance regarding the emergency planning and community right-to-know regulations. The EPCRA Hotline operates weekdays from 8:30 a.m. to 7:30 p.m., EST, excluding Federal holidays.

Clean Water Act

The primary objective of the Federal Water Pollution Control Act, commonly referred to as the Clean Water Act (CWA), is to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. Pollutants regulated under the CWA include "priority" pollutants, including various toxic pollutants; "conventional" pollutants, such as biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH; and "non-conventional" pollutants, including any pollutant not identified as either conventional or priority.

The CWA regulates both direct and indirect discharges. The **National Pollutant Discharge Elimination System (NPDES)** program (CWA §402) controls direct discharges into navigable waters. Direct discharges or "point source" discharges are from sources such as pipes and sewers. NPDES permits, issued by either EPA or an authorized State (EPA has presently authorized forty States to administer the NPDES program), contain industry-specific, technology-based and/or water quality-based limits, and establish pollutant monitoring and reporting requirements. A facility that intends to discharge into the nation's waters must obtain a permit prior to initiating its discharge. A permit applicant must provide quantitative analytical data identifying the types of pollutants present in the facility's effluent. The permit will then set forth the conditions and effluent limitations under which a facility may make a discharge.

A NPDES permit may also include discharge limits based on Federal or State water quality criteria or standards, that were designed to protect designated uses of surface waters, such as supporting aquatic life or recreation. These standards, unlike the technological standards, generally do not take into account technological feasibility or costs. Water quality criteria and standards vary from State to State, and site to site, depending on the use classification of the receiving body of water. Most States follow EPA guidelines which propose aquatic life and human health criteria for many of the 126 priority pollutants.

Storm Water Discharges

In 1987 the CWA was amended to require EPA to establish a program to address **storm water discharges**. In response, EPA promulgated the NPDES storm water permit application regulations. Storm water discharge associated with industrial activity means the discharge from any conveyance which is used for collecting and conveying storm water and which is directly related to manufacturing, processing or raw materials storage areas at an industrial plant (40 CFR 122.26(b)(14)). These regulations require that facilities with the following storm water discharges apply for a NPDES permit: (1) a discharge associated with industrial activity; (2) a discharge from a large or medium municipal storm sewer system; or (3) a discharge which EPA or the State determines to contribute to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

The term "storm water discharge associated with industrial activity" means a storm water discharge from one of 11 categories of industrial activity defined at 40 CFR 122.26. Six of the categories are defined by SIC codes while the other five are identified through narrative descriptions of the regulated industrial activity. If the primary SIC code of the facility is one of those identified in the regulations, the facility is subject to the storm water permit application requirements. If any activity at a facility is covered by one of the five narrative categories, storm water discharges from those areas where the activities occur are subject to storm water discharge permit application requirements.

Those facilities/activities that are subject to storm water discharge permit application requirements are identified below. To determine whether a particular facility falls within one of these categories, the regulation should be consulted.

Category i: Facilities subject to storm water effluent guidelines, new source performance standards, or toxic pollutant effluent standards.

Category ii: Facilities classified as SIC 24-lumber and wood products (except wood kitchen cabinets); SIC 26-paper and allied products (except paperboard containers and products); SIC 28-chemicals and allied products (except drugs and paints); SIC 29-petroleum refining; and SIC 311-leather tanning and finishing.

Category iii: Facilities classified as SIC 10-metal mining; SIC 12-coal mining; SIC 13-oil and gas extraction; and SIC 14-nonmetallic mineral mining.

Category iv: Hazardous waste treatment, storage, or disposal facilities.

Category v: Landfills, land application sites, and open dumps that receive or have received industrial wastes.

Category vi: Facilities classified as SIC 5015-used motor vehicle parts; and SIC 5093-automotive scrap and waste material recycling facilities.

Category vii: Steam electric power generating facilities.

Category viii: Facilities classified as SIC 40-railroad transportation; SIC 41-local passenger transportation; SIC 42-trucking and warehousing (except public warehousing and storage); SIC 43-U.S. Postal Service; SIC 44-water transportation; SIC 45-transportation by air; and SIC 5171-petroleum bulk storage stations and terminals.

Category ix: Sewage treatment works.

Category x: Construction activities except operations that result in the disturbance of less than five acres of total land area.

Category xi: Facilities classified as SIC 20-food and kindred products; SIC 21-tobacco products; SIC 22-textile mill products; SIC 23-apparel related products; SIC 2434-wood kitchen cabinets manufacturing; SIC 25-furniture and fixtures; SIC 265-paperboard containers and boxes; SIC 267-converted paper and paperboard products; SIC 27-printing, publishing, and allied industries; SIC 283-drugs; SIC 285-paints, varnishes, lacquer, enamels, and allied products; SIC 30-rubber and plastics; SIC 31-leather and leather products (except leather and tanning and finishing); SIC 323-glass products; SIC 34-fabricated metal products (except fabricated structural metal); SIC 35-industrial and commercial machinery and computer equipment; SIC 36-electronic and other electrical equipment and components; SIC 37-transportation equipment (except ship and boat building and repairing); SIC 38-measuring, analyzing, and controlling instruments; SIC 39-miscellaneous manufacturing industries; and SIC 4221-4225-public warehousing and storage.

Pretreatment Program

Another type of discharge that is regulated by the CWA is one that goes to a publicly-owned treatment works (POTWs). The national **pretreatment program** (CWA §307(b)) controls the indirect discharge of pollutants to POTWs by "industrial users." Facilities regulated under §307(b) must meet certain pretreatment standards. The goal of the pretreatment program is to protect municipal wastewater treatment plants from damage that may occur when hazardous, toxic, or other wastes are discharged into a sewer system and to protect the quality of sludge generated by these plants. Discharges to a POTW are regulated primarily by the POTW itself, rather than the State or EPA.

EPA has developed technology-based standards for industrial users of POTWs. Different standards apply to existing and new sources within each category. "Categorical" pretreatment standards applicable to an industry on a nationwide basis are developed by EPA. In addition, another kind of pretreatment standard, "local limits," are developed by the POTW in order to assist the POTW in achieving the effluent limitations in its NPDES permit.

Regardless of whether a State is authorized to implement either the NPDES or the pretreatment program, if it develops its own program, it may enforce requirements more stringent than Federal standards.

EPA's Office of Water, at (202) 260-5700, will direct callers with questions about the CWA to the appropriate EPA office. EPA also maintains a bibliographic database of Office of Water publications which can be accessed through the Ground Water and Drinking Water resource center, at (202) 260-7786.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) mandates that EPA establish regulations to protect human health from contaminants in drinking water. The law authorizes EPA to develop national drinking water standards and to create a joint Federal-State system to ensure compliance with these standards. The SDWA also directs EPA to protect underground sources of drinking water through the control of underground injection of liquid wastes.

EPA has developed primary and secondary drinking water standards under its SDWA authority. EPA and authorized States enforce the primary drinking water standards, which are, contaminant-specific concentration limits that apply to certain public drinking water supplies. Primary drinking water standards consist of maximum contaminant level goals (MCLGs), which are non-enforceable health-based goals, and maximum contaminant levels (MCLs), which are enforceable limits set as close to MCLGs as possible, considering cost and feasibility of attainment.

The SDWA **Underground Injection Control (UIC)** program (40 CFR Parts 144-148) is a permit program which protects underground sources of drinking water by regulating five classes of injection wells. UIC permits include design, operating, inspection, and monitoring requirements. Wells used to inject hazardous wastes must also comply with RCRA corrective action standards in order to be granted a RCRA permit, and must meet applicable RCRA land disposal restrictions standards. The UIC permit program is primarily State-enforced, since EPA has authorized all but a few States to administer the program.

The SDWA also provides for a Federally-implemented Sole Source Aquifer program, which prohibits Federal funds from being expended on projects that may contaminate the sole or principal source of drinking water for a given area, and for a State-implemented Wellhead Protection program, designed to protect drinking water wells and drinking water recharge areas.

EPA's Safe Drinking Water Hotline, at (800) 426-4791, answers questions and distributes guidance pertaining to SDWA standards. The Hotline operates from 9:00 a.m. through 5:30 p.m., EST, excluding Federal holidays.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) granted EPA authority to create a regulatory framework to collect data on chemicals in order to evaluate, assess, mitigate, and control risks which may be posed by their manufacture, processing, and use. TSCA provides a variety of control methods to prevent chemicals from posing unreasonable risk.

TSCA standards may apply at any point during a chemical's life cycle. Under TSCA §5, EPA has established an inventory of chemical substances. If a chemical is not already on the inventory, and has not been excluded by TSCA, a premanufacture notice (PMN) must be submitted to EPA prior to manufacture or import. The PMN must identify the chemical and provide available information on health and environmental effects. If available data are not sufficient to evaluate the chemical's effects, EPA can impose restrictions pending the development of information on its health and environmental effects.

EPA can also restrict significant new uses of chemicals based upon factors such as the projected volume and use of the chemical.

Under TSCA §6, EPA can ban the manufacture or distribution in commerce, limit the use, require labeling, or place other restrictions on chemicals that pose unreasonable risks. Among the chemicals EPA regulates under §6 authority are asbestos, chlorofluorocarbons (CFCs), and polychlorinated biphenyls (PCBs).

EPA's TSCA Assistance Information Service, at (202) 554-1404, answers questions and distributes guidance pertaining to Toxic Substances Control Act standards. The Service operates from 8:30 a.m. through 4:30 p.m., EST, excluding Federal holidays.

Clean Air Act

The Clean Air Act (CAA) and its amendments, including the Clean Air Act Amendments (CAAA) of 1990, are designed to "protect and enhance the nation's air resources so as to promote the public health and welfare and the productive capacity of the population." The CAA consists of six sections, known as Titles, which direct EPA to establish national standards for ambient air quality and for EPA and the States to implement, maintain, and enforce these standards through a variety of mechanisms. Under the CAAA, many facilities will be required to obtain permits for the first time. State and local governments oversee, manage, and enforce many of the requirements of the CAAA. CAA regulations appear at 40 CFR Parts 50-99.

Pursuant to Title I of the CAA, EPA has established national ambient air quality standards (NAAQS) to limit levels of "criteria pollutants," including carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur dioxide. Geographic areas that meet NAAQS for a given pollutant are classified as attainment areas; those that do not meet NAAQS are classified as non-attainment areas. Under §110 of the CAA, each State must develop a State Implementation Plan (SIP) to identify sources of air pollution and to determine what reductions are required to meet Federal air quality standards.

Title I also authorizes EPA to establish New Source Performance Standards (NSPS), which are nationally uniform emission standards for new stationary sources falling within particular industrial categories. NSPS are based on the pollution control technology available to that category of industrial source but allow the affected industries the flexibility to devise a cost-effective means of reducing emissions.

Under Title I, EPA establishes and enforces National Emission Standards for Hazardous Air Pollutants (NESHAP), nationally uniform standards oriented towards controlling particular hazardous air pollutants (HAPs). Title III of the CAAA further directed EPA to develop a list of sources that emit any of 189 HAPs, and to develop regulations for these categories of sources. To date, EPA has listed 174 categories and developed a schedule for the establishment of emission standards. The emission standards will be developed for both new and existing sources based on "maximum achievable control technology" (MACT). The MACT is defined as the control technology achieving the maximum degree of reduction in the emission of the HAPs.

Title II of the CAA pertains to mobile sources, such as cars, trucks, buses, and planes. Reformulated gasoline, automobile pollution control devices, and vapor recovery nozzles on gas pumps are a few of the mechanisms EPA uses to regulate mobile air emission sources.

Title IV establishes a sulfur dioxide emissions program designed to reduce the formation of acid rain. Reduction of sulfur dioxide releases will be obtained by granting to certain sources limited emissions allowances, which, beginning in 1995, will be set below previous levels of sulfur dioxide releases.

Title V of the CAAA of 1990 created a permit program for all "major sources" (and certain other sources) regulated under the CAA. One purpose of the operating permit is to include in a single document all air emissions requirements that apply to a given facility. States are developing the permit programs in accordance with guidance and regulations from EPA. Once a State program is approved by EPA, permits will be issued and monitored by that State.

Title VI is intended to protect stratospheric ozone by phasing out the manufacture of ozone-depleting chemicals and restrict their use and distribution. Production of Class I substances, including 15 kinds of chlorofluorocarbons (CFCs), will be phased out entirely by the year 2000, while certain hydrochlorofluorocarbons (HCFCs) will be phased out by 2030.

EPA's Control Technology Center, at (919) 541-0800, provides general assistance and information on CAA standards. The Stratospheric Ozone

Information Hotline, at (800) 296-1996, provides general information about regulations promulgated under Title VI of the CAA, and EPA's EPCRA Hotline, at (800) 535-0202, answers questions about accidental release prevention under CAA §112(r). In addition, the Technology Transfer Network Bulletin Board System (modem access (919) 541-5742)) includes recent CAA rules, EPA guidance documents, and updates of EPA activities.

VI.B. Industry Specific Requirements

Clean Air Act (CAA)

Under the CAA, the National Ambient Air Quality Standards (NAAQS) have been established for six pollutants. The only one that significantly impacts the electronics/computer industry is the standard for ozone. While the electronics/computer industry is not a major source of ozone, it is a major source of volatile organic compounds (VOC). A source defined as "major" in ozone nonattainment areas must install Reasonable Available Control Technology (RACT) as prescribed in the applicable State Implementation Plan (SIP). A major source is both defined by the size of the source's emissions and the category of the nonattainment area. A determination of the necessary RACT requirements is made on the basis of a case by case review of each facility. In an attempt to issue uniform guidelines, EPA has begun to issue Control Technology Guidance (CTG) for each industrial category. The following CTGs may apply to the semiconductor industry:

- Miscellaneous Metal Parts and Products
- Plastic Parts
- Alternative Control Technology (ATG) for Solvent Cleaning.

Clean Water Act (CWA)

The National Pollution Discharge Elimination System (NPDES) permit program regulates the discharge of pollutants to the waters of the United States. A permit is required if a source discharges directly to surface waters. Facilities must provide the results of biological toxicity tests and any information on its "effluent characteristics.” The electronics/computer industry must test for all 126 priority pollutants listed in 40 CFR 122, Appendix D. Facilities must provide quantifiable data only for discharges of priority pollutants which the applicant knows or has reason to believe will be greater than trace amounts. Priority pollutants likely to be discharged by facilities in the electronics/computer industry include copper, lead, lead compounds, silver, chromium, and trichloroethylene.

Quantitative testing is required for non-conventional pollutants if they are expected to be present in discharges. Examples of hazardous substances and non-conventional pollutants likely to be discharged by the electronics/computer industry include butyl acetate, xylene, formaldehyde, tin-total, nitrate/nitrites, titanium-total, and chlorine-total residual.

The electronics/computer industry must satisfy the following technology-based effluent limitation guidelines:

- 40 CFR Part 469 applies to discharges from all processes associated with semiconductor manufacturing except sputtering, vapor deposition, and electroplating.
- 40 CFR Part 433 applies to semiconductor manufacturing plants that perform any of six metal finishing operations - electroplating, electroless plating, anodizing, coating, chemical etching, milling, and printed wired board manufacturing.
- 40 CFR Part 433 applies to discharges associated with the manufacture of printed wiring boards (PWB), except indirect discharging job shops and independent PWB manufacturers who discharge to POTWs, which are covered by Part 413.
- 40 CFR Part 469, Subpart C applies to discharges from display manufacturing.
- 40 CFR Part 469, Subpart D applies to discharges from the manufacturing of luminescent materials which are used in coatings in fluorescent lamps and cathode ray tubes. Luminescent materials include, but are not limited to, calcium halophosphate, zinc sulfide, and zinc-cadmium.
- 40 CFR Part 413 applies to electroplating of common metals, chemical etching and milling, and electroless plating. Subpart A refers to discharges of pollutants from processes that involve ferrous or nonferrous material electroplated with (or any combination of) copper, nickel, chromium, zinc, tin, lead, cadmium, iron, or aluminum. Subpart F applies to process wastewaters from chemical milling or etching of ferrous or nonferrous materials. Subpart G applies to process wastewaters

from the electroless plating of a metallic layer on a metallic or nonmetallic substrate.

Facilities that discharge to POTWs must comply with categorical and general pretreatment requirements:

- 40 CFR Part 413, Subpart B applies to electroplating of precious metals or to discharges from a process in which a ferrous or nonferrous material is plated with, or a combination of, gold, silver, iridium, palladium, platinum, rhodium, or ruthenium.

Resource Conservation and Recovery Act (RCRA)

Many wastes generated by the electronics/computer industry are considered RCRA toxicity characteristic (TC) hazardous wastes due to constituents such as silver, trichloroethylene, and lead. The greatest quantities of RCRA listed waste and characteristic hazardous waste present in the electronics/computer industry are identified in Exhibit 30. For more information on RCRA hazardous waste, refer to 40 CFR Part 261.

Exhibit 34 Hazardous Wastes Relevant to the Electronics/Computer Industry

EPA Hazardous Waste No.	Hazardous Waste
D006 (cadmium) D007 (chromium) D008 (lead) D011 (silver)	Wastes which are hazardous due to the characteristic of toxicity for each of the constituents.
F001	Halogenated solvents used in degreasing: tetrachloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; all spent solvent mixtures/blends used in degreasing containing, before use, a total of 10 percent or more (by volume) of one or more of the above halogenated solvents or those solvents listed in F002, F004, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F002	Spent halogenated solvents; tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, trichlorofluoromethane, and 1,1,2-trichloroethane; all spent solvent mixtures/blends containing, before use, one or more of the above halogenated solvents or those listed in F001, F004, F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F003	Spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; all spent solvent mixtures/blends containing, before use, only the above spent non-halogenated solvents; and all spent solvent mixtures/blends containing, before use, one or more of the above non-halogenated solvents, and, a total of 10% or more (by volume) of one of those solvents listed in F001, F002, F004, F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F004	Spent non-halogenated solvents: cresols and cresylic acid, and nitrobenzene; all spent solvent mixtures/blends containing, before use, a total of 10% or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, and F005; and still bottoms from the recovery of these spent solvents and spent solvent mixtures.
F005	Spent non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulfide, isobutanol, pyridine, benzene, 2-ethoxyethanol, and 2-nitropropane; all spent solvent mixtures/blends containing, before use, a total of 10% or more (by volume) of one or more of the above non-halogenated solvents or those solvents listed in F001, F002, or F004; and still bottoms from the recovery of these spent solvents and spent solvents mixtures.
F006	Wastewater treatment sludges from electroplating operations except from the following processes: (1) sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.
F007	Spent cyanide plating bath solutions from electroplating operations.
F008	Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.
F009	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process.

Source: Based on 1994 Sustainable Industry: Promoting Strategic Environmental Protection in the Industrial Sector, Phase 1 Report.

VI.B.1. Notable State Regulations

California's *Hazardous Waste Source Reduction and Management Review Act of 1988*, commonly referred to as SB14, requires generators that produce over 12,000 kilograms of hazardous waste or 12 kilograms of extremely hazardous waste to produce two documents every four years. The documents include a Source Reduction Plan and a Management Performance Report. The Act intends to promote hazardous waste reduction at the source and recycling. For more information on the compilation of these reports by the semiconductor industry, see the October 1994 *Assessment of the Semiconductor Industry Source Reduction Planning Efforts*, by the California Department of Toxic Substances Control.

According to Daryl Burn of the California Air Resources Board, the Board has promulgated Rule 830, Semiconductor Manufacturing Operations, which regulates VOC emissions from semiconductor manufacturing facilities. VOCs are released during wafer preparation, photolithography, and cleaning operations. Rule 830 was developed in 1988 for the Bay Area Air Quality Management District (San Francisco area) because a large concentration of semiconductor manufacturing facilities are located in South Bay and San Francisco. The Board does not provide assistance to facilities to help achieve compliance.

VI.C. Pending and Proposed Regulatory Requirements

SDWA / Underground Injection Control Wells (UIC)

New regulations are being developed for UIC which will amend 40 CFR 144 and 146. The regulations will establish minimum Federal requirements for the permitting, operating, monitoring, and closure of several types of shallow injection wells. Restrictions will be imposed on the operation of certain types of shallow disposal wells, especially those that inject industrial wastes. Computer manufacturing facilities located in areas without sewer systems that rely on shallow waste injection wells to dispose of industrial and non-sanitary wastes will be impacted by these regulations.

Resource Conservation and Recovery Act (RCRA)

RCRA prohibits the land disposal of most hazardous wastes until they meet a waste specific treatment standard. While most hazardous wastes have already been assigned treatment standards, EPA must still promulgate additional rule makings to address newly listed wastes and to make changes to the land disposal restrictions (LDR) program. Rules are required every time EPA lists a waste.

The Phase III LDR rulemaking proposes to establish treatment standards for some newly listed wastes and RCRA equivalent treatment standards for certain formerly characteristic hazardous wastes that are injected into UIC wells under the Safe Drinking Water Act (SDWA) or managed in Subtitle D surface impoundments prior to discharge pursuant to the Clean Water Act (CWA). By consent decree, EPA must promulgate the final rule for Phase III by January 1996.

Phase IV will similarly consider restrictions on other newly listed or identified wastes from land disposal and evaluate what, if any, treatment standards may be needed to mitigate the impact of sludges, leaks, and air emissions from surface impoundments that manage decharacterized wastes. In addition to considering restrictions on the land disposal of the previously exempt Bevill wastes and wastes from wood preserving, Phase IV will also consider adjustments to the treatment standards applicable to wastes that exhibit the toxicity characteristic for a metal constituent. Subject to the same consent decree, Phase IV has been assigned a judicial deadline of June 1996 for promulgation of a final rule.

Clean Air Act (CAA)

Lead NAAQS may impact the electronics/computer industry in the future. It is believed that emissions from the use of lead in soldering and other processes are not significant enough to subject facilities to air pollution control requirements. However, EPA has not yet studied the electronics/computer industry as a source of lead emissions.

Clean Air Act Amendments of 1990 (CAAA)

EPA promulgated a final NESHAP for chromium emissions from new and existing electroplating operations on January 25, 1995. The 1990 CAA Amendments (CAAA) list chromium compounds as a criteria air pollutant under §112. The purpose of the rule is to limit chromium emissions to the level of Maximum Achievable Control Technology (MACT) (60 FR 4948).

A NESHAP for halogenated solvent cleaning was issued December 2, 1994. The regulation applies to organic halogenated solvent cleaners (degreasers) using specified halogenated HAP solvents.

Several hazardous air pollutants (HAP) which are used in printed wired board manufacturing as well as semiconductor manufacturing and assembly are scheduled for MACT standards. According to IPC and EPA, these HAPs include: ethylene glycol; hydrochloric acid; hydrofluoric acid; lead compounds; and nickel compounds.

EPA is in the process of identifying industries that emit any substantial quantities of the 189 HAPs. Regulations that apply specifically to the semiconductor industry are expected in 1997.

Clean Water Act (CWA)

EPA is scheduled to propose effluent limitation guidelines and standards for metal products and machinery. These guidelines and standards will address facilities that generate wastewater while processing metal parts, products, and machinery. The proposal will also include facilities that generate wastewater during the following processes: manufacturing, assembly, repairing, rebuilding, and maintenance. Phase I of these guidelines and standards covers seven industries. The industries relevant to SIC code 36 and 35 are stationary industrial equipment (electrical equipment) and electronic equipment (including communication equipment). A notice of proposed rule making is expected to be published by November 1994, and final action on this proposed regulation is scheduled for May 1996.

VII. COMPLIANCE AND ENFORCEMENT HISTORY

Background

To date, EPA has focused much of its attention on measuring compliance with specific environmental statutes. This approach allows the Agency to track compliance with the Clean Air Act, the Resource Conservation and Recovery Act, the Clean Water Act, and other environmental statutes. Within the last several years, the Agency has begun to supplement single-media compliance indicators with facility-specific, multimedia indicators of compliance. In doing so, EPA is in a better position to track compliance with all statutes at the facility level, and within specific industrial sectors.

A major step in building the capacity to compile multimedia data for industrial sectors was the creation of EPA's Integrated Data for Enforcement Analysis (IDEA) system. IDEA has the capacity to "read into" the Agency's single-media databases, extract compliance records, and match the records to individual facilities. The IDEA system can match Air, Water, Waste, Toxics/Pesticides/EPCRA, TRI, and Enforcement Docket records for a given facility, and generate a list of historical permit, inspection, and enforcement activity. IDEA also has the capability to analyze data by geographic area and corporate holder. As the capacity to generate multimedia compliance data improves, EPA will make available more in-depth compliance and enforcement information. Additionally, sector-specific measures of success for compliance assistance efforts are under development.

Compliance and Enforcement Profile Description

Using inspection, violation, and enforcement data from the IDEA system, this section provides information regarding the historical compliance and enforcement activity of this sector. In order to mirror the facility universe reported in the Toxic Chemical Profile, the data reported within this section consists of records only from the TRI reporting universe. With this decision, the selection criteria are consistent across sectors with certain exceptions. For the sectors that do not normally report to the TRI program, data have been provided from EPA's Facility Indexing System (FINDS) which tracks facilities in all media databases. Please note, in this section, EPA does not attempt to define the actual number of facilities that fall within each sector. Instead, the section portrays the records of a subset of facilities within the sector that are well defined within EPA databases.

As a check on the relative size of the full sector universe, most notebooks contain an estimated number of facilities within the sector according to the Bureau of Census (See Section II). With sectors dominated by small businesses, such as metal finishers and printers, the reporting universe within the EPA databases may be small in comparison to Census data. However, the group selected for inclusion in this data analysis section should be consistent with this sector's general make-up.

Following this introduction is a list defining each data column presented within this section. These values represent a retrospective summary of inspections and enforcement actions, and solely reflect EPA, State, and local compliance assurance activities that have been entered into EPA databases. To identify any changes in trends, the EPA ran two data queries, one for the past five calendar years (August 10, 1990 to August 9, 1995) and the other for the most recent twelve-month period (August 10, 1994 to August 9, 1995). The five-year analysis gives an average level of activity for that period for comparison to the more recent activity.

Because most inspections focus on single-media requirements, the data queries presented in this section are taken from single media databases. These databases do not provide data on whether inspections are State/local or EPA-led. However, the table breaking down the universe of violations does give the reader a crude measurement of the EPA's and States' efforts within each media program. The presented data illustrate the variations across regions for certain sectors.[3] This variation may be attributable to State/local data entry variations, specific geographic concentrations, proximity to population centers, sensitive ecosystems, highly toxic chemicals used in production, or historical noncompliance. Hence, the exhibited data do not rank regional performance or necessarily reflect which regions may have the most compliance problems.

[3] EPA Regions include the following States: I (CT, MA, ME, RI, NH, VT); II (NJ, NY, PR, VI); III (DC, DE, MD, PA, VA, WV); IV (AL, FL, GA, KY, MS, NC, SC, TN); V (IL, IN, MI, MN, OH, WI); VI (AR, LA, NM, OK, TX); VII (IA, KS, MO, NE); VIII (CO, MT, ND, SD, UT, WY); IX (AZ, CA, HI, NV, Pacific Trust Territories); X (AK, ID, OR, WA).

Compliance and Enforcement Data Definitions

General Definitions

Facility Indexing System (FINDS) -- this system assigns a common facility number to EPA single-media permit records. The FINDS identification number allows EPA to compile and review all permit, compliance, enforcement, and pollutant release data for any given regulated facility.

Integrated Data for Enforcement Analysis (IDEA) -- is a data integration system that can retrieve information from the major EPA program office databases. IDEA uses the FINDS identification number to "glue together" separate data records from EPA's databases. This is done to create a "master list" of data records for any given facility. Some of the data systems accessible through IDEA are: AIRS (Air Facility Indexing and Retrieval System, Office of Air and Radiation), PCS (Permit Compliance System, Office of Water), RCRIS (Resource Conservation and Recovery Information System, Office of Solid Waste), NCDB (National Compliance Data Base, Office of Prevention, Pesticides, and Toxic Substances), CERCLIS (Comprehensive Environmental and Liability Information System, Superfund), and TRIS (Toxic Release Inventory System). IDEA also contains information from outside sources such as Dun and Bradstreet and the Occupational Safety and Health Administration (OSHA). Most data queries displayed in notebook Sections IV and VII were conducted using IDEA.

Data Table Column Heading Definitions

Facilities in Search -- are based on the universe of TRI reporters within the listed SIC code range. For industries not covered under TRI reporting requirements, the notebook uses the FINDS universe for executing data queries. The SIC code range selected for each search is defined by each notebook's selected SIC code coverage described in Section II.

Facilities Inspected --- indicates the level of EPA and State agency inspections for the facilities in this data search. These values show what percentage of the facility universe is inspected in a 12 or 60 month period. This column does not count non-inspectional compliance activities such as the review of facility-reported discharge reports.

Number of Inspections -- measures the total number of inspections conducted in this sector. An inspection event is counted each time it is entered into a single media database.

Average Time Between Inspections -- provides an average length of time, expressed in months, that a compliance inspection occurs at a facility within the defined universe.

Facilities with One or More Enforcement Actions -- expresses the number of facilities that were party to at least one enforcement action within the defined time period. This category is broken down further into Federal and State actions. Data are obtained for administrative, civil/judicial, and criminal enforcement actions. Administrative actions include Notices of Violation (NOVs). A facility with multiple enforcement actions is only counted once in this column (facility with 3 enforcement actions counts as 1). All percentages that appear are referenced to the number of facilities inspected.

Total Enforcement Actions -- describes the total number of enforcement actions identified for an industrial sector across all environmental statutes. A facility with multiple enforcement actions is counted multiple times (a facility with 3 enforcement actions counts as 3).

State Lead Actions -- shows what percentage of the total enforcement actions are taken by State and local environmental agencies. Varying levels of use by States of EPA data systems may limit the volume of actions accorded State enforcement activity. Some States extensively report enforcement activities into EPA data systems, while other States may use their own data systems.

Federal Lead Actions -- shows what percentage of the total enforcement actions are taken by the U.S. EPA. This value includes referrals from State agencies. Many of these actions result from coordinated or joint State/Federal efforts.

Enforcement to Inspection Rate -- expresses how often enforcement actions result from inspections. This value is a ratio of enforcement actions to inspections, and is presented for comparative purposes only. This measure is a rough indicator of the relationship between inspections and enforcement. This measure simply indicates historically how many enforcement actions can be attributed to inspection activity. Related inspections and enforcement actions under the Clean Water Act (PCS), the Clean Air Act (AFS) and the Resource

Conservation and Recovery Act (RCRA) are included in this ratio. Inspections and actions from the TSCA/FIFRA/EPCRA database are not factored into this ratio because most of the actions taken under these programs are not the result of facility inspections. This ratio does not account for enforcement actions arising from non-inspection compliance monitoring activities (e.g., self-reported water discharges) that can result in enforcement action within the CAA, CWA and RCRA.

Facilities with One or More Violations Identified -- indicates the number and percentage of inspected facilities having a violation identified in one of the following data categories: In Violation or Significant Violation Status (CAA); Reportable Noncompliance, Current Year Noncompliance, Significant Noncompliance (CWA); Noncompliance and Significant Noncompliance (FIFRA, TSCA, and EPCRA); Unresolved Violation and Unresolved High Priority Violation (RCRA). The values presented for this column reflect the extent of noncompliance within the measured time frame, but do not distinguish between the severity of the noncompliance. Percentages within this column can exceed 100 percent because facilities can be in violation status without being inspected. Violation status may be a precursor to an enforcement action, but does not necessarily indicate that an enforcement action will occur.

Media Breakdown of Enforcement Actions and Inspections -- four columns identify the proportion of total inspections and enforcement actions within EPA Air, Water, Waste, and TSCA/FIFRA/EPCRA databases. Each column is a percentage of either the "Total Inspections," or the "Total Actions" column.

VII.A. Electronics/Computer Industry Compliance History

The exhibit below contains a Regional breakdown of the inspection and enforcement action over the last five years in the electronics/computer industry. As expected, the largest number of electronics/computer industry facilities is located in Region IX. However, other Regions (i.e., Regions I and II) inspected a greater number of electronics facilities than Region IX. Also, Regions IX and X have significantly higher enforcement to inspection ratios than the other Regions. In addition, 100 percent of Region VI and VII enforcement actions are led by the Federal government and 100 percent of Region VIII were enforcement actions were State-lead.

Exhibit 35
Five Year Enforcement and Compliance Summary for the Computer Industry

A	B	C	D	E	F	G	H	I	J
Computers SIC 35	Facilities in Search	Facilities Inspected	Number of Inspections	Average Number of Months Between Inspections	Facilities w/one or more Enforcement Actions	Total Enforcement Actions	State Lead Actions	Federal Lead Actions	Enforcement to Inspection Rate
Region I	—	—	—	—	—	—	—	—	—
Region II	2	2	15	8	—	—	—	—	—
Region III	2	2	11	11	—	—	0%	0%	0.18
Region IV	4	3	49	5	2	6	80%	20%	0.12
Region V	8	3	17	30	1	5	100%	—	0.29
Region VI	2	1	2	63	1	4	100%	—	2.00
Region VII	—	—	—	—	—	—	—	—	—
Region VIII	1	1	1	63	—	—	—	—	—
Region IX	3	—	—	8	—	—	—	—	—
Region X	—	—	—	—	—	—	—	—	—
Total/Average	22	12	95	15	4	15	92%	8%	0.16

VII.B. Comparison of Enforcement Activity Between Selected Industries

Exhibits 36 and 37 below present five and one year enforcement and compliance summaries for selected industries. The exhibits show that the number of inspections for the electronics/computer industry is low in comparison to other industries, and the average time between inspections is longer than other industries.

Exhibit 38 and 39 present five and one year inspection and enforcement summaries by statute. As expected, a significant percentage of inspections and enforcement actions involving electronics facilities are RCRA-related. This is in part due to the large amount of solvents used and sludges generated during various stages of the manufacturing process. The exhibit also shows a significantly lower percentage of Clean Air Act and Clean Water Act inspections and actions. This is somewhat surprising in light of the VOC emissions and the wastewaters and rinsewaters contaminated with spent solvents and acids generated by this industry.

Exhibit 36
Five Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E	F	G	H	I	J
Industry Sector	Facilities in Search	Facilities Inspected	Number of Inspections	Average Number of Months Between Inspections	Facilities w/One or More Enforcement Actions	Total Enforcement Actions	State Lead Actions	Federal Lead Actions	Enforcement to Inspection Rate
Metal Mining	873	339	1,519	34	67	155	47%	53%	0.10
Non-metallic Mineral Mining	1,143	631	3,422	20	84	192	76%	24%	0.06
Lumber and Wood	464	301	1,891	15	78	232	79%	21%	0.12
Furniture	293	213	1,534	11	34	91	91%	9%	0.06
Rubber and Plastic	1,665	739	3,386	30	146	391	78%	22%	0.12
Stone, Clay, and Glass	468	268	2,475	11	73	301	70%	30%	0.12
Nonferrous Metals	844	474	3,097	16	145	470	76%	24%	0.15
Fabricated Metal	2,346	1,340	5,509	26	280	840	80%	20%	0.15
Electronics/Computers	405	222	777	31	68	212	79%	21%	0.27
Motor Vehicle Assembly	598	390	2,216	16	81	240	80%	20%	0.11
Pulp and Paper	306	265	3,766	5	115	502	78%	22%	0.13
Printing	4,106	1,035	4,723	52	176	514	85%	15%	0.11
Inorganic Chemicals	548	298	3,034	11	99	402	76%	24%	0.13
Organic Chemicals	412	316	3,864	6	152	726	66%	34%	0.19
Petroleum Refining	156	145	3,257	3	110	797	66%	34%	0.25
Iron and Steel	374	275	3,555	6	115	499	72%	28%	0.14
Dry Cleaning	933	245	633	88	29	103	99%	1%	0.16

Exhibit 37
One Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E		F		G	H
Industry Sector	Facilities in Search	Facilities Inspected	Number of Inspections	Facilities w/One or More Violations		Facilities w/One or More Enforcement Actions		Total Enforcement Actions	Enforcement to Inspection Rate
				Number	Percent*	Number	Percent*		
Metal Mining	873	114	194	82	72%	16	14%	24	0.13
Non-metallic Mineral Mining	1,143	253	425	75	30%	28	11%	54	0.13
Lumber and Wood	464	142	268	109	77%	18	13%	42	0.58
Furniture	293	160	113	66	41%	3	2%	5	0.55
Rubber and Plastic	1,665	271	435	289	107%	19	7%	59	0.14
Stone, Clay, and Glass	468	146	330	116	79%	20	14%	66	0.20
Nonferrous Metals	844	202	402	282	140%	22	11%	72	0.18
Fabricated Metal	2,346	477	746	525	110%	46	10%	114	0.15
Electronics/Computers	405	60	87	80	133%	8	13%	21	0.24
Motor Vehicle Assembly	598	169	284	162	96%	14	8%	28	0.10
Pulp and Paper	306	189	576	162	86%	28	15%	88	0.15
Printing	4,106	397	676	251	63%	25	6%	72	0.11
Inorganic Chemicals	548	158	427	167	106%	19	12%	49	0.12
Organic Chemicals	412	195	545	197	101%	39	20%	118	0.22
Petroleum Refining	156	109	437	109	100%	39	36%	114	0.26
Iron and Steel	374	167	488	165	99%	20	12%	46	0.09
Dry Cleaning	933	80	111	21	26%	5	6%	11	0.10

*Percentages in Columns E and F are based on the number of facilities inspected (Column C). Percentages can exceed 100% because violations and actions can occur without a facility inspection.

Exhibit 38
Five Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Number of Facilities Inspected	Total Inspections	Enforcement Actions	Clean Air Act		Clean Water Act		Resource Conservation and Recovery Act		FIFRA/TSCA/ EPCRA/Other*	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Metal Mining	339	1,519	155	35%	17%	57%	60%	6%	14%	1%	9%
Non-metallic Mineral Mining	631	3,422	192	65%	46%	31%	24%	3%	27%	<1%	4%
Lumber and Wood	301	1,891	232	31%	21%	8%	7%	59%	67%	2%	5%
Furniture	293	1,534	91	52%	27%	1%	1%	45%	64%	1%	8%
Rubber and Plastic	739	3,386	391	39%	15%	13%	7%	44%	68%	3%	10%
Stone, Clay and Glass	268	2,475	301	45%	39%	15%	5%	39%	51%	2%	5%
Nonferrous Metals	474	3,097	470	36%	22%	22%	13%	38%	54%	4%	10%
Fabricated Metal	1,340	5,509	840	25%	11%	15%	6%	56%	76%	4%	7%
Electronics/ Computers	222	777	212	16%	2%	14%	3%	66%	90%	3%	5%
Motor Vehicle Assembly	390	2,216	240	35%	15%	9%	4%	54%	75%	2%	6%
Pulp and Paper	265	3,766	502	51%	48%	38%	30%	9%	18%	2%	3%
Printing	1,035	4,723	514	49%	31%	6%	3%	43%	62%	2%	4%
Inorganic Chemicals	302	3,034	402	29%	26%	29%	17%	39%	53%	3%	4%
Organic Chemicals	316	3,864	726	33%	30%	16%	21%	46%	44%	5%	5%
Petroleum Refining	145	3,237	797	44%	32%	19%	12%	35%	52%	2%	5%
Iron and Steel	275	3,555	499	32%	20%	30%	18%	37%	58%	2%	5%
Dry Cleaning	245	633	103	15%	1%	3%	4%	83%	93%	<1%	1%

* Actions taken to enforce the Federal Insecticide, Fungicide, and Rodenticide Act; the Toxic Substances and Control Act, and the Emergency Planning and Community Right-to-Know Act as well as other Federal environmental laws.

Exhibit 39
One Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Number of Facilities Inspected	Total Inspections	Enforcement Actions	Clean Air Act		Clean Water Act		Resource Conservation and Recovery Act		FIFRA/TSCA/ EPCRA/Other	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Metal Mining	114	194	24	47%	42%	43%	34%	10%	6%	<1%	19%
Non-metallic Mineral Mining	253	425	54	69%	58%	26%	16%	5%	16%	<1%	11%
Lumber and Wood	142	268	42	29%	20%	8%	13%	63%	61%	<1%	6%
Furniture	293	160	5	58%	67%	1%	10%	41%	10%	<1%	13%
Rubber and Plastic	271	435	59	39%	14%	14%	4%	46%	71%	1%	11%
Stone, Clay, and Glass	146	330	66	45%	52%	18%	8%	38%	37%	<1%	3%
Nonferrous Metals	202	402	72	33%	24%	21%	3%	44%	69%	1%	4%
Fabricated Metal	477	746	114	25%	14%	14%	8%	61%	77%	<1%	2%
Electronics/ Computers	60	87	21	17%	2%	14%	7%	69%	87%	<1%	4%
Motor Vehicle Assembly	169	284	28	34%	16%	10%	9%	56%	69%	1%	6%
Pulp and Paper	189	576	88	56%	69%	35%	21%	10%	7%	<1%	3%
Printing	397	676	72	50%	27%	5%	3%	44%	66%	<1%	4%
Inorganic Chemicals	158	427	49	26%	38%	29%	21%	45%	36%	<1%	6%
Organic Chemicals	195	545	118	36%	34%	13%	16%	50%	49%	1%	1%
Petroleum Refining	109	439	114	50%	31%	19%	16%	30%	47%	1%	6%
Iron and Steel	167	488	46	29%	18%	35%	26%	36%	50%	<1%	6%
Dry Cleaning	80	111	11	21%	4%	1%	22%	78%	67%	<1%	7%

* Actions taken to enforce the Federal Insecticide, Fungicide, and Rodenticide Act; the Toxic Substances and Control Act, and the Emergency Planning and Community Right-to-Know Act as well as other Federal environmental laws.

VII.C. Review of Major Legal Actions

This section provides a listing of major legal cases and supplemental enforcement projects that pertain to the Electronics/Computer Industry. Information in this section is provided by EPA's *Enforcement Accomplishments Report, FY 1991, FY 1992, FY 1993* and the Office of Enforcement.

VII.C.1. Review of Major Cases

This section provides summary information about major cases that have affected this sector. As indicated in the EPA's *Enforcement Accomplishments Report, FY 1991, FY 1992, FY 1993* publications, 16 significant enforcement actions involving the electronics/computer industry were resolved between 1991 and 1993. CERCLA violations comprised nine of these cases, the most of any statute. Following CERCLA violations were five cases involving CWA violations, three involving RCRA violations, and one involving a TSCA violation. Two of the sites were Superfund sites. Several of the settlements required reimbursement of Superfund response costs or payment of the remedial costs. The companies against which the cases were brought are primarily manufacturers of electrical components such as printed wiring boards. The other companies performed electroplating operations and manufactured electrical equipment.

Four of the sixteen actions resulted in the assessment of a penalty. Penalties ranged from $25,000 to $300,000. The average penalty was approximately $178,125. In a case involving General Electric, the company was subject to a penalty and agreed to pay for removal and disposal of PWB electrical equipment over a period of three years at an estimated cost of one million dollars. In the case of U.S. v. Electrochemical Co., Inc., the court stated it would suspend $225,000 of a $250,000 fine if the company would clean up the contaminated area.

Although many cases involved civil penalties, four of the cases involved criminal convictions, resulting in penalties and/or jail sentences for the owners and operators of the facilities. All of these cases involved electroplating facilities and CWA violations. In one case, U.S. v. Robert H. Schmidt and Lawrence B. Schmidt, the owner was sentenced to 30 months in prison, followed by two years of probation. His son, the plant supervisor, was sentenced to 24 months of jail and two years of probation. Father and son were subject to penalties of $50,000 and $25,000 respectively.

VII.C.2. Supplemental Environmental Projects

Below is a list of Supplementary Environmental Projects (SEPs). SEPs are compliance agreements that reduce a facility's stipulated penalty in return for an environmental project that exceeds the value of the reduction. Often, these projects fund pollution prevention activities that can significantly reduce the future pollutant loadings of a facility.

In December, 1993, the Regions were asked by EPA's Office of Enforcement and Compliance Assurance to provide information on the number and type of SEPs entered into by the Regions. Exhibit 40 contains a representative sample of the Regional responses addressing the electronics and computer industries. The information contained in the chart is not comprehensive and provides only a sample of the types of SEPs developed for the electronics and computer industries.

Exhibit 40
Supplemental Environmental Projects
Electronics (SIC 36)

Case Name	EPA Region	Statute/ Type of Action	Type of SEP	Estimated Cost to Company	Expected Environmental Benefits	Final Assessed Penalty	Final Penalty After Mitigation
Lane Electronic Cooperative Eugene, OR	10	TSCA	Pollution Reduction	$ 9,775	Early disposal of PCBs or PCB contaminated electrical equipment.	$ 9,775	$ 4,888
Cirtech, Inc.	9	RCRA	Pollution Prevention	$ 9,900	Purcahse and install a device to eliminate copper from the waste stream and to reduce the hazardous waste stream. Will allow corrosive etch water to be reused.	$11,400	$ 7,630
Universal Circuits	9	EPCRA	Pollution Prevention		Implement a waste water recycling project which permanently reduces the consumption of water. Sponsor and conduct an outreach program		
Trojan Battery	9	EPCRA			Eliminate wastewater discharges. Operate a battery recycling center.		
G & W Electric Company Blue Island, IL	5	EPCRA	Pollution Prevention	$ 97,000	Implement process modifications designed to eliminate the use of 72,000 lbs/yr of 1,1,1,-trichloroethane.	$ 68,000	$ 7,825
Manu-Tronics Kenosha, WI	5	EPCRA	Pollution Prevention	$ 81,700	Modify the industrial processes eliminate the use and release of 25,000 lbs/yr of Freon 113.	$ 34,000	$ 3,400
Anchor Electric Co. Manchester, NH	1	EPCRA	Pollution Prevention	$40,000	Purchase, install, and operate an aqueous washer system in place of current vapor degreaser. Change will result in virtual elimination of the use of 1,1,1,-trichloroethane.	$51,000	$13,650

VIII. COMPLIANCE ASSURANCE ACTIVITIES AND INITIATIVES

This section highlights the activities undertaken by this industry sector and public agencies to voluntarily improve the sector's environmental performance. These activities include those independently initiated by industrial trade associations. In this section, the notebook also contains a listing and description of national and regional trade associations.

VIII.A. Sector-Related Environmental Programs and Activities

VIII.A.1. Federal Activities

Common Sense Initiative (CSI)

The Common Sense Initiative (CSI), a partnership between EPA and private industry, aims to create environmental protection strategies that are cleaner for the environment and cheaper for industry and taxpayers. As part of CSI, representatives from Federal, State, and local governments; industry; community-based and national environmental organizations; environmental justice groups; and labor organizations, come together to examine the full range of environmental requirements affecting the following six selected industries: automobile manufacturing; computers and electronics, iron and steel, metal finishing, petroleum refining; and printing.

CSI participants are looking for solutions that:

- Focus on the industry as a whole rather than one pollutant
- Seek consensus-based solutions
- Focus on pollution prevention rather than end-of-pipe controls
- Are industry-specific.

The Common Sense Initiative Council (CSIC), chaired by EPA Administrator Browner, consists of a parent council and six subcommittees (one per industry sector). Each of the subcommittees have met and identified issues and project areas for emphasis, and workgroups have been established to analyze and make recommendations on these issues.

Design for the Environment (DfE)

DfE is an EPA program operated by the Office of Pollution Prevention and Toxics. DfE is a voluntary program which promotes the use of safer chemicals, processes, and technologies in the earliest product design stages. The DfE program assists industry in making informed, environmentally responsible design choices by providing standardized analytical tools for industry application and providing information on the comparative environmental and human health risk, cost, and performance of chemicals, processes, and technologies. DfE also helps small businesses by analyzing pollution prevention alternatives and disseminating the information to industry and the public. By helping to translate pollution prevention into meaningful terms, DfE contributes to building the institutional structure in corporations to support pollution prevention. DfE activities fall into two broad categories: (1) the industry-specific projects which encourage businesses to incorporate pollution prevention into their designs; and (2) long-term projects that translate pollution prevention into terms that make sense to professions such as chemistry, chemical engineering, marketing, accounting, and insurance.

DfE currently is working with the PWB industry because it is a critical component of the electronics, automotive, and defense industries. Also, MCC's lifecycle assessment of a computer work station study recognized that chemical processes such as those used in PWB fabrication are a significant source of hazardous waste and consume large amounts of water and energy. The potential for improvement in those areas led EPA's DfE Program to sponsor a project to assist the PWB industry in evaluating substitute materials and processes for making PWB holes conductive. DfE also plans to help the PWB industry identify multi-media environmental issues and the trade-offs of competing environmental objectives.

Industry/Government Partnerships

In 1993, the initial results of a six month lifecycle assessment of a computer workstation was released in a report called *Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics and Computer Industry; Comprehensive Report: Analyses and Synthesis, Task Force Reports, and Appendices.* The study was conducted by Microelectronics and Computer Technology Corp. (MCC), SEMATECH (sponsored by the Semiconductor Industry Association), EPA, and the Department of Energy (DOE).

As a result of the assessment, the Department of Defense funded an industry led effort, the first phase of which involved development of the *Electronics Industry Environmental Roadmap*, which prioritizes the electronics and computer industries' environmental needs over the next ten years. The goal of the *Roadmap* is to assist U.S. companies to compete with foreign competitors who have established partnerships with their governments. MCC produced the *Electronics Industry Environmental Roadmap* in November 1993. MCC has received funding from the Department of Defense Advanced Research Projects Agency (ARPA) and EPA to continue to working with industry task groups to compile information, learn the needs of industry, and to suggest possible solutions to environmental/economic problems.

VIII.A.2. State Activities

Several States are actively involved in promoting pollution prevention by initiating partnerships with industry to develop and implement pollution prevention and waste minimization practices. Following is a description of some State pollution prevention initiatives related to the electronics/computer industry.

The **Minnesota Technical Assistance Program (MnTAP)** is supported by a grant to the University of Minnesota's School of Public Health. MnTAP staff and interns assists Minnesota businesses in the electronics and computer industries by identifying effective waste reduction opportunities. MnTAP researches treatment options, makes on-site visits to discuss recommendations, and coordinates documentation. MnTAP developed a checklist for businesses to evaluate their waste streams and identify waste reduction opportunities. MnTAP gathered vendor and technical information that may assist facilities in the industry in their evaluations in addition to a list of recycling vendors if the options on the checklists are not feasible to implement. Pollution prevention techniques for the electronics and computer industries that were recommended by MnTAP include material substitution, process modification, and recycling.

The **State of Minnesota's Office of Waste Management (OWM)** also has a Pollution Prevention Research Award Program. The program is part of Minnesota's efforts to promote pollution prevention. OWM contracts with private industry to investigate available pollution prevention alternatives in the electronics and computer industries. The process involves literature searches, telephone surveys, case study development, and working with trade associations and MnTAP. In July 1992, four cases studies were written as part of a report on alternatives to cyanide solutions in electroplating. OWM encourages implementation of pollution prevention techniques such as material substitution, recycling, process modification, wastewater treatment, electroplating, and the recycling of spent printed wiring boards.

The **North Carolina Department of Natural Resources and Community Development** has a Pollution Prevention Pays Program. The program provides technical, cost (operating and capital), economic benefit, and environmental benefit information to the public and facilities in the electronics and computer industries. The program recommends equipment modification, recycling, and process modification/pollution prevention techniques for the treatment of wastewater generated by electroplating processes.

The **City of Los Angeles' Board of Public Works** has a Hazardous and Toxic Materials Project (HTMP). HTMP provides fact sheets to the public and facilities in the electronics and computer industry describing different strategies to reduce the cost and quantity of waste generated. Pollution prevention techniques include material substitution, process modification, and recycling. HTMP also provides information on vendors who provide alternative waste management services.

The **City of Santa Monica's Department of General Services** provides fact sheets and information on pollution prevention to businesses. The City outlines pollution prevention techniques for printed circuit board manufacturing in fact sheets. The fact sheets rate waste reduction practices in terms of easiest, more difficult, and most difficult to implement. The fact sheets also provide contacts from the Department of Health Services, small business assistance loan programs, and California agencies with waste reduction programs.

Other pollution prevention initiatives that have targeted the electronics and computer industries include: the Hazardous Waste Reduction Program of the Oregon Department of Environmental Quality (DEQ); the New Jersey Hazardous Waste Facilities Siting Commission of the Hazardous Waste Source Reduction and Recycling Taskforce; and the San Diego County Department of Health Services.

VIII.B. EPA Voluntary Programs

33/50 Program

The "33/50 Program" is EPA's voluntary program to reduce toxic chemical releases and transfers of 17 chemicals from manufacturing facilities. Participating companies pledge to reduce their toxic chemical releases and transfers by 33 percent as of 1992 and by 50 percent as of 1995 from the 1988 baseline year. Certificates of Appreciation have been given to participants who met their 1992 goals. The list of chemicals includes 17 high-use chemicals reported in the Toxics Release Inventory.

Thirty-four companies and 72 facilities listed under SIC 36 (the electronics/computer industry) are currently participating in the 33/50 program. They account for approximately 17 percent of the 406 companies under SIC 36, which is slightly higher than the average for all industries of 14 percent participation. (Contact: Mike Burns 202-260-6394 or the 33/50 Program 202-260-6907)

Exhibit 41 lists those companies participating in the 33/50 program that reported under SIC code 36 to TRI. Many of the participating companies listed multiple SIC codes (in no particular order), and are therefore likely to conduct operations in addition to electronics/computer industry. The table shows the number of facilities within each company that are participating in the 33/50 program; each company's total 1993 releases and transfers of 33/50 chemicals; and the percent reduction in these chemicals since 1988.

Exhibit 41
Electronics/Computer Industry Facilities (SIC 36) Participating in the 33/50 Program

Parent Facility name	Parent City	ST	SIC Codes	# of Participating Facilities	1993 Releases and Transfers (lbs.)	% Reduction 1988 to 1993
Aluminum Company Of America	Pittsburgh	PA	3674	1	2,403,017	51
American Telephone & Telg Co	New York	NY	3672, 3661	3	512,618	50
Amp-Akzo Corporation	Chadds Ford	PA	3672	3	51,196	1
Benton International Inc	North Haven	CT	3672	1	26	2
Boeing Company	Seattle	WA	3728, 3769, 3672	1	4,789,875	50
Buckbee-Greig Holding Corp	Minneapolis	MN	3672	1	500	**
Burle Industries Inc	Lancaster	PA	3671, 3663, 3699	1	12,200	*
Eaton Corporation	Cleveland	OH	3674	1	450,211	50
General Motors Corporation	Detroit	MI	3651, 3694, 3679, 3672, 3471	3	16,751,198	
Gti Corporation	San Diego	CA	3674	1	13,961	*
Hadco Corporation	Salem	NH	3672	2	63,469	91
Harris Corporation	Melbourne	FL	3674	3	110,355	**
Hewlett-Packard Company	Palo Alto	CA	3674	2	7,400	50
IBM	Armonk	NY	3674	6	1,411,304	1
Intel Corporation	Santa Clara	CA	3674	3	18,105	50
Itt Corporation	New York	NY	3670, 3674	2	735,332	7
Litton Industries Inc	Beverly Hills	CA	3672	1	332,264	**
Lucerne Products Inc	Hudson	OH	3699, 3674	1	2,505	***
Martin Marietta Corporation	Bethesda	MD	3672, 3761, 3812	1	223,286	73
Motorola Inc	Schaumburg	IL	3674	4	226,357	50
National Semiconductor Corp.	Santa Clara	CA	3674	3	23,173	6
North American Philips Corp	New York	NY	3674	2	1,281,928	50
Photocircuits Corporation	Glen Cove	NY	3672, 3471	2	292,178	92
Raytheon Company	Lexington	MA	3674	2	706,045	50
Rockwell International Corp	Seal Beach	CA	3669, 3672	1	1,007,043	50
Seh America Inc.	Vancouver	WA	3674, 3339	1	53,140	100
Sony USA Inc	New York	NY	3674	2	869,577	51
Talley Industries Inc	Phoenix	AZ	3672, 3822, 3548	1	3,804	***
Tektronix Inc	Beaverton	OR	3672	1	12,393	*
Texas Instruments Incorporated	Dallas	TX	3674	5	344,225	25
Thomson Consumer Electronics	Indianapolis	IN	3671	4	2,110,314	43
Varian Associates Inc	Palo Alto	CA	3671	3	67,417	50
Westinghouse Electric Corp	Pittsburgh	PA	3672, 3812	3	1,137,198	28
Zenith Electronics Corporation	Glenview	IL	3671	1	917,894	25

*** = not quantifiable against 1988 data.**
**** = use reduction goal only.**
***** = no numerical goal.**

Energy Star Computer Program

The Energy Star Computer program is a voluntary partnership between the EPA and computer companies that manufacture energy-efficient computer equipment such as desktop computers, printers, and monitors. The companies that participate in this program comprise 70 percent of all U.S. sales of desktop computers and 90 percent of laser printers. In order for a computer to qualify and display the EPA Energy Star logo, it must operate on low power when inactive and can "sleep" or "power-down," and then awaken by touching the mouse or keyboard. The program requires that the central processing unit, printer, and monitor of the computer must enter a standby mode when not in use and use no more than 30 watts. Energy-efficient computers were available to the public and businesses as of June 1993.

Computer equipment is the fastest growing user of electricity in the commercial sector. Currently, computers account for five percent of commercial electricity consumption, and this is expected to grow to 10 percent by the year 2000. The Energy Star sleep feature can reduce electricity consumption by 50 to 75 percent. In addition, the efficient systems generate less heat while the computer sleeps, which reduces electricity needed to cool a building by five to ten percent. These computers are predicted to diminish electricity consumption by 25 billion kilowatts hours per year by the year 2000. The reduction of electricity use would eliminate the need for 10 coal-fired plants and reduce carbon-dioxide emissions by up to 20 million tons. An Executive Order, which was issued in April 1993 and took effect in October 1993, directed the U.S. government to purchase only Energy Star computer equipment where available and if performance needs are met. Implementation of the Executive Order is expected to save $40 million annually. (Contact: Maria Tikoff (202) 233-9178)

Environmental Leadership Program

The Environmental Leadership Program (ELP) is a national initiative piloted by EPA and State agencies in which facilities have volunteered to demonstrate innovative approaches to environmental management and compliance. EPA has selected 12 pilot projects at industrial facilities and Federal installations which will demonstrate the principles of the ELP program. These principles include: environmental management systems, multimedia compliance assurance, third-party verification of compliance, public measures of accountability, community involvement, and mentoring programs. In return for participating, pilot participants receive public recognition and are given a period of time to correct any violations discovered during these experimental projects. (Contact: Tai-ming Chang, ELP Director (202) 564-5081 or Robert Fentress (202) 564-7023)

Motorola ELP Project

Motorola is participating in a pilot phase of the Environmental Leadership Program with EPA and the State of Texas. Their Oak Hill facility located in Austin, Texas, will encompass two key projects, both in the pursuit of better environmental compliance. They are mentoring another facility and applying an environmental management system that aims to go beyond compliance status. (Contact: Steve Hoover (202) 564-7007)

Project XL

Project XL was initiated in March 1995 as a part of President Clinton's *Reinventing Environmental Regulation* initiative. The projects seek to achieve cost effective environmental benefits by allowing participants to replace or modify existing regulatory requirements on the condition that they produce greater environmental benefits. EPA and program participants will negotiate and sign a Final Project Agreement, detailing specific objectives that the regulated entity shall satisfy. In exchange, EPA will allow the participant a certain degree of regulatory flexibility and may seek changes in underlying regulations or statutes. Participants are encouraged to seek stakeholder support from local governments, businesses, and environmental groups. EPA hopes to implement fifty pilot projects in four categories including facilities, sectors, communities, and government agencies regulated by EPA. Applications will be accepted on a rolling basis and projects will move to implementation within six months of their selection. For additional information regarding XL Projects, including application procedures and criteria, see the May 23, 1995 Federal Register Notice. (Contact: Jon Kessler at (202) 260-4034)

Green Lights Program

EPA's Green Lights program was initiated in 1991 and has the goal of preventing pollution by encouraging U.S. institutions to use energy-efficient lighting technologies. The program has over 1,500 participants which include major corporations; small and medium sized businesses; Federal, State and local governments; non-profit groups; schools; universities; and health care facilities. Each participant is required to survey their facilities and upgrade lighting wherever it is profitable. EPA provides technical assistance to the participants through a decision support software package, workshops and manuals, and a financing registry. EPA's Office of Air and Radiation is responsible for operating the Green Lights Program. (Contact: Susan Bullard at (202) 233-9065 or the Green Light/Energy Star Hotline at (202) 775-6650)

WasteWi$e Program

The WasteWi$e Program was started in 1994 by EPA's Office of Solid Waste and Emergency Response. The program is aimed at reducing municipal solid wastes by promoting waste minimization, recycling collection, and the manufacturing and purchase of recycled products. As of 1994, the program had about 300 companies as members, including a number of major corporations. Members agree to identify and implement actions to reduce their solid wastes and must provide EPA with their waste reduction goals along with yearly progress reports. EPA in turn provides technical assistance to member companies and allows the use of the WasteWi$e logo for promotional purposes. (Contact: Lynda Wynn (202) 260-0700 or the WasteWi$e Hotline at (800) 372-9473)

Climate Wise Recognition Program

The Climate Change Action Plan was initiated in response to the U.S. commitment to reduce greenhouse gas emissions in accordance with the Climate Change Convention of the 1990 Earth Summit. As part of the Climate Change Action Plan, the Climate Wise Recognition Program is a partnership initiative run jointly by EPA and the Department of Energy. The program is designed to reduce greenhouse gas emissions by encouraging reductions across all sectors of the economy, encouraging participation in the full range of Climate Change Action Plan initiatives, and fostering innovation. Participants in the program are required to identify and commit to actions that reduce greenhouse gas emissions. The program, in turn, gives organizations early recognition for their reduction commitments; provides technical assistance through consulting services, workshops, and guides; and provides access to the program's centralized information system. At EPA, the program is operated by the Air and Energy Policy Division within the Office of Policy Planning and Evaluation. (Contact: Pamela Herman (202) 260-4407)

NICE^3

The U.S. Department of Energy and EPA's Office of Pollution Prevention are jointly administering a grant program called The National Industrial Competitiveness through Energy, Environment, and Economics (NICE^3). By providing grants of up to 50 percent of the total project cost, the program encourages industry to reduce industrial waste at its source and become more energy-efficient and cost-competitive through waste minimization efforts. Grants are used by industry to design, test, demonstrate, and assess the feasibility of new processes and/or equipment with the potential to reduce pollution and increase energy efficiency. The program is open to all industries; however, priority is given to proposals from participants in the pulp and paper, chemicals, primary metals, and petroleum and coal products sectors. (Contact: DOE's Golden Field Office (303) 275-4729)

VIII.C. Trade Association Activity

Many trade associations have been involved in researching ways to reduce pollution associated with the manufacturing of semiconductors, printed wiring boards, and cathode ray tubes. Following is description of the trade association environmental programs or partnerships. A list of some of the major trade associations and contacts is also provided.

VIII.C.1. Environmental Programs

The Semiconductor Industry Association (SIA), in association with EPA and DOE, released a report in March 1993 called *Environmental Consciousness: A Strategic Competitiveness Issue for the Electronics and Computer Industry*. This report contains the initial results of a six month, lifecycle assessment of a computer workstation. The report indicates that the industry should pursue the development of pollution prevention and waste minimization techniques in the printed wired board (PWB) manufacturing industry. As a result of this study, EPA provided funding to the Institute for Interconnecting and Packaging Electronic Circuits (IPC) and Microelectronics and Computer Technology Corporation (MCC) to redesign PWB manufacturing processes in order to reduce the amount of chemicals used during production.

According to IPC, environmental research is also being conducted by the Interconnection Technology Research Institute (ITRI) and by many independent companies.

According to SIA, the Department of Defense has awarded SEMATECH $10 million to perform research into pollution prevention and environmentally friendly microchip manufacturing processes. As part of a separate initiative, SIA produced a report, *The National Technology Roadmap for Semiconductors.* The *Roadmap* acts as a guide for R&D investment decisions.

SIA's *Roadmap* calls for reducing the use of approximately 60 hazardous chemicals in various stages of the manufacturing process (e.g., mask making, photolithography, cleaning, leadframe plating, deflashing, and soldering). The chemicals include solvents, acids, toxics, alcohols, and other organic and inorganic substances. The goal of the *Roadmap* is to phase out ozone depleting substances and targeted ethylene glycol ethers during the next 15 years. The *Roadmap* identifies 46 projects for implementation in 1994 that involved process modifications. The majority of the process modifications center around alternatives to wet chemical processes and continued progress in development of alternative technologies for applying layers of silicon to the wafer. The development of water-based (or gas process) cleaners and resists is also a priority.

VIII.C.2. Trade Associations

Electronic Industries Association (EIA) 2500 Wilson Boulevard Arlington, VA 22201 Phone: (703) 907-7500 Fax: (703) 907-7501	Members: 1200 Staff: 150 Budget: $25,000,000 Contact: Peter McCloskey

EIA was founded in 1924, and represents manufacturers of electronic components, parts, systems, and equipment for communications, industrial, government, and consumer use. EIA publishes a free, semiannual *EIA Publications Index* that contains price, content, and ordering information for their publications. EIA works to develop sound environmental practices by promoting research, workshops, and tool development through a variety of industry committees.

American Electronics Association (AEA) 5201 Great American Parkway, Suite 520 Santa Clara, CA 95054 Phone: (408) 987-4200 Fax: (408) 970-8565	Members: 3500 Staff: 140 Budget: NA Contact: J. Richard Iverson

AEA was founded in 1943, and is a trade association that represents the U.S. electronics/computer industry. Formerly known as the West Coast Electronic Manufacturer Association (WEMA), AEA's programs and services include: public affairs, educational meetings conferences, and executive summits. AEA publishes an annual directory; a monthly association and trade news publication, *American Electronics Association*, which includes legislative briefs, industry statistics, and a calendar of events; a periodic California Legislative Bulletin; and handbooks, manuals, and surveys. In addition, AEA sponsors an annual Systems/USA trade show.

National Electronic Manufacturing Association (NEMA) 2101 L Street, NW, Suite 300 Washington, DC 20037 Phone: (202) 457-8400 Fax: (202) 457-8411	Members: 600 Staff: 100 Budget: $10,000,000 Contact: Malcolm O'Hagan

NEMA was established in 1926. NEMA represents companies that manufacture equipment used for the generation, transmission, distribution, control, and utilization of electric power. NEMA was formed by the merger of Associated Manufacturers of Electrical and Supplies and the Electronic Power Club. NEMA's areas of interest include: electrical machinery; motors; and industrial automation, construction, utility, medial diagnostic imaging, transportation, communication, and lighting equipment. NEMA's objectives are to maintain and enhance the quality and reliability of products, ensure safety standards in the manufacturing and use of products, and to organize and act upon members' interest in areas such as energy conservation, efficiency and foreign competition. NEMA conducts regulatory and legislative analysis on issues of concern to electronic manufacturers, and compiles periodic summaries of statistical data on sales and production. In addition, NEMA publishes a periodic directory; a free, semiannual catalog of its publications and materials; *Tech Alert* bimonthly; and manuals, guidebooks, and other material on wiring, equipment installation, lighting, and standards.

Semiconductor Equipment and Materials International (SEMI) 805 E. Middlefield Road Mountain View, CA 94043 Phone: (415) 964-5111 Fax: (415) 967-5375	Members: 1750 Staff: NA Budget: NA Contact: William H. Reeds

SEMI was founded in 1970, and represents firms, corporations, and individuals who participate in supplying fabrication equipment, materials, or services to the semiconductor industry. SEMI operates an industry data collection program, conducts SEMI Technical Education Programs, and provides an annual Information Services Seminar (ISS) forecast. SEMI is the former Semiconductor Equipment and Materials Institute. SEMI publishes an annual *Book of SEMI Standards,* the annual *Business Outlook for the Semiconductor Equipment and Materials Industry*; a bimonthly newsletter providing general industry news; a quarterly newsletter, *SEMI Outlook*, that provides information on industry trends, analyses, and opinions; and the SEMICON Technical Proceedings which contains the proceedings and paper topics from the Institute's technical symposia.

Institute for Interconnecting and Packaging Electronic Circuits (IPC) 2215 Sanders Road, Suite 200 South Northbrook, IL 60062 Phone: (708) 677-2850 Fax: (708) 677-9570	Members: 1900 Staff: 42 Budget: NA Contact: Thomas Dammrich

Founded in 1957, IPC represents companies that produce and use electronic interconnections for electronic equipment. IPC's primary members are independent PWB manufacturers and contract assembly companies that mount components onto bare PWBs to produce printed wiring assemblies (PWAs) or electronic assemblies. IPC also represents original equipment manufacturers (OEMs), suppliers, academia, and technical members of the industry. IPC has over 100 committees, that cover all aspects of the industry including: technical standards; specifications and guidelines; education and training; technology research and development; market research and publications; management practices; environmental and safety programs; and government regulations.

Semiconductor Industry Association (SIA) 4300 Stevens Creek Boulevard Suite 271 San Jose, CA 95129 Phone: (408) 246-2711 Fax: (408) 246-2830	Members: 40 Staff: 14 Budget: $2,000,000 Contact: Andrew Procassini

SIA represents companies that produce semiconductor products including discrete components, integrated circuits, and microprocessors. This association compiles industry trade statistics and maintains a private library and sponsors the Semiconductor Research Corporation and SEMATECH. SIA's publications include the following: *Circuit*, a free, quarterly newsletter; Semiconductor Yearbook and Directory, which contains a review of programs sponsored by the association, key industry statistics, analyses by industry experts, public policy discussions, and sales volume; and essays, research reports, and proceedings.

Computer and Communications Industry Association (CCIA) 666 11th Street, NW Washington, DC 20001 Phone: (202) 783-0070 Fax: (202) 783-0534	Members: 60 Staff: 10 Budget: $1,000,000 Contact: A.G.W. Biddle

Comprised of computer manufacturers, CCIA provides information processing and telecommunication-related products and services. CCIA represents the interests of its members before Congress, Federal agencies, and the courts in the areas of domestic and foreign trade, tax policy, Federal procurement policy, and telecommunication policy. It hosts policy briefings on legislative and regulatory matters to keep members aware of policy, political, technological, and market and economic developments and trends. CCIA publishes *CEO Report* semimonthly and *Federal Procurement Policy Report*, *International Trade Report*, and *Telecommunication Report* on a monthly basis.

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