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Printed Wiring Board Cleaner Technologies Substitutes Assessment: Making Holes Conductive

Volume 2

Design for the Environment Printed Wiring Board Project

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Appendix A

Data Collection Sheets

Appendix A includes:

A.1 Workplace Practices Questionnaire

A.2 Observer Data Sheet

A.3 Facility Background Information Sheet

A.4 Supplier Data Sheet

A.1 Workplace Practices Questionnaire

WORKPLACE PRACTICES QUESTIONNAIRE FOR THE MAKING HOLES CONDUCTIVE PROCESS

DESIGN FOR THE ENVIRONMENT (DfE) PRINTED WIRING BOARD PROJECT

This document is prepared by the University of Tennessee Center for Clean Products and Clean Technologies in Partnership with U.S. EPA Design for the Environment (DfE) Program, IPC, PWB manufacturers, and other DfE Partners

March 1995

Note: This survey is <u>not</u> as long as it looks since you will only complete a part of it. This survey has 7 sections; however, we ask you to complete only sections 1,2,3 and the section that pertains to <u>your</u> making holes conductive (MHC) process.

WORKPLACE PRACTICES QUESTIONNAIRE FOR THE MAKING HOLES CONDUCTIVE PROCESS

Design for the Environment Project

PLEASE RETURN BY FRIDAY, MARCH 31, 1995 TO: IPC - ATTN: STAR SUMMERFIELD, 7380 N. LINCOLN AVENUE, LINCOLNWOOD, IL 60646-1705

DO NOT COMPLETE ALL SECTIONS OF THE QUESTIONNAIRE. The following explains which sections you should complete based on the type of making holes conductive (MHC) process used at your facility, provides background information on the questionnaire, and describes how the data will be handled to ensure confidentiality.

1. This questionnaire was prepared by the University of Tennessee Center for Clean Products and Clean Technologies in partnership with the EPA DfE Program, IPC, PWB manufacturers, and other members of the DfE PWB Industry Project.

2. For the purposes of this survey and the DfE Project, the “Making Holes Conductive (MHC)” process is defined as beginning after the desmear and etchback steps and ending prior to the dry film resist outer layer step (if required) and copper electroplating step.

3. Shaded sections of the questionnaire denote areas where responses to questions should be entered. Unshaded sections are instructions or keys required to answer the question.

4. Throughout the questionnaire, many questions request specific data, such as chemical volumes, the amount of water consumed by the MHC line or the characteristics of wastewater from the MHC line. If specific data are not readily available, estimates based on your knowledge of the process and the facility, are adequate. In cases where no data are available and there is no basis for an accurate estimate, mark your response as “ND.”

5. Please complete Sections 1 through 3 of the questionnaire, regardless of which process is used at your facility to make drilled through-holes conductive prior to electroplating.

6. After completing Sections 1 through 3, please complete only the section(s) of the survey that corresponds to the MHC process(es) currently being operated at your facility, as listed below.

Electroless Copper......................	Section 4
Graphite-based............................	Section 5
Carbon-based..............................	Section 6
Palladium-based..........................	Section 7

If the MHC process used at your facility is not listed, you have completed the questionnaire.

7. If your responses do not fit in the spaces provided, please photocopy the section to provide more space or use ordinary paper and mark the response with the section number to which it applies.

8. Appendix A contains the definitions of certain terms and acronyms used in the survey form.

9. **Confidentiality**
All information and data entered into this survey form are confidential. The sources of responses will not be known by IPC, University of Tennessee, EPA, or other project participants. Any use or publication of the data will not identify the names or locations of the respondent companies or the individuals completing the forms.

Please use the following procedures to ensure confidentiality:

(1) Compete the survey form. Make a copy of the completed form and retain it for your records.
(2) Separate the facility and contact information page of the survey form from the remainder of the form. Place the facility and contact information into Envelope # 1 and seal the envelope.
(3) Place the remainder of the survey form plus any additional sheets or exposure monitoring data into Envelope # 2 and seal it.
(4) Place sealed envelopes # 1 and # 2 into the larger return envelope and mail it to IPC.
(5) When the package is received by IPC, only Envelope # 1 will be opened. IPC will place a code number on the outside of Envelope # 2 and forward it to the Center for Clean Products and Clean Technologies at the University of Tennessee. Envelope # 1 will not be sent to the University of Tennessee.
(6) Questions, clarifications, or requests for further information from the University of Tennessee will be relayed by code number to IPC, who will be able to contact the respondent. When it is determined that no further communications with respondents are necessary, the matrix of code numbers and respondents will be destroyed by IPC.

10. If you have any questions regarding the survey form, please contact Jack Geibig of the University of Tennessee Center for Clean Products and Clean Technologies at 615-974-6513 (e-mail: JGEIBIG@UTKVX.UTK.EDU).

PLEASE RETURN BY FRIDAY, MARCH 31, 1995 TO: IPC - ATTN: STAR SUMMERFIELD, 7380 N. LINCOLN AVENUE, LINCOLNWOOD, IL 60646-1705 (PH: 708-677-2850 EXT. 347; FAX: 708-677-9570)

Section 1. Facility Characterization

Estimate manufacturing data for the previous 12 month period or other convenient time period of 12 consecutive months (e.g., FY94). Only consider the portion of the facility dedicated to PWB manufacturing when entering employee and facility size data.

1.1 General Information

Size of portion of facility used for manufacturing PWBs:	sq.ft.	Number of days MHC line is in operation:	days/yr
Number of full-time equivalent employees (FTEs):		Total PWB panel sq. footage processed by the MHC process:	sq.ft./yr
Number of employee work days per year:	days/yr		

1.2 Facility Type

Type of PWB manufacturing facility (check one)	Independent		OEM	

1.3 Process Type

Estimate the percentage of PWBs manufactured at your facility using the following methods for making holes conductive (MHC). Specify "other" entry.

Standard electroless copper	%
Palladium-based system	%
Carbon-based system	%
Graphite-based system	%
Electroless nickel	%
Other:	%
TOTAL	100%

1.4 General Process Line Data

Process Data	Shift			
	1	2	3	4
Number of hours per shift:				
Numbers of hours the MHC line is in operation per shift:				
Average square feet of PWB panel processed by the MHC line per shift:				

1.5 Process Area Employees

Complete the following table by indicating the number of employees of each type that perform work duties in the same process room as the MHC line for each shift and for what length of time. Report the number of hours per employee by either the month or the shift, whichever is appropriate for the worker category. Consider only workers who have regularly scheduled responsibilities physically within the process room. Specify "other" entry.

Type of Process Area Worker	Number of Employees per Shift				Hours per Shift per Employee in Process Area (first shift)	Hours per Month per Employee in Process Area (first shift)
	1	2	3	4		
Line Operators					Hrs	Hrs
Lab Technicians					Hrs	Hrs
Maintenance Workers					Hrs	Hrs
Wastewater Treatment Operators					Hrs	Hrs
Supervisory Personnel					Hrs	Hrs
Contract workers					Hrs	Hrs
Other:					Hrs	Hrs
Other:					Hrs	Hrs

Section 2. General Process Data

The information in this section will be used to identify the physical parameters of the process equipment as well as any operating conditions common to the entire process line.

2.1 Process Parameters

MHC process line dimensions Length:	ft.	
Width:	ft.	
Average time for panel to complete process:	min.	
Size of the room containing the process:	sq.ft.	
Temperature of the process room:	°F	
Is the process area ventilated (circle one)?	Yes	No
Air flow rate:	cu.ft./min.	
Type of ventilation? (Check one) general	☐ local	☐

2.2 General Water Usage

Amount of water used by the MHC process line when operating:	gal./day

2.3 Wastewater Characterization

Estimate the average and maximum values for the wastewater from the making holes conductive line.

	AVERAGE	MAXIMUM
Flow	gpm	gpm
TDS	mg/l	mg/l
pH		
Cu	mg/l	mg/l

	AVERAGE	MAXIMUM
Pd	mg/l	mg/l
Sn	mg/l	mg/l
TSS	mg/l	mg/l
TTO	mg/l	mg/l

2.4 Wastewater Discharge and Sludge Data

Wastewater discharge type (check one) Direct	☐	Indirect	☐	Zero	☐	
Annual quantity of sludge generated:						
Percent solids of sludge						
Percentage of total quantity generated by the MHC process:						
Method of sludge recycle/disposal (see key at right)						

Methods of Sludge Recycle/Disposal

[R] - Metals reclaimed
[D] - Stabilized and landfilled
[O] - Other

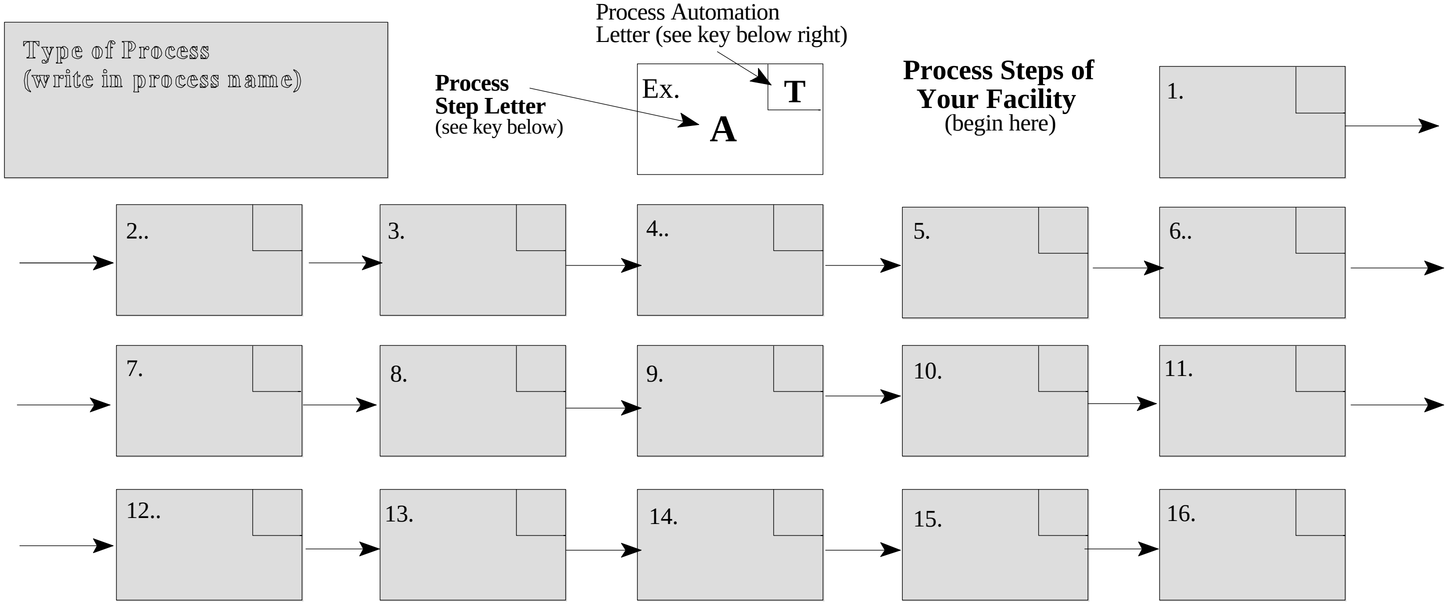
2.5 Panel Rack Specifications - (non-conveyorized MHC process only)

Average number of panels per rack:			
Average space between panels in rack:	in.		
Average size of panel in rack: Length	in.	Width	in.

Section 3. Process Description

3.1 Process Schematic

Fill in the table below by identifying what type of making holes conductive process (e.g., electroless copper) your facility uses. Then, using the proper key at the bottom of the page, identify which letter corresponds with the first step in your process and write that letter in the first box (see example). Continue using the key to fill in boxes for each step in your process until your entire making holes conductive process is represented. If your process is not represented by a key below, complete the chart by writing in the name of each process step in your particular making holes conductive line. Finally, consult the process automation key at bottom right and enter the appropriate type of automation for the MHC process line. If the process is partially automated, enter the appropriate process automation letter for each step in the upper right-hand corner box (see example.



ELECTROLESS COPPER PROCESS STEPS
[A] - Conditioner/Cleaner
[B] - Micro Etch
[C] - Pre-dip
[D] - Activator/Catalyst
[E] - Accelerator
[F] - Electroless Copper
[G] - Reducer/Neutralizer
[H] - Anti-tarnish / Anti-oxidant
[W]- Water rinse
[O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
[A] - Cleaner/Conditioner
[B] - Graphite
[C] - Fixer
[D] - Air Knife/Oven
[E] - Post-clean Etch
[F] - Anti-tarnish/ Anti-oxidant
[W] - Water rinse
[O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
[A] - Cleaner/Conditioner
[B] - Graphite
[C] - Fixer
[D] - Air Knife/Oven
[E] - Post-clean Etch
[F] - Anti-tarnish/ Anti-oxidant
[W] - Water rinse
[O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
[A] - Cleaner/Conditioner
[B] - Graphite
[C] - Fixer
[D] - Air Knife/Oven
[E] - Post-clean Etch
[F] - Anti-tarnish/ Anti-oxidant
[W] - Water rinse
[O] - Other (specify step)

PROCESS AUTOMATION

TYPE OF PROCESS AUTOMATION FOR ENTIRE MHC PROCESS
(Coonsult the key below)
* If the MHC process is partially automated (option R) enter 'R' on above line. Then, for each process step in chart above, consult the key below and enter the appropriate process automation letter in the box located in the upper right-hand corner of each process step (see example.

Process Automation Key
[P] - Automated non-conveyorized
[Q] - Automated conveyorized
[R] - Partially automated *
[S] - Manually controlled hoist
[T] - Manual (no automation)
[V] - Other (specify)

3.2 Rinse Bath Water Usage

Consult the process schematic in Section 3.1 to obtain the process step numbers associated with each of the water rinse baths present. Enter, in the table below, the process step number along with the flow control and flow rate data requested for each water rinse bath. If the water rinse bath is part of a cascade, you need only report the daily water flow rate of one bath in the cascade.

Process Step Number[a]	Flow Control[b]	Daily Water Flow Rate[c]	Cascade Water Process Steps[d]
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	

[a] **Process Step Number** - Consult the process schematic in question 4.1 and enter the process step number of the specific water rinse tank.

[b] **Flow Control** - Consult key at right and enter the letter for the flow control method used for that specific rinse bath.

[c] **Daily Water Flow Rate** - Enter the average daily flow rate for the specific water rinse tank.

[d] **Cascade Water Process Steps** - Enter the process step number for each water rinse tank in cascade with the present tank.

Flow Control Methods Key

[C] - Conductivity meter
[P] - PH meter
[V] - Operator control valve
[R] - Flow restricter
[N] - None (continuous flow)
[O] - Other (explain)

3.3 Rack Cleaning - (non-conveyorized MHC process only)

Complete the following section by using the keys to the right of the table to identify the rack cleaning process used.

Frequency of cleaning:	
Number of personnel involved:	
Personal protective equipment (see key at right):	
Rack cleaning method used (see key at right): *If the above answer is [C], also enter the process step number from the process schematic (section 3.1) and do not complete section 3.4 below.	
Average time required to chemically clean rack (if applicable):	min.
Cleaning schedule (see key at right):	
Is rack cleaning attended (circle one)	Yes No

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except Respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

Rack Cleaning Methods Key

[C] - Chemical bath on making holes conductive line
[D] - Chemical bath on another line
[T] - Temporary chemical bath
[S] - Manual scrubbing with chemical
[M] - Non-chemical cleaning
[N] - None

Rack Cleaning Schedule

[A] - After hours
[L] - During operating hours - in MHC process room
[M] - During operating hours - outside MHC process room

3.4 Rack Cleaning Chemical Composition (non-conveyorized MHC process only)

Chemical Name	Conc.	Volume
		gal.
		gal.
		gal.

3.5 Conveyor Equipment Cleaning

Complete the following table on conveyorized equipment cleaning in the MHC process line by providing the information requested for each cleaning operation performed. If more space is needed or more than two cleaning operations occur, report them on a separate sheet of paper.

Equipment Cleaning Data	Cleaning Operation No. 1	Cleaning Operation No. 2
Description of cleaning operation: (briefly describe equip. cleaned)		
Process steps affected[a]		
Frequency of cleaning:		
Duration of cleaning:	min.	min.
Number of personnel involved:		
Personal protective equipment (see key at right):		
Cleaning method used (see key at right):		
Cleaning chemical used[b]		

Personal Protective Equipment Key
[E] - Eye protection
[G] - Gloves
[L] - Labcoat/sleeved garment
[A] - Apron
[R] - Respiratory protection
[B] - boots
[Z] - All except Respiratory protection
[N] - None

Conveyor Cleaning Methods Key
[C] - Chemical rinsing or soaking
[S] - Manual scrubbing with chemical
[M] - Non-chemical cleaning
[N] - None

[a] **Process Steps Affected** - Consult the process schematic from section 4.1 and enter the process step numbers of the specific steps affected by the cleaning operation.

[b] **Cleaning Chemical Used** - Enter the name of the chemical or chemical product (or bath type, if applicable) used in the specific cleaning operation.

3.6 Filter Replacement

Complete the following table on filter replacement in the MHC process line by providing the information requested for each set of filters replaced.

Replacement Information	Filter Assembly No. 1	Filter Assembly No. 2	Filter Assembly No. 3
Bath filtered (enter process step from 3.1):			
Frequency of replacement:			
Duration of replacement:	min.	min.	min.
Number of personnel involved:			
Personal protective equipment (see key below):			
Type of filter (see key below):			
Number of filters changed in assembly:			
Area of filter:	sq. in.	sq. in.	sq. in.

Personal Protective Equipment Key
[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

Filter Type Key
[B] - Bag Filter
[O] - Other (specify)

3.7 Process History

Complete the table below by indicating what making holes conductive process(es) your facility has employed in the past. Briefly explain the reasons for the process change and summarize how the change has had an affect upon production.

FORMER MAKING HOLES CONDUCTIVE PROCESS	DATE OF CHANGE TO CURRENT PROCESS
ELECTROLESS COPPER	
PALLADIUM-BASED	
GRAPHITE-BASED	
CARBON-BASED	
COPPER SEED	
ELECTROLESS NICKEL	
OTHER (specify)	

REASONS FOR CHANGE AND RESULTS		
Reason (see key)		**Result** (see key)
	Water Consumption	
	Process Cycle-time	
	Cost	
	Worker Exposure	
	Performance	
	Customer Acceptance	
	Product Quality	
	Process Maintenance	
	Other:	
	Other:	
	Other:	

Reasons
[X] - Mark all of the selections that apply

Results of Change
[B] - Better
[W] - Worse
[N] - No change

The remainder of the survey is dedicated to questions that are strictly specific to the type of making holes conductive process operated at your facility. **You should complete only the section(s) of the survey that corresponds to the MHC process(es) that is currently being operated.**

Select the making holes conductive process(es) that your facility currently operates and complete only the section(s) listed. If your process is not listed, then you have completed the questionnaire.

Electroless Copper .... Section 4 (pgs. 9-17)
Graphite-Based..................... Section 5 (pgs. 19-26)
Carbon-Based........................ Section 6 (pgs. 27-34)
Palladium-Based.................... Section 7 (pgs. 35-43)

Section 4. Electroless Copper Process

The information requested below will allow us to generate an exposure assessment and risk characterization profile for each of the following baths and the associated activities involved in the operation and upkeep of the electroless copper process.

NOTE: You need to complete this section only if your facility uses an electroless copper process for making the holes conductive during the PWB manufacturing process.

4.1 Physical, Process, and Operating Conditions

Complete the table below by entering the data requested for each specific type of chemical bath listed. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH	PHYSICAL DATA			PROCESSING DATA		OPERATING CONDITIONS		
	LENGTH (inches)	WIDTH (inches)	NOMINAL VOLUME	IMMERSION[a] (seconds)	DRIP TIME[b] (seconds)	TEMP °F	AGITATION[c]	VAPOR CONTROL[d]
CLEANER/ CONDITIONER	in.	in.	gal.	sec.	sec.	°F		
MICRO-ETCH	in.	in.	gal.	sec.	sec.	°F		
PRE-DIP	in.	in.	gal.	sec.	sec.	°F		
ACTIVATOR/ CATALYST	in.	in.	gal.	sec.	sec.	°F		
ACCELERATOR	in.	in.	gal.	sec.	sec.	°F		
ELECTROLESS COPPER	in.	in.	gal.	sec.	sec.	°F		
REDUCER/ NEUTRALIZER	in.	in.	gal.	sec.	sec.	°F		
ANTI-TARNISH/ ANTI-OXIDANT	in.	in.	gal.	sec.	sec.	°F		
OTHER (specify)	in.	in.	gal.	sec.	sec.	°F		

[a] **Immersion Time** - Enter the average elapsed time a rack of panels is immersed in the specific process bath.

[b] **Drip Time** - Eenter the average elapsed time that a rack of panels is allowed to hang above the specific bath to allow chemical drainage from panels.

[c] **Agitation** - Consult the key at right and enter the letter for the agitation method used in the specific chemical bath.

[d] **Vapor Control** - Consult key at right and enter the letter of the vapor control method used for that specific chemical bath.

Agitation Methods Key
[P] - Panel agitation
[F] - Fluid circulation pump
[A] - Air sparge
[O] - Other (explain)

Vapor Control Methods Key
[P] - Push-Pull
[C] - Bath cover (when not in use)
[B] - Plastic balls (floating)
[E] - Fully enclosed
[O] - Other (explain)

4.2 Initial Chemical Bath Make-Up Composition

Complete the chart below for each chemical component of the bath type listed. Provide the manufacturer name if the chemical used is known only by trade name. If more room is needed, please attach another sheet with the additional information. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME [a] (gallons)	CONCENTRATION [b]	ANNUAL QTY. USED[c] (gallons)
CLEANER/ CONDITIONER	1.					
	2.					
	3.					
	4.					
MICRO-ETCH	1.					
	2.					
	3.					
	4.					
PRE-DIP	1.					
	2.					
	3.					
	4.					
ACTIVATOR/ CATALYST	1.					
	2.					
	3.					
	4.					
ACCELERATOR	1.					
	2.					
	3.					
	4					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

4.2 Initial Chemical Bath make-Up Composition - CONTINUED

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME [a] (gallons)	CONCENTRATION [b]	ANNUAL QTY. USED[c] (gallons)
ELECTROLESS COPPER	1.					
	2.					
	3.					
	4.					
REDUCER/ NEUTRALIZER	1.					
	2.					
	3.					
	4.					
ANTI-TARNISH/ ANTI-OXIDANT	1.					
	2.					
	3.					
	4.					
OTHER (specify)	1.					
	2.					
	3.					
	4.					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: Enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

4.3 Chemical Bath Replacement

Complete the chart below by providing information on the process of replacing, treating, and disposing of a spent chemical bath.

BATH TYPE	CRITERIA FOR REPLACEMENT[a]	FREQUENCY[b]	DURATION OF REPLACEMENT PROCEDURE[c]	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[d]	ON-SITE METHOD OF TREATMENT OR DISPOSAL[c]	ANNUAL VOLUME TREATED OR DISPOSED[f]	OFF-SITE METHOD OF TREATMENT OR DISPOSAL[e]
CLEANER/ CONDITIONER								
MICRO-ETCH								
PRE-DIP								
ACTIVATOR/ CATALYST								
ACCELERATOR								
ELECTROLESS COPPER								
REDUCER/ NEUTRALIZER								
ANTI-TARNISH/ ANTI-OXIDANT								
OTHER (specify)								

[a] **Criteria for Replacement** - Consult the key at right and enter the letter for the criteria typically used to determine when bath replacement is necessary.

[b] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[c] **Duration of Replacement** - Enter the elapsed time from the beginning of bath removal until the replacement bath is finished.

[d] **Personal Protective Equip.** - Consult key at right and enter the letters of **all** the protective equipment worn by the workers physically replacing the spent bath.

[e] **Methods of Treatment or Disposal** - Consult keys at right and enter the letter of the method used.

[f] **Annual Volume Treated or Disposed** - Enter the yearly amount of the specific bath treated or disposed.

On-Site Method of Treatment or Disposal

[P] - Precipitation pretreatment on-site
[N] - PH neutralization pretreatment on-site
[S] - Disposed directly to sewer with no treatment
[D] - Drummed for off-site treatment or disposal
[R] - Recycled on-site
[O] - Other (specify)

Off-Site Method of Treatment or Disposal

[R] - Sent to recycle
[P] - Discharged to POTW
[O] - Other

Criteria for Bath Replacement

[S] - Statistical process control
[P] - Panel sq. ft. processed
[C] - Chemical testing
[T] - Time
[O] - Other (Specify)

Personal Protective Equipment

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

4.4 Chemical Handling Activities: Chemical Bath Replacement

Complete the table below by indicating the options your facility uses to replace each type of spent chemical bath. **If the same options are used to replace each of the various chemical baths, enter “ALL” as the type of bath and fill out only one table.** Otherwise, please photocopy and attach additional charts, as necessary.

TYPES OF BATHS [a]

REMOVAL OF SPENT BATH			**CLEANING OF EQUIPMENT**			**NEW BATH MAKE-UP**		
Method of Removing Spent Bath	Pump:		**Tank Cleaning Method**	Chemical flush:		**Chemical Retrieval from** **Stock into Container**	Pump:	
	Siphon:			Hand scrub:			Pour:	
	Drain/spigot:			Other (specify):			Scoop (solid):	
	Other (specify):						Other (specify):	
Remove Spent Bath	Directly to wastewater treatment:		**CHEMICALS USED IN CHEMICAL FLUSH**			**Container Type**	Open-top container:	
	Directly to sewer:		**Chemical**	**Gallons Per Year**			Closed-top container:	
	To open-top container:						Safety container:	
	To closed-top container:						Other (specify):	

[a] **Type of Baths** - Enter the types of baths where the activities are used. If the chemical handling activities are the same for each bath type, enter ‘**ALL.**’

4.5 Chemical Bath Sampling

Provide information on the chemical bath sampling procedures used in your facility. Duration of sampling and personnel involved should include only the portion of the testing procedure involving the manual sampling of the chemical baths, not automated sampling or the testing that may occur in another part of the facility, such as the lab.

BATH TYPE	TYPE OF SAMPLING[a]	FREQUENCY[b]	DURATION OF SAMPLING[c]	NO. OF PEOPLE[d]	PROTECTIVE EQUIPMENT[e]
CLEANER/ CONDITIONER			min.		
MICRO-ETCH			min.		
PRE-DIP			min.		
ACTIVATOR/ CATALYST			min.		
ACCELERATOR			min.		
ELECTROLESS COPPER			min.		
REDUCER/ NEUTRALIZER			min.		
ANTI-TARNISH/ ANTI-OXIDANT			min.		
OTHER (specify)			min.		

[a] **Type of Sampling** - Consult the key at right and enter the type of sampling performed on the specific chemical bath.

[b] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. processed between samples. Clearly specify units (e.g., hours, square feet, etc.).

[c] **Duration of Sampling** - Enter the average time for manually taking a sample from the specific chemical tank. Consider only time spent at the chemical bath..

[d] **Number of People** - Enter the number of people actually involved in manually taking the chemical samples. Exclude people doing the testing but not the sampling.

[e] **Personal Protective Equipment** - Consult key at right and enter the letters for **<u>all</u>** protective equipment worn by the people performing the chemical sampling.

<u>Type of Sampling Key</u>

[A] - Automated sampling	[B] - Both
[M] - Manual sampling	[N] - None

<u>Personal Protective Equipment Key</u>

[E] - Eye protection	[G] - Gloves
[L] - Labcoat/sleeved garment	[A] - Apron
[R] - Respiratory protection	[B] - Boots
[Z] - All except respiratory protection	[N] - None

4.6 Chemical Handling Activities: Chemical Sampling

Complete the table below by indicating what method your facility uses to manually collect bath samples and the type of container used.

Method of Obtaining Samples	Drain/Spigot:	
	Pipette:	
	Ladle:	
	Other (specify):	
Chemical Sample Container	Open-top container:	
	Closed-top container:	

4.7 Chemical Bath Additions

Complete the following chart detailing the typical chemical additions that are made to maintain the chemical balance of each specific process baths. If more than four chemicals are added to a specific bath, attach another sheet with the additional information. If chemical additions to a bath are made automatically, do not complete the last three columns for that bath. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH TYPE		**CHEMICAL ADDED**	**AVERAGE VOLUME ADDED**[a]	**CONCENTRATION**[b]	**FREQUENCY**[c]	**CHEMICAL ADDITION METHOD**[d]	**DURATION OF ADDITION**[e] **(minutes)**	**NO. OF PEOPLE**	**PERSONAL PROTECTIVE EQUIPMENT**[f]
CLEANER/ CONDITIONER	1.						min.		
	2.								
	3.								
	4.								
MICRO-ETCH	1.						min.		
	2.								
	3.								
	4.								
PRE-DIP	1.						min.		
	2.								
	3.								
	4.								
ACTIVATOR/ CATALYST	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.)

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/liter, etc.) of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory Protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

4.7 Chemical Bath Additions - CONTINUED

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED [a]	CONCENTRATION [b]	FREQUENCY [c]	CHEMICAL ADDITION METHOD [d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT [f]
ACCELERATOR	1.						min.		
	2.								
	3.								
	4.								
ELECTROLESS COPPER	1.						min.		
	2.								
	3.								
	4.								
REDUCER/ NEUTRALIZER	1.						min.		
	2.								
	3.								
	4.								
ANTI-TARNISH/ ANTI-OXIDANT	1.						min.		
	2.								
	3.								
	4.								
OTHER (specify)	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.).

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/litre, etc.) Of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key
[A] - Automatic [*]
[M] - Manual

[*] If additions are automatic [A] then do not complete the last 3 columns

Personal Protective Equipment Key
[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

4.8 Chemical Handling Activities: Chemical Additions

Complete the following table by indicating the methods your facility uses while performing chemical additions.

ACTIVITY	OPTIONS	
Chemical Retrieval from Stock into Container	Pump:	
	Pour:	
	Scoop (solid):	
	Other (specify):	
Container	Open-top container:	
	Closed-top container:	
	Safety container:	
	Other (specify):	
Method of Chemical Addition	Pour directly into tank:	
	Stir into tank:	
	Pour into automated chemical addition system:	
	Other (specify):	

4.9 Other Bath Related Activities

Complete the following table for any other bath related activities that your facility engages in.

BATH TYPE	TYPE OF ACTIVITY (describe)	FREQUENCY [a]	DURATION OF ACTIVITY[b]	NO. OF PEOPLE	PROTECTIVE EQUIPMENT [c]
CLEANER/ CONDITIONER					
MICRO-ETCH					
PRE-DIP					
ACTIVATOR/ CATALYST					
ACCELERATOR					
ELECTROLESS COPPER					
REDUCER/ NEUTRALIZER					
ANTI-TARNISH/ ANTI-OXIDANT					
OTHER (specify)					

[a] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. Processed since the last time the activity was performed. Clearly specify units (e.g., hours, square feet, etc.)

[b] **Duration of Activity** - Enter the average time for performing the specified activity. Clearly specify units.

[c] **Personal Protective Equipment** - Consult key on the previous page and enter the letters for **all** protective equipment worn by the people performing the activity.

Section 5. Graphite-Based Process

The information requested below will allow us to generate an exposure assessment and risk characterization profile for each of the following baths and the associated activities involved in the operation and upkeep of the graphite-based process.

NOTE: You need to complete this section only if your facility uses a graphite-based process for making the holes conductive during the PWB manufacturing process.

5.1 Physical, Process, and Operating Conditions

Complete the table below by entering the data requested for each specific type of chemical bath listed. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH	PHYSICAL DATA			PROCESSING DATA		OPERATING CONDITIONS		
	LENGTH (inches)	WIDTH (inches)	NOMINAL VOLUME	IMMERSION[a] (seconds)	DRIP TIME[b] (seconds)	TEMP °F	AGITATION[c]	VAPOR CONTROL[d]
CLEANER/ CONDITIONER	in.	in.	gal.	sec.	sec.	°F		
GRAPHITE	in.	in.	gal.	sec.	sec.	°F		
FIXER	in.	in.	gal.	sec.	sec.	°F		
POST-CLEAN ETCH	in.	in.	gal.	sec.	sec.	°F		
ANTI-TARNISH/ ANTI-OXIDANT	in.	in.	gal.	sec.	sec.	°F		
OTHER (specify)	in.	in.	gal.	sec.	sec.	°F		

[a] **Immersion Time** - Enter the average elapsed time a rack of panels is immersed in the specific process bath.

[b] **Drip Time** - Enter the average elapsed time that a rack of panels is allowed to hang above the specific bath to allow chemical drainage from panels.

[c] **Agitation** - Consult the key at right and enter the letter for the agitation method used in the specific chemical bath.

[d] **Vapor Control** - Consult key at right and enter the letter of the vapor control method used for that specific chemical.

Agitation Methods Key	Vapor Control Methods Key
[P] - Panel agitation	[P] - Push-Pull
[F] - Fluid circulation pump	[C] - Bath cover (when not in use)
[A] - Air sparge	[B] - Plastic balls (floating)
[O] - Other (explain)	[E] - Fully enclosed
	[O] - Other (explain)

AIR KNIFE/OVEN PROCESS STEP	
Air pressure:	psi.
Air temperature	°F
Processing time per panel	min.
Contained unit (circle one):	Yes No

5.2 Initial Chemical Bath Make-Up Composition

Complete the chart below for each chemical component of the bath type listed. Provide the manufacturer name if the chemical used is known only by trade name. If more room is needed, please attach another sheet with the additional information. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME[a] (gallons)	CONCENTRATION[b]	ANNUAL QTY. USED[c] (gallons)
CLEANER/ CONDITIONER	1.					
	2.					
	3.					
	4.					
GRAPHITE	1.					
	2.					
	3.					
	4.					
FIXER	1.					
	2.					
	3.					
	4.					
POST-CLEAN ETCH	1.					
	2.					
	3.					
	4.					
ANTI-TARNISH/ ANTI-OXIDANT	1.					
	2.					
	3.					
	4					
OTHER (specify)	1.					
	2.					
	3.					
	4.					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: Enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

5.3 Chemical Bath Replacement

Complete the chart below by providing information on the process of replacing, treating, and disposing of a spent chemical bath.

BATH TYPE	CRITERIA FOR REPLACEMENT[a]	FREQUENCY[b]	DURATION OF REPLACEMENT PROCEDURE[c]	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[d]	ON-SITE METHOD OF TREATMENT OR DISPOSAL[c]	ANNUAL VOLUME TREATED OR DISPOSED[f]	OFF-SITE METHOD OF TREATMENT OR DISPOSAL[e]
CLEANER/ CONDITIONER								
GRAPHITE								
FIXER								
POST-CLEAN ETCH								
ANTI-TARNISH/ ANTI-OXIDANT								
OTHER (specify)								

[a] **Criteria for Replacement** - Consult the key at right and enter the letter for the criteria typically used to determine when bath replacement is necessary.

[b] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[c] **Duration of Replacement** - Enter the elapsed time from the beginning of bath removal until the replacement bath is finished.

[d] **Personal Protective Equip.** - Consult key at right and enter the letters of **all** the protective equipment worn by the workers physically replacing the spent bath.

[e] **Methods of Treatment or Disposal** - Consult keys at right and enter the letter of the method used.

[f] **Annual Volume Treated or Disposed** - Enter the yearly amount of the specific bath treated or disposed.

On-Site Method of Treatment or Disposal

[P] - Precipitation pretreatment on-site
[N] - PH neutralization pretreatment on-site
[S] - Disposed directly to sewer with no treatment
[D] - Drummed for off-site treatment or disposal
[R] - Recycled on-site
[O] - Other (specify)

Off-Site Method of Treatment or Disposal

[R] - Sent to recycle
[P] - Discharged to POTW
[O] - Other

Criteria for Bath Replacement

[S] - Statistical process control
[P] - Panel sq. ft. processed
[C] - Chemical testing
[T] - Time
[O] - Other (Specify)

Personal Protective Equipment

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

5.4 Chemical Handling Activities: Chemical Bath Replacement

Complete the table below by indicating the options your facility uses to replace each type of spent chemical bath. **If the same options are used to replace each of the various chemical baths, enter "ALL" as the type of bath and fill out only one table.** Otherwise, please photocopy and attach additional charts, as necessary.

TYPES OF BATHS [a]

REMOVAL OF SPENT BATH			**CLEANING OF EQUIPMENT**			**NEW BATH MAKE-UP**		
Method of Removing Spent Bath	Pump:		**Tank Cleaning Method**	Chemical flush:		**Chemical Retrieval from** **Stock into Container**	Pump:	
	Siphon:			Hand scrub:			Pour:	
	Drain/spigot:			Other (specify):			Scoop (solid):	
	Other (specify):						Other (specify):	
Remove Spent Bath	Directly to wastewater treatment:		**CHEMICALS USED IN CHEMICAL FLUSH**			**Container Type**	Open-top container:	
	Directly to sewer:		**Chemical**	**Gallons Per Year**			Closed-top container:	
	To open-top container:						Safety container:	
	To closed-top container:						Other (specify):	

[a] **Types of Baths** - Enter the types of baths where the activities are used. If the chemical handling activities are the same for each bath type, enter **'ALL.'**

5.5 Chemical Bath Sampling

Provide information on the chemical bath sampling procedures used in your facility. Duration of sampling and personnel involved should include only the portion of the testing procedure involving the manual sampling of the chemical baths, not automated sampling or the testing that may occur in another part of the facility, such as the lab.

BATH TYPE	TYPE OF SAMPLING[a]	FREQUENCY [b]	DURATION OF SAMPLING[c]	NO. OF PEOPLE[d]	PROTECTIVE EQUIPMENT[e]
CLEANER/ CONDITIONER			min.		
GRAPHITE			min.		
FIXER			min.		
POST-CLEAN ETCH			min.		
ANTI-TARNISH/ ANTI-OXIDANT			min.		
OTHER (specify)			min.		

[a] **Type of Sampling** - Consult the key at right and enter the type of sampling performed on the specific chemical bath.

[b] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. processed between samples. Clearly specify units (e.g., hours, square feet, etc.).

[c] **Duration of Sampling** - Enter the average time for manually taking a sample from the specific chemical tank. Consider only time spent at the chemical bath..

[d] **Number of People** - Enter the number of people actually involved in manually taking the chemical samples. Exclude people doing the testing but not the sampling.

[e] **Personal Protective Equipment** - Consult key at right and enter the letters for **all** protective equipment worn by the people performing the chemical sampling.

Type of Sampling Key

[A] - Automated sampling
[B] - Both
[M] - Manual sampling
[N] - None

Personal Protective Equipment Key

[E] - Eye protection
[G] - Gloves
[L] - Labcoat/sleeved garment
[A] - Apron
[R] - Respiratory protection
[B] - Boots
[Z] - All except respiratory protection
[N] - None

5.6 Chemical Handling Activities: Chemical Sampling

Complete the table below by indicating what method your facility uses to manually collect bath samples and the type of container used.

Method of Obtaining Samples	Drain/Spigot:	
	Pipette:	
	Ladle:	
	Other (specify):	
Chemical Sample Container	Open-top container:	
	Closed-top container:	

5.7 Chemical Bath Additions

Complete the following chart detailing the typical chemical additions that are made to maintain the chemical balance of each specific process baths. If more than four chemicals are added to a specific bath, attach another sheet with the additional information. If chemical additions to a bath are made automatically, do not complete the last three columns for that bath. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED[a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD [d]	DURATION OF ADDITION [e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[f]
CLEANER/ CONDITIONER	1.						min.		
	2.								
	3.								
	4.								
GRAPHITE	1.						min.		
	2.								
	3.								
	4.								
FIXER	1.						min.		
	2.								
	3.								
	4.								
POST-CLEAN ETCH	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.).

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/liter, etc.) of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

5.7 Chemical Bath Additions - CONTINUED

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED[a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD[d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[f]
ANTI-TARNISH/ ANTI-OXIDANT	1.						min.		
	2.								
	3.								
	4.								
OTHER (specify)	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.).

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/litre, etc.) Of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

5.8 Chemical Handling Activities: Chemical Additions

Complete the following table by indicating the methods your facility uses while performing chemical additions.

ACTIVITY	OPTIONS	
Chemical Retrieval from Stock into Container	Pump:	
	Pour:	
	Scoop (solid):	
	Other (specify):	
Container	Open-top container:	
	Closed-top container:	
	Safety container:	
	Other (specify):	
Method of Chemical Addition	Pour directly into tank:	
	Stir into tank:	
	Pour into automated chemical addition system:	
	Other (specify):	

5.9 Other Bath Related Activities

Complete the following table for any other bath related activities that your facility engages in.

BATH TYPE	TYPE OF ACTIVITY (describe)	FREQUENCY [a]	DURATION OF ACTIVITY[b]	NO. OF PEOPLE	PROTECTIVE EQUIPMENT [c]
CLEANER/ CONDITIONER					
GRAPHITE					
FIXER					
POST-CLEAN ETCH					
ANTI-TARNISH/ ANTI-OXIDANT					
OTHER (specify)					

[a] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. Processed since the last time the activity was performed. Clearly specify units (e.g., hours, square feet, etc.)

[b] **Duration of Activity** - Enter the average time for performing the specified activity. Clearly specify units.

[c] **Personal Protective Equipment** - Consult key on the previous page and enter the letters for **all** protective equipment worn by the people performing the activity.

Section 6. Carbon-Based Process

The information requested below will allow us to generate an exposure assessment and risk characterization profile for each of the following baths and the associated activities involved in the operation and upkeep of the carbon-based process.

NOTE: You need to complete this section only if your facility uses a carbon-based process for making the holes conductive during the PWB manufacturing process.

6.1 Physical, Process, and Operating Conditions

Complete the table below by entering the data requested for each specific type of chemical bath listed. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH	PHYSICAL DATA			PROCESSING DATA		OPERATING CONDITIONS		
	LENGTH (inches)	WIDTH (inches)	NOMINAL VOLUME	IMMERSION[a] (seconds)	DRIP TIME[b] (seconds)	TEMP °F	AGITATION[c]	VAPOR CONTROL[d]
CLEANER	in.	in.	gal.	sec.	sec.	°F		
CONDITIONER	in.	in.	gal.	sec.	sec.	°F		
CARBON	in.	in.	gal.	sec.	sec.	°F		
POST-CLEAN ETCH	in.	in.	gal.	sec.	sec.	°F		
ANTI-TARNISH/ ANTI-OXIDANT	in.	in.	gal.	sec.	sec.	°F		
OTHER (specify)	in.	in.	gal.	sec.	sec.	°F		

[a] **Immersion Time** - Enter the average elapsed time a rack of panels is immersed in the specific process bath.

[b] **Drip Time** - Enter the average elapsed time that a rack of panels is allowed to hang above the specific bath to allow chemical drainage from panels.

[c] **Agitation** - Consult the key at right and enter the letter for the agitation method used in the specific chemical bath.

[d] **Vapor Control** - Consult key at right and enter the letter of the vapor control method used for that specific chemical.

<u>Agitation Methods Key</u>
[P] - Panel Agitation
[F] - Fluid Circulation Pump
[A] -Air Sparge
[O] - Other (explain)

<u>Vapor Control Methods Key</u>
[P] - Push-Pull
[C] - Bath cover (when not in use)
[B] - Plastic Balls (floating)
[E] - Fully Enclosed
[O] - Other (explain)

AIR KNIFE/OVEN PROCESS STEP	
Air pressure:	psi.
Air temperature	°F
Processing time per panel	min.
Contained unit (circle one):	Yes No

6.2 Initial Chemical Bath Make-Up Composition

Complete the chart below for each chemical component of the bath type listed. Provide the manufacturer name if the chemical used is known only by trade name. If more room is needed, please attach another sheet with the additional information. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME [a] (gallons)	CONCENTRATION [b]	ANNUAL QTY. USED[c] (gallons)
CLEANER	1.					
	2.					
	3.					
	4.					
CONDITIONER	1.					
	2.					
	3.					
	4.					
CARBON	1.					
	2.					
	3.					
	4.					
POST-CLEAN ETCH	1.					
	2.					
	3.					
	4.					
ANTI-TARNISH/ ANTI-OXIDANT	1.					
	2.					
	3.					
	4					
OTHER (specify)	1.					
	2.					
	3.					
	4.					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: Enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

6.3 Chemical Bath Replacement

Complete the chart below by providing information on the process of replacing, treating, and disposing of a spent chemical bath.

BATH TYPE	CRITERIA FOR REPLACEMENT[a]	FREQUENCY[b]	DURATION OF REPLACEMENT PROCEDURE[c]	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[d]	ON-SITE METHOD OF TREATMENT OR DISPOSAL[c]	ANNUAL VOLUME TREATED OR DISPOSED[f]	OFF-SITE METHOD OF TREATMENT OR DISPOSAL[e]
CLEANER								
CONDITIONER								
CARBON								
POST-CLEAN ETCH								
ANTI-TARNISH/ ANTI-OXIDANT								
OTHER (specify)								

[a] **Criteria for Replacement** - Consult the key at right and enter the letter for the criteria typically used to determine when bath replacement is necessary.

[b] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[c] **Duration of Replacement** - Enter the elapsed time from the beginning of bath removal until the replacement bath is finished.

[d] **Personal Protective Equip.** - Consult key at right and enter the letters of **all** the protective equipment worn by the workers physically replacing the spent bath.

[e] **Methods of Treatment or Disposal** - Consult keys at right and enter the letter of the method used.

[f] **Annual Volume Treated or Disposed** - Enter the yearly amount of the specific bath treated or disposed.

On-Site Method of Treatment or Disposal

[P] - Precipitation pretreatment on-site
[N] - PH neutralization pretreatment on-site
[S] - Disposed directly to sewer with no treatment
[D] - Drummed for off-site treatment or disposal
[R] - Recycled on-site
[O] - Other (specify)

Off-Site Method of Treatment or Disposal

[R] - Sent to recycle
[P] - Discharged to POTW
[O] - Other

Criteria for Bath Replacement

[S] - Statistical process control
[P] - Panel sq. ft. processed
[C] - Chemical testing
[T] - Time
[O] - Other (Specify)

Personal Protective Equipment

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory Protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

6.4 Chemical Handling Activities: Chemical Bath Replacement

Complete the table below by indicating the options your facility uses to replace each type of spent chemical bath. **If the same options are used to replace each of the various chemical baths, enter "ALL" as the type of bath and fill out only one table.** Otherwise, please photocopy and attach additional charts, as necessary.

TYPES OF BATHS [a]

REMOVAL OF SPENT BATH			**CLEANING OF EQUIPMENT**			**NEW BATH MAKE-UP**		
Method of Removing Spent Bath	Pump:		**Tank Cleaning Method**	Chemical flush:		**Chemical Retrieval from** **Stock into Container**	Pump:	
	Siphon:			Hand scrub:			Pour:	
	Drain/spigot:			Other (specify):			Scoop (solid):	
	Other (specify):						Other (specify):	
Remove Spent Bath	Directly to wastewater treatment:		**CHEMICALS USED IN CHEMICAL FLUSH**			Container Type	Open-top container:	
	Directly to sewer:		**Chemical**	**Gallons Per Year**			Closed-top container:	
	To open-top container:						Safety container:	
	To closed-top container:						Other (specify):	

[a] **Types of Baths -** Enter the types of baths where the activities are used. If the chemical handling activities are the same for each both type, enter '**ALL.'**

6.5 Chemical Bath Sampling

Provide information on the chemical bath sampling procedures used in your facility. Duration of sampling and personnel involved should include only the portion of the testing procedure involving the manual sampling of the chemical baths, not automated sampling or the testing that may occur in another part of the facility, such as the lab.

BATH TYPE	TYPE OF SAMPLING[a]	FREQUENCY [b]	DURATION OF SAMPLING[c]	NO. OF PEOPLE[d]	PROTECTIVE EQUIPMENT[e]
CLEANER			min.		
CONDITIONER			min.		
CARBON			min.		
POST-CLEAN ETCH			min.		
ANTI-TARNISH/ ANTI-OXIDANT			min.		
OTHER (specify)			min.		

[a] **Type of Sampling** - Consult the key at right and enter the type of sampling performed on the specific chemical bath.

[b] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. processed between samples. Clearly specify units (e.g., hours, square feet, etc.).

[c] **Duration of Sampling** - Enter the average time for manually taking a sample from the specific chemical tank. Consider only time spent at the chemical bath..

[d] **Number of People** - Enter the number of people actually involved in manually taking the chemical samples. Exclude people doing the testing but not the sampling.

[e] **Personal Protective Equipment** - Consult key at right and enter the letters for **<u>all</u>** protective equipment worn by the people performing the chemical sampling.

<u>Type of Sampling Key</u>

[A] - Automated sampling
[B] - Both
[M] - Manuals Sampling
[N] - None

<u>Personal Protective Equipment Key</u>

[E] - Eye protection
[G] - Gloves
[L] - Labcoat/sleeved garment
[A] - Apron
[R] - Respiratory protection
[B] - Boots
[Z] - All except respiratory protection
[N] - None

6.6 Chemical Handling Activities: Chemical Sampling

Complete the table below by indicating what method your facility uses to manually collect bath samples and the type of container used.

Method of Obtaining Samples	Drain/Spigot:	
	Pipette:	
	Ladle:	
	Other (specify):	
Chemical Sample Container	Open-top container:	
	Closed-top container:	

6.7 Chemical Bath Additions

Complete the following chart detailing the typical chemical additions that are made to maintain the chemical balance of each specific process baths. If more than four chemicals are added to a specific bath, attach another sheet with the additional information. If chemical additions to a bath are made automatically, do not complete the last three columns for that bath. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED [a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD[d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT [f]
CLEANER	1.						min.		
	2.								
	3.								
	4.								
CONDITIONER	1.						min.		
	2.								
	3.								
	4.								
CARBON	1.						min.		
	2.								
	3.								
	4.								
POST-CLEAN ETCH	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.).

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/liter, etc.) of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

6.7 Chemical Bath Additions - CONTINUED

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED[a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD[d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[f]
ANTI-TARNISH/ ANTI-OXIDANT	1.						min.		
	2.								
	3.								
	4.								
OTHER (specify)	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.).

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/litre, etc.) Of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

<u>Chemical Addition Method Key</u>

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

<u>Personal Protective Equipment Key</u>

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

6.8 Chemical Handling Activities: Chemical Additions

Complete the following table by indicating the methods your facility uses while performing chemical additions.

ACTIVITY	OPTIONS	
Chemical Retrieval from Stock into Container	Pump:	
	Pour:	
	Scoop (solid):	
	Other (specify):	
Container	Open-top container:	
	Closed-top container:	
	Safety container:	
	Other (specify):	
Method of Chemical Addition	Pour directly into tank:	
	Stir into tank:	
	Pour into automated chemical addition system:	
	Other (specify):	

6.9 Other Bath Related Activities

Complete the following table for any other bath related activities that your facility engages in.

BATH TYPE	TYPE OF ACTIVITY (describe)	FREQUENCY [a]	DURATION OF ACTIVITY[b]	NO. OF PEOPLE	PROTECTIVE EQUIPMENT [c]
CLEANER					
CONDITIONER					
CARBON					
POST-CLEAN ETCH					
ANTI-TARNISH/ ANTI-OXIDANT					
OTHER (specify)					

[a] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. Processed since the last time the activity was performed. Clearly specify units (e.g., hours, square feet, etc.)

[b] **Duration of Activity** - Enter the average time for performing the specified activity. Clearly specify units.

[c] **Personal Protective Equipment** - Consult key on the previous page and enter the letters for **all** protective equipment worn by the people performing the activity.

Section 7. Palladium-Based Process

The information requested below will allow us to generate an exposure assessment and risk characterization profile for each of the following baths and the associated activities involved in the operation and upkeep of the palladium-based process.

NOTE: You need to complete this section only if your facility uses a palladium-based process for making the holes conductive during the PWB manufacturing process.

7.1 Physical, Process, and Operating Conditions

Complete the table below by entering the data requested for each specific type of chemical bath listed. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH	PHYSICAL DATA			PROCESSING DATA		OPERATING CONDITIONS		
	LENGTH (inches)	WIDTH (inches)	NOMINAL VOLUME	IMMERSION[a] (seconds)	DRIP TIME[b] (seconds)	TEMP °F	AGITATION[c]	VAPOR CONTROL[d]
CLEANER/ CONDITIONER	in.	in.	gal.	sec.	sec.	°F		
PRE-DIP	in.	in.	gal.	sec.	sec.	°F		
CATALYST	in.	in.	gal.	sec.	sec.	°F		
ACCELERATOR	in.	in.	gal.	sec.	sec.	°F		
ENHANCER								
POST-CLEAN ETCH								
ANTI-TARNISH/ ANTI-OXIDANT	in.	in.	gal.	sec.	sec.	°F		
OTHER (specify)	in.	in.	gal.	sec.	sec.	°F		

[a] **Immersion Time** - Enter the average elapsed time a rack of panels is immersed in the specific process bath.

[b] **Drip Time** - Enter the average elapsed time that a rack of panels is allowed to hang above the specific bath to allow chemical drainage from panels.

[c] **Agitation** - Consult the key at right and enter the letter for the agitation method used in the specific chemical bath.

[d] **Vapor Control** - Consult key at right and enter the letter of the vapor control method used for that specific chemical.

<u>Agitation Methods Key</u>
[P] - Panel agitation [
[F] - Fluid circulation pump
[A] - Air sparge
[O] - Other (explain)

<u>Vapor Control Methods Key</u>
P] - Push-Pull
[C] - Bath cover (when not in use)
[B] - Plastic balls (floating)
[E] - Fully enclosed
[O] - Other (explain)

AIR KNIFE/OVEN PROCESS STEP	
Air pressure:	psi.
Air temperature	°F
Processing time per panel	min.
Contained unit (circle one):	Yes No

7.2 Initial Chemical Bath Make-Up Composition

Complete the chart below for each chemical component of the bath type listed. Provide the manufacturer name if the chemical used is known only by trade name. If more room is needed, please attach another sheet with the additional information. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME[a] (gallons)	CONCENTRATION[b]	ANNUAL QTY. USED[c] (gallons)
CLEANER/ CONDITIONER	1.					
	2.					
	3.					
	4.					
PRE-DIP	1.					
	2.					
	3.					
	4.					
PALLADIUM CATALYST	1.					
	2.					
	3.					
	4.					
ACCELERATOR	1.					
	2.					
	3.					
	4.					
ENHANCER	1.					
	2.					
	3.					
	4					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: Enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

7.2 Initial Chemical Bath Make-Up Composition - CONTINUED

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	WORKING VOLUME[a] (gallons)	CONCENTRATION[b]	ANNUAL QTY. USED[c] (gallons)
POST-CLEAN ETCH	1.					
	2.					
	3.					
	4.					
ANTI-TARNISH/ ANTI-OXIDANT	1.					
	2.					
	3.					
	4.					
OTHER (specify)	1.					
	2.					
	3.					
	4.					

[a] **Working Volume**: Enter the volume of the chemical used in the initial make-up of the bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

[b] **Concentration**: Enter the concentration of the chemical in the working volume and specify units (e.g., molarity, grams/liter, etc.) of the chemical used.

[c] **Annual Quantity Used**: If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

7.3 Chemical Bath Replacement

Complete the chart below by providing information on the process of replacing, treating, and disposing of a spent chemical bath.

BATH TYPE	CRITERIA FOR REPLACEMENT[a]	FREQUENCY[b]	DURATION OF REPLACEMENT PROCEDURE[c]	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[d]	ON-SITE METHOD OF TREATMENT OR DISPOSAL[c]	ANNUAL VOLUME TREATED OR DISPOSED[f]	OFF-SITE METHOD OF TREATMENT OR DISPOSAL[e]
CLEANER/ CONDITIONER								
PRE-DIP								
PALLADIUM CATALYST								
ACCELERATOR								
ENHANCER								
POST-CLEAN ETCH								
ANTI-TARNISH/ ANTI-OXIDANT								
OTHER (specify)								

[a] **Criteria for Replacement** - Consult the key at right and enter the letter for the criteria typically used to determine when bath replacement is necessary.

[b] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[c] **Duration of Replacement** - Enter the elapsed time from the beginning of bath removal until the replacement bath is finished.

[d] **Personal Protective Equip.** - Consult key at right and enter the letters of **all** the protective equipment worn by the workers physically replacing the spent bath.

[e] **Methods of Treatment or Disposal** - Consult keys at right and enter the letter of the method used.

[f] **Annual Volume Treated or Disposed** - Enter the yearly amount of the specific bath treated or disposed.

On-Site Method of Treatment or Disposal

[P] - Precipitation pretreatment on-site
[N] - PH neutralization pretreatment on-site
[S] - Disposed directly to sewer with no treatment
[D] - Drummed for off-site treatment or disposal
[R] - Recycled on-site
[O] - Other (specify)

Off-Site Method of Treatment or Disposal

[R] - Sent to recycle
[P] - Discharged to POTW
[O] - Other

Criteria for Bath Replacement

[S] - Statistical process control
[P] - Panel sq. ft. processed
[C] - Chemical testing
[T] - Time
[O] - Other (Specify)

Personal Protective Equipment

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

7.4 Chemical Handling Activities: Chemical Bath Replacement

Complete the table below by indicating the options your facility uses to replace each type of spent chemical bath. **If the same options are used to replace each of the various chemical baths, enter "ALL" as the type of bath and fill out only one table.** Otherwise, please photocopy and attach additional charts, as necessary.

TYPES OF BATHS [a]

REMOVAL OF SPENT BATH			**CLEANING OF EQUIPMENT**			**NEW BATH MAKE-UP**		
Method of Removing Spent Bath	Pump:		**Tank Cleaning Method**	Chemical flush:		**Chemical Retrieval from** **Stock into Container**	Pump:	
	Siphon:			Hand scrub:			Pour:	
	Drain/spigot:			Other (specify):			Scoop (solid):	
	Other (specify):						Other (specify):	
Remove Spent Bath	Directly to wastewater treatment:		**CHEMICALS USED IN CHEMICAL FLUSH**			**Container Type**	Open-top container:	
	Directly to sewer:		**Chemical**	**Gallons Per Year**			Closed-top container:	
	To open-top container:						Safety container:	
	To closed-top container:						Other (specify):	

[a] **Types of Baths -** Enter the types of baths where the activities are used. If the chemical handling activities are the same for each both type, enter '**ALL.'**

7.5 Chemical Bath Sampling

Provide information on the chemical bath sampling procedures used in your facility. Duration of sampling and personnel involved should include only the portion of the testing procedure involving the manual sampling of the chemical baths, not automated sampling or the testing that may occur in another part of the facility, such as the lab.

BATH TYPE	TYPE OF SAMPLING[a]	FREQUENCY [b]	DURATION OF SAMPLING[c]	NO. OF PEOPLE[d]	PROTECTIVE EQUIPMENT[e]
CLEANER/ CONDITIONER			min.		
PRE-DIP			min.		
PALLADIUM CATALYST			min.		
ACCELERATOR			min.		
ENHANCER			min.		
POST-CLEAN ETCH			min.		
ANTI-TARNISH/ ANTI-OXIDANT			min.		
OTHER (specify)			min.		

[a] **Type of Sampling** - Consult the key at right and enter the type of sampling performed on the specific chemical bath.

[b] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. processed between samples. Clearly specify units (e.g., hours, square feet, etc.).

[c] **Duration of Sampling** - Enter the average time for manually taking a sample from the specific chemical tank. Consider only time spent at the chemical bath..

[d] **Number of People** - Enter the number of people actually involved in manually taking the chemical samples. Exclude people doing the testing but not the sampling.

[e] **Personal Protective Equipment** - Consult key at right and enter the letters for **all** protective equipment worn by the people performing the chemical sampling.

Type of Sampling Key

[A] - Automated sampling [B] - Both
[M] - Manual sampling [N] - None

Personal Protective Equipment Key

[E] - Eye protection [G] - Gloves
[L] - Labcoat/sleeved garment [A] - Apron
[R] - Respiratory protection [B] - Boots
[Z] - All except respiratory protection [N] - None

7.6 Chemical Handling Activities: Chemical Sampling

Complete the table below by indicating what method your facility uses to manually collect bath samples and the type of container used.

Method of Obtaining Samples	Drain/Spigot:	
	Pipette:	
	Ladle:	
	Other (specify):	
Chemical Sample Container	Open-top container:	
	Closed-top container:	

7.7 Chemical Bath Additions

Complete the following chart detailing the typical chemical additions that are made to maintain the chemical balance of each specific process baths. If more than four chemicals are added to a specific bath, attach another sheet with the additional information. If chemical additions to a bath are made automatically, do not complete the last three columns for that bath. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED[a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD [d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[f]
CLEANER/ CONDITIONER	1.						min.		
	2.								
	3.								
	4.								
PRE-DIP	1.						min.		
	2.								
	3.								
	4.								
PALLADIUM CATALYST	1.						min.		
	2.								
	3.								
	4.								
ACCELERATOR	1.						min.		
	2.								
	3.								
	4.								

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.)

[b] **Concentration** - Enter the concentration (e.g., molarity, volume %, grams/liter, etc.) of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.)

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

7.7 Chemical Bath Additions - CONTINUED

BATH TYPE		CHEMICAL ADDED	AVERAGE VOLUME ADDED[a]	CONCENTRATION[b]	FREQUENCY[c]	CHEMICAL ADDITION METHOD[d]	DURATION OF ADDITION[e] (minutes)	NO. OF PEOPLE	PERSONAL PROTECTIVE EQUIPMENT[f]
ENHANCER									
POST-CLEAN **ETCH**									
ANTI-TARNISH/ **ANTI-OXIDANT**	1.								
	2.								
	3.								
	4.						min.		
OTHER (specify)	1.								
	2.								
	3.								
	4.						min.		

[a] **Average Volume Added** - Enter the average volume in gallons of each chemical added to maintain the specific bath. If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weights in pounds and clearly specify the units (lbs.)

[b] **Concentration** - enter the concentration (e.g., molarity, volume %, grams/litre, etc.) Of the chemical in the volume being added.

[c] **Frequency** - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[d] **Duration of Addition Method** - Consult key at right and enter the appropriate letter for the method used for that specific bath.

[e] **Duration of Addition** - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] **Personal Protective Equipment** - Consult key at right and enter the letters for all of the protective equipment worn by the people physically making the addition.

Chemical Addition Method Key

[A] - Automatic *
[M] - Manual

*** If additions are automatic [A] then do not complete the last 3 columns**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

7.8 Chemical Handling Activities: Chemical Additions

Complete the following table by indicating the methods your facility uses while performing chemical additions.

ACTIVITY	OPTIONS	
Chemical Retrieval from Stock into Container	Pump:	
	Pour:	
	Scoop (solid):	
	Other (specify):	
Container	Open-top container:	
	Closed-top container:	
	Safety container:	
	Other (specify):	
Method of Chemical Addition	Pour directly into tank:	
	Stir into tank:	
	Pour into automated chemical addition system:	
	Other (specify):	

7.9 Other Bath Related Activities

Complete the following table for any other bath related activities that your facility engages in.

BATH TYPE	TYPE OF ACTIVITY (describe)	FREQUENCY [a]	DURATION OF ACTIVITY[b]	NO. OF PEOPLE	PROTECTIVE EQUIPMENT [c]
CLEANER/ CONDITIONER					
PRE-DIP					
PALLADIUM CATALYST					
ACCELERATOR					
ENHANCER					
POST-CLEAN ETCH					
ANTI-TARNISH/ ANTI-OXIDANT					
OTHER (specify)					

[a] **Frequency** - Enter the average amount of time elapsed or number of panel sq. ft. Processed since the last time the activity was performed. Clearly specify units (e.g., hours, square feet, etc.)

[b] **Duration of Activity** - Enter the average time for performing the specified activity. Clearly specify units.

[c] **Personal Protective Equipment** - Consult key on the previous page and enter the letters for **all** protective equipment worn by the people performing the activity.

Definitions and Abbreviations

Direct discharge	Wastewater discharge directly to a stream or river
Indirect discharge	Wastewater discharge to a publicly owned treatment works (POTW)
Zero discharge	No industrial wasteater discharge

Cu	copper
cu.ft.	cubic feet
DfE	Design for the Environment
EPA	U.S. Environmental Protection Agency
F	fahrenheit
ft.	feet
gal.	gallons
gal./day	gallons per day
gpm	gallons per minute
hrs.	hours
lbs.	pounds
MHC	making holes conductive
min.	minutes
mg/l	milligrams per liter
OEM	original equipment manufacturer
Pd	palladium
PWB	printed wiring board
sec.	seconds
sq.ft.	square feet
sq.in.	square inch
Sn	tin
TDS	total dissolved solids
TSS	total suspended solids
TTO	total toxic organics
yr.	year

A.2 Observer Data Sheet

Observer Data Sheet
DfE PWB Performance Demonstrations

Facility name and location:____

MHC Process type: ____Installation Date: _______________

Date: ___________________ Contact name: ____

Test Panel Run	
Make and Model of rack or panel transport system:	
Overall MHC process line dimensions Length (ft.): Width (ft.): Height (ft.):	
Temperature of the process room:	
Desmear type (permanganate or plasma):	
Average number of panels per rack:	Average space between panels in rack:
Average size of panel in rack: Length (in.): Width (in.):	
At what % of capacity is the line currently running?	At what % of capacity is the line typically running?
Open the panel bags. Were the bags still sealed the day of the demonstration? If no, when was the bag opened and where/how were the panels stored?	
Place the panels in the system. For rack systems, note the rack configuration (diagram the rack configuration and note the locations of the 3 test panels):	
While running the test panels, verify each process step and complete the table on the next page.	
Overall System Timing: from system start (after loading racks) to system stop (before unloading racks); *[Do not include desmear time]*:	
After processing the panels through the MHC line, flash plate with 0.1 mil copper. Record the current used and time used: **Current = _________ A** **Time = ___________ sec.**	

Test Panel Run					
Test Board Serial Numbers: 1. _____________ 2. _____________ 3. _____________					
Bath Name (from schematic)	**Tank or Station #**	**Equipment**[a]	**Bath Temp**	**Immersion Time**	**Drip Time**
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					

[a] List number, type of:

Agitation:	**Vapor Control:**	**Filter Type:**	**Heater Control:**	**Water Rinses:**
[PA] - Panel Agitation	[PP] - Push/Pull	[BF] - Bag	[TH] - Thermostat	[CN] - Continuous
[CP] - Circulation Pump	[BC] - Bath Cover	[CF] - Cartridge	[TM] - Timer	[DP] - Continuous During Process
[AS] - Air Sparge	[FB] - Floating Balls	[OF] - Other	[PR] - Programmed	[PP] - Partial During Process
[OA] - Other (describe)	[FE] - Fully Enclosed	[OH] - Other (describe)	[OW] - Other (describe)	
	[OV] - Other (describe)			

Verification of Part A (mark any changes on working copy of Part A):

Throughput:

Verify the overall throughput (Part A, Q1.1) is recorded as **surface square feet** and that it is equal to the per shift throughput (Part A, Q1.4): **G**

Ventilation:

Verify the type of ventilation as recorded in Part A, Question 2.1: **Q**

Wastewater characterization:

Review discharge and sludge data recorded in Part A, Question 2.3 with wastewater treatment plant operator. Did the data recorded refer to plant-wide data or MHC process line-specific data?

Verify the estimate of the percentage of waste treatment due to MHC process: **Q**

Tank volumes:

Verify the length, width, and nominal volume of each tank, as recorded in Part A: **Q**

Water Use:

Verify Part A, Question 3.2, for each tank:

Flow Controls verified	**Q**
Daily water flow rate verified	**Q**
Cascade process steps verified	**Q**

Have you implemented any other water conservation measures on the MHC line?

If yes, describe:

Is water consumption dependent upon capacity of the line?

Pollution Prevention:

Have you used any other pollution prevention techniques on the MHC line? (e.g., covered tanks to reduce evaporation, measures to reduce dragout, changes to conserve water, etc.)

If yes, describe and quantify results (note: if results have not been quantify, please provide an estimate):

If your throughput changed during the time new pollution prevention techniques were implemented, estimate how much (if any) of the pollution prevention reductions are due the throughput changes:

Filter Replacement			
Replacement Information	**Filter Ass'y Type 1**	**Filter Ass'y Type 2**	**Filter Ass'y Type 3**
Bath(s) filtered (enter process step #)			
Frequency of replacement:			
Duration of replacement process:			
Number of personnel involved:			
Personal protective equipment (see key):			
Type of filter (see key):			
Number of filters changed in assembly:			
Filter make and model number:			

Personal Protective Equipment Key:
[E]-Eye Protection
[L]-Labcoat/Sleeved garment
[R]-Respiratory Protection
[G]-Gloves
[A]-Apron
[B]-Boots
[Z]-All except Respiratory Protection
[N]-None

Filter Type Key:
[B]-Bag
[C]-Cartridge
[O]-Other (specify)

Equipment Maintenance

Estimate the maintenance requirements (excluding filter changes and bath changes) of the MHC process equipment for both outside server calls (maintenance by vendor or service company) and in-house maintenance (by facility personnel).

Describe the typical maintenance activities associated with the MHC process line (e.g., vibration rack repairs, motor repair/replacement, conveyor repairs, valve leaks, etc.):

OUTSIDE SERVICE CALLS	
Average time spent per week:	
Average cost:	
Average downtime:	
Do you call service for a recurring problem? If yes, describe:	
IN-HOUSE MAINTENANCE	
Average time spent per week:	
Average downtime:	
Is there a recurring maintenance problem? If yes, describe:	

Rack or Conveyor Cleaning	
Is rack or conveyor cleaned continuously during the process?	
Frequency of rack or conveyor cleaning:	
Number of personnel involved:	
Personal protective equipment (see key):	
Rack Cleaning Method (see key): **OR**	
Conveyor Cleaning Method (see key):	
Average time required to clean:	
Cleaning chemical used:	
Cleaning schedule (after hours, during hours in MHC room, or during hours outside MHC room)	

Personal Protective Equipment Key:

[E]-Eye Protection	[G]-Gloves
[L]-Labcoat/Sleeved garment	[A]-Apron
[R]-Respiratory Protection	[B]-Boots
[Z]-All except Respiratory Protection	[N]-None

Rack Cleaning Method:
[C]-Chemical bath on MHC process line
[D]-Chemical bath on another line
[T]-Temporary chemical bath
[S]-Manual scrubbing with chemical
[M]-non-chemical cleaning
[N]-None

Conveyor Cleaning Method:
[C]-Chemical rinsing or soaking
[S]-Manual scrubbing with chemical
[M]-Non-chemical cleaning
[N]-None

Chemical Bath Sampling

Bath Type	Type of Sampling[a]	Frequency[b]	Duration of Sampling[c]	Protective Equipment[d]	Method of Sampling[e]	Sample Container[f]
Cleaner/ Conditioner						
Micro Etch						
Activator/ Catalyst						
Accelerator						
Electroless Copper						
Reducer/ Neutralizer						
Anti-tarnish/ Anti-oxidant						
Other (specify)						
Other (specify)						

a Type of Sampling
[A]-Automated
[M]-Manual
[N]-None

b Frequency: Enter the average time elapsed or number of panel sq. ft. processed between samples. Clearly specify units (e.g., hours, sq. ft., etc.)

c Duration of Sampling: Enter the average time for manually taking a sample from the tank.

d Protective Equipment: Consult the key for the above table and enter the letters for all protective equipment worn by the person performing the chemical sampling.

e Method of Obtaining Samples:
[D]-Drain or spigot
[P]-Pipette
[L]-Ladle
[O]-Other (specify)

f Chemical Sample Container
[O]-Open-top container
[C]-Closed-top container

Energy Usage

For each piece of equipment in the MHC line using energy, complete the table below:

Equipment Type, Make, Model	Tank or Station #[a]	Power Rating (from nameplate)	Load (% capacity in use)	Period of Usage	Machine Control
				Q continuous Q continuous during process cycle Q partial during process cycle. If partial, record how often: Q other:	Q timer Q program Q operator/manual Q other:
				Q continuous Q continuous during process cycle Q partial during process cycle. If partial, record how often: Q other:	Q timer Q program Q operator/manual Q other:
				Q continuous Q continuous during process cycle Q partial during process cycle. If partial, record how often: Q other:	Q timer Q program Q operator/manual Q other:
				Q continuous Q continuous during process cycle Q partial during process cycle. If partial, record how often: Q other:	Q timer Q program Q operator/manual Q other:
				Q continuous Q continuous during process cycle Q partial during process cycle. If partial, record how often: Q other:	Q timer Q program Q operator/manual Q other:

[a] Specify whether tank number or process flow diagram step numbers are used.

Comparative Evaluation
If the facility has switched from a previous system to the current system, complete this page.

Process History:
In Part A, Question 3.4, the facility recorded their reason(s) for changing to their current system.
Have they realized this benefit to a greater or lesser extent than expected? Explain and obtain (attach) quantitative information if not given in Part A.

Were any changes made when the line was installed that were not part of the system or were optional (e.g., flow control valves added to water rinses? cascaded water rinses? etc.)? Explain:

Product Quality:
What, if any, changes were noticed in the quality of the boards produced?

Ease of Use:
Does the current process require more or less effort than the previous process and why (e.g., chemical bath replacement, process steps or activities created or eliminated, such as rack loading, etc.)?

Does this process require more "fine tuning" than the previous process? (e.g., can it handle a range of operating concentrations, such as bath temperature variations? does it need more frequent chemical additions or monitoring? etc.). Explain:

Installation:
How long was the debug period when this system was installed?

What were the types of problems encountered?

How does this compare with the previous system installation?

Manufacturing Process Changes: How did you change your upstream or downstream processes when this system was installed? (e.g., did you change your desmear? did you have to make changes in your electrolytic line?)

Personnel: Do you need the same number of operators to operate the current line as your previous line? [Verify that any changes were not caused by a change in throughput].

Waste Treatment:
Have any of your waste treatment methods or volumes changed due to the installation of this system (not associated with volume changes due to throughput changes)?

If yes, describe the change(s) and attach quantitative information, if available:

Process Safety:
Have any additional OSHA-related procedures or issues arisen as a result of changing to the present system (e.g., machinery lock-outs while cleaning, etc.)? If so, describe:

International Sites

For international sites only, do any bans or phase-outs of chemicals affect your choice of chemicals or technologies used in the MHC process? (e.g., Quadrol or EDTA ban)

For international sites only, what is the regulatory atmosphere in the country and what effects does it have on the MHC process? Are applicable regulations local, regional, or national?

A.3 Facility Background Information Sheet

Design
for the
Environment

Printed Wiring Board Project
Performance Demonstrations Questionnaire

Please complete this questionnaire, make a copy for your records, and send the original to:

Cheryl Keenan
Abt Associates
55 Wheeler Street
Cambridge, MA 02138

NOTE: The completed questionnaire must be returned <u>PRIOR TO</u> the scheduled site visit.

FACILITY AND CONTACT INFORMATION

Facility Identification

Company Name:					
Site Name:					
Street Address:					
City:		State:		Zip:	

Contact Identification

Enter the names of the persons who can be contacted regarding this survey.

Name:		
Title		
Phone:		
Fax:		
E-Mail:		

Section 1. Facility Characterization

Estimate manufacturing data for the previous 12 month period or other convenient time period of 12 consecutive months (e.g., FY94). Only consider the portion of the facility dedicated to PWB manufacturing when entering employee and facility size data.

1.1 General Information

Size of portion of facility used for manufacturing PWBs:	sq. ft.	Number of days MHC line is in operation:	days/yr
Number of full-time equivalent employees (FTEs):		Total PWB panel sq. footage processed by the MHC process:	surface sq.ft/yr
Number of employee work days per year:	days/yr		

1.2 Facility Type

Type of PWB manufacturing facility (check one)	Independent		OEM	

1.3 Process Type

Estimate the percentage of PWBs manufactured at your facility using the following methods for making holes conductive (MHC). Specify "other" entry.

Type of PWB Process	Percent of Total	Type of PWB Process	Percent of Total
Standard electroless copper	%	Conductive polymer	%
Palladium-based system	%	Conductive inks	$
Carbon-based system	%	Other:	%
Graphite-based system	%	Other:	%
Non-formaldehyde electroless	%	TOTAL	100 %

1.4 General Process Line Data

Process Data	Shift			
	1	2	3	4
Number of hours per shift:				
Number of hours the MHC line is in operation per shift:				
Average surface square feet of PWB panel processed by the MHC line per shift.				

1.5 Process Area Employees

Complete the following table by indicating the number of employees of each type that perform work duties in the same process room as the MHC line for each shift and for what length of time. Report the number of hours per employee. Consider only workers who have regularly scheduled responsibilities physically within the process room. Specify "other" entry. Enter "N/A" in any category not applicable.

Type of Process Area Worker	Number of Employees per Shift				Hours per Shift per Employee in Process Area (first shift)
	Shift 1	Shift 2	Shift 3	Shift 4	
Line Operators					Hrs.
Lab Technicians					Hrs.
Maintenance Workers					Hrs.
Wastewater Treatment Operators					Hrs.
Supervisory Personnel					Hrs.
Other:					Hrs.
Other:					Hrs.
EXAMPLE	3	2	2		8 Hrs.

Section 2. General Process Data

The information in this section will be used to identify the physical parameters of the process equipment as well as any operating conditions common to the entire process line.

2.1 Process Parameters

Size of the room containing the process:	sq. ft.		
Is the process area ventilated (circle one)?	Yes	No	
Air flow rate:	cu. ft./min.		
Type of ventilation? (Check one) General		Local	
Amount of water used by the MHC process line when operating:	gal./day		

2.2 Wastewater Characterization

Estimate the average and maximum values for the wastewater from the making holes conductive line before treatment. Enter “ND” for not detectable.

	AVERAGE	MAXIMUM
Flow	gpm	gpm
TDA	mg/l	mg/l
Ph		
Cu	mg/l	mg/l

	AVERAGE	MAXIMUM
Pd	mg/l	mt/l
Sn	mg/l	mg\l
TSS	mg/l	mg/l
TTO	mg/l	mg/l

2.3 Wastewater Discharge and Sludge Data

Wastewater discharge type: (check one) Direct		Indirect		Zero	
Annual weight (pounds) of sludge generated:					
Duration of treatment (e.g., length of time for a gallon to be treated):					
Number of employees in waste treatment:					
Hazardous chemical disposal costs (annual):					
Percent solids of sludge:					
Percentage of total quantity generated by the MHC process:					
Method of sludge recycle/disposal: [R] - Metals Reclaimed [D] - Stabilized and Landfilled [O] - Other (specify)					

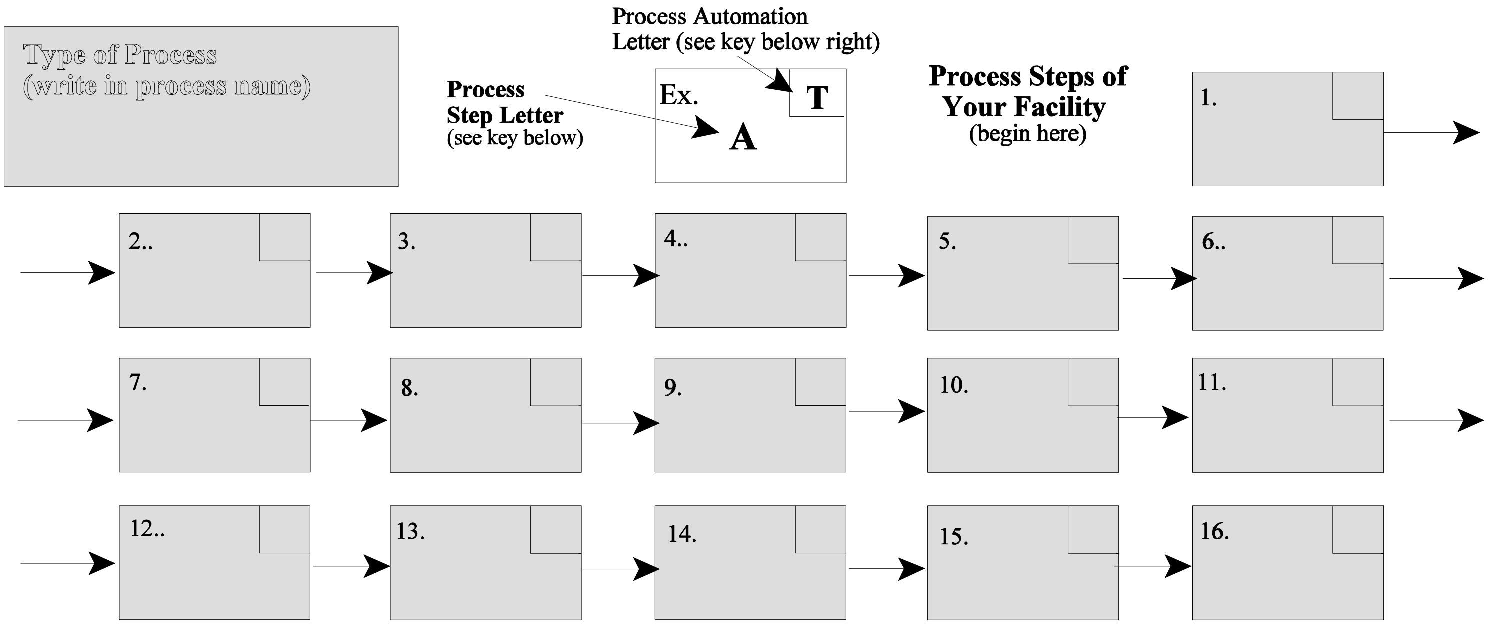
Waste treatment chemicals used for treatment of MHC process line wastewater:

Type (Chemical Name)	**Quantity (gal./yr.)**

Section 3. Process Description

3.1 Process Schematic

Fill in the table below by identifying what type of making holes conductive process (e.g., electroless copper) your facility uses. Then, using the proper key at the bottom of the page, identify which letter corresponds with the first step in your process and write that letter in the first box (see example). Continue using the key to fill in boxes for each step in your process until your entire making holes conductive process is represented. If your process is not represented by a key below, complete the chart by writing in the name of each process step in your particular making holes conductive line. Finally, consult the process automation key at bottom right and enter the appropriate type of automation for the MHC process line. If the process is partially automated, enter the appropriate process automation letter for each step in the upper right-hand corner box (see example.



ELECTROLESS COPPER PROCESS STEPS
- [A] - Conditioner/Cleaner
- [B] - Micro Etch
- [C] - Pre-dip
- [D] - Activator/Catalyst
- [E] - Accelerator
- [F] - Electroless Copper
- [G] - Reducer/Neutralizer
- [H] - Anti-tarnish / Anti-oxidant
- [W]- Water rinse
- [O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
- [A] - Cleaner/Conditioner
- [B] - Graphite
- [C] - Fixer
- [D] - Air Knife/Oven
- [E] - Post-clean Etch
- [F] - Anti-tarnish/ Anti-oxidant
- [W] - Water rinse
- [O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
- [A] - Cleaner/Conditioner
- [B] - Graphite
- [C] - Fixer
- [D] - Air Knife/Oven
- [E] - Post-clean Etch
- [F] - Anti-tarnish/ Anti-oxidant
- [W] - Water rinse
- [O] - Other (specify step)

GRAPHITE-BASED PROCESS STEPS
- [A] - Cleaner/Conditioner
- [B] - Graphite
- [C] - Fixer
- [D] - Air Knife/Oven
- [E] - Post-clean Etch
- [F] - Anti-tarnish/ Anti-oxidant
- [W] - Water rinse
- [O] - Other (specify step)

PROCESS AUTOMATION

TYPE OF PROCESS AUTOMATION FOR ENTIRE MHC PROCESS
(Coonsult the key below)
* If the MHC process is partially automated (option R) enter 'R' on above line. Then, for each process step in chart above, consult the key below and enter the appropriate process automation letter in the box located in the upper right-hand corner of each process step (see example.

Process Automation Key
- [P] - Automated non-conveyorized
- [Q] - Automated conveyorized
- [R] - Partially automated *
- [S] - Manually controlled hoist
- [T] - Manual (no automation)
- [V] - Other (specify)

3.2 Rinse Bath Water Usage

Consult the process schematic in Section 3.1 to obtain the process step numbers associated with each of the water rinse baths present. Enter, in the table below, the process step number along with the flow control and flow rate data requested for each water rinse bath. If the water rinse bath is part of a cascade, you need only report the daily water flow rate of one bath in the cascade.

Process Step Number [a]	**Flow Control** [b]	**Daily Water Flow Rate** [c]	**Cascade Water Process Steps** [d]
Example: 8	R	2,400 gal./day	8 - 6
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	
		gal./day	

[a] Process Step Number - Consult the process schematic in question 3.1 and enter the process step number of the specific water rinse tank.
[b] Flow Control - Consult key at right and enter the letter for the flow control method used for that specific rinse bath.
[c] Daily Water Flow Rate - Enter the average daily flow rate for the specific water rinse tank.
[d] Cascade Water Process Steps - Enter the process step number for each water rinse tank in cascade with the present tank.

Flow Control Methods Key
[C] - Conductivity Meter
[P] - pH Meter
[V] - Operator control valve
[R] - Flow Restricter
[N] - None (continuous flow)
[O] - Other (explain)

3.3 Rack or Conveyor Cleaning

Complete the following table for your rack cleaning chemicals (for non-conveyorized MHC processes) or for conveyor cleaning equipment.

Are chemicals listed below used in rack cleaning or conveyor cleaning?	Rack		Conveyor	

Chemical	**Grade**	**Quantity used per year**
		gal.
		gal.
		gal.

3.4 Process History (complete only if you have changed from one system to another)

Complete the table below by indicating what making holes conductive process (es) your facility has employed in the past. In the second table, indicate the reasons for the process change and estimate or quantify, if possible, how the change has had an effect upon production.

FORMER MAKING HOLES CONDUCTIVE PROCESS	DATE OF CHANGE TO CURRENT PROCESS
ELECTROLESS COPPER	
PALLADIUM-BASED	
GRAPHITE-BASED	
CARBON-BASED	
COPPER SEED	
ELECTROLESS NICKEL	
OTHER (specify)	

REASONS FOR CHANGE AND RESULTS

Reason (check all that apply)		Prior to this System [a]	Present System
	Water Consumption	gal/day	gal/day
	Process Cycle-Time	min/cycle	min/cycle
	Cost	$/ft^2	$/ft^2
	Worker Exposure (provide monitoring data if available)		
	Performance (provide data on changes in rejection rate, number of cycles before failure, etc.)		
	Customer Acceptance		
	Product Quality		
	Process Maintenance		
	Other:		
	Other:		
	Other:		

[a] If no quantitative information is available, enter [B] - Better, [W] - Worse, [N] - No change.

Section 4. Palladium-Based Process

The information requested below will allow us to generate an exposure assessment and risk characterization profile for each of the following baths and the associated activities involved in the operation and upkeep of the palladium-based process.

4.1 Physical, Process, and Operating Conditions

Complete the table below by entering the data requested for each specific type of chemical bath listed. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH	LENGTH (inches)	WIDTH (inches)	NOMINAL VOLUME
CLEANER/ CONDITIONER	in.	in.	gal.
PRE-DIP	in.	in.	gal.
ACCELERATOR	in.	in.	gal.
ENHANCER	in.	in.	gal.
POST-CLEAN ETCH	in.	in.	gal.
ANTI-TARNISH/ ANTI-OXIDANT	in.	in.	gal.
OTHER (specify)	in.	in.	gal.
	in.	in.	gal.
	in.	in.	gal.
	in.	in.	gal.

4.2 Initial Chemical Bath Make-Up Composition

Complete the chart below for each chemical component of the bath type listed. Provide the manufacturer name if the chemical used is known only by trade name. If more room is needed, please attach another sheet with the additional information. If two tanks of the same type are used within the process, list the data for a single tank only.

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	ANNUAL QTY. USED [a] (gallons)
CLEANER/ CONDITIONER	1.			
	2.			
	3.			
	4.			
PRE-DIP	1.			
	2.			
	3.			
	4.			
PALLADIUM CATALYST	1.			
	2.			
	3.			
	4.			
ACCELERATOR	1.			
	2.			
	3.			
	4.			
ENHANCER	1.			
	2.			
	3.			
	4.			

[a] Annual Quantity Used - If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs.).

4.2 Initial Chemical Bath Make-Up Composition - CONTINUED

BATH		CHEMICAL NAME	MANUFACTURER (if applicable)	ANNUAL QTY. USED [a] (gallons)
POST-CLEAN ETCH	1.			
	2.			
	3.			
	4.			
ANTI-TARNISH/ ANTI-OXIDANT	1.			
	2.			
	3.			
	4.			
OTHER (specify)	1.			
	2.			
	3.			
	4.			

[a] Annual Quantity Used - If the amount of a particular chemical used is measured by weight (i.e., crystalline chemicals) instead of volume, enter the weight in pounds and clearly specify the units (lbs).

4.3 Chemical Bath Replacement

Complete the chart below by providing information on the process of replacing, treating, and disposing of a spent chemical bath.

Bath Type	Criteria for Replacement [a]	Frequency [b]	Tank Cleaning Method [c]	Duration of Replacement Procedure [d]	Personal Protective Equipment [e]	Chemicals Used in Tank Flush [f]		Method of Treatment or Disposal [g]	Annual Volume Treated or Disposed [h]	New Bath Make-Up Method [i]
Cleaner/ Conditioner						Name:	gal/yr.			
Pre-Dip						Name:	gal/yr.			
Palladium Catalyst						Name:	gal/yr.			
Accelerator						Name:	gal/yr.			
Enhancer						Name:	gal/yr.			
Post-Clean Etch						Name:	gal/yr.			
Anti-Tarnish/ Anti-Oxidant						Name	gal/yr.			
Other (specify)						Name:	gal/yr.			

Personal Protective Equipment

[E] - Eye protection
[L] - Labcoat/Sleeved garment
[R] - Respiratory protection
[Z] - All except respiratory protection
[G] - Gloves
[A] - Apron
[B] - Boots
[N] - None

Tank Cleaning Method

[C] - Chemical Flush
[W] - Water Rinse
[H] - Hand Scrub
[O] - Other (specify)

Criteria for Bath Replacement

[S] - Statistical process control
[P] - Panel sq. ft. processed
[C] - Chemical testing
[T] - Time
[O] - Other (specify)

Method of Treatment or Disposal

[P] - Precipitation pretreatment on-site
[N] - pH neutralization pretreatment on-site
[S] - Disposed directly to sewer with no treatment
[D] - Drummed for off-site treatment or disposal
[RN] - Recycled on-site
[RF] - Recycled off-site
[O] - Other (specify)

New Bath Make-Up Method

[PA] - Pumped automatically
[PM] - Pumped manually
[R] - Poured
[S] - Scooped (solid)
[O] - Other (specify)

---

[a] Criteria for Replacement - Consult the key at right and enter the letter for the critieria typically used to determine when bath replacement is necessary.

[b] Frequency - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Clearly specify units (e.g., hours, sq. ft., etc.).

[c] Tank Cleaning Method - Consult the key at right and enter the letters for the method typically used to clean the tanks.

[d] Duration of Replacement - Enter the elapsed time from the beginning of bath removal until the replacement bath is finished.

[e] Personal Protective Equip. - Consult key at right and enter the letters of all the protective equipment worn by the workers physically replacing the spent bath.

[f] Chemicals Used in Tank Flush - enter the name of any chemicals used to clean the tanks (including water) and estimate the yearly amounts used.

[g] Methods of Treat. or Disp. - Consult keys at right and enter the letter of the method used.

[h] Annual Voll. Treat. or Disp. - Enter th yearly amount of the specific bath treated or disposed.

[i] New Bath Make-Up Method - Consult the key at right and enter the letter for the method used to fill the tanks with new bath.

4.4 Chemical Bath Additions

Complete the following chart detailing the typical chemical additions that are made to maintain the chemical balance of each specific process baths. If more than four chemicals are added to a specific bath, attach another sheet with the additional information. If chemical additions to a bath are made automatically, do not complete the last three columns for that bath. If two tanks of the same type are used within the process, list the data for a single tank only.

Bath Type		Chemical Added	Frequency [a]	Method of Chemical Retrieval From Stock [b]	Chemical Container Type [c]	Method of Chemical Addition to Tank [d]	Duration of Addition [e] (minutes)	Personal Protective Equipment [f]
CLEANER/ CONDITIONER	1.							
	2.							
	3.							
	4.							
PRE-DIP	1.							
	2.							
	3.							
	4.							
PALLADIUM CATALYST	1.							
	2.							
	3.							
	4.							
ACCELERATOR	1.							
	2.							
	3.							
	4.							

[a] Frequency - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Cleanly specify units (e.g., hours, sq. ft., etc.).

[b] Method of Chemical Retrieval from Stock - Consult the key at right and enter the letter for the method used to obtain chemicals from the stock for addition to the tanks.

[c] Chemical Container Type - Consult the key at right and enter the letters for the type of container used to transfer chemicals from stock to the tanks.

[d] Method of Chemical Addition to Tank - Consult the key at right and enter the letters for the method typically used to add chemicals to the tanks.

[e] Duration of Addition - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] Personal Protective Equipment - Consult key at right and enter the letters of all the protective equipment worn by the workers physically replacing the spent bath.

Method Chemical Retrieval Key

[P] - Pumped
[PR] - Poured
[S] - Scooped
[O] - Other

Container Type

[OT] - Open-top
[CT] - Closed-top
[SC] - Safety container
[O] - Other (specify)

Method of Chemical Addition Key

[A] - Automatic [a]
[P] - Pumped manually
[PR] - Poured
[S] - Scooped
[O] - Other (specify)

*** If additions are automatic [A] then do not complete the last two columns.**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/Sleeved garment protection
[B] - Boots
[Z] - All except respiratory
[G] - Gloves
[A] - Apron
[R] - Respiratory protection
[N] - None

4.4 Chemical Bath Additions - CONTINUED

Bath Type		Chemical Added	Frequency [a]	Method of Chemical Retrieval From Stock [b]	Chemical Container Type [c]	Method of Chemical Addition to Tank [d]	Duration of Addition [e] (minutes)	Personal Protective Equipment [f]
CLEANER/ CONDITIONER	1.							
	2.							
	3.							
	4.							
PRE-DIP	1.							
	2.							
	3.							
	4.							
PALLADIUM CATALYST	1.							
	2.							
	3.							
	4.							
ACCELERATOR	1.							
	2.							
	3.							
	4.							

[a] Frequency - Enter the average amount of time elapsed or number of square feet processed between bath replacements. Cleanly specify units (e.g., hours, sq. ft., etc.).

[b] Method of Chemical Retrieval from Stock - Consult the key at right and enter the letter for the method used to obtain chemicals from the stock for addition to the tanks.

[c] Chemical Container Type - Consult the key at right and enter the letters for the type of container used to transfer chemicals from stock to the tanks.

[d] Method of Chemical Addition to Tank - Consult the key at right and enter the letters for the method typically used to add chemicals to the tanks.

[e] Duration of Addition - Enter the average elapsed time from the retrieval of the chemical stock through the completion of the addition of all chemicals.

[f] Personal Protective Equipment - Consult key at right and enter the letters of all the protective equipment worn by the workers physically replacing the spent bath.

Method Chemical Retrieval Key

[P] - Pumped
[PR] - Poured
[S] - Scooped
[O] - Other

Container Type

[OT] - Open-top
[CT] - Closed-top
[SC] - Safety container
[O] - Other (specify)

Method of Chemical Addition Key

[A] - Automatic [a]
[P] - Pumped Manually
[PR] - Poured
[S] - Scooped
[O] - Other (specify)

*** If additions are automatic [A] then do not complete the last two columns.**

Personal Protective Equipment Key

[E] - Eye protection
[L] - Labcoat/Sleeved garment protection
[B] - Boots
[Z] - All except respiratory
[G] - Gloves
[A] - Apron
[R] - Respiratory protection
[N] - None

4.5 Other Bath Related Activities

Complete the following table for any other bath related activities that your facility engages in.

BATH TYPE	TYPE OF ACTIVITY (Describe)	FREQUENCY[a]	DURATION OF ACTIVITY[b]	NUMBER OF PEOPLE [c]	PROTECTIVE EQUIPMENT
CLEANER/ CONDITIONER					
PRE-DIP					
CATALYST					
ACCELERATOR					
ENHANCER					
POST-CLEAN ETCH					
ANTI-TARNISH/ ANTI-OXIDANT					
OTHER (specify)					

[a] Frequency **-** Enter the average amount of time elapsed or number of panel sq. ft. processed since the last time the activity was performed. Clearly specify units (e.g., hours, square feet, etc.).

[b] Duration of Activity **-** Enter the average time for performing the specified activity. Clearly specify units.

[c] Personal Protect. Equip. **-** Consult key on the previous page and enter the letters for **all** protective equipment worn by the people performing the activity.

A.4 Supplier Data Sheet

DfE Printed Wiring Board Project
Alternative Technologies for Making Holes Conductive (MHC)

Manufacturer/Supplier Product Data Sheet

Manufacturer Name: ____________________
Address: ____________________
____
Contact: ____________________
Phone: ____________________
Fax: ____________________

How many alternative making holes conductive product lines will you submit for testing?__________

Please complete a Data Sheet for each product line you wish to submit for testing. In addition, if you have not already done so, please submit the material safety data sheets (MSDS), product literature, and the standard manufacturer instructions for each product line submitted.

Product Line Name: ____________________ **Category:*** _______

*** Categories of Product Lines:**

A. Electroless copper
B. Carbon-based
C. Graphite-based
D. Palladium-based
E. Non-formaldehyde electroless
F. Copper seed
G. Anisotropic
H. Electroless Nickel
I. Drill Smear (Lomerson)
J. Conductive inks
K. Conductive polymer
L. Other

For the product line listed above, please identify one or two facilities that are currently using the product line at which you would like your product demonstrated. Also, identify the location of the site (city, state) and whether the site is 1) a customer production site, 2) a customer test site, or 3) your own supplier testing site.

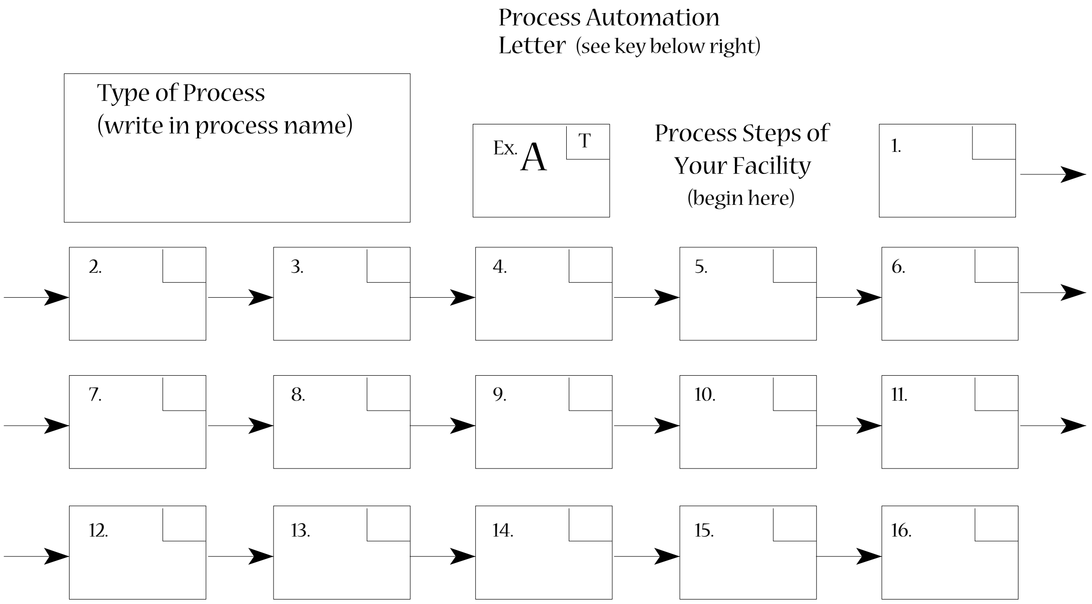
Facility 1 Name and Location:____________________
Type of Site: ____________________
Facility Contact: ____________________
May we contact the facility at this time (yes or no):____________________

Facility 2 Name and Location: ____________________
Type of Site: ____________________
Facility Contact: ____________________ Phone: ____________________
May we contact the facility at this time (yes or no): ____________________

Process Description

Process Schematic

Fill in the table below by identifying what type of making holes conductive process (e.g., electroless copper) your facility uses. Then, using the key at the bottom left of the page, identify which letter corresponds with the first bath step in your process and write that letter in the first box (see example). Continue using the key to fill in boxes for each step in your process until your entire making holes conductive process is represented. If your process step is not represented by the key below, complete the chart by writing in the name of the process step in your particular making holes conductive line. Finally, consult the process automation key at bottom right and enter the appropriate type of automation for the MHC process line. If the process is partially automated, enter the appropriate process automation letter for each step in the upper right-hand corner box (see example).



Standard Bath Types

- [A] - Center
- [B] - Conditioner
- [C] - Micro-Etch
- [D] - Pro-dip
- [E] - Catalyst
- [F] - Activator
- [G] - Accelerator
- [H] - Enhancer
- [J] - Electroless Copper
- [K] - Graphite
- [L] - Carbon
- [M] - Fixer
- [N] - Reducer
- [P] - Air Knife/Oven
- [Q] - High pressure water
- [R] - Neutralizer
- [S] - Anti-tarnish
- [W] - Water rinse
- [O] - Other (specify step)

Process Automation

Type of Process Automation for Entire MHC Process
(Consult the key below)
If the MHC process is partially automated (option R), enter 'R" on above line. Then, for each process step in chart above, consult the key below and enter the appropriate process automation letter in the box located in the upper right hand corner of each process step (see example).

Process Automation Key

- [P] - Automated on-conveyorized
- [Q] - Automated conveyorized
- [R] - Partially automated
- [S] - Manually controlled hoist
- [T] - Manual (no information)
- [A] - All of the above
- [V] - Other (specify)

Product Line Name ____

Please fill in the following table (for bath listings, please refer back to your process description on page 2):

Baths — Chemical Composition	**Chemical Composition/Characteristics of Spent Bath**[a]	**Standard Container Size**
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
Comments:		

[a] Do not include drag-out.

Special Product Characteristics

1. Does the process operate as a vertical process, horizontal process, or either? ____________________

2. Is the process pattern-plate or panel-plate? ____________________

3. Does the process require scrubbing of panel after completion? ____________________

4. Does the process require spray etch, scrub, or high-pressure rinse before imaging or electroplating? If so, which? ____________________

5. Are there any limitations for the acid copper plating process (e.g., pattern microetch, tank configuration, ASF)? Please explain.

____

____

6. Are there any constraints on hold times as a result of the MHC process? ____________________

____

7. Please state cycle time. ____________________

8. Please describe any special process equipment recommended (e.g. high pressure rinse, air knife, dryer, aging equipment, etc.). ____________________

____

Product Line Constraints

1. Please list substrate compatibilities (e.g. BT, cyanate ester, Teflon, Kevlar, copper invar copper, polyethylene, other [specify]). ____________________

2. Please list compatibilities with drilling techniques. ____________________

____

3. Please list compatibilities with desmear processes (e.g. neutralization after permanganate, plasma, etc.).

____

4. List range of aspect ratio capacity. ____________________

5. List range of hole sizes. ____________________

6. List recommended oxide processes. ____________________

Other general comments about the product line (include any known impacts on other process steps).

____

____

____

Bath Life

Please fill in the following table (for bath listings, please refer back to your process description on page 2):

Bath	Recommended Treatment/ Disposal Method[a]	Criteria for Dumping Bath[b] (e.g., time, ft^2 of panel processed, conductivity, etc.)	Recommended Bath Life
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

[a] Attach and reference additional materials, if necessary

Please specify criteria for calculation in the space below:

Costs:

Fill in the price of your product for each facility category.

	Estimated manufacturer price of product line to be tested based on recommended bath life*			
		Chemical cost per square foot panel per day	Equipment cost per square foot panel per day	Water use (gallons per minute)
Horizontal Process	Low-level throughput shop[a]			
	Medium-level throughput shop[b]			
	High-level throughput shop[c]			
Vertical Process	Low-level throughput shop			
	Medium-level throughput shop			
	High-level throughput shop			
Other (specify)	Low-level throughput shop			
	Medium-level throughput shop			
	High-level throughput shop			

[a] 2,000 surface square feet per day; 18" x 24" panel = 6 square feet
[b] 6,000 surface square feet per day
[c] 15,000 surface square feet per day
* Please include a description of the basis for your estimates (including assumptions about holes sizes, dragout, replenishment/replacement times, equipment life, and frequencies) in the space below.

Cost Estimate Calculation:

Appendix B

Publicly-Available Bath Chemistry Data

Table B.1 Range of Bath Concentrations for the Electroless Copper Technology

Bath	Chemicals[a]	Bath Concentration (g/l)		
		Low	High	Average
Cleaner/Conditioner	Sulfuric Acid	9.90		
	p-Toluene Sulfonic Acid	9.90		
	Isopropyl Alcohol; 2-Propanol	1.65	6.44	3.36
	Hydroxyacetic Acid	34.7		
	Potassium Hydroxide	0.53		
	Ammonium Chloride	12.9		
	Formic Acid	12.9		
	Cationic Emulsifier	6.44		
	Triethanolamine	30.3		
	Phosphate Ester	30.3		
	Ethylene Glycol	2.44		
	Dimethylformamide	1.32		
	Confidential Ingredients	2.00		
	Ethanolamine	16.3		
Micro-Etch	Potassium Peroxymonosulfate	25.8		
	Potassium Bisulfate	13.8		
	Potassium Sulfate	19.2		
	Magnesium Carbonate	1.20		
	Potassium Persulfate	9.80		
	Sulfuric Acid	1.84	340	121
	Hydrogen Peroxide	13.8	35.9	19.9
	Sodium Hydroxide	0.30		
	Copper Sulfate - Pentahydrate	0.50		
	Ethylene Glycol	1.93		
Predip	Sodium Bisulfate	2.58	46.6	24.6
	HCL	31.7	182	85.6
	Sulfuric Acid	2.58		
Catalyst	Hydrochloric Acid	1.98	158	50.9
	Stannous Chloride as Tin (II)	6.32	16.6	10.3
	Palladium (Dissolved)	0.36		
	Methanol	2.52		
	Sodium Bisulfate	45.2		
	Sodium Sulfate	12.6		
	Sodium Hydroxide	2.53		
Accelerator	Sodium Chlorite	4.52		
	Sulfuric Acid	18.2		
	Sodium Hypophosphite	8.58		
	Fluoboric Acid	60.0	60.0	60.0

Bath	Chemicals[a]	Bath Concentration (g/l)		
		Low	High	Average
Electroless Copper	Formaldehyde	1.58	5.59	3.68
	Copper Chloride	5.06	8.32	6.69
	Copper Sulfate as Copper	4.79	11.6	6.98
	Hydrochloric Acid	0.48		
	Sodium Hydroxide	5.78	15.7	10.1
	Ethylenediamine-Tetraacetic Acid Tetrasodium Salt (EDTA)	34.2	56.2	45.2
	Methanol	0.04	2.80	1.39
	Potassium Cyanide	0.22		
	Potassium-Sodium Tartrate	31.4		
	Sodium Carbonate	0.05		
	Tartaric Acid	1.03		
	Sodium Cyanide	0.23		
	Alkaline Mixture	154		
	Sulfuric Acid	1.15		
Acid Dip	Sulfuric Acid	NR		
	Dimethylaminoborane	0.72		
	Boric Acid	5.00		
Anti-Tarnish	Methanol	0.95	1.25	1.10
	Sulfuric Acid	28.8		
	Isopropyl Alcohol	2.02		
	Potassium Hydroxide	0.30		
	Benzotriazole	0.12		
	2-Ethoxyethanol	45.9		
	Sodium m-Nitrobenzenesulfonate	0.12		
Cleaner/Conditioner	Nonionic Surfactant	4.50		
	Potassium Carbonate	6.16		
	Monoethanolamine; 2-Aminoethanol	14.2	25.4	19.8
	Triethanolamine; 2,2'2''-Nitrilotris (Ethanol)	5.1	25.4	15.2
	2-Propanol	2.04		
	Surface Agent (non-haz)	15.3		
Predip	Sodium Bisulfate	46.6		
	Sodium Chloride	360		
	Hydrochloric Acid	1.85	17.1	10.3
Catalyst	Sodium Bisulfate	42.9		
	Sodium Chloride	653		
	Hydrochloric Acid	9.60	46.0	22.9
	Tin(II) chloride, Stannous Chloride as Tin	21.1	46.0	31.8
	Palladium (Dissolved)	0.96		
	Palladium Chloride	0.50	0.70	0.60
	Vanillin	1.50		
	1,3-Benzenediol	0.73		

Bath	Chemicals[a]	Bath Concentration (g/l)		
		Low	High	Average
Accelerator	Fluoroboric Acid as Fluoride	18.9		
	Copper as CU(II)	2.55		
	Copper Sulfate	0.23	1.38	0.81
	Sulfuric Acid	0.93		
	Sodium Hydroxide	14.4	43.5	29.0
	Potassium Carbonate	318		
	Lithium Hydroxide	20.3		
	Monoethanolamine	3.49	20.3	11.9
Micro-Etch	Copper Sulfate as Copper	13.3		
	Sulfuric Acid	9.20	35.0	20.9
	Phosphoric Acid	NR		
	Hydrogen Peroxide	17.5		
	Sodium Persulfate: Disodium Peroxydisulate	135	175	151
Acid Dip	Sulfuric Acid	191		

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.2 Bath Concentrations for the Carbon Technology, Non-Conveyorized[a]

Bath	Chemicals[b]	Concentration in Bath
Cleaner	Monoethanolamine Ethylene Glycol	11.6 NR
Conditioner	Monoethanolamine	11.5
Carbon Black	Potassium Carbonate Potassium Hydroxide Sulfuric Acid Carbon Black	62.3 0.46 0.04 NR
Micro-Etch	Sodium Persulfate Sulfuric Acid Copper Sulfate Pentahydrate	200 1.84 5.0

[a] The carbon technology was the only MHC technology listing different chemical concentrations depending on the equipment configuration (e.g., conveyorized or non-conveyorized.)

[b] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.3 Bath Concentrations for the Carbon Technology, Conveyorized[a]

Bath	Chemicals[b]	Concentration in Bath
Cleaner	Monoethanolamine Ethylene Glycol	12.7 NR
Conditioner	Monoethanolamine	34.5
Carbon Black	Potassium Hydroxide Carbon Black	20.4 NR
Micro-Etch	Sodium Persulfate Sulfuric Acid Copper Sulfate Pentahydrate	200 1.84 5.0

[a] The carbon technology was the only MHC technology listing different chemical concentrations depending on the equipment configuration (e.g., conveyorized or non-conveyorized.)

[b] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.4 Product Concentrations for the Conductive Ink Technology

Bath		Chemicals[a]	Constituent Concentration (weight %)
Micro-Etch	Conventional micro-etch cleaning processes may be used as well as light brushing		
Screen Print Ink (5 different product formulations are listed)	Formulation A	Silver 2-Butoxyethanol Acetate Phenol-Formaldehyde Resin Trade Secret Resin* Methanol Isophorone Modifiers	60 - 80 15 - 25 5 - 10 1-5 < 5 1 - 2 < 1
	Formulation B	Additives & Modifiers Silver-Coated Copper Powder Phenol-Formaldehyde Co-Polymer Diethylene Glycol Monomethyl Ether	< 5 70 - 90 1 0 -20 < 10
	Formulation C	Additives & Modifiers Silver-Coated Copper Powder Phenol-Formaldehyde Co-Polymer Diethylene Glycol Monomethyl Ether	< 5 70 - 90 10-20 < 10
	Formulation D	Silver-Plated Copper Powder Phenol-Formaldehyde Polymer Diethylene Glycol Monomethyl Ether Modifiers	80- 90 10 - 20 5 - 15 < 3
	Formulation E	Phenol-Formaldehyde Resin Trade Secret Resin* Graphite Diethylene Glycol Butyl Ether Diethylene Glycol Ethyl Ether Carbon Black Butyl Cellosolve Acetate Methanol	20 - 30 25 - 35 10 - 20 10 - 20 < 10 5 - 10 5 - 10 < 5

[a] May not include trade secret chemicals or those materials identified as "non-hazardous materials" on the MSDSs.

Table B.5 Bath Concentrations for the Conductive Polymer Technology

Bath	Chemicals [a]	Bath Concentration (g/l)
Micro-Etch	Potassium Peroxymonosulfate Sulfuric Acid	100 20
Cleaner/Conditioner	Natrium Carbonate (Sodium Carbonate)	7.5
Catalyst	Phosphoric Acid Alkali Permanganate Sodium Hydroxide	2.75 815 0.9
Conductive Polymer	Phosphoric Acid Potassium Hydroxide in Azoles	26.8 3

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.6 Range of Bath Concentrations for the Graphite Technology

Bath	Chemicals[a]	Concentration in Bath (g/l)		
		Low	High	Average
Cleaner/Conditioner	Non-Haz-Ingredients	437		
	Surfactant	2.06		
	Potassium Carbonate	7.39		
	Ethanolamine	19.7		
Graphite	Graphite	29.8	61.2	45.5
	Non-Haz-Ingredients	127		
	Ammonia	1.95		
Micro-Etch	Sulfuric Acid	28.0	90.3	59.1
	Sodium Persulfate	23.5	90.3	56.9
	Potassium Peroxymonosulfate	30.1		
	Copper Sulfate as Copper	2.67		
	Non-Haz Ingredients	15.6		

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.7 Bath Concentrations for the Non-Formaldehyde Electroless Copper Technology

Bath	Chemicals[a]	Bath Concentration
Cleaner/Conditioner		
Micro-Etch	Potassium Persulfate Sulfuric Acid Hydrogen Peroxide Sodium Hydroxide Copper Sulfate - Pentahydrate	9.80 20.2 16.1 0.30 0.50
Predip		
Catalyst	Hydrochloric Acid Stannous Chloride	2.96 9.48
Postdip	Hydrochloric Acid	NR
Accelerator	Sodium Chlorite	4.52
Electroless Copper/Copper Flash	Copper Sulfate Sulfuric Acid Sodium Hydroxide	22.4 2.56 NR
Anti-Tarnish	Isophopyl Alcohol Potassium Hydroxide	2.02 0.30

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.8 Bath Concentrations for the Organic-Palladium Technology[a]

Bath	Chemicals	Concentration in Bath (g/l)
Conditioner	Trade Secret AQ Solution, Cationic Resin Sodium Carbonate Sodium Bicarbonate	5 NR 3 5
Micro-Etch	Sodium Persulfate Sodium Bisulfate	75 75
Predip	HCL Acid (25% pure)	3.12
Conductor	HCL Acid Trade Secret Sodium Hypophosphite-1Hydrate	3 3 3.06
Postdip	Sodium Carbonate Trisodium Citrate - 5.5 Hydrate Trade Secret	12.6 12.6 34.5

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Table B.9 Range of Bath Concentrations for the Tin-Palladium Technology

Bath	Chemicals[a]	Low	High	Average
Cleaner/Conditioner	Nonionic Surfactant	4.50		
	Potassium Carbonate	6.16		
	Monoethanolamine; 2-Aminoethanol	14.2	25.4	19.8
	Triethanolamine; 2,2',2"-Nitrilotris (ethanol)	5.1	25.4	15.2
	2-Propanol	2.04		
	Surface Agent (non-haz)	15.3		
Predip	Sodium Bisulfate	46.6		
	Sodium Chloride	360		
	Hydrochloric Acid	1.85	17.10	10.3
Catalyst	Sodium Bisulfate	42.9		
	Sodium Chloride	653		
	Hydrochloric Acid	9.60	46.0	22.9
	Tin(II) Chloride, Stannous Chloride as Tin	21.1	46.0	31.8
	Palladium (dissolved)	0.96		
	Palladium Chloride	0.50	0.70	0.60
	Vanillin	1.50		
	1,2-Benzenediol	0.73		
Accelerator	Fluoroboric Acid as Fluoride	18.9		
	Copper as Cu (II)	2.55		
	Copper Sulfate	0.23	1.38	0.81
	Sulfuric Acid	0.93		
	Sodium Hydroxide	14.4	43.5	29.0
	Potassium Carbonate	318		
	Lithium Hydroxide	20.3		
	Monoethanolamine	3.49	20.3	11.9
Micro-Etch	Copper Sulfate as Copper	13.3		
	Sulfuric Acid	9.20	35.0	20.9
	Phosphoric Acid	NR		
	Hydrogen Peroxide	17.5		
	Sodium Persulfate; Disodium Peroxydisulfate	135	175	151
Acid Dip	Sulfuric Acid	191		

[a] May not include trade secret chemicals or those materials identified as “non-hazardous materials” on the MSDSs.

Appendix C
Chemical Properties Data

Chemical Summary for . . .

1,3-BENZENEDIOL

1 H-PYRROLE

2-BUTOXYETHANOL ACETATE

2-ETHOXYETHANOL

AMMONIA

AMMONIUM CHLORIDE

BENZOTRIAZOLE

BORIC ACID

CARBON BLACK

COPPER AND SELECTED COPPER COMPOUNDS

DIETHYLENE GLYCOL MONOETHYL ETHER ACETATE

DIETHYLENE GLYCOL METHYL ETHER

DIETHYLENE GLYCOL N-BUTYL ETHER

***N*,*N*-DIMETHYLFORMAMIDE**

ETHANOLAMINE

ETHYLENE GLYCOL

ETHYLENEDIAMINE TETRAACETIC ACID (EDTA)

FLUOROBORIC ACID (FLUORIDE)

FORMALDEHYDE

FORMIC ACID

GRAPHITE

HYDROCHLORIC ACID

HYDROGEN PEROXIDE

HYDROXYACETIC ACID

ISOPHORONE

ISOPROPANOL

LITHIUM HYDROXIDE

m-NITROBENZENE SULFONIC ACID, SODIUM SALT

MAGNESIUM CARBONATE

METHANOL

***p*-TOLUENE SULFONIC ACID**

PALLADIUM AND PALLADIUM CHLORIDE

PEROXYMONOSULFURIC ACID, MONOPOTASSIUM SALT

PHENOL-FORMALDEHYDE COPOLYMER

PHOSPHORIC ACID

POTASSIUM BISULFATE

POTASSIUM CARBONATE

POTASSIUM AND SODIUM CYANIDE

POTASSIUM HYDROXIDE

POTASSIUM PERSULFATE

POTASSIUM SULFATE

POTASSIUM SODIUM TARTRATE

SILVER

SODIUM BISULFATE

SODIUM CARBONATE

SODIUM CHLORIDE

SODIUM CHLORITE

SODIUM HYDROXIDE

SODIUM HYPOPHOSPHITE

SODIUM HYPOPHOSPHITE 1-HYDRATE

SODIUM PERSULFATE

SODIUM SULFATE

STANNOUS CHLORIDE AND STANNOUS CHLORIDE AS TIN

SULFURIC ACID

TARTARIC ACID

TETRASODIUM EDTA (Na_4EDTA)

TRIETHANOLAMINE

SODIUM CITRATE

VANILLIN

CITED REFERENCES

ATTACHMENT C-1 (Standard References Searched)

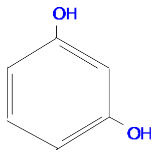
CHEMICAL SUMMARY FOR 1,3-BENZENEDIOL

This chemical was identified by one or more suppliers as a bath ingredient for the tin-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of 1,3-benzenediol are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF 1,3-BENZENEDIOL

Characteristic/Property	Data	Reference
CAS No.	108-46-3	
Common Synonyms	resorcinol: m-dihydroxybenzene	Budavari et al. 1989
Molecular Formula	$C_6H_6O_2$	Budavari et al. 1989
Chemical Structure		Budavari et al. 1989
Physical State	white, needle-like crystals	Budavari et al. 1989
Molecular Weight	110.11	Budavari et al. 1989
Melting Point	109-111°C	Budavari et al. 1989
Boiling Point	280°C	Budavari et al. 1989
Water Solubility	1 g in 0.9 mL	Budavari et al. 1989
Density	1.272	Budavari et al. 1989
Vapor Density (air = 1)	3.79	Keith and Walters 1985
K_{OC}	10.36, measured	HSDB 1995
Log K_{OW}	0.80, measured	CHEMFATE 1995
Vapor Pressure	2×10^{-4} mm Hg @ 25°C	Keith and Walters 1985
Reactivity	hygroscopic; sensitive to light, air; may react with iron	Keith and Walters 1985
	incompatible: acetanilide, albumin, alkalies, antipyrine, camphor, ferric salts, menthol, spirit nitrous ether, urethan	Budavari et al. 1989
Flammability	combustible	Keith and Walters 1985
Flash Point	127.2°C	Keith and Walters 1985
Dissociation Constant	pKa, 9.32, measured	CHEMFATE 1995
	7.11×10^{-10} @ 30°C	HSDB 1995
Henry's Law Constant	8.1×10^{-11} atm-m^3/mole @ 25°C	HSDB 1995
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	2.4 (estimated)	HSDB 1995
Odor Threshold	faint, characteristic odor	Allan 1994
Conversion Factors	1 mg/m^3 = 0.22 ppm;	Calculated using:
	1 ppm = 4.55 mg/m^3	ppm = 1 mg/m^3 x 24.45/MW

II. ENVIRONMENTAL FATE

A. Environmental Release

1,3-Benzenediol may be released into the environment in waste effluents associated with coal gassification and conversion, coal-tar production, shale oil processing, and from the combustion of wood and tobacco (HSDB 1995). 1,3-Benzenediol is found in cigarette smoke (HSDB 1995). 1,3-

Benzenediol is not one of the chemicals reported to the Toxics Release Inventory (TRI) by certain types of U.S. industries.

B. Transport

1,3-Benzenediol is expected to leach readily in soil; however, leaching may not be important if concurrent biodegradation occurs at a rapid rate (HSDB 1995).

C. Transformation/Persistence

1. Air — If released to the atmosphere, 1,3-benzenediol can be expected to exist almost entirely in the gas-phase in the ambient atmosphere. Gas-phase 1,3-benzenediol is expected to degrade rapidly in air (estimated half-life 1.9 hours) by reaction with photochemically produced hydroxyl radicals. Night-time reaction with nitrate radicals may also contribute to atmospheric transformation (HSDB 1995).
2. Soil — 1,3-Benzenediol is readily degradable in soil. The degradation rate decreases at low temperatures (CHEMFATE 1995).
3. Water — 1,3-Benzenediol is confirmed to be significantly degradable in water (CHEMFATE 1995). By analogy to other phenol compounds, 1,3-benzenediol may react relatively rapidly in sunlit natural water with photochemically produced oxidants such as hydroxyl and peroxyl radicals (HSDB 1995). Hydrolysis, volatilization, and adsorption to sediments are not expected to be important (HSDB 1995).
4. Biota — Bioconcentration of 1,3-benzenediol is not expected to be important (HSDB 1995).

CHEMICAL SUMMARY FOR 1 H-PYRROLE

This chemical was identified by one or more suppliers as a bath ingredient for the conductive polymer process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of 1H-pyrrole are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF 1H-PYRROLE

Characteristic/Property	Data	Reference
CAS No.	109-97-7	
Common Synonyms	pyrrole; azole; divinylenimine; imidole	Trochimowicz et al. 1994
Molecular Formula	C_4H_5N	Trochimowicz et al. 1994
Chemical Structure		
Physical State	liquid (colorless when freshly distilled)	Budavari et al. 1996
Molecular Weight	67.09	Budavari et al. 1996
Melting Point	-23°C	Trochimowicz et al. 1994
Boiling Point	129.8°C @ 760 mm Hg	Budavari et al. 1996
Water Solubility	sparingly soluble	Budavari et al. 1996
Density	specific gravity, $0.9691^{20/4}$	Trochimowicz et al. 1994
Vapor Density (air = 1)	2.31	Trochimowicz et al. 1994
K_{OC}	not found	
Log K_{OW}	0.75 (measured)	Mackay et al. 1995
Vapor Pressure	1100-1136 Pa @ 25°C (8.3-8.5 mm Hg)[a]	Mackay et al. 1995
Reactivity	can react with oxidizing materials; when heated to decomposition, emits highly toxic fumes of oxides of nitrogen	HSDB 1996
Flammability	must be moderately heated before ignition occurs	HSDB 1996
Flash Point	102°F (390°C)	Budavari et al. 1996
Dissociation Constant	pK_a, -3.8 to -4.4	Mackay et al. 1995
Henry's Law Constant	1.640 Pa m^3/mol (calculated) (1.6 x 10^{-5} atm-m^3/mol)[b]	Mackay et al. 1995
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	1 ppm = 2.74 mg/m^3 1 mg/m^3 = 0.36 ppm	HSDB 1996

a) mm Hg calculated from Pa based on the formula: mm Hg = Pa ÷ 1.333 x 10^2 (Lukens 1979).

b) Pa converted to atm by the following formula: atm = Pa ÷ 1.013 x 10^5 (Lukens 1979).

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of 1H-pyrrole. 1H-pyrrole is one of a group of compounds containing five-membered rings with one or more nitrogen atoms (Trochimowicz et al. 1994). The industrial use of the simpler members of this group of chemicals is limited (Trochimowicz et al. 1994). 1H-pyrrole may be released to the environment from plants that manufacture it or use it either as a chemical intermediate in the production of drugs, dyes, herbicides, and perfumes, or as a cross-linking agent for resins (HSDB 1996). However, its limited use would likely preclude the release of large volumes of the chemical to the environment. 1H-pyrrole occurs naturally as part of the structure of pigments such as bilirubin and heme and is a constituent of coal tar and bone oil (Trochimowicz et al. 1994).

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of 1H-pyrrole. The vapor pressure (1100-1136 Pa [Mackay et al. 1995]) and the Henry's Law Constant (1.6 x 10^{-5} atm-m^3/mol) of the chemical indicate that some volatilization from soil or water could occur. 1H-pyrrole is slightly soluble in water and small amounts may move through the soil, possibly to groundwater.

C. Transformation/Persistence

1. Air — 1H-pyrrole in air would undergo oxidation, probably within hours. For gas-phase reaction at room temperature the rate constant has been estimated at 1.2 x 10^{-10} cm^3 $molecule^{-1}$ sec^{-1}, assuming the concentration of OH radicals to be 1 x $10^6/cm^3$ during the daytime. This value corresponds to a calculated lifetime of 2.3 hours (Mackay et al. 1995). In other studies, the calculated lifetime was 1.4 minutes for reaction with NO_3 radicals during nighttime hours and 24 hours for reaction with O_3 molecules (Mackay et al. 1995).
2. Soil — No information was found in the secondary sources searched regarding the degradation of 1H-pyrrole in the soil.
3. Water — No information was found in the secondary sources searched regarding the degradation of 1H-pyrrole in water.
4. Biota — The log K_{OW} for 1H-pyrrole (0.75 [Mackay et al. 1995]) indicates that the chemical has a low to moderate potential to bioaccumulate in aquatic organisms.

CHEMICAL SUMMARY FOR 2-BUTOXYETHANOL ACETATE

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online data bases, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of 2-butoxyethanol acetate are listed below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF 2-BUTOXYETHANOL ACETATE

Characteristic/Property	Data	Reference
CAS No.	112-07-2	
Common Synonyms	ethylene glycol monobutyl ether acetate; Butyl Cellosolve acetate	HSDB 1996
Molecular Formula	$C_8H_{16}H_3$	Gingell et al. 1994
Chemical Structure	C_4H_9-O-$(CH_2)_2$-$OCOCH_3$	NIOSH 1994
Physical State	colorless liquid	HSDB 1996
Molecular Weight	160.21	Gingell et al. 1994
Melting Point	-64.5°C	Howard 1993
Boiling Point	192.3°C	Howard 1993
Water Solubility	15,000 mg/L at 20°C	Verschueren 1996
Density	0.9422 @ 20/20°C	HSDB 1996
Vapor Density (air = 1)	5.5	HSDB 1996
K_{OC}	26 (calculated)	HSDB 1996
Log K_{OW}	1.51 (measured)	Verschueren 1996
Vapor Pressure	0.375 mm Hg @ 20°C	Howard 1993
Reactivity	can react with oxidizers	NIOSH 1994
Flammability	NFPA rating = 2; must be moderately heated before ignition can occur	HSDB 1996
Flash Point	71°C (160°F) (closed cup)	HSDB 1996
Dissociation Constant	no data	
Air Diffusivity Constant	no data	
Molecular Diffusivity Constant	no data	
Henry's Law Constant	7.19×10^{-6} atm-m^3/mole	Howard 1993
Fish Bioconcentration Factor	3.2 (calculated)	Howard 1993
Odor Threshold	0.10 ppm, abs. perception limit; 0.35 ppm, 50% recognition; 0.48 ppm, 100% recognition	Verschueren 1996
Conversion Factors	1 ppm = 6.64 mg/m^3 1 mg/m^3 = 0.15 ppm	Verschueren 1996

II. ENVIRONMENTAL FATE

A. Environmental Release

2-Butoxyethanol acetate may be released to the atmosphere by evaporation when it is used as a solvent in paints, lacquers, thinners, inks, and resins. The emission rate into the atmosphere from painting operations in an automobile assembly plant in Wisconsin was estimated at 37.9 gallons/hour (Howard 1993). 2-Butoxyethanol acetate was detected in 0.4% of 275 solvent products that were sampled in various industries and analyzed between 1978 and 1982 (HSDB 1996).

In 1993, releases of all glycol ethers to environmental media, as reported in the TRI by certain types of industries, totaled about 45.9 million pounds; 2-butoxyethanol acetate is not listed separately (TRI93 1995).

B. Transport

The estimated relatively low K_{OC} of 26 suggests that 2-butoxyethanol acetate can leach readily into groundwater from soils. However, if rapid biodegradation occurs, leaching may be less important. Volatilization from water is expected to be slow, with the possible exception from very shallow rivers. Physical removal via wet deposition is likely because the chemical is soluble in water (Howard 1993; HSDB 1996).

C. Transformation/Persistence

1. Air — Based on a vapor pressure of 0.375 mm Hg at 20°C, 2-butoxyethanol acetate should exist almost entirely in the vapor phase in the atmosphere. It is expected that 2-butoxyethanol acetate will degrade by reaction with hydroxyl radicals with an estimated half-life of about 18.4 hours (HSDB 1996).
2. Soil — When released to soils, biodegradation is expected to be the most important removal process. One biodegradation screening study demonstrated that the chemical is readily (>90%) biodegraded (HSDB 1996).
3. Water — Biodegradation is likely to be the most important removal mechanism of 2-butoxyethanol acetate from aquatic systems. In a screening assay, 2-butoxyethanol acetate total degradation exceeded 90%, with a measured rate of 12%/day under the test conditions. No observable lag period was required before onset of degradation. Estimated volatilization half-lives from a model river (1 meter deep) and model pond are 6.6 and 74 days, respectively. Adsorption to sediment is not expected to be important (HSDB 1996).
4. Biota — The estimated bioconcentration factor of 3.2 suggests that 2-butoxyethanol acetate would not bioconcentrate significantly in aquatic organisms (Howard 1993).

CHEMICAL SUMMARY FOR 2-ETHOXYETHANOL

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of 2-ethoxyethanol are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF 2-ETHOXYETHANOL

Characteristic/Property	Data	Reference
CAS No.	110-80-5	
Common Synonyms	ethylene glycol monoethyl ether; Cellusolve; Oxitol	Budavari et al. 1996
Molecular Formula	$C_4H_{10}O_2$	Budavari et al. 1996
Chemical Structure	$HOCH_2CH_2OC_2H_5$	Budavari et al. 1996
Physical State	colorless liquid	Budavari et al. 1996
Molecular Weight	90.12	Budavari et al. 1996
Melting Point	-70°C	Budavari et al. 1996
Boiling Point	135°C	Budavari et al. 1996
Water Solubility	miscible	Budavari et al. 1996
	$\geq$100 mg/mL	Keith and Walters 1985
Density	0.93	Budavari et al. 1996
Vapor Density (air = 1)	3.10	Verschueren 1996
K_{OC}	0.12 (calculated)	Howard 1990
Log K_{OW}	-0.10	Howard 1990
Vapor Pressure	3.8 mm Hg at 20°C	Verschueren 1996
Reactivity	reacts with strong oxidizers	Keith and Walters 1985
Flammability	combustible	Keith and Walters 1985
Flash Point	44°C (closed cup) 49°C (open cup)	Budavari et al. 1996
Dissociation Constant	no data	
Henry's Law Constant	5.13×10^{-2} atm-m^3/mol	Howard 1990
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	0.55 ppm (50% recognition)	Verschueren 1996
	1.33 ppm (100% recognition)	Verschueren 1996
Conversion Factors	1 ppm = 3.75 mg/m^3 1 mg/m^3 = 0.27 ppm	Verschueren 1996

II. ENVIRONMENTAL FATE

A. Environmental Release

Environmental release of 2-ethoxyethanol can occur from wastewater effluents and atmospheric emissions from production and use facilities. Information on the amount of 2-ethoxyethanol released to the environment was not found in the secondary sources searched. Chemical concentrations detected in the Hayashida River (Japan) were 250-1200 ppb (Howard 1990; U.S. EPA 1985a). Effluent from a facility in Brandenburg, KY contained 0.10 µg/L in 1974 (U.S. EPA 1985a).

B. Transport

The Henry's Law constant of 5.13×10^{-2} atm-m^3/mol (Howard 1990) indicates rapid volatilization from soils and surface waters. The complete water solubility and low K_{OC} indicate that leaching from soils into ground water may occur.

C. Transformation/Persistence

1. Air — In the atmosphere, 2-ethoxyethanol will react with both nitrogen oxides and hydroxyl radicals. The half-life of the chemical was 9.8 hour when mixed with nitrogen oxides (20:1, 2-ethoxyethanol:nitrogen dioxides) in a smog chamber. For reaction with photochemically produced hydroxy radicals, the estimated half-life is 11.41 hours (Howard 1990).
2. Soil — Volatilization and biodegradation are the main removal mechanisms for 2-ethoxyethanol from soils. Adsorption is not expected to be significant, so leaching into ground waters may occur (Howard 1990). A soil microbe acclimated to triethylene glycol was capable of utilizing 2-ethoxyethanol as a sole carbon source. In a standard evaporation test at 77°C and 15% relative humidity, 100% loss of the chemical occurred in 20 minutes (U.S. EPA 1985a).
3. Water — 2-Ethoxyethanol will volatilize readily from surface waters with biodegradation also contributing to removal. After incubation of the chemical for 5 days with either sewage seed or activated sludge, 7.6% and up to 65%, respectively, of the theoretical biological oxygen demand was achieved. Adsorption to suspended particulates and sediments is not expected to occur (Howard 1990). Hydrolysis of 2-ethoxyethanol is not expected to be important (U.S. EPA 1985a).
4. Biota — Based on the complete water solubility and low K_{OW} of 2-ethoxyethanol, the chemical is not expected to accumulate in aquatic organisms (U.S. EPA 1985a).

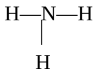
CHEMICAL SUMMARY FOR AMMONIA

This chemical was identified by one or more suppliers as a bath ingredient for the graphite process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of ammonia are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF AMMONIA

Characteristic/Property	Data	Reference
CAS No.	7664-41-7	
Common Synonyms	ammonia gas; liquid ammonia; ammonia, anhydrous; Spirit of Hartshorn; Nitro-Sil	Lockheed Martin 1995a
Molecular Formula	H_3N	
Chemical Structure	 $H-\underset{H}{\underset{\vert}{N}}-H$	
Physical State	colorless gas	Budavari et al. 1989
Molecular Weight	17.03	Budavari et al. 1989
Melting Point	-77.7°C	Budavari et al. 1989
Boiling Point	-33.35°C	Budavari et al. 1989
Water Solubility	47% @ 0°C; 38% @ 15°C; 34% @ 20°C	Budavari et al. 1989
Density	0.7710 g/L (gas)	ATSDR 1990a
Vapor Density (air = 1)	0.59	HSDB 1995
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	7.508×10^3 mm Hg @ 25°C	CHEMFATE 1995
Reactivity	incompatible with halogens, acid chlorides, acid, acid anhydrides, oxidizing agents, chloroformates, galvanized iron; reacts with zinc, copper, tin, and their alloys; pH of 1N solution = 11.6	Lockheed Martin 1995a Budavari et al. 1989
Flammability	flammable	
Flash Point	no data; autoignition @ 649°C	Lockheed Martin 1995a
Dissociation Constant	pKa = 9.249; pKb = 4.751 @ 25°C	U.S. EPA 1981a
Henry's Law Constant	7.3×10^{-6} atm-m^3/mole (pH 7, 23.4°C) 1.6×10^{-5} atm-m^3/mole (25°C)	ATSDR 1990a
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	1.5 ppm (water); 25 ppm (air)	ATSDR 1990a
Conversion Factors	1 ppm = 0.708 mg/m^3 1 mg/m^3 = 1.41 ppm	ATSDR 1990a

II. ENVIRONMENTAL FATE

A. Environmental Release

Ammonia is an important component of the nitrogen cycle such that concentrations in nature and natural media are in dynamic equilibrium (ATSDR 1990a). Natural sources of ammonia include volcanic eruptions, forest fires, microbial fixation of nitrogen, microbial decomposition of dead plants and animals, and decay of livestock, pet, and human wastes (ATSDR 1990a). Approximately 80% of the ammonia produced in the U.S. is applied to soils as fertilizer (ATSDR 1990a).

Average concentrations have been measured at <0.18 mg/L in surface waters and approximately 0.5 mg/L in waters near metropolitan areas; concentrations were lower in the summer than in the winter (U.S. EPA 1981a). Average global atmospheric ammonia concentrations are 1-3 ppb (ATSDR 1990a).

In 1993, as reported to the TRI, a total of 353 million pounds of ammonia were released to the environment. Of the total, 138 million pounds were released to the atmosphere, 36 million pounds were released surface waters, 169 million pounds were released to underground injection sites, and 10 million pounds were released to land (TRI93 1995).

B. Transport

As a key component of the nitrogen cycle, ammonia in water and soils undergoes microbial mediated nitrification. The resulting nitrates are assimilated into plants and other microbes. This process is dependent upon dissolved oxygen, temperature, pH, the microbial population, and the nitrogen forms present (U.S. EPA 1981a; ATSDR 1990a). From natural waters, ammonia also volatilizes to the atmosphere or strongly adsorbs to sediment so that leaching is not likely (U.S. EPA 1981a). Once in the atmosphere, the chemical can be removed in rain or snow or dissolve in clouds (ATSDR 1990a).

C. Transformation/Persistence

1. Air — In the atmosphere, ammonia reacts with acid air pollutants such as HNO_3 and H_2SO_4 to form particulate ammonium compounds that can be removed by wet or dry deposition (ATSDR 1990a). In unpolluted air, the half-life for ammonia reaction with hydroxyl radicals is about 16 days (U.S. EPA 1981a).
2. Soil — In soils, ammonia is transformed to nitrate by soil microbes and taken up by plants as a nutrient source. The ammonium cation adsorbs to negatively charged clay colloids in soils and is relatively immobile. Volatilization is another removal mechanism from soil (ATSDR 1990a; U.S. EPA 1981a).
3. Water — In natural waters, ammonia undergoes nitrification with the products being taken up by aquatic plants or other organisms. Ammonia can also adsorb to sediments or volatilize to the atmosphere (ATSDR 1990a; U.S. EPA 1981a).
4. Biota — Ammonia is a natural waste product of fish and is released to the surrounding water through the gills. If water concentrations are abnormally high, the concentration gradient is reversed and the direction of passive transport is into the gills (ATSDR 1990a).

CHEMICAL SUMMARY FOR AMMONIUM CHLORIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of ammonium chloride are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF AMMONIUM CHLORIDE

Characteristic/Property	Data	Reference
CAS No.	12125-02-9	
Common Synonyms	ammonium muriate; sal ammoniac	Sax and Lewis 1989
Molecular Formula	ClH_4N	Budavari et al. 1989
Chemical Structure	H_4N-Cl	
Physical State	white crystalline solid, somewhat hygroscopic	ACGIH 1991
Molecular Weight	53.50	Budavari et al. 1989
Melting Point	sublimes @ 350°C without melting	ACGIH 1991
Boiling Point	520°C	Sax and Lewis 1989
Water Solubility	28.3% (w/w) @ 25°C	Budavari et al. 1989
Density	1.5274 at 25°C	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	1 mm Hg @ 160.4°C	Sax and Lewis 1989
Reactivity	reacts with alkalis & their carbonates; lead & silver salts; strong oxidizers; ammonium nitrate; potassium chlorate; and bromine trifluoride; corrodes most metals	NIOSH 1994
Flammability	not flammable	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Ammonium chloride, a somewhat hygroscopic crystalline solid with a cooling saline taste, is highly soluble in water (Budavari et al. 1989). It is used in dry batteries; soldering; manufacture of various ammonia compounds; as a fertilizer; in electroplating; in medicine; and in the food industry (ACGIH 1991; Verschueren 1983). Large amounts of ammonium chloride are frequently evolved from galvanizing operations, with concentrations generally below 5 mg/m^3, although peak concentrations are higher (ACGIH 1991). Ammonium chloride occurs naturally in crevices in the vicinity of volcanoes (Young 1978).

B. Transport

No information on the transport of ammonium chloride was found in the secondary sources searched. The water solubility suggests that the chemical would leach through soil.

C. Transformation/Persistence

No information on the transformation/persistence of ammonium chloride was found in the secondary sources searched. Low vapor pressure and its water solubility suggest the chemical would remain in the aqueous phase.

CHEMICAL SUMMARY FOR BENZOTRIAZOLE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of benzotriazole are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF BENZOTRIAZOLE

Characteristic/Property	Data	Reference
CAS No.	95-14-7	
Common Synonyms	1,2,3-benzotriazole; 1H-benzotriazole; azimino-benzene; 1,2-aminozophenylene; benzene azimide	RTECS 1995
Molecular Formula	$C_6H_5N_3$	
Chemical Structure		
Physical State	white to light tan crystalline powder	HSDB 1995
Molecular Weight	119.14	RTECS 1995
Melting Point	98.5°C	HSDB 1995
Boiling Point	204°C @ 15 mm Hg	HSDB 1995
Water Solubility	19.8 g/L @ 25°C (measured)	CHEMFATE 1995
Density	not found	
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	1.34 (measured)	CHEMFATE 1995
Vapor Pressure	0.4×10^{-1} Torr @ 20°C (measured)	CHEMFATE 1995
Reactivity	stable toward acids, alkalies, oxidation and reduction; forms stable metallic salts; may explode during vacuum distillation	HSDB 1995
Flammability	1.6 @ 20°C (measured)	CHEMFATE 1995
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	1 ppm = 4.87 mg/m^3 1 mg/m^3 = 0.205 ppm	Calculated using: ppm = mg/m^3 x 24.45/m.w

II. ENVIRONMENTAL FATE

A. Environmental Release

Benzotriazole may be released to the environment during its production and its use in a wide range of commercial products. Uses of the chemical include: as a chemical intermediate; as a pickling inhibitor in boiler scale removal; as a restrainer, developer and antifogging agent in photographic emulsions; as a corrosion inhibitor for copper; as a component of military deicing fluid; and as a plastics stabilizer (HSDB 1995). The NCI (1977) selected the chemical for study in the bioassay program because of its use in dishwashing detergents and the possibility that such use could result in the contamination of water supplies.

B. Transport

The considerable water solubility of benzotriazole (19.8 g/L [CHEMFATE 1995]) suggests that the chemical may exist in solution in the soil and leach into ground water. The low vapor pressure (0.04 Torr at 20°C [CHEMFATE 1995]) indicates that volatilization is not a significant transport mechanism for benzotriazole in soil or water. In one instance, benzotriazole evaporated from water in 438 hours (~18 days) (CHEMFATE 1995). Because of its water solubility, benzotriazole present in the atmosphere may be removed by wet deposition.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of benzotriazole in air. The considerable water solubility of benzotriazole (see section II.B) suggests that the chemical would be removed from the atmosphere by wet deposition.
2. Soil — The sensitivity of benzotriazole to photodegradation is solvent-dependent (CHEMFATE 1995). The chemical was 100% degraded when irradiated for 60 hours at 300 nm in methanol (CHEMFATE 1995). The products of degradation (also solvent-dependent) were aniline (1-1.6%) and *O*-anisidine (2-8.2%).
3. Water — In one study, benzotriazole as the sole source of carbon was not degraded by acclimated sludge in water (CHEMFATE 1995). Other investigators observed that elective cultures and continuous enrichment failed to biodegrade benzotriazole and indicated that the chemical is expected to resist degradation in the environment (Rollinson and Callely 1986). In the aquatic environment, the chemical could undergo some photolysis at the water's surface (see section II.C.2).
4. Biota — The log octanol/water partition coefficient for benzotriazole, 1.34 (CHEMFATE 1995), suggests that the chemical has a low to moderate potential for partitioning to lipids. However, no information was found to indicate whether the chemical will bioaccumulate.

CHEMICAL SUMMARY FOR BORIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of boric acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF BORIC ACID

Characteristic/Property	Data	Reference
CAS No.	10043-35-3	
Common Synonyms	boracic acid	Budavari et al. 1989
	orthoboric acid	HSDB 1995
Molecular Formula	H_3BO_3	
Chemical Structure		
Physical State	colorless, odorless, transparent crystals; or white granules or powder	Budavari et al. 1989
Molecular Weight	61.84	Budavari et al. 1989
Melting Point	171°C	Budavari et al. 1989
Boiling Point	300°C	U.S. EPA 1990a
Water Solubility	1 g/18 ml cold H_2O	Budavari et al. 1989
Density	1.435 @ 15°C	U.S. EPA 1990a
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	low for boron compounds	U.S. EPA 1990
Reactivity	incompatible with alkali carbonates and hydroxides	Budavari et al. 1989
	mixtures with potassium may explode on impact	HSDB 1995
Flammability	not flammable	HSDB 1995
Flash Point	not flammable	HSDB 1995
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Boric acid is a naturally occurring compound formed from the breaks of other boron compounds. It is released into the atmosphere during volcanic eruptions; however, most of this is captured by the oceans. Boric acid also enters the environment as a contaminant from the manufacture and industrial and household use of boron-containing compounds; the mining and processing of borax; coal, oil and geothermal power generation; and sewage and sludge disposal (U.S. EPA 1990a). Boric acid is not listed on the EPA’s TRI, requiring certain types of U.S. industries to report on chemical releases to the environment.

B. Transport

Groundwater movement studies indicate that boron is relatively mobile in sand and gravel aquifers, with retardation only occurring as a result of adsorption to clay or organic materials. An equilibrium exists between adsorbed and dissolved boron in soils (U.S. EPA 1990a).

C. Transformation/Persistence

1. Air — Boron does not appear to persist in the atmosphere as a vapor. As a particulate, boron can be removed by either wet or dry deposition (U.S. EPA 1990a).
2. Soil — Boric acid is adsorbed onto soil at acidic pH levels, and does not appear to be chemically or biologically degraded in soils (U.S. EPA 1990a).
3. Water — In natural waters, boron does not appear to be chemically or biologically degraded, but exists as undissociated boric acid (U.S. EPA 1990a). Because of its low vapor pressure, volatilization is not expected to be a contributing factor for the release of boron at the air-water interface (U.S. EPA 1990a).
4. Biota — No specific information was found in the secondary sources searched regarding the bioaccumulation of boric acid. However, boron accumulation appears to occur in relation to its availability in the surrounding aquatic systems. Tissue concentrations of boron in fish from freshwater aquatic systems of varying water quality containing boron or boron compounds (not necessarily just boric acid) have been reported to range from 1.8 μg/g in lake charr from a Precambrian shield lake to 20 μg/g in carp from a river system receiving agricultural subsurface drainage (U.S. EPA 1990a).

CHEMICAL SUMMARY FOR CARBON BLACK

This chemical was identified by one or more suppliers as a bath ingredient for the carbon and conductive ink processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of carbon black are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF CARBON BLACK

Characteristic/Property	Data	Reference
CAS No.	1333-86-4	
Common Synonyms	lamp black; thermal black; furnace black; acetylene black; channel black; CI pigment black 7; philblack N 550; raven; regal; carbon, amorphous	HSDB 1996
Molecular Formula	C	
Chemical Structure	microscopic hexagonal crystallites oriented randomly	U.S. EPA 1981b
Physical State	extremely fine, smoke-like powder; black	HSDB 1996
Molecular Weight	12; may vary with manufacturing process	NIOSH 1994; U.S. EPA 1981b
Melting Point	sublimates @ 3652-3697°C	HSDB 1996
Boiling Point	4200°C; 4827°C	HSDB 1996; U.S. EPA 1981b
Water Solubility	insoluble	U.S. EPA 1981b
Density	1.8-2.1	U.S. EPA 1981b
Vapor Density (air = 1)	not applicable	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	0 mm Hg (approximately)	NIOSH 1994
Reactivity	reacts with strong oxidizers, such as chlorates, bromates and nitrates; carbon dust may form explosive mixtures in air	NIOSH 1994; HSDB 1996
Flammability	flammable	HSDB 1996
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	odorless	HSDB 1996
Conversion Factors	not applicable	

Analytical properties of commercially produced carbon blacks (all with CAS No. 1333-86-4) are summarized below. Contaminants, including polynuclear aromatic hydrocarbons (PAHs), adsorb to carbon-black particles (IARC 1984). These contaminants (some are known carcinogens) are extractable with organic solvents such as benzene, naphthalene, and toluene (IARC 1984). The efficiency of the extraction depends on the solvent, extraction time, type of carbon black, relationship between sample weight/solvent volume and the amount of extractable material. The bioavailability of these potential carcinogens is an important issue in the assessment of the health effects of carbon black (IARC 1984). Available evidence indicates that when carbon blacks are exposed to biological material, including human albumin, some release of PAHs occurs, depending on the amount of adsorbed material and the available adsorptive surface (IARC 1984).

Analytical Data for Carbon Blacks Produced Commercially in the U.S.

Property	Channel Black[a]	Acetylene	Furnace	Lampblack	Thermal	
					Medium	Fine
Average particle diameter (nm)	29	40	28	65	500	180
Benzene extract (%)		0.1	0.06	0.2	0.3	0.8
pH	acidic	4.8	7.5	3.0	8.5	9.0
Volatile material (%)	5-17%	0.3	1.0	1.5	0.5	0.5
Composition (%)						
Carbon		99.7	97.9	98	99.3	99.2
Hydrogen		0.1	0.4	0.2	0.3	0.5
Sulfur		0.02	0.6	0.8	0.01	0.01
Oxygen		0.2	0.7	0.8	0.1	0.3

a) No longer produced in the U.S. Certain carbon blacks made in Germany by an impingement process reportedly have the same properties as the old channel black (IARC 1984). Only general properties were available for channel black.

Source: IARC (1984)

II. ENVIRONMENTAL FATE

A. Environmental Release

Carbon black may be released to the environment from various production facilities and from rubber tires in which carbon black is used as a reinforcing agent (U.S. EPA 1981b). The objective of the carbon-black industry is to produce large quantities of dense carbon smoke that would, under ordinary circumstances, be considered an undesired by-product (U.S. EPA 1981b). Consequently, for economic reasons, releases from production facilities are limited by highly efficient collection methods. In the thermal and furnace process plants, systems of electrostatic precipitators, cyclones, and bag filters collect over 99% of the black (U.S. EPA 1981b). In the channel production process (no longer used in the U.S.), carbon black was collected by a less effective method, impingement on long-channel irons, and larger quantities of carbon black were released (U.S. EPA 1981b). Releases to the atmosphere may also occur during maintenance procedures, from leaks in plant conveying systems, or during loading and unloading operations (U.S. EPA 1981b). In 1979, average particulate carbon-black emissions during the manufacture of carbon blacks by the oil furnace process ranged from 0.1 kg/thousand kg for fugitive emissions to 3.27 kg/thousand kg from uncontrolled main process vents (IARC 1984). More recent monitoring data were not found in the secondary sources searched.

As a result of tire wear, carbon black is deposited in significant quantities along roadways, apparently settling out within a few feet of the road (U.S. EPA 1981b).

In 1978, the U.S. EPA issued its final regulation on water discharge permits that called for zero discharge of carbon black using the best available technology (U.S. EPA 1981b).

B. Transport

Carbon black entering the atmosphere or lost from tires ultimately enters the soil or is washed into the waterways (U.S. EPA 1981b). No other information was found in the secondary sources searched regarding environmental transport of carbon black.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of carbon black in the atmospheric, aquatic, or terrestrial environment or in biota. It is expected to be inert under normal conditions (U.S. EPA 1981b).

CHEMICAL SUMMARY FOR COPPER AND SELECTED COPPER COMPOUNDS

These chemicals were identified by one or more suppliers as bath ingredients for the electroless copper, carbon, graphite, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of copper, cupric sulfate, cuprous chloride, cupric chloride, and cupric ethylenediaminetetraacetate (Cu-EDTA) are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF COPPER

Characteristic/Property	Data	Reference
CAS No.	7440-50-8	
Common Synonyms	None	
Molecular Formula	Cu	
Chemical Structure	Cu^0	
Physical State	Reddish metal	U.S. EPA 1987a
Molecular Weight	63.55	U.S. EPA 1987a
Melting Point	1083.4°C	U.S. EPA 1987a
Boiling Point	2567°C	U.S. EPA 1987a
Water Solubility	Insoluble (as Cu^o)	U.S. EPA 1987a
Specific Gravity	8.92	U.S. EPA 1987a
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	1 mm Hg @ 1629°C	U.S. EPA 1987a
Reactivity	Reacts with dil. HNO_3, conc. H_2SO_4, and organic acids; slowly with HCl in the presence of oxygen. Forms carbonate salt on the metal surface in moist air. Forms soluble salts on the metal surface in water. Violent reaction with hydrazoic acid, hydrogen sulfide, lead azide, sodium azide, hydrazine mononitrate, ammonium nitrate, bromates, chlorates, iodates, chlorine, fluorine, and peroxides. Can react with acetylene to form explosive acetylides.	Budavari et al. 1989 U.S. Air Force 1990 HSDB 1995
Flammability	No data	
Flash Point	No data	
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	10-100	ATSDR 1990b
Shellfish Bioconcentration Factor	30,000 in oysters	ATSDR 1990b
Taste Threshold (copper in water)	2.6 ppm	ATSDR 1990b
Conversion Factors	Not applicable, associated with particulate matter	

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF CUPRIC SULFATE

Characteristic/Property	Data	Reference
CAS No.	7758-98-7	
Common Synonyms	Copper Sulfate; Blue Vitriol	ATSDR 1990b
Molecular Formula	$CuSO_4$	ATSDR 1990b
Chemical Structure	CuO_4S	ATSDR 1990b
Physical State	Solid, White powder (anhydrous), blue crystals (hydrated)	ATSDR 1990b
Molecular Weight	159.60 (dehydrated)	ATSDR 1990b
	249.68 (pentahydrate)	U.S. EPA 1987a
Melting Point	Decomposes @ 110°C	U.S. EPA 1987a
Boiling Point	Decomposes to CuO @ 650°C	ATSDR 1990b
Water Solubility	143 g/L @ 0°C	ATSDR 1990b
Specific Gravity	3.603 (anhydrous)	ATSDR 1990b
	2.284 (pentahydrate)	U.S. EPA 1987a
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	No data	
Reactivity	Reacts with Mg to produce Cu_2O, $MgSO_4$, and H_2; reacts with NH_4Cl producing $(NH_4)_2SO_4$ and $CuCl_2$; reacts with alkali (R)OH to produce $Cu(OH)_2$ and RSO_4; reacts with excess aq. NH_3 producing $Cu(NH_3)_2^{++} + OH^-$; decomposition products include SO_2.	U.S. Air Force 1990 HSDB 1995
Flammability	Non-flammable	HSDB 1995
Flash Point	Non-flammable	HSDB 1995
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	10-100 for copper	ATSDR 1990b
Shellfish Bioconcentration Factor	30,000 for copper in oysters	ATSDR 1990b
Taste Threshold (copper in water)	2.6 ppm for copper	ATSDR 1990b
Conversion Factors	Not applicable, associated with particulate material	

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF CUPROUS CHLORIDE

Characteristic/Property	Data	Reference
CAS No.	7758-89-6	
Common Synonyms	Copper (I) chloride	U.S. EPA 1987a
Molecular Formula	CuCl	U.S. EPA 1987a
Chemical Structure	CuCl (or Cu_2Cl_2)	U.S. EPA 1987a
Physical State	Solid, White crystal	U.S. EPA 1987a
Molecular Weight	98.99	U.S. EPA 1987a
Melting Point	430°C	U.S. EPA 1987a
Boiling Point	1490°C	U.S. EPA 1987a
Water Solubility	0.062 g/L (cold water)	U.S. EPA 1987a
Specific Gravity	4.14	U.S. EPA 1987a
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	1 mm Hg @ 546°C	U.S. EPA 1987a
Reactivity	Reactive with oxidizing agents, alkali metals; decomposition products include HCL gas.	Aldrich Chemical Co. 1985
Flammability	Not combustible	
Flash Point	Not combustible	
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	10-100 for copper	ATSDR 1990b
Shellfish Bioconcentration Factor	30,000 for copper in oysters	ATSDR 1990b
Taste Threshold (copper in water)	2.6 ppm	ATSDR 1990b
Conversion Factors	Not applicable, associated with particulate material	

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF CUPRIC CHLORIDE

Characteristic/Property	Data	Reference
CAS No.	7447-39-4	
Common Synonyms	Copper (II) chloride	U.S. EPA 1987a
Molecular Formula	$CuCl_2$	U.S. EPA 1987a
Chemical Structure	$CuCl_2$	U.S. EPA 1987a
Physical State	Brown or yellow powder Green to blue crystals when hydrated	U.S. EPA 1987a EM Industries 1987
Molecular Weight	134.44	U.S. EPA 1987a
Melting Point	620°C	U.S. EPA 1987a
Boiling Point	Decomposes @ 993°C	U.S. EPA 1987a
Water Solubility	706 g/L @ 0°C	U.S. EPA 1987a
Specific Gravity	$3.386^{4/25}$	U.S. EPA 1987a
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	No data	
Reactivity	HCl gas can be produced in fires or in contact with acids; corrosive to aluminum. Reacts with alkali metals.	U.S. Air Force 1990 EM Industries 1987
Flammability	Not combustible	U.S. Air Force 1990
Flash Point	Not combustible	U.S. Air Force 1990
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	10-100 for copper	ATSDR 1990b
Shellfish Bioconcentration Factor	30,000 for copper in oysters	ATSDR 1990b
Taste Threshold (copper in water)	2.6 ppm	ATSDR 1990b
Conversion Factors	Not applicable, associated with particulate material	

II. ENVIRONMENTAL FATE

A. Environmental Release

Copper (Cu) commonly exists in three valence states, Cu^0 (metal), Cu^+ (cuprous), and Cu^{++} (cupric). It can also be oxidized to a Cu^{+++} state, but there are no important industrial Cu^{+++} chemicals, and Cu^{+++} ions are rapidly reduced to Cu^{++} in the environment (ATSDR 1990b). Cupric sulfate and cupric chloride are very soluble in water [143 and 706 g/L, respectively (U.S. EPA 1987a; ATSDR 1990b)] and, when dissolved, become sources of Cu^{++} ions; cupro chloride is a source of Cu^+ ions in solution, but it has comparatively low water solubility [0.062 g/L (U.S. EPA 1987a)]. Ethylenediaminetetraacetate (EDTA) has the ability to chelate divalent metal ions such as Cu^{++}. The release of Cu^{++} from the Cu-EDTA complex depends on the concentration of other divalent metal ions in solution. Copper occurs naturally in the environment primarily as Cu^{++} salts, oxides, and complexes; but Cu^+ compounds and metallic copper (Cu^0) also occur naturally (U.S. EPA 1984a). Copper and its compounds are ubiquitous in nature as part of the earth's crust and are found in plants and animals (ATSDR 1990b). The average concentration of copper found in the earth's crust is about 50 ppm (ATSDR 1990b).

Releases to the air from natural sources primarily involve windblown dust; however, volcanoes, decaying vegetation, forest fires, and sea water spray also contribute (ATSDR 1990b). Anthropogenic sources include releases from copper smelting industries, iron and steel industries, coal burning power plants and fabricating operations involving copper (U.S. EPA 1984a). The mean concentration of airborne copper is 5-200 ng/m^3, which is associated with particulate matter (ATSDR 1990b). Copper is also released to water from industrial and sewage treatment discharges and naturally from soil weathering. Most of this copper is adsorbed to particulate matter. Natural sources of copper account for about 68% of copper released to streams and waterways. Domestic wastewater is the largest anthropogenic source of copper released to water. Copper can enter the drinking water from the water distribution system and can exceed 1.3 ppm when the pipes have not been flushed during a period of disuse. The total amount of copper released to water was estimated at 28,848,000,000 tons for 1976; this represents about 2.4% of the total amount copper released to the environment. The majority of copper is released to the land primarily from copper mines and mills and is in the form of insoluble sulfides or silicates. Other sources include sludge from sewage treatment plants, municipal refuse, waste from electroplating, iron and steel producers, and discarded copper-containing products (plumbing and wiring) (ATSDR 1990b).

In 1992, releases of copper to environmental media, as reported to the TRI by certain types of U.S. industries, totaled about 55,294,095 pounds of which 41,093,203 pounds were copper compounds and 14,200,892 pounds were metallic copper. Of these amounts, 6,329,997 pounds of copper compounds and 1,495,369 pounds of metallic copper (14.2%) were released to the atmosphere, 72,423 pounds of copper compounds and 41,474 pounds of metallic copper (0.2%) were released to surface water, 201,431 pounds of copper compounds and 16,736 pounds of metallic copper (0.4%) were released in underground injection sites, and 34,489,362 pounds of copper compounds and 12,647,313 pounds of metallic copper (85.2%) were released to land (TRI92 1994).

B. Transport

C. Transformation/Persistence

1. Air — Most of the copper in the air is in the form of particulate matter (dust) or is adsorbed to particulate matter. Larger particles (>5 µm) are removed by gravitational settling, smaller particles are removed by other forms of dry and wet deposition (ATSDR 1990b). Atmospheric copper resulting from combustion is associated with sub-micron particles that can remain in the troposphere for an estimated 7-30 days and may be carried long distances (ATSDR 1990b). In southern Ontario, Canada, the average copper concentration in rainwater was 1.57 ppb during 1982, and the average annual wet deposition of copper was 1.36 mg/m^2. The average annual wet deposition for both central and northern Ontario was 1.13 mg/m^2 (ATSDR 1990b).
2. Soil — Most of the copper deposited in the soil is strongly adsorbed primarily to organic matter, carbonate minerals, clay minerals, and hydrous iron and manganese oxides. Movement through the soil is dependent on the presence of these substances, the pH, and other physical and chemical parameters. The greatest potential for leaching is seen in sandy soils with low pH (ATSDR 1990b). Laboratory experiments using controlled models and field experiments utilizing core samples have shown that very little copper moves through the soil. Core samples showed that some movement occurred as far as the 22.5-25 cm layer of soil, but little, if any, moved below this zone. The evidence indicates that hazardous amounts of copper should not leach into groundwater from sludge, even from sandy soils (ATSDR 1990b).
3. Water — Copper in solution is present almost exclusively as the Cu^{++} valence state (U.S. EPA 1987a). The Cu^+ ion is unstable in solution and disproportionates to Cu^{++} and copper metal unless a stabilizing ligand is present (ATSDR 1990b). In sea water, Cu^+ was found to be more stable than in fresh water existing as $CuClOH^-$ ions. A photochemical reduction mechanism involving H_2O_2 is thought to be partly responsible. The presence of Cu^+ is highest in the surface layer of seawater and can account for as much as 15% of the copper in seawater (ATSDR 1990b). Copper in the Cu^{++} valence state forms compounds and complexes with a variety of organic and inorganic ligands binding to $-NH_2$, -SH, and, to a lesser extent, -OH groups (ATSDR 1990b). The predominant form of copper in aqueous solution is dependent on the pH of the solution. Below pH 6, the cupric ion (Cu^{++})

predominates; copper complexes with carbonate usually predominate above pH 6 (U.S. EPA 1987a; ATSDR 1990b). The association of copper with organic or inorganic ligands also depends on the pH and on the $CaCO_3$ alkalinity. Rivers in the northwestern U.S. with a relatively high pH (7.0-8.5) and 24-219 ppm $CaCO_3$ were found to contain copper associated primarily with CO_3^{--} and OH^- ions. Under these conditions, copper can precipitate as malachite ($Cu_2(OH)_2CO_3$). Copper was found to be largely associated with organic matter in lakes and rivers with a lower pH (4.6-6.3) and $CaCO_3$ concentration (1-30 ppm) such as found in southern Maine (ATSDR 1990b).

Most of the copper entering surface water is in the form of particulate matter, which settles out, precipitates, or adsorbs to organic matter, hydrous iron and manganese oxides, and clay; however, the predominating form can change with the amount of rain, pH, content of runoff, and the availability of ligands (ATSDR 1990b). The processes of complexation, adsorption and precipitation limit the concentration of copper (Cu^{++}) to very low values in most natural waters (ATSDR 1990b). Copper discharged into a river upstream from the Chesapeake Bay was measured at 53 ppb. Copper associated with particulate material that were settleable solids accounted for 36 ppb. The copper concentration decreased rapidly downstream to 7 ppb 2-3 km from the pollution source. The copper concentration in the settlement, however, was 10 times the concentration in uncontaminated areas (ATSDR 1990b).

4. Biota — Calculations of the bioconcentration factor in fish for copper have ranged from 10 to 100; however, the majority of copper measurements in fish tissues under environmental conditions have indicated little, if any, bioconcentration. The copper content of fish muscle tissue taken from copper-contaminated lakes near Sudbury, Ontario were found to contain about the same level of copper as fish from uncontaminated areas (ATSDR 1990b). Filter feeding shellfish, especially oysters, however, were found to significantly concentrate copper with bioconcentration factors as high as 30,000 (ATSDR 1990b).

CHEMICAL SUMMARY FOR DIETHYLENE GLYCOL MONOETHYL ETHER ACETATE

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of diethylene glycol monoethyl ether acetate (DGEEA) are summarized below. In the body, glycol ether esters are apparently saponified (hydrolyzed) to the parent glycol ether and an organic acid. Systemic effects of the esters are typical of those of the corresponding parent glycol ethers (HSDB 1996), which for DGEEA, is diethylene glycol monoethyl ether (DGEE). Therefore, this report will also provide information on DGEE.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF DGEEA

Characteristic/Property	Data	Reference
CAS No.	112-15-2	
Common Synonyms	DGEEA; 2-(2-ethoxyethoxy)ethanol acetate; Carbitol® acetate	Gingell et al. 1994
Molecular Formula	$C_8H_{16}O_4$	Gingell et al. 1994
Chemical Structure	$C_2H_5OCH_2CH_2OCH_2CH_2OOCCH_3$	Gingell et al. 1994
Physical State	colorless liquid; hygroscopic	HSDB 1996
Molecular Weight	176.2	
Melting Point	-11°C, -25°C	Verschueren 1996
Boiling Point	217.4°C @ 760 mm Hg	Gingell et al. 1994
Water Solubility	miscible	HSDB 1996
Density	specific gravity (25/4°C), 1.01	Gingell et al. 1994
Vapor Density (air = 1)	6.07	Gingell et al. 1994
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	0.05 mm Hg @ 25°C	Gingell et al. 1994
Reactivity	not found	
Flammability	must be preheated before ignition	HSDB 1996
Flash Point	open cup, 225°F (107°C)	HSDB 1996
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	50% recognition, 0.157 ppm 100% recognition, 0.263 ppm	Verschueren 1996
Conversion Factors	1 ppm ≈ 7.20 mg/m^3 @ 25°C, 760 mm Hg 1 mg/m^3 ≈ 0.1389 ppm	Gingell et al. 1994

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of DGEEA. The ester probably enters the environment as does its parent ether, DGEE, i.e., via effluents from sites where it is produced or used as a solvent and from other industries (Howard 1993). In a national survey of wastewater effluents, DGEE occurred in 5 of 21 industrial categories (Howard 1993) . Average concentrations of DGEE in wastewater from various industries were as follows: 497 mg/L (iron and steel); 52,189 mg/L (printing and publishing); 175 mg/L (amusement and athletic goods); and 40 mg/L (pulp and paper) (Howard 1993). DGEE has also been found in effluents from publicly-owned treatment works (Howard 1993). A drinking-water survey identified DGEE as a contaminant in 11 U.S. cities and 1 county (Howard 1993).

B. Transport

The low vapor pressure of DGEEA (0.05 mm Hg [Gingell et al. 1994]) suggests that volatilization from soil or water will not be a significant transport mechanism for the chemical. DGEEA is miscible with water and may move through the soil, possibly to groundwater.

The parent ether, DGEE, is also miscible with water and has an estimated Henry's Law Constant of 8.63×10^{-10} atm-m^3/mole at 25°C (Howard 1993). This indicates that volatilization from natural bodies of water and moist soils should not be a significant fate process for the ether. The calculated K_{OC} value (20) for DGEE indicates that the chemical will be highly mobile in soil and should not partition from the water column to organic matter in sediments and suspended solids (Howard 1993).

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of DGEEA in the environment. However, inferences can be drawn regarding the fate of DGEEA, based on the following data for its parent ether, DGEE.

1. Air — DGEE in ambient air exists mostly in the vapor phase (Howard 1993). The putative removal mechanisms for atmospheric DGEE are vapor phase reactions with photochemically produced hydroxyl radicals (Howard 1993). The estimated rate constant of 2.93×10^{-11} cm^3/molecule-sec @ 25°C for DGEE corresponds to a half-life of about 13 hours, assuming the atmospheric concentration of hydroxyl radicals is 5×10^5 per cm^3 (Howard 1993). Wet deposition of DGEE is limited by its short residence time (Howard 1993).
2. Soil — The results of aqueous screening tests indicate that biodegradation is the most significant mechanism for the removal of DGEE from aerobic soil (see the results of screening tests in section II.C.3) (Howard 1993). Hydrolysis and direct photolysis are not important mechanisms for the removal of DGEE from soil (Howard 1993).
3. Water — The results of aqueous screening tests indicate that biodegradation is the primary mechanism for the removal of DGEE from water (Howard 1993). After 16 days of acclimation, losses of 39.8% and 34.3% were recorded using an 8-hour Warburg test and a 5-day BOD (biochemical oxygen demand) test, respectively (Howard 1993). In two assays conducted without acclimation, the BODT values after 20-day incubation periods were 48 and 87% (Howard 1993). Using the Zahn-Wellens screening method, a >90% loss of the original concentration of DGEE (400 ppm) occurred in 28 days (Howard 1993). DGEE should not undergo hydrolysis or direct photolysis in the aquatic environment (Howard 1993).
4. Biota — The calculated log BCF (bioconcentration factor) of -0.34 for DGEE and its miscibility with water indicate that the chemical will not bioconcentrate in aquatic organisms (Howard 1993).

CHEMICAL SUMMARY FOR DIETHYLENE GLYCOL METHYL ETHER

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of diethylene glycol methyl ether are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF DIETHYLENE GLYCOL METHYL ETHER

Characteristic/Property	Data	Reference
CAS No.	111-77-3	
Common Synonyms	2-(2-methoxyethoxy) ethanol, methyl carbitol, MECB, Dowanol DM, DGME	HSDB 1995 CHEMFATE 1995
Molecular Formula	$C_5H_{12}O_3$	
Chemical Structure	$CH_3OCH_2OCH_2CH_2OH$	
Physical State	colorless liquid	HSDB 1995
Molecular Weight	120.15	CHEMFATE 1995
Melting Point	< -84°C	HSDB 1995
Boiling Point	193°C	HSDB 1995
Water Solubility	completely miscible	U.S. EPA 1984b
	1 x 10^6 mg/L at 25°C	CHEMFATE 1995
Density	$d^{20/4}$, 1.035	HSDB 1995
Vapor Density (air = 1)	4.14	HSDB 1995
K_{OC}	10	HSDB 1995
Log K_{OW}	-0.68 (calculated)	CHEMFATE 1995
	-0.79 - -0.93	U.S. EPA 1984b
Vapor Pressure	0.18 mm Hg at 25°C	CHEMFATE 1995
Reactivity	can react with oxidizing materials	HSDB 1995
Flammability	moderate when exposed to heat or flame	HSDB 1995
Flash Point	200°F (93°C)	HSDB 1995
Dissociation Constant	no data	
Henry's Law Constant	6.5 x 10^{-10} atm-cm^3/mole at 25°C	HSDB 1995
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Log Bioconcentration Factor	-0.75 (estimated)	HSDB 1995
Odor Threshold	no data; mild, pleasant	HSDB 1995
Conversion Factors	1 ppm = 4.91 mg/m^3	
	1 mg/m^3 = 0.204 ppm	HSDB 1995

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found regarding the quantity of diethylene glycol methyl ether (DGME) released to the environment. The chemical has been identified as a contaminate in drinking water samples (concentrations not listed) from cities across the continental U.S. (HSDB 1995. An average concentration of 3571 mg/L was found in the wastewater from paint and ink industries (HSDB 1995).

B. Transport

Because of the high water solubility and low Henry’s Law Constant, most of the DGME released to the environment should end up in aquatic environments. The low K_{OC} indicates that the chemical can leach into ground water from soils; volatilization from water and soils is not an important transport process (HSDB 1995). Removal from the atmosphere in precipitation is possible (HSDB 1995).

C. Transformation/Persistence

1. Air — DGME should not undergo direct photolysis. The reaction rate constant with hydroxyl radicals has been estimated to be 2.44 x 10^{-11} cm^3/molecule-sec and corresponds to an atmospheric half-life of about 16 hours (HSDB 1995).
2. Soil — In general, biodegradation and leaching would be the most important removal processes for glycol ethers in soils (U.S. EPA 1984b).
3. Water — DGME was degraded by 0, 21, and 66% after 5, 10, and 20 days respectively when settled waste water or sewage sludge was used as inoculum (HSDB 1995).
4. Biota — Based on the high water solubility and low estimated bioconcentration factor of DGME, the chemical would not be expected to bioconcentrate in aquatic animals (HSDB 1995).

CHEMICAL SUMMARY FOR DIETHYLENE GLYCOL N-BUTYL ETHER

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of diethylene glycol n-butyl ether are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF DIETHYLENE GLYCOL N-BUTYL ETHER

Characteristic/Property	Data	Reference
CAS No.	112-34-5	
Common Synonyms	diethylene glycol monobutyl ether; butyl carbitol	Budavari et al. 1989
Molecular Formula	$C_8H_{18}O_3$	Budavari et al. 1989
Chemical Structure	$HOCH_2CH_2OCH_2CH_2OC_4H_9$	Budavari et al. 1989
Physical State	liquid	Budavari et al. 1989
Molecular Weight	162.22	Budavari et al. 1989
Melting Point	-68°C	Budavari et al. 1989
Boiling Point	230.4°C	Budavari et al. 1989
Water Solubility	1×10^6 mg/L at 25°C	CHEMFATE 1995
Density	0.9536	Budavari et al. 1989
Vapor Density (air = 1)	5.58	Gingell et al. 1994
K_{OC}	75 (calculated)	HSDB 1995
Log K_{OW}	0.91 (calculated)	CHEMFATE 1995
Vapor Pressure	0.0219 mm Hg at 25°C	CHEMFATE 1995
Reactivity	non reactive; NFPA rating: 0.0	HSDB 1995
Flammability	must be heated	HSDB 1995
Flash Point	500°F	Gingell et al. 1994
Dissociation Constant	no data	
Henry's Law Constant	1.52×10^{-9} atm-m^3/ mole at 25°C	HSDB 1995
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	2.88 (estimated)	HSDB 1995
Odor Threshold	practically odorless	Budavari et al. 1989
Conversion Factors	1 ppm = 6.63 mg/m^3 1 mg/m^3 = 0.15 ppm	Gingell et al. 1994

II. ENVIRONMENTAL FATE

A. Environmental Release

In 1993 as reported to the TRI by certain types of U.S. industries, environmental releases of all glycol ethers totaled 45.9 million pounds; diethylene glycol n-butyl ether is not reported separately (TRI93 1995). The chemical has been detected in the waste water effluents from industries at average concentrations ranging from 7 to 244 mg/L (HSDB 1995).

B. Transport

Because of its miscibility with water, diethylene glycol n-butyl ether will partition to the water column and be highly mobile in soils. In the atmosphere, the chemical may be removed by precipitation and dissolution in clouds (HSDB 1995).

C. Transformation/Persistence

1. Air — In the atmosphere, diethylene glycol n-butyl ether should exist almost entirely in the vapor phase. The estimated half-life for reaction with hydroxyl radical is 11 hours (HSDB 1995).
2. Soil — Diethylene glycol n-butyl ether should partition to the water column of moist soils and volatilization will not be significant (HSDB 1995).
3. Water — Diethylene glycol n-butyl ether is not expected to undergo hydrolysis and the Henry's Law Constant indicates that volatilization would be slow. However, aerobic biodegradation may be an important removal mechanism from aquatic systems (HSDB 1995). No other information was found.
4. Biota — Based on the estimated bioconcentration factor of 2.88 (HSDB 1995), diethylene glycol n-butyl ether should not bioaccumulate in aquatic organisms.

CHEMICAL SUMMARY FOR *N,N*-DIMETHYLFORMAMIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online data bases, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of *N,N*-dimethylformamide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF *N,N*-DIMETHYLFORMAMIDE

Characteristic/Property	Data	Reference
CAS No.	68-12-1	
Common Synonyms	DMF; DMFA; dimethylformamide; *N,N*-dimethylmethanamide; *N*-formyldimethylamine	IARC 1989
Molecular Formula	C_3H_7NO	Budavari et al. 1989
Chemical Structure	$HCON(CH_3)_2$	Budavari et al. 1989
Physical State	colorless to slightly yellow liquid	Budavari et al. 1989
Molecular Weight	73.09	Budavari et al. 1989
Melting Point	-61°C	Budavari et al. 1989
Boiling Point	153°C @ 760 mm Hg	Budavari et al. 1989
Water Solubility	miscible with water	Budavari et al. 1989
Density	0.9445 @ 25/4°C	Budavari et al. 1989
Vapor Density (air = 1)	2.51	Verschueren 1983
K_{OC}	7 (calculated)	HSDB 1996
Log K_{OW}	-1.01	CHEMFATE 1996
Vapor Pressure	3.87 mm Hg @ 25°C	CHEMFATE 1996
Reactivity	can react vigorously with oxidizing agents, halogenated hydrocarbons, and inorganic nitrates; pH of 0.5 molar soln. = 6.7	HSDB 1996; Budavari et al. 1989
Flammability	combustible	HSDB 1996
Flash Point	67°C (153°F) (open cup)	Budavari et al. 1989
Dissociation Constant 0.3		CHEMFATE 1996
Air Diffusivity Constant	no data	
Molecular Diffusivity Constant	no data	
Henry's Law Constant	7.39 X $10E^{-8}$ atm-m^3/mole @ 25°C	HSDB 1996
Fish Bioconcentration Factor	-1.01 (log; calculated)	HSDB 1996
Odor Threshold	0.14 mg/m^3 (nonperception); 0.88 mg/m^3 (perception); fishy odor	Verschueren 1983
Conversion Factors	1 ppm = 3.04 mg/m^3 1 mg/m^3 = 0.33 ppm	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

N,N-Dimethylformamide is a widely used solvent for organic compounds where a low rate of evaporation is required. The chemical may be emitted to the environment by effluents from a variety of petrochemical industries (Howard 1993).

N,N-Dimethylformamide has been identified in the air over a hazardous waste site in Lowell, MA and a neighboring industry at concentrations of 2.18 and >50 ppb, respectively; in 1 of 63 industrial wastewater effluents (<10 μg/L); and in waste effluent of a plastics manufacturer (28,378 ng/μL extract). The chemical was listed as a contaminant found in drinking water samples in several U.S. cities, and in 1 of 204 samples in a national survey of surface waters (Howard 1993).

B. Transport

Volatilization of *N*,*N*-dimethylformamide from land or water is not expected to be significant (Howard 1993). The complete water solubility suggests that the chemical can be removed from the atmosphere by rainfall. *N*,*N*-dimethyl-formamide is expected to be highly mobile in soils and will probably leach into groundwater (U.S. EPA 1986).

C. Transformation/Persistence

1. Air — Based upon the vapor pressure (3.87 mm Hg @ 25°C), *N*,*N*-dimethyl-formamide is expected to exist almost entirely in the gaseous phase in the atmosphere. The vapor phase reaction of *N*,*N*-dimethylformamide with photochemically produced hydroxyl radicals is likely to be an important fate process. The rate constant for the vapor phase reaction with photochemically produced hydroxyl radicals is estimated to be 2.24 x 10^{-10} cm^3/molecule-sec at 25°C, which corresponds to an atmospheric half-life of about 2 hours (Howard 1993). In smog chamber studies, *N*,*N*-dimethylformamide was relatively nonreactive with regard to photochemical oxidant formation (U.S. EPA 1986).
2. Soil — The calculated K_{OC} of 7 indicates that *N*,*N*-dimethylformamide will be highly mobile in soils and the Henry's Law Constant (7.39 x $10E^{-8}$ atm-m^3/mole) suggests that volatilization from soils will not be important (Howard 1993). Aqueous screening and a river die-away test suggests that biodegradation of *N*,*N*-dimethylformamide in soil will be rapid (HSDB 1996). When wastewater containing 250 mg/L *N*,*N*-dimethylformamide was aerobically treated with activated sludge, 95% of the chemical was degraded in 18 hours (U.S. EPA 1986).
3. Water — The estimated K_{OC} (ranging in the high mobility class for soil) indicates that *N*,*N*-dimethylformamide will not partition from the water column to organic matter contained in the sediments and suspended solids. The Henry's Law Constant suggests that volatilization from environmental waters will not be important (Howard 1993). *N*,*N*-Dimethylformamide hydrolyzes slowly in neutral pH water, but hydrolysis is accelerated by acids and bases (U.S. EPA 1986). *N*,*N*-Dimethylformamide can be biodegraded by activated sludge, although an acclimation period is usually required. River die-away data suggest that the biodegradation of the chemical should be rapid (Howard 1993).
4. Biota — The bioconcentration factor of -1.01 (log) indicates that *N*,*N*-dimethyl-formamide will not bioconcentrate in aquatic organisms (Howard 1993).

CHEMICAL SUMMARY FOR ETHANOLAMINE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, carbon, graphite, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of ethanolamine are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF ETHANOLAMINE

Characteristic/Property	Data	Reference
CAS No.	141-43-5	
Common Synonyms	2-amino-1-ethanol; monoethanolamine; 2-hydroxyethylamine; beta-aminoethanol; glycinol; MEA	HSDB 1995
Molecular Formula	C_2H_7NO	Budavari et al. 1989
Chemical Structure	$HOCH_2CH_2NH_2$	Benya and Harbison 1994
Physical State	viscous hygroscopic liquid	Budavari et al. 1989
Molecular Weight	61.08	Budavari et al. 1989
Melting Point	10.3°C	Budavari et al. 1989
Boiling Point	170.8°C @ 760 mm Hg	Budavari et al. 1989
Water Solubility	completely soluble	Benya and Harbison 1994 Density
	1.0117 @ 25/4°C	Budavari et al. 1989
Vapor Density (air = 1)	2.1	HSDB 1995
K_{OC}	5	HSDB 1995
Log K_{OW}	-1.31	CHEMFATE 1995
Vapor Pressure	0.26 mm Hg at 25°C	HSDB 1995
Reactivity	reacts with strong oxidizers, strong acids, iron; may attack copper, brass, rubber;	NIOSH 1994
	pH = 12.1 (0.1 N aqueous solution);	Budavari et al. 1989
	single or double substitution of the amine group leads to formation of a variety of compounds	Benya and Harbison 1994
Flammability	2 (liquid which must be moderately heated before ignition will occur)	HSDB 1995
Flash Point	85°C, closed cup; 93.33°C open cup	ACGIH 1991
Air Diffusion Coefficient	no data	
Dissociation Constant	9.4994	CHEMFATE 1995
Molecular Diffusivity Coefficient	no data	
Henry's Law Constant	4xE-8 atm-m^3/mole @ 25°C	CHEMFATE 1995
Fish Bioconcentration Factor	<1 (calculated)	HSDB 1995
Odor Threshold	3-4 ppm	ACGIH 1991
Conversion Factors	1 ppm = 2.54 mg/m^3; 1 mg/m^3 = 0.39 ppm	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

Ethanolamine is a colorless viscous liquid with an unpleasant, fishy, ammoniacal odor (Budavari et al. 1989; Grant 1986). It is released to the environment primarily from emissions and effluents from sites of industrial production or use, from disposal of consumer products containing ethanolamine such as cleaning products, and use of agricultural products in which it is used as a dispersing agent. Ethanolamine can also be released to the environment in urine. Ethanolamine was one of the primary amines identified in aerosol samples collected over the North Atlantic Ocean. Highest concentrations were found in samples taken near North America, Bermuda, the Azores, and in the Arctic Circle, and low concentrations in the Gulf stream and in the equatorial North Atlantic (Gorzelska and Galloway 1990, as reported in TOXLINE).

B. Transport

Ethanolamine is completely soluble in water (Benya and Harbison 1994), and if released to the soil, would not be expected to adsorb appreciably to organic material [calculated K_{OC} = 5 (HSDB 1995)]. Ethanolamine has the potential to leach into groundwater. The volatilization of ethanolamine from water is believed to be negligible [Henry's Law constant = 4E-8 atm-m^3/mole @ 25°C (CHEMFATE 1995)].

C. Transformation/Persistence

1. Air — The dominant removal mechanism is expected to be reaction with photochemically generated hydroxyl radicals. The calculated half-life for ethanolamine vapor reacting with hydroxyl radicals is 11 hours. The complete water solubility of ethanolamine suggests that this compound may also be removed from the atmosphere in precipitation (HSDB 1995).
2. Soil — If released to soil, ethanolamine is expected to biodegrade fairly rapidly following acclimation and to leach in soil. The half-life is on the order of days to weeks. Volatilization from soil surfaces is not expected to be an important removal process (HSDB 1995).
3. Water — If released to water, ethanolamine is expected to undergo biodegradation. The half-life of this compound may range from a few days to a few weeks depending, in large part, on the degree of acclimation of the system. Bioconcentration in aquatic organisms, adsorption to suspended solids and sediments, and volatilization are not important removal processes (HSDB 1995). Tests utilizing settled sewage seed showed that 0%, 58.4%, or 75% of added compound was biodegraded after 5, 10, or 50 days, respectively. In a closed activated sludge system, 93.6% of the added chemical was biodegraded (CHEMFATE 1995).
4. Biota — The bioconcentration factor of <1 (based on a log K_{OW} of -1.31) and the complete water solubility of ethanolamine suggest that the compound does not bioconcentrate in aquatic organisms (HSDB 1995).

CHEMICAL SUMMARY FOR ETHYLENE GLYCOL

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and carbon processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of ethylene glycol are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF ETHYLENE GLYCOL

Characteristic/Property	Data	Reference
CAS No.	107-21-1	
Common Synonyms	1,2-ethanediol, 1,2-dihydroxyethane	CHEMFATE 1995
Molecular Formula	$C_2H_6O_2$	CHEMFATE 1995
Chemical Structure	$HOCH_2CH_2OH$	Budavari et al. 1989
Physical State	slightly viscous liquid	Budavari et al. 1989
Molecular Weight	62.07	Budavari et al. 1989
Melting Point	-13°C	Budavari et al. 1989
Boiling Point	197.6°C at 760 mm Hg	Budavari et al. 1989
Water Solubility	miscible	CHEMFATE 1995
	absorbs twice its weight of water at 100% relative humidity	Budavari et al. 1989
Density	$d^{20/4}$, 1.114	Budavari et al. 1989
Vapor Density (air = 1)	2.14	Verschueren 1983
K_{OC}	4 (calculated)	CHEMFATE 1995
Log K_{OW}	-1.36	CHEMFATE 1995
Vapor Pressure	0.092 mm Hg at 25°C	CHEMFATE 1995
Reactivity	reacts violently with chlorosulfonic acid, sulfuric acid, and oleum	Keith and Walters 1985
Flammability	combustible	Keith and Walters 1985
Flash Point	115°C (open cup)	Budavari et al. 1989
Dissociation Constant	15.1	CHEMFATE 1995
Molecular Diffusivity Constant	no data	
Air Diffusivity Constant	no data	
Henry's Law Constant	6.0×10^{-8} atm-m^3/mole	CHEMFATE 1995
Fish Bioconcentration Factor	10 (*Leucisius idus melanotus*, golden ide)	CHEMFATE 1995
Odor Threshold	odorless	ATSDR 1993a
Conversion Factors	1 ppm = 2.58 mg/m^3 1 mg/m^3 = 0.39 ppm	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

In 1992 as reported to the TRI by certain types of U.S. industries, a total of 17.2 million pounds of ethylene glycol was released to the environment. The total consisted of 10.25 million pounds released to the atmosphere, 6.25 million pounds to ground and surface waters, and 0.7 million pounds to land (TRI92 1994). The major source of ethylene glycol in the environment is the disposal of used antifreeze. The chemical was found in concentrations of <0.05-0.33 mg/m^3 as aerosol and <0.05-10.4 mg/m^3 as vapor in ambient air samples collected above bridges following spray application of a deicing fluid containing 50% ethylene glycol (ATSDR 1993a).

B. Transport

The low Henry’s Law Constant and high water solubility indicate that ethylene glycol will not volatilize from surface waters. Based on the calculated K_{OC} the chemical is expected to be highly mobile in soils and can leach into ground waters; however, ethylene glycol is readily biodegraded (ATSDR 1993a; U.S. Air Force 1989a). Removal from the atmosphere in rainfall is possible (ATSDR 1993a).

C. Transformation/Persistence

1. Air — The half-life for reaction of ethylene glycol with hydroxy radicals in the atmosphere is 2.1 days (CHEMFATE 1995). Estimated half-lives for photochemical oxidation range from 24 to 50 hours (ATSDR 1993a).
2. Soil — Several genera of soil microbes have been shown to completely degrade concentrations of 1-3% ethylene glycol within 3 days (ATSDR 1993a). *Clostridium glycolicum*, isolated from mud, degraded the chemical under anaerobic conditions (concentration and time not given) (CHEMFATE 1995).
3. Water — Biodegradation of ethylene glycol has been demonstrated by acclimated and unacclimated microorganisms from a variety of aqueous media (ATSDR 1993; U.S. Air Force 1989a). Complete degradation occurred with activated sewage sludge in approximately 80 hours (CHEMFATE 1995). Several *Mycobacterium* sp. and *Alcaligenes* sp. are capable of utilizing ethylene glycol as a sole carbon source (CHEMFATE 1995). In contrast, the half-life for reaction with hydroxy radicals in aqueous solution has been calculated as 2.84 years (CHEMFATE 1995).
4. Biota — The high water solubility, rapid microbial degradation, and low to moderate bioconcentration factor indicate that ethylene glycol would not be expected to bioaccumulate in aquatic organisms.

CHEMICAL SUMMARY FOR ETHYLENEDIAMINE TETRAACETIC ACID (EDTA)

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of EDTA are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF EDTA

Characteristic/Property	Data	Reference
CAS No.	60-00-4	
Common Synonyms	acetic acid, (ethylenedinitrilo)-tetra-; edetic acid; EDTA; EDTA acid; Trilon BW; Versene	HSDB 1995
Molecular Formula	$C_{10}H_{16}N_{2}0_{8}$	
Chemical Structure		
Physical State	colorless crystals	HSDB 1995
Molecular Weight	292.28	HSDB 1995
Melting Point	decomposes @ 240°C	HSDB 1995
Boiling Point	not found	
Water Solubility	0.5 g/L @ 25°C	Budavari et al. 1989
Density	not found	
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	not found	
Reactivity	chelates di- and tri-valent metals	HSDB 1995
Flammability	may burn, but does not ignite readily	HSDB 1995
Flash Point	not found	
Dissociation Constant	0.26 (measured)	CHEMFATE 1995
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	<2 (bluegill, measured) 19 (@25°C, calculated)	HSDB 1995
Odor Threshold	not found	
Conversion Factors	1 ppm = 11.9 mg/m^3 1 mg/m^3 = 0.084 ppm	Calculated using: mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

EDTA does not occur naturally in the environment (HSDB 1995). The main sources of EDTA released to the environment are probably domestic sewage and industrial effluents, resulting from the chelating applications of the chemical (HSDB 1995). Other sources of release of the chemical include the use of herbicides and the land disposal of products that contain EDTA (HSDB 1995).

In 1974 in England, concentrations of EDTA ranging from 0 to 1120 ppb were detected in the Lea River and concentrations ranging from 200 to 1200 ppb were detected in the effluent from the Rye Meads sewage treatment plant (HSDB 1995). In other studies, EDTA concentrations of 100 to 550 ppb were detected in sewage effluents (no other details were available) (Verschueren 1983). Other monitoring data were not found in the secondary sources searched.

B. Transport

Under environmental conditions (pH 5-10), EDTA completely dissociates, as is indicated by pKa_1 = 0.26, pKa_2 = 0.96, pKa_3 = 2.60 and pKa_4 = 2.76 (HSDB 1995). This suggests that volatilization from water or soil would not be significant for EDTA. A study of EDTA degradation in soils detected no volatilization (HSDB 1995).

EDTA and complexes of EDTA with alkaline earth metals and trace metals demonstrate negligible adsorption to silica, humic acid, kaolin, kaolinite (EDTA only), river sediments, and humus solids (HSDB 1995). According to at least one report, EDTA leaches readily in soil (HSDB 1995).

C. Transformation/Persistence

1. Air — EDTA released to the atmosphere may undergo direct photolysis or may react with photochemically-generated hydroxyl radicals (HSDB 1995). The estimated half-life for the reaction of EDTA vapor with photochemically generated hydroxyl radicals in the atmosphere is 3.01 days (HSDB 1995).
2. Soil — EDTA released to the soil is expected to complex with trace metals and alkaline earth metals that occur in the soil, increasing their total solubility (HSDB 1995). Eventually, EDTA may exist predominantly as the Fe(III) chelate in acidic soils and as the Ca chelate in alkaline soils (HSDB 1995).

   Biodegradation is the predominant removal mechanism for EDTA in aerobic soils, whereas biodegradation of the chemical is negligible in anaerobic soils (HSDB 1995). Mineralization values for 2-4 ppm EDTA in various soils range from 13 to 45% after 15 weeks and from 65 to 70% after 45 weeks (HSDB 1995).
3. Water — EDTA released to water is expected to complex with trace metals and alkaline earth metals (HSDB 1995). In water under aerobic conditions, EDTA undergoes biodegradation relatively slowly. As in soil, the anaerobic biodegration of EDTA in water is negligible (HSDB 1995). Possible biodegradation products of the ammonium ferric chelate of EDTA include the following: ethylenediamine triacetic acid (ED3A), iminodiacetic acid (IDA), N,N-ethylenediamine diacetic acid (N,N-EDDA), N,N'-EDDA, ethylenediamine monoacetic acid (EDMA), nitrilotriacetic acid (NTA) and glycine (HSDB 1995).

   In water, EDTA may react with photochemically-generated hydroxyl radicals (half-life, 229 days) or undergo photodegradation. In an aqueous solution, the Fe(III) complex of EDTA degraded with a half-life of 11.3 minutes when exposed to artificial sunlight (HSDB 1995). The following were photodegradation products of Fe(III)-EDTA: carbon monoxide, formaldehyde, ED3A, N,N-EDDA, N,N'-EDDA, IDA, EDMA and glycine (HSDB 1995).
4. Biota — The fish bioconcentration factors for EDTA (<2 and 19) suggest that the chemical will not bioaccumulate in aquatic organisms (HSDB 1995). It is not expected to adsorb to suspended solids or sediments (HSDB 1995).

CHEMICAL SUMMARY FOR FLUOROBORIC ACID (FLUORIDE)

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources. Very little information on the environmental fate and toxicity of fluoroboric acid or fluoroborates was found in the available secondary sources. Supplemental information is provided for fluoride which may be a degradation product and for sodium bifluoride.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of fluoroboric acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF FLUOROBORIC ACID

Characteristic/Property	Data	Reference
CAS No.	16872-11-0	HSDB 1995
Common Synonyms	hydrogen tetrafluoroborate fluoboric acid hydrofluoroboric acid	HSDB 1995
Molecular Formula	HBF_4	HSDB 1995
Chemical Structure	$B\text{-}F_4\text{-}H$	Fisher Scientific 1993
Physical State	colorless liquid	HSDB 1995
Molecular Weight	87.82	HSDB 1995
Melting Point	-90°C	Fisher Scientific 1993
Boiling Point	130°C (decomposes)	HSDB 1995
Water Solubility	miscible; sol. in hot water	HSDB 1995
Density	~1.84 g/mL	HSDB 1995
K_{OC}	NA	
Log K_{OW}	NA	
Vapor Pressure	5.1 mm Hg at 20°C	Fisher Scientific 1993
Vapor Density	3.0	Fisher Scientific 1993
Reactivity	strong acid; corrosive	HSDB 1995
Flammability	NA	
Flash Point	NA	
Dissociation Constant (-pK)	-4.9	HSDB 1995
Henry's Law Constant	NA	
Molecular Diffusivity Coefficient	NA	
Air Diffusivity Coefficient	NA	
Fish Bioconcentration Factor	NA	
Odor Threshold	NA	
Conversion Factors	NA	

The chemical identity and physical/chemical properties of sodium tetrafluoroborate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM TETRAFLUOROBORATE

Characteristic/Property	Data	Reference
CAS No.	013755-29-8	Lockheed Martin 1994a
Common Synonyms	sodium fluoroborate STB sodium borfluoride sodium boron tetrafluoride	Lockheed Martin 1994a
Molecular Formula	$NaNF_4$	
Chemical Structure	Na-F_4-B	
Physical State	white crystalline powder	Sigma-Aldrich 1992
Molecular Weight	109.82	Budavari et al. 1989
Melting Point	384°C	Budavari et al. 1989
Boiling Point		
Water Solubility	108 g/100 mL at 26°C 210 g/100 mL at 100°C	Budavari et al. 1989
Density	2.470	Sigma-Aldrich 1992
K_{OC}	NA	
Log K_{OW}	NA	
Vapor Pressure	NA	
Reactivity	reacts with strong oxidizing agents; sensitive to moisture	Sigma-Aldrich 1992
Flammability	noncombustible	Lockheed Martin 1994a
Flash Point	NA	
Dissociation Constant (-pK)	NA	
Henry's Law Constant	NA	
Molecular Diffusivity Coefficient	NA	
Air Diffusivity Coefficient	NA	
Fish Bioconcentration Factor	NA	
Odor Threshold	NA	
Conversion Factors	NA	

The chemical identity and physical/chemical properties of sodium fluoride are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM FLUORIDE

Characteristic/Property	Data	Reference
CAS No.	7681-49-4	
Common Synonyms	sodium hydrofluoride sodium monfluoride floridine	
Molecular Formula	NaF	
Chemical Structure	Na-F	
Physical State	crystals	Budavari et al. 1989
Molecular Weight	42.00	Budavari et al. 1989
Melting Point	993°C	Budavari et al. 1989
Boiling Point	1704°C	Budavari et al. 1989
Water Solubility	4.0 g/100 mL at 15°C 4.3 g/100 mL at 25°C	Budavari et al. 1989
Density	2.78	Budavari et al. 1989
K_{OC}	NA	
Log K_{OW}	NA	
Vapor Pressure	1 mm Hg at 1077°C	Keith and Walters 1985
Reactivity	stable under normal conditions	Keith and Walters 1985
Flammability	nonflammable	Keith and Walters 1985
Flash Point	NA	
Dissociation Constant (-pK)	NA	
Henry's Law Constant	NA	
Molecular Diffusivity Coefficient	NA	
Air Diffusivity Coefficient	NA	
Fish Bioconcentration Factor	NA	
Odor Threshold	NA	
Conversion Factors	NA	

The chemical identity and physical/chemical properties of sodium bifluoride are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM BIFLUORIDE

Characteristic/Property	Data	Reference
CAS No.	1333-83-1	HSDB 1995
Common Synonyms	sodium hydrogen difluoride sodium hydrogen fluoride sodium acid fluoride	HSDB 1995
Molecular Formula	$NaHF_2$	Lewis 1993
Chemical Structure	F_2-H-Na	HSDB 1995
Physical State	white, crystalline powder	Budavari et al. 1989
Molecular Weight	62.01	Budavari et al. 1989
Melting Point	decomposes on heating	Lewis 1993
Boiling Point	NA	
Water Solubility	soluble in cold and hot water	Lide 1991
Density	2.08	Lewis 1993
K_{OC}	NA	
Log K_{OW}	NA	
Vapor Pressure	NA	
Vapor Density	NA	
Reactivity	aqueous solution corrodes glass	Budavari et al. 1989
Flammability	slightly combustible	Lockheed Martin 1990
Flash Point	NA	
Dissociation Constant (-pK)	NA	
Henry's Law Constant	NA	
Molecular Diffusivity Coefficient	NA	
Air Diffusivity Coefficient	NA	
Fish Bioconcentration Factor	NA	
Odor Threshold	NA	
Conversion Factors	NA	

II. ENVIRONMENTAL FATE

A. Environmental Release

Fluoroboric acid may be released into the environment in emissions and effluents from facilities involved in its manufacture or use. It is used primarily in industrial metal plating solutions (60%), in the synthesis of diazo salts (20%), and in metal finishing (20%) (HSDB 1995). It is used in bright dipping solutions for Sn-Pb alloys in printed circuits and other electrical components (HSDB 1995).

B. Transport

No information was found in the available secondary sources on the environmental transport of fluoroboric acid. Its miscibility with water indicates that transport in aqueous systems is very likely.

C. Transformation/Persistence

FLUOROBORIC ACID:

1. Air — No information was found in the available secondary sources on the transformation and persistence of fluoroboric acid or fluoroborates in the atmosphere.
2. Soil — No information was found in the available secondary sources on the transformation and persistence of fluoroboric acid or fluoroborates in soil. Fluoroboric acid may undergo limited hydrolysis in moist soils (Budavari et al. 1989).
3. Water — Fluoroboric acid undergoes limited hydrolysis in water to form hydroxyfluoroborate ions, the major product is BF_3OH^- (Budavari et al. 1989).
4. Biota — No information was found in the available secondary sources on the biotransformation or bioconcentration of fluoroboric acid or fluoroborates. Rapid urinary excretion of tetrafluoroborates suggests that these salts would not bioaccumulate.

FLUORIDES:

1. Air — Gaseous inorganic fluorides undergo hydrolysis in the atmosphere; however, particulate forms are relatively stable and do not hydrolyze readily (ATSDR 1993b).
2. Soil — Fluorides tend to persist in soils as fluorosilicate complexes under acidic conditions and as calcium fluoride under alkaline conditions. Sandy acidic soils favor the formation of soluble forms (ATSDR 1993b).
3. Water — In dilute solutions and at neutral pH, fluoride is generally present as dissolved fluoride ion. High calcium carbonate levels may lead to precipitation as calcium fluoride (ATSDR 1993b).
4. Biota — Fluorides have been shown to accumulate in some aquatic organisms (ATSDR 1993b). Soluble forms of fluoride are taken up by terrestrial plants and converted into fluoro-organic compounds (ATSDR 1993b).

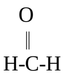
CHEMICAL SUMMARY FOR FORMALDEHYDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information from these databases or secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of formaldehyde are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF FORMALDEHYDE

Characteristic/Property	Data	Reference
CAS No.	50-00-0	
Common Synonyms	methanal; oxymethane; methyl aldehyde; formalin (solution)	U.S. EPA 1985b
Molecular Formula	CH_2O	
Chemical Structure	 $\overset{\overset{O}{\|}}{H\text{-}C\text{-}H}$	
Physical State	gas	U.S. EPA 1985b
Molecular Weight	30.03	U.S. EPA 1985b
Melting Point	-118°C	U.S. EPA 1985b
Boiling Point	-19°C @ 1 atm	U.S. EPA 1985b
Water Solubility	≥100 mg/mL @ 20°C	Keith and Walters 1985
Specific Gravity	0.815 @ -20/4°C	Verschueren 1983
Vapor Density (air = 1)	1.03	Verschueren 1983
K_{OC}	≈5 (calculated)	U.S. EPA 1985b
Log K_{OW}	0.00 (calculated)	Verschueren 1983
Vapor Pressure	10 mm Hg @ -88°C 3883 mm Hg @ 25°C	Verschueren 1983 Howard 1989
Reactivity	flammable gas; in solution reacts with acids, bases, metal salts, and NO_2; reducing agent especially in alkali; oxidizes in air to formic acid. Reacts explosively with peroxides and performic acid.	Keith and Walters 1985 Budavari et al. 1989 IARC 1995
Dissociation Constant	No data	
Air Diffusivity Coefficient	No data	
Molecular Diffusivity Coefficient	No data	
Flash Point	50-60°C	Keith and Walters 1985
Henry's Law Constant	1.43×10^{-7} atm-m^3/mole @ 25°C 3.27×10^{-7} atm-m^3/mole @ 25°C	U.S. EPA 1985b Howard 1989
Fish Bioconcentration Factor	0.2 (calculated)	U.S. EPA 1985b
Odor Threshold	perception, 0.07 mg/m^3	Verschueren 1983
Conversion Factors	1 ppm = 1.248 mg/m^3; 1 mg/m^3 = 0.815 ppm	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

Formaldehyde is a colorless gas at room temperature with a characteristic pungent, straw-like odor that becomes suffocating and intolerable at increasing concentrations (U.S. EPA 1985b; Budavari et al. 1989; Verschueren 1983). It is released into the environment from natural and man-made sources. It is a product of combustion and is found in smoke from wood, wood products, and tobacco; gasoline and diesel engine exhaust; and in the effluent from power plants, incinerators, and refineries (Howard 1989). It can also be made indirectly in the atmosphere by the photochemical oxidation of other organic molecules, many of which are also products of combustion (U.S. EPA 1985b; Howard 1989). The contribution of formaldehyde to the atmosphere from this indirect source has been estimated to be twice that from automobiles (U.S. EPA 1985b). Formaldehyde is found in some fruits and vegetables including apples (17.3-22.3 µg/g), green onions (13.3-26.3 µg/g), carrots (6.7-10.0 µg/g), and tomatoes (5.7-7.3 µg/g). It has also been measured in commercial shrimp at 0.39-2.15 mg/kg (U.S. EPA 1985b). Solutions of the gas in water (typically, 37% formaldehyde) are known as formalin and are commonly used as biological preserving agents (U.S. EPA 1985b). Atmospheric levels of formaldehyde have been extensively monitored around the world. Air concentrations range from 0-1 parts-per-billion (ppb) measured off the West coast of Ireland to 24-59 ppb in Los Angeles during a photochemical smog episode (U.S. EPA 1985b). Only 25% of 749 air samples taken from suburban/urban sites across the U.S. were found to contain over 2.7 ppb formaldehyde (U.S. EPA 1985b). Concentrations increase with automobile traffic and during photochemical smog episodes (Howard 1989; U.S. EPA 1985b), and decrease markedly with altitude (U.S. EPA 1985b). Formaldehyde concentrations in indoor air vary with activities involving combustion and materials used in construction. Levels of 33-380 ppb were measured in a test kitchen with a gas stove, concentrations of 0.06-1.83 ppb were measured in homes using urea-formaldehyde particle board, and levels of <0.41-8.2 parts-per-million (ppm) were measured in homes with urea-formaldehyde foam insulation (U.S. EPA 1985b). Higher levels are also measured in areas where formaldehyde solutions (formalin) are used, such as funeral homes (0.35-1.39 ppm), anatomy laboratories (1 ppm, mean), and academic laboratories (1.33-2.48 ppm) (U.S. EPA 1985b). Drinking water supplies were found to be free from formaldehyde contamination in a national survey of suspected carcinogens in drinking water. Formaldehyde was also not found in seawater, and was found in only 1/204 samples at 12 ppb from heavily industrialized river basins in the U.S. It was found in the effluent streams from two chemical plants and one sewage treatment plant (Howard 1989).

In 1992, releases of formaldehyde to environmental media, as reported to the TRI by certain types of U.S. industries, totaled about 16,435,148 pounds. Of this amount, 10,903,227 pounds (66.34%) were released to the atmosphere, 4,916,248 pounds (29.91%) were released in underground injection sites, 441,244 pounds (2.68%) were released to surface water, and 174,429 pounds (1.06%) were released to land (TRI92 1994).

B. Transport

Formaldehyde in solution reacts with water to become hydrated. In this form, it becomes less volatile than water; thus, volatilization from the aquatic environment is not expected to be significant (U.S. EPA 1985b). Formaldehyde is known to leach into the soil, and its high water solubility and calculated soil sorption coefficient (Koc ≈5) indicate relatively high mobility, but the actual fate of formaldehyde in the soil is largely unknown (Howard 1989; U.S. EPA 1985b). In the atmosphere, formaldehyde will transfer into rainwater and also adsorb to aerosol particulates (U.S. EPA 1985b). Half-lives of 50 and 19 hours were predicted from a model system for wet and dry deposition, respectively (Howard 1989).

C. Transformation/Persistence

1. <u>Air</u> — Formaldehyde rapidly reacts with free radicals produced by sunlight in the atmosphere. These include primarily hydroxyl radicals and, to a lesser extent, other radicals, especially chlorine and nitrate. A half-life for formaldehyde of about 0.8 days was calculated for the reaction with hydroxyl radicals (U.S. EPA 1985)b. Formaldehyde also undergoes direct photolysis (significant absorption of wavelengths between 290 and 370 nm.). The atmospheric half-life of formaldehyde was calculated to be 0.17 days at sea level with the sun at 30° zenith angle. Calculated for the same conditions, but at an altitude of 10 km, the half-life was reduced to 0.08 days (U.S. EPA 1985b).

2. Soil — No information is available on the fate of formaldehyde in the natural soil environment. However, a number of bacteria and yeasts isolated from soil were able to degrade formaldehyde, suggesting that formaldehyde released to the soil is susceptible to microbial degradation (U.S. EPA 1985b; Howard 1989).
3. Water — Formaldehyde in water is subject to biodegradation. Under aerobic conditions complete degradation was observed in about 30 hours at 20°C utilizing natural water from a lake in Japan and a known amount of formaldehyde. Degradation occurred in about 48 hours under anaerobic conditions. No degradation was seen with sterilized lake water (U.S. EPA 1985b). Activated sludges were shown to be efficient in decomposing formaldehyde in aqueous effluents, and various *Pseudomonas* strains were shown to use formaldehyde as a sole carbon source (U.S. EPA 1985b).
4. Biota — Experiments on fish and shrimp have shown no bioconcentration of formaldehyde. It is a natural metabolic product and not thought to be subject to bioaccumulation (U.S. EPA 1985b).

CHEMICAL SUMMARY FOR FORMIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of formic acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF FORMIC ACID

Characteristic/Property	Data	Reference
CAS No.	64-18-6	
Common Synonyms	methanoic acid; formylic acid; hydrogen carboxylic acid	HSDB 1995
Molecular Formula	CH_2O_2	Budavari et al. 1989
Chemical Structure	HCOOH	Parmeggiani 1983
Physical State	colorless liquid	Budavari et al. 1989
Molecular Weight	46.02	Budavari et al. 1989
Melting Point	8.4°C	Budavari et al. 1989
Boiling Point	100.5°C	Budavari et al. 1989
Water Solubility	miscible with water	Budavari et al. 1989
Density	1.220 @ 20/4°C	Budavari et al. 1989
Vapor Density (air = 1)	1.59	HSDB 1995
K_{OC}	not estimated due to ionization	CHEMFATE 1995
Log K_{OW}	-0.54	CHEMFATE 1995
Vapor Pressure	42.59 mm Hg at 25°C	CHEMFATE 1995
Reactivity	strong acid in aqueous solution;	ACGIH 1991
	can react as an acid or aldehyde;	NTP 1992
	reacts explosively with strong oxidizing agents	HSDB 1995
Flammability	2 (liquid which must be moderately heated before ignition will occur)	HSDB 1995
Flash Point	68.89°C, open cup	ACGIH 1991
Dissociation Constant	3.7515 @ 25°C	CHEMFATE 1995
Henry's Law Constant	1.67×10^{-7} atm-m^3/mole	CHEMFATE 1995
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	0.22 (calculated)	HSDB 1995
Odor Threshold	10 mg/m^3	Verschueren 1983
Conversion Factors	1 mg/m^3 = 0.52 ppm; 1 ppm = 1.91 mg/m^3	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

Formic acid is a colorless, highly caustic liquid with a pungent odor (Budavari et al. 1989; NTP 1992). It is produced in large quantities (48 million pounds in 1984) and is released to the environment primarily from industrial sources during its production and uses including textile dying and finishing (21% of production); pharmaceuticals (20%); rubber intermediate (16%); leather and tanning treatment (15%); and catalysts (12%). Formic acid is also a component of certain paint strippers and is released in photoprocessing effluents (HSDB 1995). Other sources of formic acid include releases from forest fires, lacquer manufacturing, trash and plastic burning, thermal degradation of polyethylene, and tobacco smoke (NTP 1992). Formic acid also occurs naturally in plants and insects, as a product of microbial degradation of organic matter, and as a product of photooxidation of biogenic and anthropogenic compounds (HSDB 1995). A constituent of ant, wasp, and bee venom, formic acid occurs in mammalian muscle tissue, sweat, and urine (NTP 1992). Formic acid has been measured at concentrations ranging from 4 to 72 ppm in the atmosphere. It has been detected in river and surface water, in unfinished industrial waste water, and in municipal sewage and discharge water at concentrations ranging from 10 to 80,000 μg/L (SRI 1981, as reported in NTP 1992).

B. Transport

Formic acid is soluble in water and would not be expected to adsorb significantly to soil or sediments. Formic acid should leach from some soils into groundwater where it probably would biodegrade. The Henry's Law Constant for formic acid (1.67×10^{-7} atm-m^3/mole) indicates that volatilization from water would not be significant. The potential for bioconcentration is low (HSDB 1995).

C. Transformation/Persistence

1. Air — In the atmosphere, formic acid is rapidly scavenged by rain and dissolved in cloud water and aerosols, reacting with dissolved hydroxyl radicals. In the vapor phase, the acid also reacts with photochemically produced hydroxyl radicals (half-life 34 days) and possibly with alkenes that may be present in urban air (HSDB 1995).
2. Soil — If released on land, formic acid is expected to leach from soils where it would probably biodegrade based on the results of screening studies (HSDB 1995). A field study followed an industrial waste containing 11.4% formic acid that was disposed of by deep well injection as it traveled a distance of 427-823 meters over a 2 to 4-year period. Formic acid was not detected in two observation wells, while a third well contained 0.4%. The disappearance of the acid was attributed to anaerobic degradation or to reaction with mineral material in ground water (HSDB 1995).
3. Water — If released to water, formic acid should biodegrade and not adsorb significantly to sediment (HSDB 1995).
4. Biota — The estimated bioconcentration factor of 0.22 (based on a log/water partition coefficient of -0.54) suggests that formic acid would not bioaccumulate in aquatic organisms (HSDB 1995).

CHEMICAL SUMMARY FOR GRAPHITE

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink and graphite process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of graphite are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF GRAPHITE

Characteristic/Property	Data	Reference
CAS No.	7782-42-5	
Common Synonyms	plumbago; black lead; mineral carbon	Budavari et al. 1989
Molecular Formula	C	ACGIH 1991
Chemical Structure	C	
Physical State	compact crystalline mass of black or gray color with metallic luster	Pendergrass 1983
Molecular Weight	12	NIOSH 1994
Melting Point	3652-3697°C	Pendergrass 1983
Boiling Point	4200°C	Pendergrass 1983
Water Solubility	insoluble	NIOSH 1994
Density	2.0-2.25	NIOSH 1994
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	0 mm Hg at 68°F	NIOSH 1994
Reactivity	reacts with very strong oxidizers such as fluorine, chlorine trifluoride, and potassium peroxide	NIOSH 1994
Flammability	combustible	NIOSH 1994
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	not applicable	

II. ENVIRONMENTAL FATE

A. Environmental Release

Graphite exists as a black or gray crystalline mass and occurs naturally in lump, amorphous, and flake forms (Pendergrass 1983). It is found in most parts of the world (Pendergrass 1983) and is usually found with impurities such as quartz, mica, iron oxide, and granite. The crystalline silica content can range from 2% to 25% (ACGIH 1991). Synthetic graphite is produced by heating a mixture of coal or petroleum coke, a binder, and a petroleum-based oil to facilitate extrusion (ACGIH 1991). Although graphite occurs naturally, exposure to graphite is expected to be primarily occupational. No information on the environmental release of graphite was found in the secondary sources searched.

B. Transport

Graphite is insoluble in water (NIOSH 1994) and, therefore, would not be expected to be transported in surface of ground water. No volatilization is expected to occur under natural conditions.

C. Transformation/Persistence

1. Air — Graphite could be present in air as particulate matter which has a settling time of days.
2. Soil — No information on the transformation/persistence of graphite in soil was found in the secondary sources searched.
3. Water — No information on the transformation/persistence of graphite in water was found in the secondary sources searched.
4. Biota — Graphite does not dissociate in water. Although it may be ingested by bottom feeders, it is not expected to accumulate in aquatic organisms..

CHEMICAL SUMMARY FOR HYDROCHLORIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, non-formaldehyde electroless copper, organic-palladium, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

Hydrochloric acid is formed when the gaseous and highly soluble hydrogen chloride (HCl) is dissolved in water; hydrochloric acid usually contains 20% HCl (constant boiling acid) or 38% HCl (muriatic acid) (Perry et al. 1994). The chemical identity and physical/chemical properties of hydrochloric acid and/or HCl are summarized below, depending on availability.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF HYDROCHLORIC ACID

Characteristic/Property	Data	Reference
CAS No.	7647-01-0	
Common Synonyms	anhydrous hydrochloric acid; chlorohydric acid; hydrogen chloride; muriatic acid	RTECS 1995
Molecular Formula	HCl	
Chemical Structure	Cl-H	
Physical State	colorless liquid (hydrochloric acid); colorless gas (HCl)	HSDB 1995; WHO 1982
Molecular Weight	36.46	HSDB 1995
Melting Point	—114.8°C @ 1 atm (freezing point, HCl)	WHO 1982
Boiling Point	—84.9 °C @ 1 atm (HCl)	WHO 1982
Water Solubility	56.1 g/100 mL @ 60°C (HCl);	HSDB 1995
	82.3 g/100 mL @ 0°C (HCl)	WHO 1982
pH	0.1 (1.0 N), 1.1 (0.1 N), 2.02 (0.01 N), 3.02 (0.001 N)	HSDB 1995
Density	$1.05^{15/4^\circ C}$ (hydrochloric acid)	HSDB 1995
Vapor Density (air = 1)	1.268 (HCl)	ACGIH 1991
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	3.54 x 10^4 mm Hg @ 25°C (hydrochloric acid)	CHEMFATE 1995
Reactivity	hydrochloric acid with formaldehyde may form bis(chloromethyl)ether, a human carcinogen; hydrochloric acid in contact with various metals or metal salts may form flammable gases or may undergo energetic reactions; hydrochloric acid is corrosive to most metals, HCl is not; pressurized container may explode releasing toxic vapors.	HSDB 1995
Flammability	HCl will not burn	HSDB 1995
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	0.26-5 ppm; irritating pungent odor	HSDB 1995
Conversion Factors	1 ppm = 1.49 mg/m^3	Calculated using:
	1 mg/m^3 = 0.67 ppm	ppm = mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

HCl occurs naturally in gases evolved from many volcanoes. There are apparently no other natural sources of the chemical, but chlorides are present in the minerals halite, sylvite, and carnallite, and in seawater (HSDB 1995).

HCl is released to the environment from its production and various other industrial processes (WHO 1982). Sources of its release include refuse incineration and the secondary metals industry (such as the smelting of scrap, rather than ore) (HSDB 1995). It is also released from the thermodecomposition of gases, as a by-product in the numerous dehydrohalogenation processes in the production of unsaturated compounds from the parent chlorinated hydrocarbon, and from coal-fired power plants (HSDB 1995).

In 1992, environmental releases of hydrochloric acid, as reported to the TRI by certain types of U.S. industries, totaled about 287.3 million pounds, including 207.8 million pounds to underground injection sites, 77.1 million pounds to the atmosphere, 1.9 million pounds to surface water, and 432,770 pounds to land (TRI92 1994). Hydrochloric acid ranks second highest in the TRI for total releases and transfers.

B. Transport

HCl, highly soluble in water, may be removed from the atmospheric environment by wet deposition. This was illustrated by a study in the Netherlands in which the chemical was washed out from the plume of a coal fired power plant (HSDB 1995).

Anhydrous HCl spilled onto the soil undergoes rapid evaporation and is not expected to infiltrate the soil (HSDB 1995). In contrast, hydrochloric acid spilled onto soil will infiltrate and will dissolve some soil materials, particularly those of a carbonate base. A portion of the acid will be neutralized, but significant amounts will remain, available for transport to the ground water table. The presence of water in the soil influences the rate of movement of the chemical (HSDB 1995).

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of HCl/hydrochloric acid in the atmosphere.
2. Soil — Hydrochloric acid spilled onto soil will infiltrate and will dissolve some soil materials, particularly those of a carbonate base, which will neutralize a portion of the acid (HSDB 1995). Information regarding other potential reactions of hydrochloric acid in the soil was not available in the secondary sources searched.
3. Water — HCl in water dissociates almost completely; the hydrogen ion is captured by the water molecules to form the hydronium ion (HSDB 1995).
4. Biota — No information was found in the secondary sources searched regarding the transformation/persistence of HCl/hydrochloric acid in biota.

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CHEMICAL SUMMARY FOR HYDROGEN PEROXIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of hydrogen peroxide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF HYDROGEN PEROXIDE

Characteristic/Property	Data	Reference
CAS No.	7722-84-1	
Common Synonyms	hydrogen dioxide; hydroperoxide; albone; hioxyl	Budavari et al. 1989
Molecular Formula	H_2O_2	Budavari et al. 1989
Chemical Structure	H_2O_2	IARC 1985
Physical State	colorless, unstable liquid bitter taste	Budavari et al. 1989
Molecular Weight	34.02	Budavari et al. 1989
Melting Point	–0.43°C	Budavari et al. 1989
Boiling Point	152°C	Budavari et al. 1989
Water Solubility	miscible	Budavari et al. 1989
Density	1.463 @ 0°C	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	1.97 mm Hg @ 25° C (measured)	CHEMFATE 1995
Reactivity	strong oxidizer; may decompose violently if traces of impurities are present	Budavari et al. 1989
	molecular additions, substitutions, oxidations, reduction; can form free radicals	IARC 1985
Flammability	not flammable, but can cause spontaneous combustion of flammable materials	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	1 ppm = 1.39 mg/m^3 1 mg/m^3 = 0.72 ppm	IARC 1985
	30% soln 1.1 kg/L anhydrous 1.46 kg/L	Budavari et al. 1989

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of hydrogen peroxide. Solutions of hydrogen peroxide gradually deteriorate (Budavari et al. 1989). Hydrogen peroxide is a naturally occurring substance. Gaseous hydrogen peroxide is recognized to be a key component and product of the earth's lower atmospheric photochemical reactions, in both clean and polluted atmospheres. Atmospheric hydrogen peroxide is also believed to be generated by gas-phase photochemical reactions in the remote troposphere (IARC 1985)

B. Transport

No information was found in the secondary sources searched regarding the transport of hydrogen peroxide.

C. Transformation/Persistence

1. Air — Hydrogen peroxide may be removed from the atmosphere by photolysis giving rise to hydroxyl radicals, by reaction with hydroxyl radicals, or by heterogenous loss processes such as rain-out (IARC 1985).
2. Soil — No information was found in the secondary sources searched regarding the transformation or persistence of hydrogen peroxide in soil, however, solutions of hydrogen peroxide gradually deteriorate (Budavari et al. 1989).
3. Water — Hydrogen peroxide is a naturally occurring substance. Surface water concentrations of hydrogen peroxide have been found to vary between 51-231 mg/L, increasing both with exposure to sunlight and the presence of dissolved organic matter (IARC 1985).
4. Biota — Hydrogen peroxide is a naturally occurring substance. Endogenous hydrogen peroxide has been found in plant tissues at the following levels (mg/kg frozen weight): potato tubers, 7.6; green tomatoes, 3.5; red tomatoes, 3.5; and castor beans in water, 4.7 (IARC 1985).

CHEMICAL SUMMARY FOR HYDROXYACETIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of hydroxyacetic acid summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF HYDROXYACETIC ACID

Characteristic/Property	Data	Reference
CAS No.	79-14-1	
Common Synonyms	glycolic acid; hydroxyethanoic acid	Budavari et al. 1989
Molecular Formula	$C_2H_4O_3$	Budavari et al. 1989
Chemical Structure	$HOCH_2COOH$	Budavari et al. 1989
Physical State	somewhat hygroscopic crystals	Budavari et al. 1989
Molecular Weight	76.05	Budavari et al. 1989
Melting Point	80°C	Budavari et al. 1989
Boiling Point	100°C (decomposes)	HSDB 1995
Water Solubility	soluble	Budavari et al. 1989
Density	1.49 @ 25°C	HSDB 1995
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	-1.11	CHEMFATE 1995
Vapor Pressure	8.1 mm Hg @ 80°C	HSDB 1995
Reactivity	incompatible with bases, oxidizing & reducing agents; pH of aqueous solution, 2.5 (0.5%), 2.33 (1%), 2.16 (2%) 1.91 (5%), 1.73 (10%)	Martin Marietta Energy Systems 1994 Budavari et al. 1989
Flammability	capable of creating dust explosion	Eastman Kodak Co. 1989
Flash Point	no data	
Dissociation Constant	3.83 (measured)	CHEMFATE 1995
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	1 mg/m^3 = 0.32 ppm; 1 ppm = 3.11 mg/m^3	Calculated: mg/m^3 = 1 ppm (MW/24.45)

II. ENVIRONMENTAL FATE

A. Environmental Release

Hydroxyacetic acid is a water soluble solid used in the processing of textiles, leather, and metals, in pH control, and wherever an inexpensive organic acid is needed (Budavari et al. 1989). The chemical can be found in spent sulfite liquor from pulp processing and occurs naturally in sugar cane syrup (HSDB 1995). Hydroxyacetic acid has been detected in the Gulf of Main at concentrations of 0-78 μg/L; in water samples collected at a 3 meter depth in the Belgian zone of the North Sea; in the eastern parts of the English Channel at concentrations ranging from 0.9 to 3.1 μmol/L; and in five Madison, Wisconsin, Lakes and in Falkland Islands waters as a product of algal photosynthesis (CHEMFATE 1995).

B. Transport

No information on the transport of hydroxyacetic acid was found in the secondary sources searched. Hydroxyacetic acid is soluble in water and would be expected to leach through soil. The vapor pressure of 8.1 mm Hg @ 80°C indicates that the chemical is moderately volatile and, therefore, may volatilize to some extent from soils and water. However, a Henry's Law Constant is not available and it is stated that the chemical is water soluble. Hence, even though the vapor pressure is relatively high, volatilization from water may be negligible due to its high water solubility.

C. Transformation/Persistence

1. Air — No information on the transformation/persistence of hydroxyacetic acid in air was found in the secondary sources searched.
2. Soil — The chemical was not biodegraded by 10 strains of *Arthobacter globiformis* and slowly degraded by *Alcalignes* sp. (CHEMFATE 1995).
3. Water — Stream and groundwater bacteria degraded the chemical with half-lives of 73 days and 4.5 days, respectively (CHEMFATE 1995).
4. Biota — The low log octanol-water coefficient (-1.11) suggests that hydroxyacetic acid would not bioaccumulate.

CHEMICAL SUMMARY FOR ISOPHORONE

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of isophorone are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF ISOPHORONE

Characteristic/Property	Data	Reference
CAS No.	78-59-1	
Common Synonyms	Isoacetophorone	NIOSH 1994
	3,5,5-Trimethyl-2-cyclo-hexenone	
	Isoforon	ATSDR 1989
Molecular Formula	$C_9H_{14}O$	
Chemical Structure		Howard 1990
Physical State	Clear liquid	Budavari et al. 1996
Molecular Weight	138.21	Budavari et al. 1996
Freezing Point	-8.1°C	ATSDR 1989
Boiling Point	215.3°C	ATSDR 1989
Water Solubility	12 g/L (20°C)	Howard 1990
	14.5 g/L (25°C)	ATSDR 1989
Specific Gravity	0.9229 (20/20°C	Keith and Walters 1985
Density	0.923 mg/L (20°C)	Keith and Walters 1985
Vapor Density (air = 1)	4.77	Verschueren 1996
Max vapor Conc.	340 ppm (20°C)	Topping et al. 1994
K_{OC}	25; 384	Howard 1990
Log K_{OW}	1.67 (20°C)	ATSDR 1989
	2.22 (est.)	Howard 1990
Vapor Pressure	0.3 mm Hg (20°C)	Budavari et al. 1996
	0.438 mm Hg (25°C)	CHEMFATE 1996
Reactivity	Incompatible with	HSDB 1996
	strong oxidizers	Keith and Walters 1985
Flammability Limits	0.8-3.5 vol %	ATSDR 1989
Flash Point (open cup)	84°C	Budavari et al. 1996
Henry's Law Constant	5.8×10^{-6} atm-m^3/mol (20°C)	Howard 1990
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	7 (bluegill)	Verschueren 1996
Odor Threshold - air	0.20 (v/v)	ATSDR 1989
Conversion Factors	1 ppm = 5.74 mg/m^3	NIOSH 1994
	1 mg/m^3 = 0.17 ppm	

II. ENVIRONMENTAL FATE

A. Environmental Release

Isophorone is not listed on the TRI (TRI93 1995). Information on the amounts released into various environmental media was not found in the available secondary sources.

B. Transport

If released to soil or water, isophorone may be transported to air by volatilization (Howard 1990). Based on a Henrys Law Constant of 5.8×10^{-6} atm-m^3/mol, the half-life from a model river 1 m deep and flowing 1 m/sec was estimated to be about 7.5 days (Howard 1990). Isophorone is not expected to be adsorbed to suspended solids or sediments. K_{oc} values of 25 and 384 have been estimated for isophorone from data on water solubility (12 g/L at 20°C) and K_{ow} (log K_{ow} = 1.67 at 20°C), indicating that leaching through soils to ground water is possible (Howard 1990). Based on its vapor pressure of 0.3 mm Hg, isophorone is expected to exist in the air primarily in the vapor phase (Howard 1990). Isophorone emitted to the atmosphere in particulate form may be removed by wet or dry deposition (Howard 1990).

C. Transformation/Persistence

1. Air — The major degradation pathway for isophorone in air is expected to be by reaction with ozone, with a estimated half-life of 39 min (Howard 1990). Reaction with photochemically generated hydroxyl radicals is not expected to be as significant (half-life 3 hr) (Howard 1990). Overall half-life in air has been estimated to be 32 min (Howard 1990).
2. Soil — The potential exists for transport of isophorone to ground water by leaching through soil (Howard 1990). Biodegradation is a likely degradation pathway in soils.
3. Water — Isophorone is not expected to be adsorbed to suspended solids or sediments, or to be photolyzed, oxidized by reaction with singlet oxygen, oxidized by alkylperoxy radicals or undergo chemical hydrolysis (Howard 1990). Isophorone may undergo biodegradation in water (Howard 1990).
4. Biota — Isophorone is not expected to bioaccumulate (Howard 1990). A bioconcentration factor of 7 was reported for bluegill sunfish (Howard 1990). The half-life of isophorone in fish tissue was estimated to be 1 day, indicating a low potential for bioaccumulation (Howard 1990)

CHEMICAL SUMMARY FOR ISOPROPANOL

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of isopropanol are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF ISOPROPANOL

Characteristic/Property	Data	Reference
CAS No.	67-63-0	
Common Synonyms	isopropyl alcohol; 2-propanol; dimethyl carbinol	U.S. EPA 1989
Molecular Formula	C_3H_8O	IARC 1977
Chemical Structure	CH_3-CHOH-CH_3	IARC 1977
Physical State	colorless liquid	IARC 1977
Molecular Weight	60.09	Budavari et al. 1989
Melting Point	-88.5°C	Budavari et al. 1989
Boiling Point	82.5°C at 760 mm Hg	Budavari et al. 1989
Water Solubility	> 10%	Weast 1985
Density	0.78505 g/mL	Budavari et al. 1989
Vapor Density (air = 1)	2.08	HSDB 1995
K_{OC}	25	CHEMFATE 1995
Log K_{OW}	0.05	CHEMFATE 1995
Vapor Pressure	32.4 mm Hg at 20°C	IARC 1977
	44 mm Hg at 25°C	Rowe and McCollister 1982
Reactivity	attacks some forms of plastic, rubber, and coatings.	HSDB 1995
Flammability	flammable/combustible	HSDB 1995
UV Absorption Coefficient	2.79 $(\text{mole-cm})^{-1}$ at 181 nm	CHEMFATE 1995
Flash Point	11.7°C (closed cup) 18.3°C (open cup)	ACGIH 1991
Dissociation Constant	17.1 (pK_a)	CHEMFATE 1995
Henry's Law Constant	7.89×10^{-6} atm m^3/mole	CHEMFATE 1995
Molecular Diffusivity Coefficient	NA	
Air Diffusivity Coefficient	NA	
Fish Bioconcentration Factor	-0.19	CHEMFATE 1995
Odor Threshold	22 and 40 ppm	Lington and Bevan 1994
Conversion Factors	1 ppm = 2.50 mg/m^3 1 mg/m^3 = 0.4 ppm	NIOSH 1994

II. ENVIRONMENTAL FATE

A. Environmental Release

Isopropanol is released into the environment in emissions from chemical manufacturing plants and as a result of its use in consumer products such as a rubbing alcohol, cosmetics, and antifreezes (HSDB 1995). The chemical is also released as a natural volatile from vegetation, nuts, and milk products, and as a result of microbial degradation of animal wastes (HSDB 1995).

Of the total 1,357,992 pounds of isopropanol released to the environment in 1993, as reported to the TRI by certain types of U.S. industries, 1,357,242 pounds were released to the atmosphere and 750 pounds were released onto land; no releases were reported for surface waters or underground injection sites (TRI93 1995).

B. Transport

Following releases onto land, isopropanol is likely to volatilize into the atmosphere due to its high vapor pressure (32.4 mm Hg at 20°C). Transport through soil to groundwater is also possible considering the chemical's water solubility (>10%) and low K_{oc} value (25). When released into water, isopropanol will slowly volatilize into the atmosphere (Henry's law constant 7.89×10^{-6} atm m^3/mole); the estimated half-life for volatilization from water 1 m deep with a 1 m/sec current and a 3 m/sec wind speed is 3.6 days (Mackay et al. 1992). Because of its miscibility with water and its low potential for adsorption to sediments, downstream transport is also possible (HSDB 1995). Transport through the atmosphere may be limited by photodegradation and removal in precipitation (HSDB 1995).

C. Transformation/Persistence

1. Air — Isopropanol exhibited a low level of reactivity when tested in a smog chamber; a 20% decrease in concentration occurred in 5 hr and 250-255 min was required for maximum NO_x production (CHEMFATE 1995). The rate constant for its reaction with OH radicals is 0.547E-11, and that for reaction with O(3P) radicals is 0.22E-12 (CHEMFATE 1995). Photo-oxidation half-lives of 6.2-72 hr (based on rate of disappearance of the hydrocarbon) and 6.2-72 hr (based on the OH reaction rate constant) have been reported (Mackay et al. 1992).
2. Soil — A half-life of 24-168 hr was calculated from an estimate of the biodegradation half-life under unacclimated aerobic aqueous conditions (Mackay et al. 1992).
3. Water — Reaction of isopropanol with hydroxyl radicals in water is slow; half-lives of 1.09 yr (CHEMFATE 1995) and 197 days to 22 yr (Mackay et al. 1992) have been estimated. Based on an estimate of the unacclimated aerobic aqueous biodegradation rate, the half-lives of isopropanol in surface and groundwater were estimated to be 26-168 hr and 48-336 hr, respectively (Mackay et al. 1992).
4. Biota — Isopropanol is subject to biodegradation in activated sludge systems (CHEMFATE 1995). Microbial species including Arthrobacter sp., Achromobacter sp., and Alcaligenes faecalis have been shown to be capable of degrading isopropanol (CHEMFATE 1995). The low log K_{ow} value of 0.05 for isopropanol indicates that bioconcentration and bioaccumulation are not likely to be important environmental fate processes (HSDB 1995).

CHEMICAL SUMMARY FOR LITHIUM HYDROXIDE

This chemical was identified by one or more suppliers as a bath ingredient for the tin-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of lithium hydroxide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF LITHIUM HYDROXIDE

Characteristic/Property	Data	Reference
CAS No.	1310-66-3	
Common Synonyms	lithium hydroxide hydrate lithium hydroxide, monohydrate	Sigma 1992
Molecular Formula	$LiOH{\cdot}H_2O$	
Chemical Structure	$LiOH{\cdot}H_2O$	
Physical State	white crystals	Sigma 1992
Molecular Weight	41.96	Beliles 1994a
Melting Point	470°C	Lewis 1993
Boiling Point	924°C (decomposes)	Lewis 1993
Water Solubility	223 g/L at 10°C	Beliles 1994a
Density	1.51	Beliles 1994a
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	incompatible with strong oxidizing agents and strong acids; binds CO_2	Sigma 1992
Flammability	no data; emits toxic fumes under fire conditions	Sigma 1992
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	not applicable	

II. ENVIRONMENTAL FATE

A. Environmental Release

For the production of lithium hydroxide, lithium ore is heated with limestone to about 1000°C; water leaching of the kiln product yields lithium hydroxide. Lithium hydroxide is used as a CO_2 absorbent in space vehicles and submarines, as a storage battery electrolyte, in lubricating greases, and in ceramics (Beliles 1994a).

Releases of lithium to the environment are most likely in the form of inorganic salts or oxides (Beliles 1994a). Lithium hydroxide is not listed on the EPA's TRI, requiring certain U.S. industries to report on chemical releases to the environment (TRI93 1995).

B. Transport

No information was found in the secondary sources searched regarding the transport of lithium hydroxide through the environment. Lithium occurs naturally in certain minerals and lithium compounds are found in natural waters and some foods (Beliles 1994a).

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of lithium hydroxide in air, water, soil, or biota.

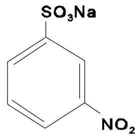
CHEMICAL SUMMARY FOR m-NITROBENZENE SULFONIC ACID, SODIUM SALT

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of m-nitrobenzene sulfonic acid, sodium salt, are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF m-NITROBENZENE SULFONIC ACID, SODIUM SALT

Characteristic/Property	Data	Reference
CAS No.	127-68-4	
Common Synonyms	sodium 3-nitrobenzenesulfonate; ludigol; nacan	HSDB 1995
Molecular Formula	$C_6H_5NO_5S.Na$	HSDB 1995
	Chemical Structure 	
Physical State	white to light	
yellow solid	Sigma-Aldrich 1993	
Molecular Weight	225.16	HSDB 1995
Melting Point	no data	
Boiling Point	no data	
Water Solubility	no data	
Density	no data	
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	–2.61	Greim et al. 1994
Vapor Pressure	no data	
Reactivity	incompatible with strong oxidizers, brass, cadmium, copper, nickel	Sigma-Aldrich 1993
Flammability	no data	
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of nitrobenzene sulfonic acid, sodium salt.

B. Transport

No information was found in the secondary sources searched regarding the transport of nitrobenzene sulfonic acid, sodium salt.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of nitrobenzene sulfonic acid, sodium salt, in air.
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of nitrobenzene sulfonic acid, sodium salt, in soil.
3. Water — The biodegradability of nitrobenzene sulfonic acid, sodium salt, is greater than 70 % in the Zahn-Wellens or coupled-unit test (Greim et al. 1994).
4. Biota — The Log P_{ow} (equivalent to a log K_{ow}) for nitrobenzene sulfonic acid, sodium salt, is –2.61; therefore, no significant bioaccumulation is expected (Greim et al. 1994).

CHEMICAL SUMMARY FOR MAGNESIUM CARBONATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of magnesium carbonate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF MAGNESIUM CARBONATE

Characteristic/Property	Data	Reference
CAS No.	546-93-0	
Common Synonyms	magnesite	ACGIH 1991
	carbonic acid, magnesium salt (1:1)	HSDB 1995
Molecular Formula	$MgCO_3$	ACGIH 1991
Chemical Structure	$MgCO_3$	ACGIH 1991
Physical State	white, yellowish, grayish-white, or brown crystalline solid	ACGIH 1991
Molecular Weight	84.33	ACGIH 1991
Melting Point	decomposes @ 350° C	Beliles 1994b
Boiling Point	900° C	ACGIH 1991
Water Solubility	106 mg/L @ 20° C	ACGIH 1991
Density	2.958	ACGIH 1991
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	readily reacts with acids	HSDB 1995
	liberates CO_2	Beliles 1994b
Flammability	no data	
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless, but readily absorbs odors	HSDB 1995
Conversion Factors	not applicable	

II. ENVIRONMENTAL FATE

A. Environmental Release

Magnesium carbonate occurs naturally as magnesite (HSDB 1995). The “cold” operations in the magnesite industry, mining and processing of raw material and clinker, and brick preparation, are characterized by a high dust content in the working environment with only insignificant amounts of solid particles escaping into the atmosphere (Reichrtova and Takac 1992). Magnesium carbonate is not one of the chemicals reported to the TRI by certain types of U.S. industries.

B. Transport

No specific information was found in the secondary sources searched regarding the transport of magnesium carbonate. It is, however, moderately soluble in water and would be expected to move through the environment.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of magnesium carbonate in air. It is, however, moderately soluble in water and would be expected to deposited in rainwater.
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of magnesium carbonate in soil.
3. Water — Magnesite occurs in seawater, seawater bitterns, and well brines. In fresh water, dissolved magnesium salts (along with calcium salts) are responsible for the hardness of water (Beliles 1994b). Magnesium carbonates comprise a significant fraction of the sediments of selected lakes and streams studied in the upper Qu'Appelle River basin in southern Saskatchewan, Canada (Oscarson et al. 1981).
4. Biota — No specific information was found in the secondary sources searched regarding the transformation/persistence of magnesium carbonate in biota.

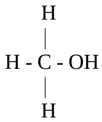
CHEMICAL SUMMARY FOR METHANOL

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and conductive ink processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical and chemical properties of methanol are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF METHANOL

Characteristic/Property	Data	Reference
CAS No.	67-56-1	
Common Synonyms	methyl alcohol, carbinol, wood spirit, wood alcohol	Budavari et al. 1989
Molecular Formula	CH_4O	Budavari et al. 1989
Chemical Structure	 $H-\overset{H}{\underset{H}{C}}-OH$	
Physical State	colorless liquid	Verschueren 1983
Molecular Weight	32.04	Budavari et al. 1989
Melting Point	-97.8°C	Budavari et al. 1989
Boiling Point	64.7°C at 760 mm Hg	Budavari et al. 1989
Water Solubility	miscible	Budavari et al. 1989
Density	$d^{20/4}$, 0.7915 g/mL	Budavari et al. 1989
Vapor Density (air = 1)	1.11	Budavari et al. 1989
K_{OC}	9	CHEMFATE 1995
Log K_{OW}	-0.77	CHEMFATE 1995
Vapor Pressure	126 mm Hg at 25°C	CHEMFATE 1995
Flammability	flammable	Budavari et al. 1989
Reactivity	may explode when exposed to flame	HSDB 1995
Dissociation Constant	15.3	CHEMFATE 1995
Flash Point	12°C	Budavari et al. 1989
Henry's Law Constant	4.55×10^{-6} atm·m^3/mol	CHEMFATE 1995
Bioconcentration Factor	0.2 (estimated)	HSDB 1995
Molecular diffusivity coefficient	no data	
Air diffusivity coefficient	no data	
Odor Threshold	100 ppm	Lington and Bevan 1994
Conversion Factors	1 ppm = 1.33 mg/m^3 1 mg/m^3 = 0.764 ppm	Verschueren 1983

II. ENVIRONMENTAL FATE

A. Environmental Release

Methanol ranked third in the U.S. among all chemicals for total releases into the environment in 1992. Of the total released, 195 million pounds were into the atmosphere, 43.5 million pounds were into surface and ground waters, and 3.3 million pounds were onto land (TRI92 1994). Methanol detected in the air from Point Barrow, Alaska averaged 0.77 ppb (CHEMFATE 1995). Ambient concentrations from Stockholm, Sweden, ranged from 3.83 to 26.7 ppb while concentrations from two remote locations in Arizona were 7.9 and 2.6 ppb (HSDB 1995). In one survey, methanol was detected in drinking waters from 6 of 10 U.S. cities (HSDB 1995) but levels were not included. The chemical has also been detected at a level of 22 ppb in rainwater collected from Santa Rita, Arizona (HSDB 1995).

B. Transport

The miscibility of methanol in water and a low K_{OC} of 9 indicate that the chemical will be highly mobile in soil (HSDB 1995). Volatilization half-lives from a model river and an environmental pond were estimated at 4.8 days and 51.7 days, respectively (HSDB 1995). Methanol can be removed from the atmosphere in rain water (HSDB 1995).

C. Transformation/Persistence

1. Air — Once in the atmosphere, methanol exists in the vapor phase with a half life of 17.8 days (HSDB 1995). The chemical reacts with photochemically produced hydroxyl radicals to produce formaldehyde (HSDB 1995). Methanol can also react with nitrogen dioxide in polluted air to form methyl nitrite (HSDB 1995).
2. Soil — Biodegradation is the major route of removal of methanol from soils. Several species of Methylobacterium and Methylomonas isolated from soils are capable of utilizing methanol as a sole carbon source (CHEMFATE 1995).
3. Water — Most methanol is removed from water by biodegradation. The anaerobic degradation products methane and carbon dioxide were detected from aqueous cultures of mixed bacteria isolated from sewage sludge (CHEMFATE 1995). Aerobic, gram-negative bacteria (65 strains) isolated from seawater, sand, mud, and weeds of marine origin utilized methanol as a sole carbon source (CHEMFATE 1995). Aquatic hydrolysis, oxidation, and photolysis are not significant fate processes for methanol (HSDB 1995).
4. Biota — Bioaccumulation of methanol in aquatic organisms is not expected to be significant based on an estimated bioconcentration factor of 0.2 (HSDB 1995).

CHEMICAL SUMMARY FOR *p*-TOLUENE SULFONIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of *p*-toluene sulfonic acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF *p*-TOLUENE SULFONIC ACID

Characteristic/Property	Data	Reference
CAS No.	104-15-4	
Common Synonyms	4-Methylbenzenesulfonic acid; tosic acid	Budavari et al. 1989
Molecular Formula	$C_7H_8O_3S$	
Chemical Structure	$CH_3C_6H_4SO_3H$	Budavari et al. 1989
Physical State	Crystalline; monoclinic leaflets or prisms	Budavari et al. 1989
Molecular Weight	172.2	Budavari et al. 1989
Melting Point	106-107°C (anhydrous) 38°C (metastable form)	Budavari et al. 1989
Boiling Point	140°C @ 20 mm Hg	Weast 1987
Water Solubility	67 g/100 mL (approximate)	Budavari et al. 1989
Specific Gravity	No data	
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	Low	HSDB 1995
Reactivity	NFPA reactivity, 1; normally stable, but may become unstable at elevated temperatures. Releases toxic fumes of SO_x when heated to decomposition.	HSDB 1995
Flammability	NFPA flammability, 1; must be preheated before ignition can occur.	HSDB 1995
Flash Point	184°C	HSDB 1995
Dissociation Constant	-1.34 (measured, uncertain)	CHEMFATE 1995
Henry's Law Constant	Very low due to low vapor pressure and high solubility.	HSDB 1995
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	No data, predicted low.	HSDB 1995
Taste Threshold	No data	
Conversion Factors	1 ppm = 7.03 mg/m^3; 1 mg/m^3 = 0.142 ppm	Calculated

a) Calculated utilizing: mg/m^3 = ppm x MW/24.5 @ 25°C & 760 mm Hg.

II. ENVIRONMENTAL FATE

A. Environmental Release

p-Toluene sulfonic acid is manufactured for use as a chemical intermediate in the synthesis of dyes, antidiabetic drugs, chemicals used in detergents, and in the synthesis of other organic chemicals (Budavari et al. 1989; HSDB 1995). The exposure of humans to *p*-toluene sulfonic acid is primarily by dermal contact or inhalation during the manufacture or use of the chemical in occupational settings (HSDB 1995). Due to its high water solubility (about 67 g/100 mL), exposure may also occur in drinking water. *p*-Toluene sulfonic acid has been detected qualitatively in lowland river water and in groundwater in Britain (HSDB 1995). Based on a 1983 National Institute for Occupational Safety and Health (NIOSH) National

Occupational Hazard Survey, 16,526 workers are potentially exposed to *p*-toluene sulfonic acid in the U.S. (HSDB 1995).

B. Transport

Because of its water solubility, p-toluene sulfonic acid is expected to be highly mobile in soils and leach rapidly into ground waters. Once in the water, the chemical should not move into the atmosphere or onto sediments, but will degrade slowly (HSDB 1995).

C. Transformation/Persistence

1. Air — Very small amounts of *p*-toluene sulfonic acid enter the atmosphere from water solutions or from the involatile solid. Once in the air, it rapidly reacts with hydroxyl radicals resulting in a half-life of about 2 days (HSDB 1995).
2. Soil — Specific studies on the transformation/persistence of *p*-toluene sulfonic acid in the soil were not available; however, *p*-toluene sulfonic acid is expected to rapidly leach from the soil into ground water because of it's high solubility. It is not expected to volatilize into the atmosphere from the soil (HSDB 1995). Although biodegradation is known to occur in water (see II.C.3.), specific information on the biodegradation of *p*-toluene sulfonic acid in the soil is not available (HSDB 1995).
3. Water — *p*-Toluene sulfonic acid primarily enters the environment in wastewater from its production and use. It is ionized in solution and does not significantly transfer into the sediment or into the atmosphere from the aquatic environment (HSDB 1995). It does not absorb light above 290 nm in solution and will not photodegrade or react with water under environmental conditions (HSDB 1995). Biodegradation is highly dependent on the presence of the proper acclimated microbial populations. Complete (100%) degradation in a few days was reported with activated sludge, whereas no degradation was seen for up to 64 days in the absence of activated microorganisms (HSDB 1995). *Pseudomonas* bacteria have been isolated from sludge and river water that can utilize *p*-toluene sulfonic acid as a sole carbon and sulfur source (CHEMFATE 1995; Kertesz et al. 1994).
4. Biota — Although no specific data are available, *p*-toluene sulfonic acid is not expected to bioconcentrate since it is highly water soluble and ionized in solution (HSDB 1995). Experiments with *Ricinus communis L.* (castor bean) have shown that plants absorb and transport *p*-toluene sulfonic acid to the leaves (Bromilow et al. 1993); however, it is not expected to bioconcentrate in food products (HSDB 1995).

CHEMICAL SUMMARY FOR PALLADIUM AND PALLADIUM CHLORIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of palladium and palladium chloride are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF PALLADIUM

Characteristic/Property	Data	Reference
CAS No.	7440-05-3	
Common Synonyms	none found in the secondary sources searched	
Molecular Formula	Pd	
Chemical Structure	Pd	
Physical State	silver-white, ductile metal	HSDB 1995
Molecular Weight	106.4	HSDB 1995
Melting Point	not found	
Boiling Point	not found	
Water Solubility	insoluble	HSDB 1995
Density	12.02 g/cm^3	HSDB 1995
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	not found	
Reactivity	appreciably volatile at high temperatures; is converted to the oxide at red heat; can absorb and retain over 800 times its volume of hydrogen, resulting in an expansion of several percent; incompatible with arsenic, carbon, ozonides, sodium tetrahydroborate, and sulfur	HSDB 1995
Flammability	palladium black or finely divided palladium is usually pyrophoric and requires handling precautions; the dust of palladium can be a fire and explosion hazard	HSDB 1995
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	not applicable	

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF PALLADIUM CHLORIDE

Characteristic/Property	Data	Reference
CAS No.	7647-10-1	
Common Synonyms	palladium(2+) chloride; palladous chloride	RTECS 1995
Molecular Formula	$PdCl_2$	
Chemical Structure	Cl_2-Pd	
Physical State	dark red cubic needles	HSDB 1995
Molecular Weight	177.30	HSDB 1995
Melting Point	678-680°C; deliquescent, decomposes at 500°C	HSDB 1995
Boiling Point	not found	
Water Solubility	soluble	HSDB 1995
Density	6.0 g/m^3	HSDB 1995
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	not found	
Reactivity	not found	
Flammability	not found	
	not found	
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	1 ppm = 7.25 mg/m^3 1 mg/m^3 = 0.138 ppm	Calculated using: ppm = mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

Palladium occurs in the earth's crust, at the concentration of 0.2 ppm, in association with the rare metals of Group VIII (platinum, ruthenium, rhodium, osmium, and iridium) (Venugopal and Luckey 1978; Amdur et al. 1991). The release of palladium to the environment may occur as a result of the mining, refining, fabrication, and use of the metal (Seiler and Sigel 1988). Palladium has been incorporated into catalysts used to control emissions in automobile exhausts; however, the minute quantities emitted are in a biologically inert form (Seiler and Sigel 1988). No significant concentrations were detected near busy highways following 10 years of this use (Seiler and Sigel 1988).

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of palladium or palladium chloride.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of palladium or palladium chloride in air.
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of palladium or palladium chloride in soil.
3. Water — No information was found in the secondary sources searched regarding the transformation/persistence of palladium or palladium chloride in water.
4. Biota — There is no evidence that palladium accumulates in mammals following ingestion (HSDB 1995); however, the metal was present in all tissues analyzed from rats 104 days after intravenous injection (Beliles 1994a).

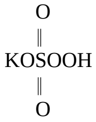
CHEMICAL SUMMARY FOR PEROXYMONOSULFURIC ACID, MONOPOTASSIUM SALT

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, conductive polymer, and graphite processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of peroxymonosulfuric acid, monopotassium salt are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF PEROXYMONOSULFURIC ACID, MONOPOTASSIUM SALT

Characteristic/Property	Data	Reference
CAS No.	10058-23-8	
Common Synonyms	monopotassium peroxymonosulfurate; potassium peroxymonosulfate	RTECS 1995
Molecular Formula	HO_5SK	RTECS 1995
Chemical Structure	 $\mathrm{KO}\underset{\underset{\displaystyle O}{\|}}{\overset{\overset{\displaystyle O}{\|}}{\mathrm{S}}}\mathrm{OOH}$	
Physical State	no data	
Molecular Weight	152.17	RTECS 1995
Melting Point	no data	
Boiling Point	no data	
Water Solubility	no data	
Density	no data	
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	no data	
Flammability	no data	
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information on the environmental release of peroxymonosulfuric acid, monopotassium salt were found in the secondary sources searched.

B. Transport

No information on the transport of peroxymonosulfuric acid, monopotassium salt was found in the secondary sources searched.

C. Transformation/Persistence

No information on the transformation/persistence of peroxymonosulfuric acid, monopotassium salt in air, soil, water, or biota was found in the secondary sources searched.

CHEMICAL SUMMARY FOR PHENOL-FORMALDEHYDE COPOLYMER

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of phenol-formaldehyde copolymer are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF PHENOL-FORMALDEHYDE COPOLYMER

Characteristic/Property	Data	Reference
CAS No.	9003-35-4	Harris and Sarvadi 1994
Common Synonyms	Phenol-formaldehyde resin	Harris and Sarvadi 1994
Molecular Formula	$(C_6H_6O.CH_2O)_n$	Harris and Sarvadi 1994
Chemical Structure	not found	
Physical State	solid (when cured) viscous liquid (uncured)	
Molecular Weight	300-700 (one-step process)[a]	Harris and Sarvadi 1994
	1200-1500 (two-step process)[a]	Harris and Sarvadi 1994
	Several hundred thousand (cured resin)	Harris and Sarvadi 1994
Melting Point	not found	
Boiling Point	not found	
Water Solubility	Soluble (non-cured resin)	Harris and Sarvadi 1994
	Insoluble (cured resin)	Harris and Sarvadi 1994
Density	not found	
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	not found	
Reactivity	High chemical resistance	Harris and Sarvadi 1994
Flammability	Fire retardant	Harris and Sarvadi 1994
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	not found	

a) "One-step" and "two-step" refer to the manufacturing process used to make the resin.

II. ENVIRONMENTAL FATE

A. Environmental Release

Phenol-formaldehyde (PF) copolymer is used in a wide variety of products including wood composites (plywood, particleboard, fiberboard), molding materials (in appliances, electric controls, telephones, and wiring services), and as a binder for thermal and sound insulation materials (e.g., glass fibers and mineral wool) (Opresko 1991). There are no reports of any detrimental toxic effects from cured phenolic resins; therefore, the greatest hazards associated with these substances is expected to occur during the manufacture, processing, and handling of the uncured resin (Opresko 1991). However, loss of both phenol and formaldehyde has been observed for many months after fabrication of foam insulation for refrigerators (Opresko 1991). Phenol was identified as one of a number of volatile organic compounds found in indoor air as a result of emissions from construction and interior finish materials and adhesives used in such products (Opresko 1991). A study on workers exposed to phenolic resin fumes for periods of less than 1 year to more than 5 years reported PF component levels of 7-10 mg phenol/m^3 and 0.5-1.0 mg formaldehyde/m^3 (Opresko 1991). Most environmental release of PF components would likely come from such manufacturing operations. Both monomeric components of PF copolymer, phenol and formaldehyde, have been profiled separately (U.S. EPA 1995a, 1996a).

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of PF copolymer. Cured PF resin is a water insoluble solid and would not be a likely groundwater contaminant. Offgassing of PF component monomers during processing and, to a lesser extent, after curing would be the most probable mode of environmental transport.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of PF copolymer in air.
2. Soil — PF copolymer is highly resistant to biological decay (Harris and Sarvadi 1994). This fact, coupled with its low water solubility, suggest that PF copolymer would be persistent in soil.
3. Water — No information was found in the secondary sources searched regarding the transformation/persistence of PF copolymer in water. Because of its very low water solubility, cured PF copolymer is not likely to be a contaminant of groundwater.
4. Biota — No information was found in the secondary sources searched regarding the bioaccumulation of PF copolymer.

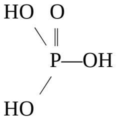
CHEMICAL SUMMARY FOR PHOSPHORIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the conductive polymer and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of phosphoric acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF PHOSPHORIC ACID

Characteristic/Property	Data	Reference
CAS No.	7664-38-2	
Common Synonyms	orthopohosphoric acid	Budavari et al.1989
Molecular Formula	H_3O_4P	Budavari et al.1989
Chemical Structure		Budavari et al.1989
Physical State	unstable, orthorhombic crystals or syrupy liquid	Budavari et al.1989
Molecular Weight	98.00	Budavari et al.1989
Melting Point	42.35	Budavari et al.1989
Boiling Point	@ 213° C losing ½ water	HSDB 1995
Water Solubility	548g/100 mL	HSDB 1995
Density	1.8741 @ 25 (100% soln.)	Budavari et al.1989
Vapor Density (air = 1)	3.4	HSDB 1995
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	0.03 mm Hg @ 20°C	
Reactivity	Hot concd acid attacks porcelain and granite ware	Budavari et al.1989
	Reacts w/metals to liberate flammable H_2 gas	HSDB 1995
	sodium tetraborate; aldehydes; cyanides	HSDB 1995
	bleach; ammonia	NIOSH 1994
Flammability	not combustible, but contact w/common metals liberates hydrogen	HSDB 1995
Flash Point	no data	
Dissociation Constant	K_1=7.107 x 10^{-3}	Budavari 1989
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	Odorless	HSDB 1995
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Of the total 206.6 million pounds of phosphoric acid released into the environment in 1992, as reported to the TRI by certain types of U.S. industries, 1.2 million pounds were released into the atmosphere, 158.7 million pounds were released into ground or surface waters, and 46.7 million pounds were released onto the land (TRI92 1994).

B. Transport

When spilled onto soil, phosphoric acid will infiltrate downward, the rate being greater with lower concentrations because of reduced viscosity. Upon reaching the groundwater table, phosphoric acid will move in the direction of the groundwater flow (HSDB 1995).

C. Transformation/Persistence

1. Air — Phosphoric acid may be present in air as a mist or a vapor, but it exists primarily as a mist because of its low volatility and its affinity for water (IARC 1992).
2. Soil — During transport through soil, phosphoric acid will dissolve some of the soil material, in particular carbonate based materials. The acid will be neutralized to some degree with adsorption of the proton and phosphate ions also possible. However significant amounts of acid will remain for transport to groundwater (HSDB 1995).
3. Water — Upon reaching groundwater, a contaminated plume will be produced with dilution and dispersion serving to reduce the acid concentration (HSDB 1995). However, while acidity may be reduced readily by natural water hardness minerals, the phosphate may persist indefinitely (HSDB 1995).
4. Biota — No information was found in the secondary sources searched regarding the transformation/persistence of phosphoric acid in biota. Phosphoric acid is a natural constituent of many fruits and their juices (HSDB 1995).

CHEMICAL SUMMARY FOR POTASSIUM BISULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium bisulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM BISULFATE

Characteristic/Property	Data	Reference
CAS No.	7646-93-7	
Common Synonyms	monopotassium sulfate; potassium acid sulfate; potassium bisulphate; sulfuric acid, monopotassium salt	RTECS 1995
Molecular Formula	$KHSO_4$	JT Baker Inc. 1992
Chemical Structure	$H\text{-}O_4\text{-}S.K$	RTECS 1995
Physical State	white, deliquescent crystals	Budavari et al. 1989
Molecular Weight	136.17	Budavari et al. 1989
Melting Point	197°C (loses water at higher temperatures, and is converted to pyrosulfate)	Budavari et al. 1989
Boiling Point	decomposes	Fisher Scientific 1991
Water Solubility	soluble in 1.8 parts water; 0.85 parts boiling water	Budavari et al. 1989
Density	2.24	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	negligible	Fisher Scientific 1991
Reactivity	0 (nonreactive, NFPA classification); can form an explosive mixture; acidic in solution	Lockheed Martin 1989 Sax and Lewis 1989 Fisher Scientific 1991
Flammability	0 (noncombustible, NFPA classification)	Lockheed Martin 1989a
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data; odorless; sulfur odor	JT Baker Inc. 1992 Fisher Scientific 1991
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Potassium bisulfate is a deliquescent solid that is soluble in water. It is used as flux in the analysis of ores, and as a cathartic (Budavari et al. 1989). No data were found on the environmental releases of potassium bisulfate in the secondary sources searched. The chemical is not listed on U.S. EPA's TRI, requiring certain U.S. industries to report on chemical releases to the environment (TRI93 1995).

B. Transport

No data were found on the environmental transport of potassium bisulfate in the secondary sources searched. Low vapor pressure and its water solubility suggest that it would remain in the water phase.

C. Transformation/Persistence

No data were found on the transformation/persistence of potassium bisulfate in the secondary sources searched.

CHEMICAL SUMMARY FOR POTASSIUM CARBONATE

This chemical was identified by one or more suppliers as a bath ingredient for the carbon, graphite, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium carbonate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM CARBONATE

Characteristic/Property	Data	Reference
CAS No.	584-08-7	
Common Synonyms	salt of tartar; pearl ash	Budavari et al. 1989
	potash	RTECS 1995
Molecular Formula	K_2CO_3	Budavari et al. 1989
Chemical Structure	K_2CO_3	
Physical State	hygroscopic, odorless granules, or granular powder	Budavari et al. 1989
Molecular Weight	138.20	Budavari et al. 1989
Melting Point	891° C	Budavari et al. 1989
Boiling Point	no data	
Water Solubility	sol. in 1 part cold, 0.7 pts boiling H_2O	Budavari et al. 1989
	112 g/100 mL cold water	HSDB 1995
Density	2.29	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	hygroscopic; aqueous soln strongly alkaline	Budavari et al. 1989
	violent reaction with ClF_3	HSDB 1995
Flammability	no data	
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Potassium carbonate is a naturally occurring compound with deposits found in southeastern New Mexico (HSDB 1995). It is one of the major inorganic particle components of cigarette smoke (Churg and Stevens 1992). Potassium carbonate is not one of the compounds reported to the TRI by certain types of U.S. industries.

B. Transport

No information was found in the secondary sources searched regarding the transport of potassium carbonate.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of potassium carbonate in air, soil, water, or biota.

CHEMICAL SUMMARY FOR POTASSIUM AND SODIUM CYANIDE

These chemicals were identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium and sodium cyanide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM CYANIDE

Characteristic/Property	Data	Reference
CAS No.	151-50-8	
Common Synonyms	hydrocyanic acid, potassium salt	RTECS 1995
Molecular Formula	CKN	Budavari et al. 1989
Chemical Structure	KCN	Budavari et al. 1989
Physical State	white deliquescent granular powder or fused pieces	Budavari et al. 1989
Molecular Weight	65.11	Budavari et al. 1989
Melting Point	634°C	Budavari et al. 1989
Boiling Point	no data	
Water Solubility	71.6 g/100 mL at 25°C	ATSDR 1995
Density	1.553 g/cm^3 at 20°C	U.S. EPA 1985c
Vapor Density (air = 1)	no data	
K_{OC}	3.0 (calculated)	HSDB 1995
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	slowly decomposed by water and very rapidly by acids to release HCN; pH of 0.1 N solution = 11; incompatible with strong oxidizers such as nitrates, chlorates, and acid salts	HSDB 1995
Flammability	not flammable itself, but contact with acids releases highly flammable HCN gas	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	0.3 (calculated)	HSDB 1995
Odor Threshold	faint odor of bitter almonds	ACGIH 1991
Conversion Factors	1 ppm = 2.707 mg/m^3 1 mg/m^3 = 0.369 ppm	U.S. EPA 1985c

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM CYANIDE

Characteristic/Property	Data	Reference
CAS No.	143-33-9	
Common Synonyms	hydrocyanic acid, sodium salt	RTECS 1995
Molecular Formula	CNaN	Budavari et al. 1989
Chemical Structure	NaCN	Budavari et al. 1989
Physical State	white granules or fused pieces	Budavari et al. 1989
Molecular Weight	49.07	Budavari et al. 1989
Melting Point	563°C	Budavari et al. 1989
Boiling Point	1500°C	ACGIH 1991
Water Solubility	freely soluble	Budavari et al. 1989
Density	1.60-1.62 g/cm^3 (temperature not given)	U.S. EPA 1985c
Vapor Density (air = 1)	1.7	JT Baker Inc. 1992b
K_{OC}	no data	
Log K_{OW}	-0.44 (K_{OW})	U.S. EPA 1985c
Vapor Pressure	0.76 mg Hg at 800°C	U.S. EPA 1985c
Reactivity	contact with acids and acid salts forms HCN immediately; incompatible with strong oxidizers, such as nitrates, chlorates, and acid salts; aqueous solution is strongly alkaline	HSDB 1995
Flammability	not combustible itself, but contact with acids releases highly flammable HCN gas	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	0.27 (calculated)	U.S. EPA 1985c
Odor Threshold	faint odor of bitter almonds	HSDB 1995
Conversion Factors	1 ppm = 2.037 mg/m^3 1 mg/m^3 = 0.491 ppm	U.S. EPA 1985c

II. ENVIRONMENTAL FATE

A. Environmental Release

Potassium and sodium cyanide are used in the extraction of gold and silver ores; electroplating; metal cleaning; as insecticides and fumigants; in heat treatment of metals; and as raw materials in the manufacture of dyes, pigments, nylon, and chelating agents (ACGIH 1991). In 1993, releases of cyanide compounds to environmental media, as reported to the TRI by certain types of industries, totaled about 3,291,307 pounds. Of this amount, a total of 898,728 pounds was released to the atmosphere, 97,666 pounds to surface waters, 2,288,870 pounds to underground injection, and 6,043 pounds to land (TRI93 1995). Potassium and sodium cyanide are not reported separately.

B. Transport

Potassium and sodium cyanide release hydrocyanic acid (HCN) to the environment. HCN is expected to volatilize from aquatic media and soils (U.S. EPA 1984c). Cyanide has the potential to be transported in air over long distances from its emission source. Alkali cyanides can be removed from air by both wet and dry deposition (ATSDR 1995). Because of their high water solubility and low sorption characteristics, cyanides are expected to leach through soils into groundwater (U.S. EPA 1985c).

C. Transformation/Persistence

1. Air — Most cyanide in the atmosphere is likely present as HCN gas, but small amounts of metal cyanides may be present as particulate matter in air. HCN slowly reacts with hydroxyl radicals in the air; the calculated half-life for this reaction is approximately 11 years, indicating no significant loss to the troposphere. Physical transfer, such as wet and dry deposition, may

dominate the fate of cyanides in the atmosphere. Considering the water solubility of alkali cyanides, wet deposition appears to be more important process (U.S. EPA 1984c).

2. Soil — In soils, the fate of cyanides is pH dependent. In acidic soils, the loss of HCN through volatilization may be the predominant mechanism of loss from soil surfaces. In subsurface soils, cyanides that are present at low concentrations (below the toxic levels for microorganisms) may undergo some microbial degradation (U.S. EPA 1984c). Because of their low soil sorption characteristics and high water solubility of cyanides, some may leach through the soil. However, cyanides have been rarely detected in groundwater. In basic soils, the mobility of cyanides is expected to be greatly restricted (U.S. EPA 1984c).
3. Water — The alkali metal salts, such as sodium and potassium cyanide, are very soluble in water and the resulting cyanide ions readily hydrolyze with water to form HCN. The extent of HCN formation is mainly dependent upon water temperature and pH. At 20°C and a pH of 8 or below, at least 96% of free cyanide exists as HCN (U.S. EPA 1980). Since the pH of most natural waters ranges between 6 and 9, a large percentage of cyanides will be present in the form of HCN which readily volatilizes from water. Cyanides can be biodegraded at low concentrations in water by single and mixed organisms. Both aerobic and anaerobic microbial degradation of cyanides during sewage treatment plant operations have been demonstrated (U.S. EPA 1985c).
4. Biota — Potassium and sodium cyanide are not expected to bioaccumulate in aquatic organisms (U.S. EPA 1984c).

CHEMICAL SUMMARY FOR POTASSIUM HYDROXIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, carbon, and non-formaldehyde electroless copper processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium hydroxide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM HYDROXIDE

Characteristic/Property	Data	Reference
CAS No.	1310-58-3	
Common Synonyms	caustic potash; lye; potassium hydrate	HSDB 1995
Molecular Formula	KOH	
Chemical Structure	K-OH	
Physical State	white or slightly yellow lumps, rods, pellets; deliquesces as moisture and carbon dioxide are absorbed from the air	HSDB 1995
Molecular Weight	56.11	HSDB 1995
Melting Point	360°C	Pierce 1994
Boiling Point	1324 °C	HSDB 1995
Water Solubility	100 g/90 mL; aqueous solution may have pH ≥13	HSDB 1995; Pierce 1994a
Density	2.044 mg/mL	HSDB 1995
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	1 mm Hg @ 714°C	HSDB 1995
pH	14 (1.0 M solution)	Lockheed Martin 1994b
Reactivity	heat generated when KOH dissolves in water, alcohol, or acid-treated solution; reacts violently with *O*-nitrophenol; heating with tetrachloroethane, 1,2-dichloroethylene, or phosphorus forms spontaneously flammable compounds; explosive when heated or reacted with certain compounds	HSDB 1995
Flammability	will not burn; however, may react with water and other substances and generate heat sufficient to ignite combustible materials	HSDB 1995; NIOSH 1994
Flash Point	not flammable	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	1 ppm = 2.29 mg/m^3 1 mg/m^3 = 0.44 ppm	Calculated using: ppm = mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of potassium hydroxide.

B. Transport

The significant water solubility of potassium hydroxide suggests that the chemical would be mobile in soil and subject to transport to ground water; however, no evidence was found to confirm this.

C. Transformation/Persistence

1. Air — When exposed to air, potassium hydroxide forms the bicarbonate and carbonate (Pierce 1994a).
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of potassium hydroxide in soil.
3. Water — No information was found in the secondary sources searched regarding the transformation/persistence of potassium hydroxide in water.
4. Biota — No information was found in the secondary sources searched regarding the transformation/persistence of potassium hydroxide in biota.

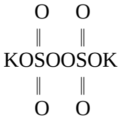
CHEMICAL SUMMARY FOR POTASSIUM PERSULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and non-formaldehyde electroless copper processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium persulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM PERSULFATE

Characteristic/Property	Data	Reference
CAS No.	7727-21-1	
Common Synonyms	peroxydisulfuric acid, dipotassium salt; dipotassium persulfate; potassium peroxydisulfate	HSDB 1995
Molecular Formula	$K_2O_8S_2$	Budavari et al. 1989
Chemical Structure	 $KO\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}OO\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}OK$	
Physical State	colorless or white crystals	Budavari et al. 1989
Molecular Weight	270.32	Budavari et al. 1989
Melting Point	decomposes @ 100°C	Budavari et al. 1989
Boiling Point	no data	
Water Solubility	1.75 g/100 mL @ 0°C; 5.2 g/100 mL @ 20°C	HSDB 1995
Density	2.477	Lide 1991
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	powerful oxidizing agent; aqueous solution is acidic	Budavari et al. 1989
Flammability	may ignite other combustible materials; reaction with fuels may be violent; combustion reaction with metallic dust in the presence of moisture	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Potassium persulfate, a crystalline solid, is moderately soluble in water (Budavari et al. 1989). No data on the environmental release of potassium persulfate were found in the secondary sources searched.

B. Transport

No information on the transport of potassium persulfate was found in the secondary sources searched. The water solubility of potassium persulfate suggests that the chemical would leach through soil.

C. Transformation/Persistence

No information on the transformation/persistence of potassium persulfate in air, soil, water, or biota was found in the secondary sources searched.

CHEMICAL SUMMARY FOR POTASSIUM SULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium sulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM SULFATE

Characteristic/Property	Data	Reference
CAS No.	7778-80-5	
Common Synonyms	sulfuric acid, dipotassium salt; dipotassium sulfate	HSDB 1995
Molecular Formula	K_2SO_4	Budavari et al. 1989
Chemical Structure	K_2O_4S	Budavari et al. 1989
Physical State	colorless or white, hard, bitter crystals; or white granules or powder	Budavari et al. 1989
Molecular Weight	174.26	Budavari et al. 1989
Melting Point	1067°C	Budavari et al. 1989
Boiling Point	1689°C	HSDB 1995
Water Solubility	1 g/8.3 mL	Budavari et al. 1989
Density	2.66	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	permanent in air non-reactive	Budavari et al. 1989 JT Baker Inc. 1992c
Flammability	non-flammable	JT Baker Inc. 1992c
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of potassium sulfate. Potassium sulfate is a minor component of pulverized fuel ash (Davison et al. 1986). Potassium sulfate is not one of the chemicals reported to the TRI by certain types of U.S. industries.

B. Transport

No information was found in the secondary sources searched regarding the transport of potassium sulfate, however it is soluble in water and could be expected to move through the environment.

C. Transformation/Persistence

1. Air — Potassium sulfate is water soluble and atmospheric potassium sulfate would be expected to be dissolved in rainwater.
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of potassium sulfate in soil.
3. Water — No information was found in the secondary sources searched regarding the transformation/persistence of potassium sulfate in water. Aqueous solutions of potassium sulfate are pH neutral (Budavari et al. 1989).
4. Biota — No information was found in the secondary sources searched regarding the transformation/persistence of potassium sulfate in biota.

CHEMICAL SUMMARY FOR POTASSIUM SODIUM TARTRATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of potassium sodium tartrate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF POTASSIUM SODIUM TARTRATE

Characteristic/Property	Data	Reference
CAS No.	6381-59-5; 304-59-6; 147-79-5	
Common Synonyms	Rochelle salt; seignette salt	Budavari et al. 1996 HSDB 1996
Molecular Formula	$C_4H_4KNaO_6$	Budavari et al. 1996
Chemical Structure	no data	
Physical State	translucent crystals of white, crystalline powder	Budavari et al. 1996
Molecular Weight	210.16	Budavari et al. 1996
Melting Point	70-80° C	Budavari et al. 1996
Boiling Point	220° C decomposes	Budavari et al. 1996
Water Solubility	soluble in 0.9 parts H_2O 52%	Budavari et al. 1996
Density	1.79	Budavari et al. 1996
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	incompatible with acids, calcium or lead salts magnesium sulfate, silver nitrate	Budavari et al. 1996
Flammability	slight	JT Baker, Inc. 1992d
Flash Point	none	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	EM Industries 1992
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of potassium sodium tartrate. Potassium sodium tartrate is not one of the chemicals reported to the TRI by certain types of U.S. industries.

B. Transport

No information was found in the secondary sources searched regarding the transport of potassium sodium tartrate. It is, however, very soluble in water.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of potassium sodium tartrate in air, soil, water, or biota. It is, however, very soluble in water.

CHEMICAL SUMMARY FOR SILVER

This chemical was identified by one or more suppliers as a bath ingredient for the conductive ink process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of silver are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SILVER

Characteristic/Property	Data	Reference
CAS No.	7440-22-4	
Common Synonyms	Argentum crede; collargol	U.S. EPA 1996b
Molecular Formula	Ag	ATSDR 1990c
Chemical Structure	Ag; Ag^{1+}; Ag^{2+}	ATSDR 1990c
Physical State	Malleable, ductile, white metal	Budavari et al. 1996
Molecular Weight	107.868	Budavari et al. 1996
Melting Point	960.5°C	Budavari et al. 1996
Boiling Point	2212°C @ 760 mm Hg	ATSDR 1990c
Water Solubility	Insoluble	ATSDR 1990c
Density	10.50 g/cm^3 @ 20°C	ATSDR 1990c
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	100 mm Hg @ 1865°C	ATSDR 1990c
Reactivity	Forms explosive acetylide; forms explosive fulminate compounds with ammonia and with nitric acid + ethanol; reacts violently or produces explosive compounds with bromazide, hydrogen peroxide, ethyleneimine, chlorine, trifluoride, oxalic acid and tartaric acid.	HSDB 1996
Flammability	Moderately flammable as dust	ATSDR 1990c
Flash Point	No data	
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	2 - 10	ATSDR 1990c
Odor Threshold	No data	
Conversion Factors	Not applicable, found in air as particulate material	ATSDR 1990c

II. ENVIRONMENTAL FATE

A. Environmental Release

Silver is a naturally occurring element that is present in the earth's crust at an average concentration of about 0.1 ppm and at about 0.3 ppm in soils (ATSDR 1990c). It is also present in unpolluted freshwater at concentrations up to 0.5 ppm and in seawater at about 0.01 ppm (HSDB 1996). Silver is released into the environment from mining and recovery processes, and industrial production processes. It is released into the atmosphere during refuse incineration and from burning of coal and petroleum products. Silver and silver compounds are also released from consumer products (ATSDR 1990c). Products and uses include photography, electroplating, electrical conductors, dental alloys, solder and brazing alloys, paints, jewelry, coins, and mirror construction (Faust 1992a). The largest source of silver release through consumer products is photographic material. Silver in the form of silver iodide has been used as cloud seeding material (ATSDR 1990c). Background atmospheric levels of silver measured in national parks away from industrialized areas are generally less than 0.2 ng/m^3, however, the concentration can be much higher near smelter plants (up to 36.5 ng/m^3) or in cloud-seeding target areas (1.0 ng/m^3) (ATSDR 1990c). Releases into surface waters have resulted in concentrations up to 38 ppm found in the Colorado River, and concentrations as high as 5 ppm in finished drinking water samples. Sediments in the Genesee River in New York downstream from a plant manufacturing photography supplies were found to contain 150 mg silver/kg dry weight (HSDB 1996).

Releases of silver and silver compounds to environmental media in 1993, as reported to the TRI by certain types of U.S. industries totaled about 8608 pounds of elemental silver and 57,168 pounds of silver compounds. Of these amounts, totals of 7080 pounds silver and 21,623 pounds silver compounds were released to the atmosphere, 318 pounds of silver and 9069 pounds of silver compounds were released to surface water, 210 pounds silver and 100 pounds silver compounds were released in underground injection, and 1000 pounds silver and 20,376 pounds of silver compounds were released to land (TRI93 1995).

B. Transport

Metallic silver released to the atmosphere as particulate material undergoes deposition to land and surface water (ATSDR 1990c). If the particulate material is finely divided (<20μ diameter), it can possibly travel long distances before depositing resulting in an enrichment of soil silver levels in areas distant from cloud seeding operations or other sources of airborne silver. Large particles (>20μ diameter) such as released during mining operations are deposited near the source (ATSDR 1990c). Transport of silver in surface waters is dependent upon the particular chemical form of the element. Silver can form a number of complexes and salts under certain aquatic conditions of pH and reactant availability. Some compounds precipitate, some adsorb onto particulate matter, and some are soluble and may travel long distances in solution. Up to 90% of the silver detected in rivers was estimated to be in a dissolved form (ATSDR 1990c). Silver tends to be removed from well drained soils; however, the pH, oxidation-reduction potential, and the presence of organic material can affect the mobility. Iron and manganese complexes can immobilize silver, and organic material adsorbs silver (ATSDR 1990c).

C. Transformation/Persistence

1. Air —Atmospheric silver is in particulate form and is likely to become coated with silver oxide, silver sulfide, or silver carbonate before deposition. Large particles (>20μ) such as released during mining operations are deposited near the source, whereas finer particles (<20μ diameter) generated by burning refuse or fossil fuels and by cloud seeding can be carried long distances before being deposited in precipitation (ATSDR 1990c).
2. Soil —Iron and magnesium complexes in the soil tend to immobilize silver and are dependent on pH and oxidation-reduction potential of the soil. Organic matter complexes with silver and also reduces its mobility. The persistence of silver in soils is also dependent on the drainage of the soil and will eventually be removed from well drained soils (ATSDR 1990c).
3. Water —Silver in water exists primarily as the monovalent ion, which can be combined with sulfate, bicarbonate, chloride, and ammonia. It was estimated that about 90% of the silver in rivers is in a dissolved form and the remaining 10% is in suspended solids. Depending on the pH and oxidation-reduction conditions, silver can be adsorbed to manganese oxide, which will eventually be deposited in sediment. It may also become adsorbed onto humic material and suspended particulates. In the presence of decaying animal and plant material, silver precipitates as the sulfide. The sediments in lakes were generally found to be about 1000 times higher in silver concentration than the overlying waters (ATSDR 1990c).

4. Biota —Silver does not tend to bioaccumulate in fish (bioaccumulation factors of 2-10). However, it can be adsorbed by marine algae and accumulated. Bioconcentration factors for marine algae of 13,000 to 66,000 have been calculated (ATSDR 1990c). Silver is absorbed by mussels, clams, and oysters. Bioconcentration factors of 1055 to 7650 have been determined for the marine mussel, *Mytilus edulis*. Biological half-lives of 26.4 and 149.1 days have been estimated for the pacific and American oysters, respectively. It is absorbed from the soil by plant roots and accumulates in the leaves from atmosphere deposition. (ATSDR 1990c).

CHEMICAL SUMMARY FOR SODIUM BISULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, organic-palladium, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium bisulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM BISULFATE

Characteristic/Property	Data	Reference
CAS No.	7681-38-1	
Common Synonyms	sodium acid sulfate; sodium hydrogen sulfate sodium pyrosulfate	Budavari et al. 1989
Molecular Formula	$NaHSO_4$	Budavari et al. 1989
Chemical Structure	$HNaO_4S$	Budavari et al. 1989
Physical State	Fused, hygroscopic pieces; monohydrate, crystalline	Budavari et al. 1989
Molecular Weight	120.07	Budavari et al. 1989
Melting Point	315 °C	Budavari et al. 1989
Boiling Point	No data	
Water Solubility	50 g/100 mL 100 g/100 mL boiling water	Budavari et al. 1989
Specific Gravity	2.435	Budavari et al. 1989
Vapor Density (air = 1)	No data	
K_{OC}	No data	
Log K_{OW}	No data	
Vapor Pressure	No data	
Reactivity	Corrosive,	RTECS 1995
	water solutions are acidic, decomposes by alcohol to liberate sulfuric acid,	Budavari et al. 1989
	SO_2 gas produced when heated to decomposition.	JT Baker Inc. 1995
Flammability	Non-flammable	JT Baker Inc. 1995
Flash Point	No data	
Dissociation Constant	No data	
Henry's Law Constant	No data	
Molecular Diffusivity Coefficient	No data	
Air Diffusivity Coefficient	No data	
Fish Bioconcentration Factor	No data	
Taste Threshold	No data	
Odor Threshold	Odorless	JT Baker Inc. 1995
Conversion Factors	Not applicable, material contained in water aerosol or present as dust	

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium bisulfate is manufactured for use as a solubilizer for minerals, for pickling metals, carbonizing wool, bleaching and swelling leather, and in the manufacture of magnesia cements (Budavari et al. 1989). It is also used in the agricultural industry as a disinfectant (RTECS 1995). The total number of individuals occupationally exposed to sodium bisulfate in a National Occupational Exposure Survey in 1983 was 151,380 (RTECS 1995).

B. Transport

No information on the transport of sodium bisulfate was found in the secondary sources searched. In areas where the chemical is used, it has been found in airborne dusts and in water aerosols (JT Baker Inc. 1995; Utell et al. 1982). Due to its high water solubility, about 50 g/100 mL (Budavari et al. 1989), transport by water is a possibility.

C. Transformation/Persistence

1. Air — No information on the transformation/persistence of sodium bisulfate was found in the secondary sources searched. Aerosols and dusts in industrial settings are controlled by exhaust ventilation (JT Baker Inc. 1995).
2. Soil — Specific studies on the transformation/persistence of sodium bisulfate in the soil were not found in the secondary sources searched; however, sodium bisulfate is likely to rapidly leach from the soil into ground water because of its high solubility. It is a non-volatile solid and should not volatize into the atmosphere from the soil, although it may become airborne in dust (JT Baker Inc. 1995).
3. Water — No studies on the transformation/persistence of sodium bisulfate in water were found in the secondary sources searched. Sodium bisulfate is strongly acidic in water solution (Budavari et al. 1989) and, therefore, is subject to neutralization and salt formation by water soluble cations.
4. Biota — No information on the transformation/persistence of sodium bisulfate in biota was found in the secondary sources searched. The water solubility and acidity of sodium bisulfate in solution make bioconcentration unlikely.

CHEMICAL SUMMARY FOR SODIUM CARBONATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, conductive polymer, and organic-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium carbonate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM CARBONATE

Characteristic/Property	Data	Reference
CAS No.	497-19-8	
Common Synonyms	carbonic acid, disodium salt; disodium carbonate; soda ash; trona; Solvay soda	RTECS 1995
Molecular Formula	CNa_2O_3	Budavari et al. 1989
Chemical Structure	Na_2CO_3	Budavari et al. 1989
Physical State	white hygroscopic powder	Pierce 1994b
Molecular Weight	106.0	Budavari et al. 1989
Melting Point	851°C, but begins to lose CO_2 @ 400°C	Budavari et al. 1989
Boiling Point	decomposes	Pierce 1994b
Water Solubility	7.1 g/100 mL water @ 0°C; 45.5 g/100 mL @ 100°C	Pierce 1994b
Density	2.53 @ 20°C	Pierce 1994b
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	decomposed by acids with effervescence; combines with water with evolution of heat; 1% aqueous solution has pH of 11.5	Budavari et al. 1989 Pierce 1994b
Flammability	noncombustible	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	not applicable	

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium carbonate is a white hygroscopic powder that is strongly caustic (Pierce 1994b). It is moderately soluble in water (Budavari et al. 1989). It is usually encountered as the decahydrate ($Na_2CO_3 \cdot 10H_2O$), commonly called washing soda or soda ash (Pierce 1994b). Sodium carbonate occurs naturally in large deposits in Africa and the U.S. as either the carbonate or trona, a mixed ore of equal molar amounts of carbonate and bicarbonate (Pierce 1994b). Naturally occurring hydrates include the monohydrate, thermonitrite, and the decahydrate, natron or natrite (Budavari et al. 1989). Sodium carbonate is used in the manufacture of glass and sodium salts; in soaps and strong cleansing agents; water softeners; pulp and paper manufacture; textile treatments; and various chemical processes. Sodium carbonate is not listed on the U.S. EPA's TRI, requiring certain U.S. industries to report on chemical releases to the environment (TRI93 1995).

B. Transport

No information on the transport of sodium carbonate was found in the secondary sources searched. The water solubility suggests that the chemical would leach through soil.

C. Transformation/Persistence

No information on the transformation/persistence of sodium carbonate was found in the secondary sources searched. The water solubility suggests that the chemical would remain in the aqueous phase.

CHEMICAL SUMMARY FOR SODIUM CHLORIDE

This chemical was identified by one or more suppliers as a bath ingredient for the tin-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium chloride are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM CARBONATE

Characteristic/Property	Data	Reference
CAS No.	7647-14-5	
Common Synonyms	table salt, rock salt, sea salt, halite	Budavari et al. 1996; HSDB 1996
Molecular Formula	NaCl	Budavari et al. 1996
Chemical Structure	Cl - Na	Budavari et al. 1996
Physical State	Cubic white crystals, granules, or powder, colorless and transparent or translucent when in large crystals	Budavari et al. 1996
Molecular Weight	58.44	Budavari et al. 1996
Melting Point	804 °C, 801°C, 804-1600°C	Budavari et al. 1996; Chapman and Hall 1996; Perry et al. 1994
Boiling Point	1413 °C	Chapman and Hall 1996
Water Solubility	1 g/2.8 mL water @ 25 °C	Budavari et al. 1996;
	35.7 g/100 cm^3@ 0 °C	Chapman and Hall 1996;
	39.12 g/100 cm^3@100 °C	Lide 1991
Density	2.165 g/mL @ 25 °C	Lide 1991
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW} (= Log P_{oct})	no data	
Vapor Pressure	1 mm Hg @ 865 °C	Sax and Lewis 1989
Reactivity	Reacts violently with BrF_3 and lithium.	Sax and Lewis 1989
Flammability	non-flammable	NTP 1996
Flash Point	non-combustible	HSDB 1996
Dissociation Constant	no data	
Air Diffusivity Constant	no data	
Molecular Diffusivity Constant	no data	
Henry's Law Constant	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium chloride (NaCl) occurs in nature as the mineral halite (i.e. salt deposits) and is dissolved in the ocean (2.6% concentration) and other bodies of water (HSDB 1996). It is produced by mining, evaporation of brine from underground salt deposits, and evaporation from sea water (Budavari et al. 1996). It is released artificially into the environment as waste from bake houses and pickling and canning factories, etc., and in its use as a snow antifreeze or de-icer on pathways (HSDB 1996).

B. Transport

No information was found on the environmental transport of sodium chloride in the secondary sources searched. Its high water solubility (1 g/2.8 mL water @ 25 °C, Budavari et al. 1996) suggests that if it were released into the soil it would be highly mobile (e.g. when dissolved in rainfall) and could eventually end up in the groundwater.

C. Transformation/Persistence

1. Air — No information was found on the transformation/persistence of sodium chloride in air in the secondary sources searched. Its low reactivity and volatility (HSDB 1996, Sax and Lewis 1989) and high water solubility (Chapman and Hall 1996) indicate that any sodium chloride released into the air (e.g. from salt mining) would either dissolve in air moisture or remain as unchanged particulates that settle out.
2. Soil — Sodium chloride is found naturally in the soil as underground rock salt deposits. These salt deposits can be dissolved in water because NaCl is highly water soluble (Chapman and Hall 1996, Lide 1991). The dissolved sodium chloride can then be either recovered above ground, as in solution mining (Perry et al. 1994), or may possibly end up in the groundwater (further information was not located in the searched secondary sources).
3. Water — Sodium chloride is very soluble in water, being stable in solution for at least 24 hours at room temperature (NTP 1996, Chapman and Hall 1996, Lide 1991). No other relevant information was located in the secondary sources searched.
4. Biota — No information was found on the transformation/persistence of sodium chloride in the biota in the secondary sources searched. Its high water solubility indicates that it would not appreciably bioconcentrate in the flora or fauna.

CHEMICAL SUMMARY FOR SODIUM CHLORITE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and non-formaldehyde electroless copper processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium chlorite are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM CHLORITE

Characteristic/Property	Data	Reference
CAS No.	7758-19-2	
Common Synonyms	chlorous acid, sodium salt; Textone	HSDB 1995
Molecular Formula	$ClNaO_2$	Budavari et al. 1989
Chemical Structure	$NaClO_2$	Budavari et al. 1989
Physical State	slightly hygroscopic crystals or flakes	Budavari et al. 1989
Molecular Weight	90.45	Budavari et al. 1989
Melting Point	decomposes at 180-200°C	Budavari et al. 1989
Boiling Point	no data	
Water Solubility	390 g/L at 17°C; 550 g/L at 60°C	Budavari et al. 1989
Density	2.468 g/m^3	HSDB 1995
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	negligible	Eastman Kodak 1986
Reactivity	powerful oxidizer, but will not explode on percussion unless in contact with oxidizable material;	Budavari et al. 1989
	in aqueous alkaline solution, chlorite ion is very stable; in acid solution, chlorite forms chlorous acid ($HClO_2$), which rapidly forms chlorine dioxide (ClO_2), chlorate, and chloride	IARC 1991
Flammability	fire hazard rating = 1; slightly combustible	Lockheed Martin 1994c
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data	
Conversion Factors	not applicable	

II. ENVIRONMENTAL FATE

A. Environmental Release

Most of the sodium chlorite used in the U.S. is in the production of aqueous chlorine dioxide solutions at the site of use. The conversion can be carried out by the disproportionation of chlorous acid formed from chlorite in aqueous hydrochloric acid solution, but is more commonly achieved by the oxidation of chlorite by chlorine or hypochlorous acid (IARC 1991). Chlorine dioxide is generated to bleach and strip textiles; to bleach wood pulp in paper processing; to eliminate tastes and odors in drinking water; to reduce loads of adsorbable organic halogenated compounds in industrial effluents; to control microbiological growth in paper mills, oil wells, petroleum systems, and food processing flume water; to bleach fats and oils; to disinfect sewage; to treat factory wastes;

to bleach natural foliage; and to control algae in industrial cooling towers. Sodium chlorite is also used in the electronics industry for etching. It is not known to occur naturally (IARC 1991).

Sodium chlorite is used in a small number of water treatment plants to generate chlorine dioxide; this may result in a low residual concentration of chlorite in drinking water (IARC 1991). Sodium chlorite is not listed on U.S. EPA's TRI, requiring certain U.S. industries to report on chemical releases to the environment (TRI93 1995).

B. Transport

No information on the transport of sodium chlorite was found in the secondary sources searched.

C. Transformation/Persistence

No information on the transformation/persistence of sodium chlorite was found in the secondary sources searched.

CHEMICAL SUMMARY FOR SODIUM HYDROXIDE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, conductive polymer, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium hydroxide are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM HYDROXIDE

Characteristic/Property	Data	Reference
CAS No.	1310-73-2	
Common Synonyms	caustic soda; soda lye	Budavari et al. 1989
Molecular Formula	NaOH	Budavari et al. 1989
Chemical Structure	NaOH	Budavari et al. 1989
Physical State	deliquescent solid	Lide 1991
Molecular Weight	40.01	Budavari et al. 1989
Melting Point	318°C	Budavari et al. 1989
Boiling Point	1390°C	Lide 1991
Water Solubility	1 g in 0.9 mL water, 0.3 mL boiling water	Budavari et al. 1989
Density	2.13 g/mL @ 25°C	Budavari et al. 1989
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	too low to be measured	HSDB 1995
Vapor Pressure	1 mm Hg @ 739°C	Sax 1984
Reactivity	reacts with all mineral acids to form the corresponding salts; with organic acids to form soluble salts;	HSDB 1995
	pH of 0.5% solution is about 13	Budavari et al. 1989
Flammability	not combustible but solid form in contact with moisture or water may generate sufficient heat to ignite combustible materials	HSDB 1995
Flash Point	no data	
Dissociation Constant	dissociates completely	HSDB 1995
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	HSDB 1995
Conversion Factors	1 mg/m^3 = 0.61 ppm;	calculated:
	1 ppm = 1.636 mg/m^3	mg/m^3 = 1 ppm x MW/24.45

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium hydroxide is a corrosive deliquescent solid available in various solid forms and as solutions, usually 45-75% in water. It is a strong alkali that is highly soluble in water (Budavari et al. 1989). When the chemical is dissolved in water, mists are frequently formed and heat is released (Pierce 1994b). As the least expensive strong base, sodium hydroxide is widely employed in industries such as rayon, cellophane and textiles, pulp and paper, soap and detergents, etching and electroplating, and many others (ACGIH 1991). Although sodium hydroxide releases are expected to occur in industrial/occupational settings, no data were found in the secondary sources searched. Consumers may be exposed to oven cleaning products that contain >5% lye (HSDB 1995).

B. Transport

No information on the transport of sodium hydroxide was found in the secondary sources searched. Because of its low vapor pressure, sodium hydroxide is not expected to partition to the atmosphere in significant amounts. The water solubility suggests that sodium hydroxide would leach through soil.

C. Transformation/Persistence

No information on the transformation/persistence of sodium hydroxide was found in the secondary sources searched. Low vapor pressure and its water solubility suggest the chemical would remain in the aqueous phase.

CHEMICAL SUMMARY FOR SODIUM HYPOPHOSPHITE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1. The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium hypophosphite are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM HYPOPHOSPHITE

Characteristic/Property	Data	Reference
CAS No.	7681-53-0	
Common Synonyms	phosphinic acid, sodium salt	Budavari et al. 1989
Molecular Formula	H_2NaO_2P	Budavari et al. 1989
Chemical Structure	H_2-O_2-P.Na	RTECS 1995
Physical State	white granules	Budavari et al. 1989
Molecular Weight	87.97	Budavari et al. 1989
Melting Point	no data	
Boiling Point	no data	
Water Solubility	100 g/100 mL at 25°C	Weast 1983-1984
Density	no data	
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	explodes when triturated with chlorates or other oxidizing agents;	Budavari et al. 1989
	explosive when heated; mixture with sodium or potassium nitrate is powerful explosive	HSDB 1995
Flammability	decomposes when heated forming phosphine, a spontaneously flammable gas	HSDB 1995
Flash Point	phosphine is spontaneously flammable	HSDB 1995
Dissociation Constant	no data;	
	aqueous solution is neutral	Budavari et al. 1989
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	Budavari et al. 1989
Conversion Factors	1 ppm = 3.60 mg/m^3 1 mg/m^3 = 0.28 ppm	Calculated using: mg/m^3 = ppm × MW/24.45

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found regarding the release of sodium hypophosphite to the environment. The chemical could potentially enter the environment from its use in removing mercury from animal feeds and manures or as an antimicrobial agent in meat, poultry, and fish (HSDB 1995). Sodium hypophosphite is not listed by the TRI requiring certain types of U.S. industries to report environmental releases (TRI93 1995).

B. Transport

No information was found in the secondary sources searched regarding the movement of sodium hypophosphite through environmental media. Based on the high water solubility, the chemical could be expected to be found in the aqueous phase.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of sodium hypophosphite in the air, soil, water, or biota.

CHEMICAL SUMMARY FOR SODIUM HYPOPHOSPHITE 1-HYDRATE

This chemical was identified by one or more suppliers as a bath ingredient for the organic-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium hypophosphite 1-hydrate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM HYPOPHOSPHITE 1-HYDRATE

Characteristic/Property	Data	Reference
CAS No.	10039-56-2	
Common Synonyms	sodium phosphinate hydrate; phosphinic acid, sodium salt, monohydrate	Lockheed Martin 1995b
Molecular Formula	H_4NaPO_3	CHEMFINDER 1996
Chemical Structure	$NaH_2PO_2 \bullet H_2O$	CHEMFINDER 1996
Physical State	white crystals	EM Industries 1991
Molecular Weight	105.99	CHEMFINDER 1996
Melting Point	230°C (decomposes)	EM Industries 1991
Boiling Point	no data	
Water Solubility	50% 100 g/100 mL	EM Industries 1991 Chapman and Hall 1995
Density	0.8	EM Industries 1991
Vapor Density (air = 1)	3.6	CHEMFINDER 1996
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	react violently with strong oxidizing agents	EM Industries 1991
Flammability	gives off toxic gases when burned	CHEMFINDER 1996
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	JT Baker Inc. 1994
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched on the amount or sources of sodium hypophosphite 1-hydrate released to the environment.

B. Transport

No information was found in the secondary sources searched to indicate how sodium hypophosphite 1-hydrate is transported in the environment. The high water solubility suggests that leaching into groundwater could occur.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation or persistence of sodium hypophosphite 1-hydrate in air, soil, water, or biota.

CHEMICAL SUMMARY FOR SODIUM PERSULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the carbon, graphite, organic-palladium, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium persulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM PERSULFATE

Characteristic/Property	Data	Reference
CAS No.	7775-27-1	
Common Synonyms	sodium peroxydisulfate	Budavari et al. 1989
	peroxydisulfuric acid, disodiuim salt	RTECS 1995
	disodium peroxydisulfate	DuPont and Co. 1992
Molecular Formula	$Na_2S_2O_8$	Budavari et al. 1989
Chemical Structure	$Na_2O_8S_2$	Budavari et al. 1989
Physical State	white crystalline powder	Budavari et al. 1989
Molecular Weight	238.13	Budavari et al. 1989
Melting Point	no data	
Boiling Point	no data	
Water Solubility	549 g/L @ 20°	Budavari et al. 1989
Density	2.4	JT Baker Inc. 1985
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	gradually decomposes; decomposition promoted by H_2O and high temperature	Budavari et al. 1989
	strong oxidizer. Contact with other material may cause fire. Can react violently with shock, friction, or heat	JT Baker Inc. 1985
Flammability	slightly combustible	Lockheed Martin 1989b
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless	JT Baker Inc. 1985
Conversion Factors	1 mg/m^3 = 0.10 ppm	Calculated using:
	1 ppm = 9.74 mg/m^3	ppm = mg/m^3 × 24.45/mol. wt.

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of sodium persulfate.

B. Transport

No information was found in the secondary sources searched regarding the transport of sodium persulfate.

C. Transformation/Persistence

No information was found in the secondary sources searched regarding the transformation/persistence of sodium persulfate in air, soil, water, or biota.

CHEMICAL SUMMARY FOR SODIUM SULFATE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium sulfate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM SULFATE

Characteristic/Property	Data	Reference
CAS No.	7757-82-6	
Common Synonyms	bisodium sulfate; disodium monosulfate disodium sulfate; sulfuric acid disodium salt	HSDB 1995
Molecular Formula	Na_2SO_4	HSDB 1995
Chemical Structure	H_2-O_4-S.2Na	HSDB 1995
Physical State	white powder or orthorhombic bipyramidal crystals	HSDB 1995
Molecular Weight	142.06	HSDB 1995
Melting Point	888°C	HSDB 1995
Boiling Point	not found	
Water Solubility	soluble in about 3.6 parts H_2O	HSDB 1995
Density	2.671	HSDB 1995
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	not found	
Reactivity	sodium sulfate and aluminum will explode at 800°C; reacts violently with magnesium	HSDB 1995
Flammability	not found	
Flash Point	nonflammable	HSDB 1995
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	odorless	HSDB 1995
Conversion Factors	1 ppm = 5.81 mg/m^3 1 mg/m^3 = 0.172 ppm	Calculated using: ppm = mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium sulfate occurs in nature in the minerals mirabilite, thenardite, hanksite, sulphohalite, galubzrite, loeweite, ferronatrite, bloedite, tychite, aphthitalite, tamarugite, and mendozite; it is relatively common in alkali lakes, ground water, and sea water (HSDB 1995).

An analysis of individual droplets in samples of fog, haze and cloud collected in Israel revealed the presence of both acid and alkaline droplets (Ganor et al. 1993). The alkaline droplets contained minerals and salt solutions of sodium sulfate, calcium sulfate or sodium chloride.

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of sodium sulfate.

C. Transformation/Persistence

1. Air — No information was found in the secondary sources searched regarding the transformation/persistence of sodium sulfate in air. HSDB (1995) states that sodium sulfate may persist indefinitely in the environment.
2. Soil — No information was found in the secondary sources searched regarding the transformation/persistence of sodium sulfate in soil. HSDB (1995) states that sodium sulfate may persist indefinitely in the environment.
3. Water — No information was found in the secondary sources searched regarding the transformation/persistence of sodium sulfate in the aquatic environment. HSDB (1995) states that sodium sulfate may persist indefinitely in the environment.
4. Biota — There is no evidence that sodium sulfate accumulates in biota or contaminates the food chain (HSDB 1995).

CHEMICAL SUMMARY FOR STANNOUS CHLORIDE AND STANNOUS CHLORIDE AS TIN

These chemicals were identified by one or more suppliers as a bath ingredient for the electroless copper, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of stannous chloride are summarized below. The valence state of the stannous ion is 2 (Sn^{2+} or Sn[II]).

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF STANNOUS CHLORIDE

Characteristic/Property	Data	Reference
CAS No.	7772-99-8	
Common Synonyms	tin (II) chloride tin dichloride tin protochloride	HSDB 1995
Molecular Formula	$SnCl_2$	
Chemical Structure	$SnCl_2$	
Physical State	crystals or flakes	Budavari et al. 1989
Molecular Weight	189.61	Budavari et al. 1989
Melting Point	246°C	Lide 1991
Boiling Point	652°C at 720 mm Hg	Lide 1991
Water Solubility	900 g/L at 20°C	HSDB 1995
Density	$d^{25/4}$ 3.95	Lide 1991
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	-2 to -3	Wong et al. 1982
Vapor Pressure	no data	
Reactivity	powerful reducing agent	Budavari et al. 1989
Flammability	not readily flammable	HSDB 1995
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	3000 (inorganic tin)[a]	ATSDR 1992
Odor Threshold	odorless	HSDB 1995
Conversion Factors	not applicable	

a) Method of calculation/measurement not given.

II. ENVIRONMENTAL FATE

A. Environmental Release

No data on the release of stannous chloride to the environment were located in the secondary sources searched; environmental levels of tin are stated in terms of inorganic tin. Tin is a naturally-occurring element found in environmental media and natural foods. Tin and tin compounds are not included in the TRI. The most significant releases of inorganic tin are from burning of fossil fuels and industrial production and use of tin (ATSDR 1992). The tin content of airborne fly ash from coal-burning plants ranged from 7-19 μg/g (ATSDR 1992). Tin in waste streams originates primarily from the production of tin cans (Brown 1983, as reported in HSDB 1995). Tin also occurs in water stored in coated metal containers and may be released in effluents from industrial processes and from municipal sewage (NRC 1977). Human exposure to tin is primarily by ingestion of canned food products (ATSDR 1992).

Public water supplies in 42 U.S. cities contained total tin at concentrations of 1.1-2.2 ug/L; water from 175 natural sources in west-central Arkansas contained 0.9-30 ug/L total tin (NRC 1977). Total tin was below the limit of detection in 56 of 59 samples of river water in the U.S. and Canada; the other three values were 1.3, 1.4, and 2.1 ug/L (NRC 1977). Seawater contains 0.2-0.3 μg/L (NRC 1977). Tin occurs in surface and groundwater at 21% of NPL sites at a geometric mean concentration of 50 μg/L (ATSDR 1992). Ambient soil levels in Canada ranged from 1-200 mg/kg total tin (mean 4 mg/kg); the ambient sediment level was 4.6 mg/kg (HSDB 1995). Tin was detected at hazardous waste sites at a geometric mean concentration of 30 mg/kg of soil (ATSDR 1992).

B. Transport

Tin released to the atmosphere in the form of particulates would be removed by gravitational settling within a matter of days. In soil, the Sn^{2+} cation will be adsorbed to some extent. Although moderately water soluble, tin in water may partition to soils and sediments; the Sn^{2+} ion will also readily precipitate as a sulfide or hydroxide (ATSDR 1992). These characteristics would limit mobility.

C. Transformation/Persistence

1. <u>Air</u> — Tin in the atmosphere is usually associated with dust particles; the deposition half-life of dust particles is on the order of days (U.S. EPA 1987c). No information on the transformation or degradation of inorganic tin compounds in the atmosphere was found.
2. <u>Soil</u> — The Sn^{2+} cation will be adsorbed by soil to some extent (ATSDR 1992), thereby retarding leaching to groundwater. The formation of insoluble salts would also limit the amount leaching to groundwater.
3. <u>Water</u> — Sn^{2+} in oxygen poor alkaline water will readily precipitate as a sulfide or hydroxide (ATSDR 1992); this would limit the amount in solution or suspension in groundwater. Inorganic tin may be transformed into organometallic compounds; a change of valence state probably does not occur (ATSDR 1992).
4. <u>Biota</u> — A log K_{ow} of -2 to -3 would indicate little potential for bioaccumulation, but reported estimates of the bioconcentration factors for inorganic tin (valance state not given) for marine and freshwater plants, invertebrates, and fish were 100, 1000, and 3000, respectively (ATSDR 1992).

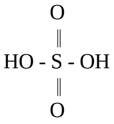
CHEMICAL SUMMARY FOR SULFURIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper, carbon, conductive polymer, graphite, non-formaldehyde electroless copper, and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sulfuric acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SULFURIC ACID

Characteristic/Property	Data	Reference
CAS No.	7664-93-9	
Common Synonyms	sulphuric acid; oil of vitriol	HSDB 1995
Molecular Formula	H_2SO_4	Budavari et al. 1989
Chemical Structure	 $HO-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OH$	
Physical State	clear, colorless, odorless, oily liquid	Budavari et al. 1989
Molecular Weight	98.08	Budavari et al. 1989
Melting Point	10°C (anhydrous acid)	Budavari et al. 1989
Boiling Point	about 290°C; decomposes at 340°C	Budavari et al. 1989
Water Solubility	miscible with water	Budavari et al. 1989
Density	1.84 (96-98% acid)	NIOSH 1994
Vapor Density (air = 1)	3.4 (at boiling point)	HSDB 1995
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	5.933×10^{-5} @ 25 mm Hg	CHEMFATE 1995
Reactivity	strong dehydrating agent; reacts violently with water with evolution of heat; corrosive to metals	ACGIH 1991 ACGIH 1994-1995
Flammability	not flammable, but capable of igniting finely divided combustible materials	HSDB 1995
Flash Point	no data	
Dissociation Constant	$K = 1.2 \times 10^{-2}$; pK = 1.92	HSDB 1995
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	1 mg/m^3	HSDB 1995
Conversion Factors	1.2 mg H_2SO_4 contains 1 mg of SO_3; 1 mg SO_3 = 0.3 ppm; 1 ppm = 3.2 mg/m^3 @ 25°C, 760 mm Hg	Beliles and Beliles 1993

II. ENVIRONMENTAL FATE

A. Environmental Release

Sulfuric acid is a clear, colorless, odorless, oily liquid. It has a high affinity for water, abstracting it from the air and many organic substances. Sulfuric acid is produced in numerous grades and strengths. Commercial sulfuric acid contains 93-98% of acid; the remainder is water (Budavari et al. 1989). The primary sources of sulfuric acid in the atmosphere are vehicular emissions, combustion sources, explosive manufacture, furnace soot, sulfuric acid manufacture, and steel manufacture (U.S. EPA 1984d). Sulfuric acid occurs naturally in the vicinity of volcanoes, particularly in volcanic gases (HSDB 1995). Sulfur dioxide in moist air or fog combines with the water to form sulfurous acid; the latter is slowly oxidized to sulfuric acid (Beliles and Beliles 1993). Based on rain chemistry data measured in southwestern Pennsylvania in 1983, an acid deposition budget was estimated as follows: 47%, sulfuric acid in rain; 23%, sulfur dioxide deposition without dew; 16%, nitric acid and sulfuric acid in fog and dew; and 0.5% aerosol dry deposition without dew (HSDB 1995).

Sulfuric acid can enter the aquatic environment from a variety of sources: in accidental spills from train derailments; in wastewaters from mining properties where sulfides are part of the ore or the rock being mined; in wastewaters from the steel industry; from the atmosphere; and as a decomposition product of effluents containing sulfur, thiosulfate, or thionates (HSDB 1995).

Sulfuric acid is the most widely used of the strong inorganic acids. Average occupational exposures to sulfuric acid mists in pickling, electroplating, and other acid treatment of metals are frequently above 0.5 mg/m^3, while lower levels are usually found in the manufacture of lead-acid batteries and in phosphate fertilizer production (IARC 1992).

In 1992, releases of sulfuric acid to environmental media, as reported to the TRI by certain types of industries, totaled about 156,809,406 pounds. Of this amount, 23,721,453 pounds (15%) were released to the atmosphere, 32,719,526 pounds (21%) were released to surface water, 98,631,395 pounds (63%) were released in underground injection sites, and 1,737,032 pounds (1%) were released on land (TRI92 1994).

B. Transport

Sulfuric acid aerosols in the atmosphere are likely to be removed through wet and dry deposition. Released to soils, most of the sulfuric acid is expected to be removed by reaction with inorganic minerals or organic matter in soils. In highly sandy soil, sulfuric acid probably leaches into groundwater (U.S. EPA 1984d).

C. Transformation/Persistence

1. Air — Sulfuric acid is present in the atmosphere in the form of aerosols. In dry weather, the aerosol is found in the sub-0.65 μm particle size fraction, while under humid conditions, it is present in the 0.65-3.6 μm particle size range. Sulfuric acid is a primary source of inorganic sulfates in the atmosphere, particularly ammonium sulfate. Depending on the amount of moisture in the atmosphere, sulfuric acid aerosols may react with organics in the atmosphere to form sulfonates.
2. Soil — The majority of sulfuric acid in soils is expected to be removed by reaction with inorganic minerals or organic matter in soils. During transport through the soil, sulfuric acid can dissolve some of the soil material, in particular carbonate-based materials (HSDB 1995). In highly sandy soil, sulfuric acid probably leaches into groundwater (U.S. EPA 1984d).
3. Water — In aquatic media of about pH >7, sulfuric acid reacts with carbonate, bicarbonate, or hydroxides in the sediment or suspended particles, with the formation of sulfates. Since the majority of sulfates, with the exception of lead and calcium, are soluble in water, this reaction may mobilize the precipitated metals from the aquatic phase and decrease the pH of the solution. In aquatic media of pH <7, at least a part of the sulfuric acid may remain ionized in solution and may be mobile (U.S. EPA 1984d).
4. Biota — No information on the transformation/persistence of sulfuric acid in biota was found in the secondary sources searched.

CHEMICAL SUMMARY FOR TARTARIC ACID

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of tartaric acid are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF TARTARIC ACID

Characteristic/Property	Data	Reference
CAS No.	87-69-4	
Common Synonyms	2,3-dihydroxybutanedioic acid; L-tartaric acid;	Katz and Guest 1994, L-threoic
acid; (+)-tartaric acid; dextrotartaric acid;	Budavari et al. 1996;	
	d-trataric acid; natural tartaric acid	Informatics, Inc. 1974
Molecular Formula	$C_4H_6O_6$	Budavari et al. 1996
Chemical Structure	$HO_2CCH(OH)CH(OH)CO_2H$	Lide 1991
Physical State	colorless or translucent solid monoclinic rhombic or spheroidal prisms, a white fine to granular crystalline powder	Lide 1991; Budavari et al. 1996 Informatics, Inc. 1974
Molecular Weight	150.09	Lide 1991
Melting Point	171-174 °C; 168-170 °C	Lide 1991; Budavari et al. 1996
Boiling Point	no data	
Water Solubility	freely soluble (139 g/100 mL @ 20 °C)	Budavari et al. 1996
Density	1.7598 @ 20 °C	Lide 1991
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW} (= Log P_{oct})	Log P_{oct} -0.76/-2.02 (calculated) for the racemic threoic acid	Verschueren 1983
Vapor Pressure	no data	
Reactivity	no data	
Flammability	no data	
Flash Point	no data	
Dissociation Constant	$pKa_1 = 2.98$, $pKa_2 = 4.34$ $pKa_1 = 2.93$, $pKa_2 = 4.23$	 Chapman and Hall 1996 Katz and Guest 1994, Budavari et al. 1996
Air Diffusivity Constant	no data	
Molecular Diffusivity Constant	no data	
Henry's Law Constant	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	odorless; odor of burnt sugar when heated to melting point	Informatics, Inc. 1974; Budavari et al. 1996
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

No information on environmental releases of tartaric acid was found in the secondary sources searched. Tartaric acid is widely used in foods, soft drinks, wine, cleaners, textile printing, pharmaceuticals, etc. and is freely water-soluble, so small quantities are likely to be released into the water supply, soil and eventually the groundwater from personal and commercial use and production.

B. Transport

No information on the environmental transport of tartaric acid was found in the secondary sources searched. Its high water solubility (139 g/100 mL @ 20°C; Budavari et al. 1996) suggests that if it did volatilize it could be removed from the atmosphere by rainfall, and if it were released onto soil it would likely be mobile and may end up in the groundwater.

C. Transformation/Persistence

1. Air – Tartaric acid is reported to be stable to air and light (Budavari et al. 1996); no other information was found in the secondary sources searched.
2. Soil – No information regarding the transformation/persistence of tartaric acid in soil was located. Its high water solubility suggests it would be highly mobile in soil and could enter the groundwater.
3. Water – No information on the transformation/persistence of tartaric acid in water was found in the secondary sources searched. Being a strong organic acid (Budavari et al. 1996), it is expected to dissociate into its ion components when in water.
4. Biota – No information on the transformation/persistence of tartaric acid in the biota was found in the secondary sources searched. Its high water solubility indicates that it would not appreciably bioconcentrate in the flora or fauna.

CHEMICAL SUMMARY FOR TETRASODIUM EDTA (Na_4EDTA)

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of Na_4EDTA are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF Na_4EDTA

Characteristic/Property	Data	Reference
CAS No.	64-02-8	
Common Synonyms	(ethylenedinitrilo)tetraacetic acid tetrasodium salt; edetate sodium; edetic acid tetrasodium salt; EDTA tetrasodium salt; Trilon B; Versene 100; Versene beads or flake	HSDB 1995
Molecular Formula	$C_{10}H_{16}N_2O_8.4Na$	HSDB 1995
Chemical Structure		
Physical State	white powder; anhydrous or $2H_2O$	HSDB 1995
Molecular Weight	380.20	HSDB 1995
Melting Point	not found	
Boiling Point	not found	
Water Solubility	103 g/100 mL; very soluble	HSDB 1995
Density	6.9 lb/gal	HSDB 1995
Vapor Density (air = 1)	not found	
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	0.24×10^2 torr @ 25°C	CHEMFATE 1995
Reactivity	reacts with most divalent and trivalent metallic ions to form soluble metal chelates	HSDB 1995
Flammability	not found	
Flash Point	not found	
Dissociation Constant	not found	
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	not found	
Conversion Factors	1 ppm = 16.7 mg/m^3 1 mg/m^3 = 0.064 ppm	Calculated using: ppm = mg/m^3 x 24.45/m.w.

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of Na_4EDTA. The chemical is probably released to air, water, and soil from industries that manufacture and use it, from the use of pesticide formulations that contain it, and from the disposal of pharmaceuticals and other consumer products that contain it.

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of Na_4EDTA. The vapor pressure for Na_4EDTA (0.24×10^2 torr [CHEMFATE 1995]) suggests that the chemical is moderately volatile and may undergo volatilization from soil and water surfaces. The high water solubility of Na_4EDTA suggests possible leaching of the chemical through the soil to groundwater.

C. Transformation/Persistence

1. Air — Estimated half-lives for the reaction of Na_4EDTA with RO_2, OH, and O_3 are 2200 years, 8 minutes, and 1 day, respectively (CHEMFATE 1995). This suggests that Na_4EDTA in the atmosphere may undergo significant reaction with photochemically-generated hydroxyl radicals and ozone.
2. Soil — Na_4EDTA released to the soil would form soluble metal chelates with most divalent and trivalent metallic ions (HSDB 1995).
3. Water — The reaction of Na_4EDTA with OH in air (CHEMFATE 1995) suggests that the chemical may also react with photochemically-generated hydroxyl radicals in water.
4. Biota — No information was found in the secondary sources searched regarding the persistence or biomagnification of Na_4EDTA in biota.

CHEMICAL SUMMARY FOR TRIETHANOLAMINE

This chemical was identified by one or more suppliers as a bath ingredient for the electroless copper and tin-palladium processes. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of triethanolamine are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF TRIETHANOLAMINE

Characteristic/Property	Data	Reference
CAS No.	102-71-6	
Common Synonyms	2,2',2''-nitrilotrisethanol	CHEMFATE 1995
Molecular Formula	$C_6H_{15}NO_3$	
Chemical Structure	$(HOCH_2CH_2)_3N$	
Physical State	pale yellow, viscous liquid	Benya and Harbison 1994
Molecular Weight	149.19	CHEMFATE 1995
Melting Point	21.57°C	CHEMFATE 1995
Boiling Point	335.4°C	CHEMFATE 1995
Water Solubility	miscible	CHEMFATE 1995
Density	$d^{20/4}$, 1.1242	HSDB 1995
Vapor Density (air = 1)	5.1	HSDB 1995
K_{OC}	no data	
Log K_{OW}	-1.59	CHEMFATE 1995
Vapor Pressure	3.59×10^{-6} mm Hg at 25°C	CHEMFATE 1995
Reactivity	may become unstable at elevated temperatures and pressure	HSDB 1995
Flammability	must be heated before ignition will occur	HSDB 1995
Flash Point	190.5°C (open cup)	HSDB 1995
Dissociation Constant (pKa)	7.92	CHEMFATE 1995
Henry's Law Constant	3.38×10^{-19} atm-m^3/mol (estimated)	CHEMFATE 1995
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	<1 (estimated) <3.9 (measured; species not given)	HSDB 1995
Odor Threshold	no data; slight ammoniacal odor	HSDB 1995
Conversion Factors	1 ppm = 6.10 mg/m^3 1 mg/m^3 = 0.164 ppm	Calculated using the formula: ppm = mg/m^3(24.45/mol. wt)

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched to indicate the specific amount of triethanolamine released to the environment in any given year. Approximately 100,000 - 500,000 tons/year of the chemical are produced worldwide (U.S. EPA 1995b). Although the production of triethanolamine is tightly controlled, a worst case estimation of production loss by industry to the environment is 0.5%. Release can also occur during the use of the chemical as a metal working/cutting fluid, as an additive to cement, as an intermediate in surfactant production, or in the manufacture of textile auxiliaries (U.S. EPA 1995b).

B. Transport

Because of the high water solubility and low octanol-water coefficient of triethanolamine, the chemical will likely partition into water. Although no data were found for the K_{OW}, adsorption onto soils is unlikely and leaching of the chemical into ground water is expected. The low vapor pressure and low Henry's Law Constant indicate that volatilization to the atmosphere will be negligible.

C. Transformation/Persistence

1. Air — The half-life for triethanolamine reaction with photochemically produced hydroxy radicals was estimated at 4 hours with a rate constant of 10.4 x 10^{-11} cm^3/molecules-sec and assuming an average hydroxyl concentration of 5 x 10^5 molecules/cm^3 (HSDB 1995). The chemical will also be removed from the atmosphere in precipitation (HSDB 1995).
2. Soil — Triethanolamine will be biodegraded rapidly in soils, following acclimation, with a half-life of days to weeks. Removal from soils also occurs through leaching (HSDB 1995).
3. Water — Triethanolamine is rapidly degraded in water following acclimation. In a batch system using activated sludge, the chemical was 89% degraded in 14 days following a 3 day acclimation period (CHEMFATE 1995). Other tests showed increases in theoretical biological oxygen demand (BODT) of 66% and 69% (sea water) in 20 days using sewage inoculum (CHEMFATE 1995; HSDB 1995).
4. Biota — Based on the low estimated bioconcentration factor and high water solubility of triethanolamine, the chemical is expected to have a low potential for bioaccumulation in aquatic organisms.

CHEMICAL SUMMARY FOR SODIUM CITRATE

This chemical was identified by one or more suppliers as a bath ingredient for the organic-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of sodium citrate are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF SODIUM CITRATE

Characteristic/Property	Data	Reference
CAS No.	68-04-2	
Common Synonyms	trisodium citrate; sodium citrate anhydrous; 2-hydroxy-1,2,3-propanetricarboxylic acid, trisodium salt	Lockheed Martin 1991
Molecular Formula	$C_6H_5Na_3O_7$	Budavari et al. 1989
Chemical Structure	$CH_2(COONa)C(OH)(COONa)CH_2COONa$	Osol 1980
Physical State	dihydrate, white crystals, granules, or powder; pentahydrate, relatively large, colorless crystals or white granules	Budavari et al. 1989
Molecular Weight	258.07	Budavari et al. 1989
Melting Point	150 °C (-2 H_2O)	Fisher Scientific 1985
Boiling Point	decomposed at red heat	Lewis 1993
Water Solubility	72 g/100 mL at 25 °C (dihydrate)	Weast 1983-1984
Density	1.9	Fisher Scientific 1985
Vapor Density (air = 1)	no data	
K_{OC}	no data	
Log K_{OW}	no data	
Vapor Pressure	no data	
Reactivity	0 (nonreactive, NFPA classification); aqueous solution slightly acid to litmus	Lockheed Martin 1991 Osol 1980
Flammability	1 (slightly combustible, NFPA classification);	Lockheed Martin 1991
Flash Point	no data	
Dissociation Constant	no data	
Henry's Law Constant	no data	
Molecular Diffusivity Coefficient	no data	
Air Diffusivity Coefficient	no data	
Fish Bioconcentration Factor	no data	
Odor Threshold	no data; odorless	Lewis 1993
Conversion Factors	no data	

II. ENVIRONMENTAL FATE

A. Environmental Release

Sodium citrate is a solid with a cool, saline taste that is soluble in water (Fisher Scientific 1985). It is used in soft drinks, frozen desserts, meat products, cheeses, and as a nutrient for cultured buttermilk; in photography; in detergents; as a sequestrant and buffer; as an anticoagulant for blood withdrawn from the body; and in the removal of sulfur dioxide from smelter waste gases (Lewis 1993). Medicinally, sodium citrate is used as expectorant and systemic alkalizer. Sodium citrate is a chelating agent and has been used to facilitate elimination of lead from the body (Osol 1980).

No data were found on the environmental releases of sodium citrate. The chemical is not listed on U.S. EPA's TRI, requiring certain U.S. industries to report on chemical releases to the environment (TRI93 1995). The chemical could potentially enter the environment when used for the removal of sulfur dioxide from smelter waste gases.

B. Transport

No data were found on the environmental transport of sodium citrate in the secondary sources searched. Its water solubility suggests that the sodium citrate would remain in the water phase.

C. Transformation/Persistence

No data were found on the transformation/persistence of potassium bisulfate in the secondary sources searched.

CHEMICAL SUMMARY FOR VANILLIN

This chemical was identified by one or more suppliers as a bath ingredient for the tin-palladium process. This summary is based on information retrieved from a systematic search limited to secondary sources (see Attachment C-1). The only exception is summaries of studies from unpublished TSCA submissions that may have been included. These sources include online databases, unpublished EPA information, government publications, review documents, and standard reference materials. No attempt has been made to verify information in these databases and secondary sources.

I. CHEMICAL IDENTITY AND PHYSICAL/CHEMICAL PROPERTIES

The chemical identity and physical/chemical properties of vanillin are summarized below.

CHEMICAL IDENTITY AND CHEMICAL/PHYSICAL PROPERTIES OF VANILLIN

Characteristic/Property	Data	Reference
CAS No.	121-33-5	
Common Synonyms	4-hydroxy-3-methoxybenzaldehyde; methyl-protocatechuic aldehyde; vanillic aldehyde; 3-methoxy-4-hydroxybenzaldehyde	Budavari et al. 1996
Molecular Formula	$C_8H_8O_3$	
Chemical Structure	$(CH_3O)C_6H_3(OH)CHO$	Kirwin and Galvin 1993
Physical State	white or slightly yellow needles	Budavari et al. 1996
Molecular Weight	152.15	Budavari et al. 1996
Melting Point	80-81°C	Budavari et al. 1996
Boiling Point	285°C	Budavari et al. 1996
Water Solubility	1 g/100 mL	Budavari et al. 1996
Density	1.056 g/mL	Budavari et al. 1996
Vapor Density (air = 1)	5.2	HSDB 1996
K_{OC}	not found	
Log K_{OW}	not found	
Vapor Pressure	2.2×10^{-3} mm Hg @ 25°C	HSDB 1996
Reactivity	can react violently with bromine, potassium tert-butoxide, tert-chlorobenzene + NaOH, formic acid + $Tl(NO_3)_3$ and perchloric acid	Keith and Walters 1985
Flammability	not found	
Flash Point	not found	
Dissociation Constant	pK_{a1} 7.40, pK_{a2} 11.4 (25°C)	Chapman and Hall 1995
Henry's Law Constant	not found	
Molecular Diffusivity Coefficient	not found	
Air Diffusivity Coefficient	not found	
Fish Bioconcentration Factor	not found	
Odor Threshold	2×10^{-1} ppm, water; 1.10×10^{-8} ppb, air	Kirwin and Galvin 1993
Conversion Factors	1 ppm = 6.2 mg/m^3 1 mg/m^3 = 0.161 ppm	Brabec 1993

II. ENVIRONMENTAL FATE

A. Environmental Release

No information was found in the secondary sources searched regarding the environmental release of vanillin. The chemical occurs naturally in vanilla, potato parings, and Siam benzoin (Budavari et al. 1996).

B. Transport

No information was found in the secondary sources searched regarding the environmental transport of vanillin. The vapor pressure (2.2×10^{-3} mm Hg [HSDB 1996]) for the chemical indicates that little volatilization from soil or water could occur. Vanillin is soluble in water (1 g/100 mL [Budavari et al. 1996]) and may move through the soil, possibly to groundwater.

C. Transformation/Persistence

1. Air — Vanillin oxidizes to some extent when exposed to moist air and is "affected" by light (Budavari et al. 1996). Vanillin absorbs UV light at wavelengths of 308 and 278 nm (Kirwin and Galvin 1993), suggesting that phototransformation is possible. Decomposition of vanillin under strict anaerobic conditions has been observed (HSDB 1996).
2. Soil — No information was found in the secondary sources searched regarding the fate of vanillin in soil.
3. Water — No information was found in the secondary sources searched regarding the fate of vanillin in the aquatic environment. Based on its absorption of UV light at wavelengths of 308 and 278 nm, vanillin in surface water could undergo some phototransformation.
4. Biota — No information was found in the secondary sources searched regarding the bioaccumulation of vanillin.

CITED REFERENCES

ACGIH. 1991. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values and Biological Exposure Indices, 6th ed. ACGIH, Cincinnati, OH.

ACGIH. 1994-1996. American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, Cincinnati, OH.

Aldrich Chemical Co. 1985. Material Safety Data Sheet for Cuprous Chloride. Aldrich Chemical Co., Milwaukee, WI.

Allan, R.E. 1994. Phenols and phenolic compounds. In: *Patty's Industrial Hygiene and Toxicology,* 4th ed, Vol. 2, Part B. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

American Heritage Dictionary. 1974. American Heritage Dictionary of the English Language. Houghton Mifflin Co., Boston.

Amdur M.O., J. Doull and C.D. Klaassen (Eds.) 1991. *Casarett and Doull's Toxicology. The Basic Science of Poisons,* 4th ed. McGraw-Hill, Inc., New York.

ATSDR. 1989. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Isophorone. ATSDR/TP-89-15. ATSDR, Chamblee, GA.

ATSDR. 1990a. Agency for Toxic Substances and Disease Registry. Toxicology Profile for Ammonia. ATSDR, Chamblee, GA.

ATSDR. 1990b. Agency for Toxic Substances and Disease Registry. Toxicology Profile for Copper. ATSDR, Atlanta, GA.

ATSDR. 1990c. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Silver. ATSDR, Atlanta, GA.

ATSDR. 1992. Agency for Toxic Substances and Disease Registry. Toxicology Profile for Tin. ATSDR, Atlanta, GA.

ATSDR. 1993a. Agency for Toxic Substances and Disease Registry. Technical Report for Ethylene Glycol/Propylene Glycol. Draft for public comment. ATSDR, Atlanta, GA.

ATSDR. 1993b. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (F). ATSDR/TP-91-17. ATSDR, Atlanta, GA.

ATSDR. 1995. Agency for Toxic Substances and Disease Registry. Toxicological Profile for Cyanide (Draft for Public Comment). ATSDR, Atlanta, GA.

Beliles, R.P. and E.M. Beliles. 1993. Phosphorus, selenium, tellurium, and sulfur. In: *Patty's Industrial Hygiene and Toxicology,* 4th ed., Vol. 2, Part A, Toxicology. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Beliles, R.P. 1994a. The metals. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Beliles, R.P. 1994b. Magnesium. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Benya, T.J. and R.D. Harbison. 1994. Aliphatic and alicyclic amines. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part B, Toxicology. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Brabec, M.J. 1993. Aldehydes and acetals. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part A. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Bromilow, R.H., K. Chamberlain, A.J. Tench and R.H. Williams. 1993. Phloem translocation of strong acids: Glyphosate, substituted phosphonic and sulfonic acids. *Ricinus communis L.* Pestic. Sci., 37(1) 39-47. (Cited in TOXLINE 1995)

Budavari, S., M.J. O'Neil, A. Smith and P.E. Heckelman (Eds.) 1989. *The Merck Index*, 11th ed. Merck & Co., Inc., Rahway, NJ.

Budavari, S., M.J. O'Neil, A. Smith, P.E. Heckelman and J.F. Kinneary (Eds.) 1996. *The Merck Index*, 12th ed. Merck & Co., Inc., Whitehouse Station, NJ.

Callery Chemical Co. 1992a. Section 8(e) submission 8EHQ-0392-2602 Init. Acute Dermal Toxicity Study in the Rabbit of Dimethylamine Borane. Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C.

Callery Chemical Co. 1992b. Section 8(e) submission 8EHQ-0392-2605 Init. Oral LD_{50} Study in the Rat of t-Butylamine Borane (tBAB). Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C.

Callery Chemical Co. 1992c. Section 8(e) submission 8EHQ-0392-2604 Init. Oral LD_{50} Study in the Rat of Tetramethylammonium Octahydrotriborate (QMB_3). Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C.

Callery Chemical Co. 1992d. Section 8(e) submission 8EHQ-0392-2603 Init. Acute Dermal Toxicity Study in the Rabbit of t-Butylamine Borane (tBAB). Office of Toxic Substances, U.S. Environmental Protection Agency, Washington, D.C.

Chapman and Hall. 1995-1996. Chapman & Hall Chemical Data Base.

CHEMFATE. 1995-1996. Syracuse Research Corporation's Environmental Fate Data Bases. Syracuse Research Corporation, Syracuse, NY.

Churg, A. and B. Stevens. 1992. Calcium containing particles as a marker of cigarette smoke exposure in autopsy lungs. *Exp Lung Res* 18:21-28. (Cited in TOXLINE 1995)

DuPont and Co. 1992. Sensitization Study with Humans. Haskell Laboratories, EI DuPont DeNemours and Co. 8EHQ-0392-2767.

Eastman Kodak Co. 1986. Material Safety Data Sheet. 5/21/86.

Eastman Kodak Co. 1989. Material Safety Data Sheet. Glycolic acid. 6/08/89.

EM Industries. 1987. Material Safety Data Sheet for Cupric Chloride. EM Science, A Division of EM Industries, Cherry Hill, NJ.

EM Industries. 1991. Material Safety Data Sheet for Sodium Hypophosphinate Hydrate. EM Science, a Division of EM Industries, Gibbstown, NJ, prepared 3/1/91.

EM Industries. 1992. Material Safety Data Sheet for Potassium Sodium Tartrate. EM Science, A Division of EM Industries, Gibbstown, NJ.

Faust, R.A. 1992. Toxicity Summary for Silver. U.S. Army Toxic and Hazardous Materials Agency. Aberdeen Proving Ground, Maryland.

Fisher Scientific. 1985. Sodium citrate. Materials Safety Data Sheet. Fisher Scientific Chemical Division, Fair Lawn, NJ.

Fisher Scientific. 1991. Material Safety Data Sheet for Potassium Bisulfate. JT Baker, Inc., Phillipsburg, NJ.

Ganor, E., Z. Levin and D. Pardess. 1993. Determining the acidity and chemical composition of fog, haze and cloud droplets in Israel. *Atmos Environ Part A Gen Top* 27:1821-1832. (Cited in TOXLINE 1995)

Gingell, R., et al. 1994. Glycol ethers and other selected glycol derivatives. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2A, Toxicology. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Gorzelska, K. and J.N. Galloway. 1990. Amine nitrogen in the atmospheric environment over the North Atlantic Ocean. *Global Biogeochem Cycles* 4:309-334.

Grant, W.M. 1986. *Toxicology of the Eye*, 3rd ed. Charles C. Thomas, Springfield, IL.

Greim, H., J. Ahlers and R. Bias, et al. 1994. Toxicity and Ecotoxicity of Sulfonic Acids: Structure-activity Relationship. *Chemosphere* 28:2203-2236.

Harris, L.R. and D.G. Sarvadi. 1994. Synthetic Polymers. In: *Patty's Industrial Hygiene and Toxicology*, Vol. 2A, 4th ed. G.C. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Howard, P.H. 1989. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*. Vol. I, Large Production and Priority Pollutants. Lewis Publishers, Chelsea, MI.

Howard, P.H. (Ed.) 1990. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*. Lewis Publishers, Chelsea, MI.

Howard, P.H. (Ed.) 1993. *Handbook of Environmental Fate and Exposure Data for Organic Chemicals*. Lewis Publishers, Boca Raton, FL.

HSDB. 1995-1996. Hazardous Substances Data Bank. MEDLARS Online Information Retrieval System, National Library of Medicine.

IARC. 1977. International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. Some Fumigants, the Herbicides 2,4-D and 2,4,5-T, Chlorinated Dibenzodioxines and Miscellaneous Industrial Chemicals*, Vol. 15. IARC, Lyon, France.

IARC. 1984. International Agency for Research on Cancer. Carbon blacks. In: *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man*, Vol. 33. IARC, Lyon, France, pp. 35-85.

IARC. 1985. International Agency for Research on Cancer. Hydrogen Peroxide. In: *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans: Allyl Compounds, Aldehydes, Epoxides and Peroxides*, Vol. 36. IARC, Lyon, France.

IARC. 1989. International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risks of Chemicals to Humans. Some Organic Solvents, Resin Monomers and Related Compounds, Pigments and Occupational Exposures in Paint Manufacture and Painting*, Vol. 47. IARC, Lyon, France.

IARC. 1991. International Agency for Research on Cancer. Sodium chlorite. In: *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Chlorinated Drinking-water; Chlorination By-products; Some Other Halogenated Compounds; Cobalt and Cobalt Compounds*, Vol. 52. IARC, Lyon, France.

IARC. 1992. International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans. Occupational Exposures to Mists and Vapors from Strong Inorganic Acids and other Industrial Chemicals*, Vol. 54. IARC, Lyon, France.

IARC. 1995. International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Humans. Wood Dust and Formaldehyde*, Vol. 62. IARC, Lyon, France.

Informatics, Inc. 1974. Scientific Literature Reviews on Generally Recognized as Safe (GRAS) Food ingredients: Tartarates. National Technical Information Service.

JT Baker, Inc. 1985. Material Safety Data Sheet for Sodium Persulfate. JT Baker Inc., Phillipsburg, NJ.

JT Baker, Inc. 1992a. Material Safety Data Sheet for Potassium Bisulfate. JT Baker Inc., Phillipsburg, NJ.

JT Baker, Inc. 1992b. Material Safety Data Sheet for Sodium Cyanide. JT Baker Inc., Phillipsburg, NJ.

JT Baker, Inc. 1992c. Material Safety Data Sheet for Potassium Sulfate. JT Baker Inc., Phillipsburg, NJ.

JT Baker, Inc. 1992d. Material Safety Data Sheet for Potassium Sodium Tartrate. JT Baker Inc., Phillipsburg, NJ.

JT Baker, Inc. 1994. Material Safety Data Sheet for Sodium Hypophosphite, Monohydrate. JT Baker Inc., Phillipsburg, NJ, issued 1/15/94.

JT Baker, Inc. 1995. Material Safety Data Sheet for Sodium Bisulfate. JT Baker Inc., Phillipsburg, NJ.

Katz, G.V. and D. Guest. 1994. Aliphatic carboxylic acids. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part E, Toxicology. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Keith, L.H. and D.B. Walters (Eds.) 1985. *Compendium of Safety Data Sheets for Research and Industrial Chemicals*. VCH Publishers, Deerfield Beach.

Kertesz, M.A., P. Kolbener, H. Stockinger, S. Beil and A.M. Cook. 1994. Desulfonation of linear alkylbenzenesulfonate surfactants and related compounds by bacteria. *Appl and Environ Microbio* 60(7) 2296-2303. (Cited in TOXLINE 1995)

Kirwin, C.J. and J.B. Galvin. 1993. Ethers. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed.,Vol. 2, Part A. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Lewis, R.J., Jr. (Ed.) 1993. *Hawley's Condensed Chemical Dictionary*, 12th ed. Van Nostrand Reinhold, New York.

Lide, D.R. (Ed.) 1991. *CRC Handbook of Chemistry and Physics*, 72nd ed. CRC Press, Boca Raton, FL.

Lington, A.W. and C. Bevan. 1994. Alcohols. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part A. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Lockheed Martin. 1989a. Lockheed Martin Energy Systems, Inc. Materials Safety Data Sheet for Potassium Bisulfate.

Lockheed Martin. 1989b. Lockheed Martin Energy Systems, Inc. Material Safety Reference Sheet for Sodium Persulfate.

Lockheed Martin. 1991. Lockheed Martin Energy Systems, Inc. Materials Safety Data Sheet for Sodium Citrate.

Lockheed Martin. 1994a. Lockheed Martin Energy Systems, Inc. Material Safety Data Sheet for Sodium Tetrafluoroborate.

Lockheed Martin. 1994b. Lockheed Martin Energy Systems, Inc. Material Safety Reference Sheet for Potassium Hydroxide.

Lockheed Martin. 1994c. Lockheed Martin Energy Systems, Inc. Materials Safety Data Sheet for Sodium Chlorite.

Lockheed Martin. 1995a. Lockheed Martin Energy Systems, Inc. Material Safety Data Sheet for Ammonia.

Lockheed Martin. 1995b. Lockheed Martin Energy Systems, Inc. Material Safety Data Sheet for Sodium Hypophosphite 1-Hydrate.

Lukens, R.P. 1979. Factors, abbreviations, and symbols. In: *Kirk-Othmer, Encyclopedia of Chemical Technology*, 3rd. Ed., Vol. 5. M. Grayson, Executive Ed. John Wiley & Sons, New York.

Mackay, D., W-Y Shiu and K-C Ma. 1992. *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals*, Vol. IV. Oxygen, Nitrogen, and Sulfur Containing Compounds. Lewis Publishers, Boca Raton, FL.

Mackay, D., W-Y Shiu and K-C Ma. 1995. *Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals*, Vol. IV. Oxygen, Nitrogen, and Sulfur Containing Compounds. Lewis Publishers, Boca Raton, FL.

Martin Marietta Energy Systems. 1994. Material Safety Data Sheet. Glycolic acid.
Mattson, V.R., et al. 1976. Acute Toxicity of Selected Organic Compounds to Fathead Minnows. EPA-600/3-76-097. Environmental Research Lab, U.S. EPA, Duluth, MN.

NCI. 1978. National Cancer Institute. Bioassay of 1H-Benzotriazole for Possible Carcinogenicity (CAS No. 95-14-7). NCI, Bethesda, MD, 116 pp. NCI-CG-TR-88.

NIOSH. 1994. National Institute for Occupational Safety and Health. *NIOSH Pocket Guide to Chemical Hazards*. NIOSH, Cincinnati, OH.

NRC. 1977. National Research Council. Drinking Water and Health. National Academy of Sciences, Washington, D.C.

NTP. 1992. National Toxicology Program. NTP Technical Report Studies on Toxicity Studies of Formic Acid (CAS No. 64-18-6) Administered by Inhalation for F344/N Rats and $B6C3F_1$ Mice. NIH Publ 92-3342. NTP, Research Triangle Park, NC.

NTP. 1995. National Toxicology Program. Management Status Report. Produced by NTP Chemtrack system. NTP, Research Triangle Park, NC.

NTP. 1996. National Toxicology Program. Online Chemical Repository. Sodium Chloride.

Opresko, D.M. 1991. Health Effects Summary and Assessment for Phenol-Formaldehyde Resin. Prepared for Existing Chemicals Assessment Division, Office of Toxic Substances, U.S. EPA, Washington, D.C.

Oscarson, D.W., J.W. Rogers, P.M. Huang and W.K. Liaw. 1981. The nature of selected prairie lake and steam sediments. *Int Rev Gesamten Hydrobiol* 66:95-107. (Cited in TOXLINE 1995)

Osol, A. 1980. *Remington's Pharmaceutical Sciences*, 16th ed. Mack Publishing Co., Easton, PA.

Parmeggiani, L. (Ed.) 1983. Formic acid. In: *Encyclopedia of Occupational Health and Safety*, 3rd ed., Vol. 1. International Labour Office, Geneva.

Pendergrass, J.A. 1983. Graphite. In: *Encyclopaedia of Occupational Health and Safety*, 3rd ed., Vol. 1. L. Parmeggiani, Ed. International Labour Office, Geneva.

Perry, W.G., F.A. Smith and M.B. Kent. 1994. *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2., Part F. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Pierce, J.O. 1994a. Alkaline materials. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part A. G.D. Clayton and F.E. Clayton Eds. John Wiley & Sons, New York.

Pierce, J.O. 1994b. Alkaline metals. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part A. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Reichrtova, E., and L. Takac. 1992. Issues Related to Dust Aerosols in the Magnesite Industry. I. Chamber Exposure. *J Hygiene, Epidemiology, Microbiology and Immunology* 36:235-244.

Rowe, V.K., and S.B. McCollister. 1982. Alcohols. In: *Patty's Industrial Hygiene and Toxicology*, 3rd ed., Vol. 2C. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York, pp. 4527-4704.

RTECS. 1995-1996. Registry of Toxic Effects of Chemical Substances. MEDLARS Online Information Retrieval System, National Library of Medicine.

Sax, N.I. 1984. Sodium hydroxide. In: *Dangerous Properties of Industrial Materials*, 6th ed. Van Nostrand Reinhold, New York.

Sax, N.I. and R.J. Lewis, Sr. 1989. *Dangerous Properties of Industrial Materials*, 7th ed. Van Nostrand Reinhold, New York.

Seiler, H.G. and H. Sigel. 1988. *Handbook on Toxicity of Inorganic Compounds*. Marcel Dekker, Inc., New York.

Sigma-Aldrich Corporation. 1992. Material Safety Data Sheet for Sodium Tetrafluoroborate. Sigma-Aldrich, Milwaukee, WI.

Sigma-Aldrich Corporation. 1993. Material Safety Data Sheet for 3-Nitrobenzenesulfonic acid, sodium salt. Sigma-Aldrich, Milwaukee, WI.

Sigma Chemical Co. 1992. Material Safety Data Sheet for Lithium Hydroxide. Sigma Chemical Co., St. Louis, MO.

Sigma Chemical Co. 1994. Biochemicals, Organic Compounds for Research and Diagnostic Reagents. Sigma Chemical Co., St. Louis, MO.

SRI. 1981. Stanford Research Institute. NCI Summary Data Sheet on Formic Acid, prepared for the National Cancer Institute by SRI International under Contract No. NO1-CP-95607.

Topping, D.C., D.A. Morgott, R.M. David and J.L. O'Donoghue. 1994. Ketones. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2, Part C. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

TRI92. 1994. Toxics Release Inventory. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, D.C.

TRI93. 1995. Toxics Release Inventory. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, D.C.

Trochimowicz, H.J., G.L. Kennedy and N.D. Krivanek. 1994. Aromatic compounds: five membered rings. In: *Patty's Industrial Hygiene and Toxicology*, 4th ed., Vol. 2. G.D. Clayton and F.E. Clayton, Eds. John Wiley & Sons, New York.

Utell, M.J., P.E. Morrow and R.W. Hyde. 1982. Comparison of normal and asthmatic subjects' responses to sulphate pollutant aerosols. *Ann Occup Hyg* 26(1-4), 691-697. (Cited in TOXLINE 1995)

U.S. Air Force. 1989a. *The Installation Restoration Program Toxicology Guide,* Vol. 3. Wright-Patterson Air Force Base, OH.

U.S. Air Force. 1989b. Phenol. In: *The Installation Restoration Program Toxicology Guide*, Vol. 2. Wright-Patterson Air Force Base, OH.

U.S. Air Force. 1990. Copper - Elemental Copper. In: *The Installation Restoration Toxicology Guide*, Vol. 5. Wright-Patterson Air Force Base, OH.

U.S. EPA. 1980. U.S. Environmental Protection Agency. Ambient Water Quality Criteria for Cyanides. Office of Water and Standards, Criteria and Standards Division, U.S. EPA, Washington, D.C.

U.S. EPA. 1981a. U.S. Environmental Protection Agency. Ambient Water Quality Criterion for the Protection of Human Health: Ammonia. Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH.

U.S. EPA. 1981b. U.S. Environmental Protection Agency. Chemical Hazard Information Profile (CHIP) on Carbon Black. Prepared by Chemical Effects Information Center, Oak Ridge National Laboratory, Oak Ridge, TN. Office of Toxic Substances, U.S. EPA.

U.S. EPA. 1984a. U.S. Environmental Protection Agency. Health Effects Assessment for Copper. Office of Research and Development, Office of Emergency and Remedial Response, Washington, D.C., Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. EPA. 1984b. U.S. Environmental Protection Agency. Health Effects Assessment for Glycol Ethers. Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH.

U.S. EPA. 1984c. U.S. Environmental Protection Agency. Health Effects Assessment for Cyanide. Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH. EPA/540/1-86-011.

U.S. EPA. 1984d. U.S. Environmental Protection Agency. Health Effects Assessment for Sulfuric Acid. Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH. EPA/540/1-86-031.

U.S. EPA. 1985a. U.S. Environmental Protection Agency. Health and Environmental Effects Profile for 2-Ethoxyethanol. Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH.

U.S. EPA. 1985b. U.S. Environmental Protection Agency. Health and Environmental Effects Profile for Formaldehyde. Office of Solid Waste and Emergency Response, U.S. EPA, Washington, D.C. ECAO-CIN-P142.

U.S. EPA. 1985c. U.S. Environmental Protection Agency. Drinking Water Criteria Document for Cyanide (Final Draft). Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH. ECAO-CIN-442; EPA-600/X-84-192-1.

U.S. EPA. 1986. U.S. Environmental Protection Agency. Health and Environmental Effects Profile for N,N-Dimethylformamide. Environmental Criteria and Assessment Office, U.S. EPA, Cincinnati, OH. ECAO-CIN-P158.

U.S. EPA. 1987a U.S. Environmental Protection Agency. Drinking Water Criteria Document for Copper. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH. ECAO-CIN-477.

U.S. EPA. 1987b. U.S. Environmental Protection Agency. Health and Environmental Effects Profile for Phenol. Revised final draft. Prepared for Office of Solid Waste and Emergency Response, U.S. EPA. Prepared by Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH. ECAO-CIN-P125.

U.S. EPA. 1987c. U.S. Environmental Protection Agency. Health Effects Assessment for Tin and Compounds. Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH. ECAO-CIN-H106.

U.S. EPA. 1990a. U.S. Environmental Protection Agency. Health and Environmental Effects Document for Boric Acid. Prepared for the Office of Solid Waste and Emergency Response by the Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH.

U.S. EPA. 1995a. U.S. Environmental Protection Agency. Chemical Summary for Formaldehyde. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, D.C.

U.S. EPA. 1995b. U.S. Environmental Protection Agency. OECD High Production Volume Chemicals Programme - Phase 3 SIDS Initial Assessment Report Triethanolamine CAS No. 102-71-6. U.S. EPA, Washington, D.C.

U.S. EPA. 1996a. U.S. Environmental Protection Agency. Chemical Summary for Phenol. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, D.C.

U.S. EPA. 1996b. U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) Online. Coversheet for Silver. Office of Health and Environmental Assessment, U.S. EPA, Cincinnati, OH.

Venugopal, B. and T.D. Luckey. 1978. Palladium. In: *Metal Toxicity in Mammals. 2. Chemical Toxicity of Metals and Metalloids*. Plenum Press, New York.

Verschueren, K. (Ed.) 1983. *Handbook of Environmental Data on Organic Chemicals*, 2nd ed. Van Nostrand Reinhold, New York.

Verschueren, K. (Ed.) 1996. *Handbook of Environmental Data on Organic Chemicals*, 3rd ed. Van Nostrand Reinhold, New York.

Weast, R.C. (Ed.) 1983-1984. *CRC Handbook of Chemistry and Physics*, 64th ed. CRC Press, Inc., Boca Raton, FL.

Weast, R.C. 1985. *CRC Handbook on Organic Compounds*. (Cited in HSDS, 1995)

Weast, R.C., M.J. Astle and W.H. Beyer. 1987. *CRC Handbook of Chemistry and Physics*, 68th ed. CRC Press, Inc., Boca Raton, FL.

WHO. 1982. World Health Organization. IPCS International Programme on Chemical Safety. Environmental Health Criteria 21. Chlorine and Hydrogen Chloride. WHO, Geneva.

Wong, P.T.S., Y.K. Chau, O. Kramar and G.A. Bengert. 1982. Structure-toxicity relationship of tin compounds on algae. *Can J Fish Aquat Sci* 39:483-488.

Young, R.D. 1978. Ammonium compounds. In: *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd ed., Vol. 2, John Wiley & Sons, New York.

ATTACHMENT C-1 (Standard References Searched)

ACGIH. 1991. American Conference of Governmental Industrial Hygienists. Documentation of Threshold Limit Values and Biological Exposure Indices, 6th ed. ACGIH, Cincinnati, OH.

ACGIH. 1994-1995. American Conference of Governmental Industrial Hygienists. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. ACGIH, Cincinnati, OH.

AQUIRE. 1994. Aquatic Information Retrieval online data base. Chemical Information Systems, Inc., a subsidiary of Fein-Marquart Assoc.

ATSDR. 1989-1994. Agency for Toxic Substances and Disease Registry. Toxicological Profiles. ATSDR, Chamblee, GA.

Budavari S, O'Neil MJ, Smith A, Heckelman PE (Eds.). 1989. The Merck Index, 11th ed. Merck & Co., Inc., Rahway, NJ.

CHEMFATE. 1995. Syracuse Research Corporation's Environmental Fate Data Bases. Syracuse Research Corporation, Syracuse, NY.

Clayton GD, Clayton FE. 1981-1982. Patty's Industrial Hygiene and Toxicology, 3rd ed., Vol. 2C. John Wiley & Sons, New York.

HSDB. 1994. Hazardous Substances Data Bank. MEDLARS Online Information Retrieval System, National Library of Medicine.

IARC. 1979-1994. International Agency for Research on Cancer. IARC Monographs on the Evaluation of Carcinogenic Risk of Chemicals to Man. IARC, Lyon.

NIOSH. 1992. National Institute for Occupational Safety and Health. NIOSH Recommendations for Occupational Safety and Health. Compendium of Policy Documents and Statements. NIOSH, Cincinnati, OH.

NIOSH. 1994. National Institute for Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards. NIOSH, Cincinnati, OH.

NTP. 1994. National Toxicology Program. Toxicology and Carcinogenesis Studies. Tech Rep Ser.

NTP. 1994. National Toxicology Program. Management Status Report. Produced from NTP Chemtrack system. April 8, 1994. National Toxicology Program, Research Triangle Park, NC.

OSHA. 1994. Occupational Safety and Health Administration. Table Z-2. Limits for Air Contaminants.

RTECS. 1994. Registry of Toxic Effects of Chemical Substances. MEDLARS Online Information Retrieval System, National Library of Medicine.

TSCA. 1995. Toxic Substances Control Act. Sect 8(e) data submissions.

U.S. Air Force. 1989. The Installation Restoration Toxicology Guide, Vols. 1-5. Wright-Patterson Air Force Base, OH.

U.S. EPA. (U.S. Environmental Protection Agency) 1991. Table 302.4 List of Hazardous Substances and Reportable Quantities 40 CFR, part 302.4:3-271.

U.S. EPA. (U.S. Environmental Protection Agency) Most current. Drinking Water Regulations and Health Advisories. Office of Drinking Water, U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. (U.S. Environmental Protection Agency) Most Current. Health Effects Assessment Summary Tables. Environmental Criteria and Assessment Office, U.S. EPA., Cincinnati, OH.

U.S. EPA. (U.S. Environmental Protection Agency) reviews such as Health and Environmental Effects Documents, Health and Environmental Effect Profiles, and Health and Environmental Assessments.

U.S. EPA. (U.S. Environmental Protection Agency) 1994. Integrated Risk Information System (IRIS) Online. Cincinnati, OH: Office of Health and Environmental Assessment.

Appendix D

Supplemental Exposure Assessment Information

D.1 Technical Memorandum RE: Modeling Worker Inhalation Exposure

D.2 Technical Memorandum RE: Sensitivity and Uncertainty Analysis of Workplace Air Concentration Models Used in the PWB Exposure Assessment

D.1 Technical Memorandum RE: Modeling Worker Inhalation Exposure

TECHNICAL MEMORANDUM

TO: Debbie Boger
PWB Project File, EPA # X823941-01-0

cc: Lori Kincaid, Jack Geibig, Dean Menke, Diane Perhac

FROM: Bruce Robinson, Chris Cox, Nick Jackson, Mary Swanson

DATE: December 22, 1995 (Revised 8/96)

RE: MODELING WORKER INHALATION EXPOSURE

I. INTRODUCTION

This technical memorandum is submitted for review by the RM2 work group. Air transport models to estimate worker inhalation exposure to chemicals from printed wiring board (PWB) making holes conductive (MHC) lines are presented here for review and comment. The purpose is to reach agreement on our technical approach before proceeding with further analysis.

Three air transport models will be required to estimate worker exposure:

- Volatilization of chemicals induced by air sparging.
- Aerosol generation induced by air sparging.
- Volatilization of chemicals from the open surface of MHC tanks.

The total transport of chemicals from the air-sparged baths will be determined by summing the releases calculated using each of the three models described above. Air-sparged baths include the electroless-copper baths and some cleaning tanks. Only the third model will be applied to determine the atmospheric releases of chemicals from unsparged baths. This document includes a review of the relevant literature, descriptions of the models, and examples demonstrating the proposed use of the models. The results of the model calculations will be compared to available occupational monitoring data.

II. VOLATILIZATION OF CHEMICALS FROM AIR-SPARGED PWB MANUFACTURING TANKS

Mixing in plating tanks, e.g., the electroless copper plating tank, is commonly accomplished by sparging the tank with air. This is similar to aeration in wastewater treatment plants, and the volatilization of chemicals from these plants has been the focus of recent research. The volatilization models used in that research are based on well accepted gas transfer theory, discussed below.

Background

Volatilization of chemicals from water to air has been investigated by many researchers (Liss and Slater, 1974; Smith *et al.*, 1980; Roberts, 1983; Peng *et al.*, 1993). In PWB manufacturing, volatilization due to air sparging of process tanks is expected to be one of the main pathways for contaminant transfer to the air. In bubble aeration systems, the volatilization rate is dependent upon the volumetric gas flow rate, partial pressure of the gas, and the mass transfer rate coefficient (Matter-Müller, 1981). The volatilization characteristics for different diffuser types and turbulent conditions were evaluated by Matter-Müller (1981), Peng (1995), and Hsieh (1994).

Volatilization from aerated systems has been mainly quantified using the two-film theory (Cohen *et al.*,1978; Mackay and Leinonen, 1975). This work is discussed below and is used to model chemical transfer rates from air-sparged PWB process tanks. The main assumption of the theory is that the velocity at a fluid interface is zero. Molecular diffusion across the interfacial liquid film is the limiting factor for mass transfer to the air, and it is used to develop a simple equation relating the overall mass transfer coefficient to the diffusion coefficient of the chemical in water.

The two-film model of gas transfer was expanded to include mass transfer in diffused aeration systems (Matter-Müller *et al.*, 1981). Matter-Müller *et al.* assumed that the system was isothermal, hydraulic conditions were steady, and that pressure and volume changes within the bubbles were negligible. Further, an overall mass transfer coefficient was applied to represent transfer of contaminants to the bubble as they rose through the homogeneous liquid volume. Parker (1993) demonstrated that liquid-phase concentration can be assumed constant during the rise time of the bubble. Under these assumptions, Matter-Müller *et al.* derived the following relationship predicting the mass transfer rate from an aerated system:

$$F_{y,s} = Q_G H_y c_{L,y} \left[1 - \exp\left(-\frac{K_{OL,y} a V_L}{H_y Q_G} \right) \right] \qquad (1)$$

where:

$F_{y,s}$ = mass transfer rate of chemical *y* out of the system by sparging (m/t)
Q_G = gas flow rate (l^3/t)
H_y = dimensionless Henry's constant for chemical *y*
$c_{L,y}$ = concentration of chemical *y* in bulk liquid (m/l^3)
$K_{OL,y}$ = overall mass transfer coefficient for chemical *y* (l/t)
a = interfacial area of bubble per unit volume of liquid (l^2/l^3)

V_L = volume of liquid (l^3)

The overall mass-transfer coefficient is defined as the inverse sum of the reciprocals of the liquid and gas-phase mass transfer coefficients; but, because molecular diffusion of oxygen and nonpolar organic substances is 10^3 times greater in air than in water (Matter-Müller *et al.*, 1981), it is set equal to the liquid phase coefficient only. The mass transfer coefficient of a chemical can then be related to oxygen using the following equation:

$$K_{OL,y} = \left(\frac{D_y}{D_{O2}} \right) K_{OL,O2} \tag{2}$$

where:

D_y = molecular diffusion coefficient for chemical *y* in water (l^2/t)
D_{O2} = molecular diffusion coefficient for oxygen in water (l^2/t)
= 2.1×10^{-5} cm^2/cm @ 25° C (Cussler, 1984)
$K_{OL,y}$ = overall mass transfer coefficient for chemical *y* (l/t)
$K_{OL,O2}$ = overall mass transfer coefficient for oxygen in water (l/t)

The value of $K_{OL,O2}$ at 25°C in diffused aeration systems can be estimated using a correlation developed by Bailey and Ollis (1977):

$$K_{OL,O_2} = 0.31 * \left(\frac{d_b^3 (\rho_{H2O} - \rho_{air}) g}{\mu_{H2O} D_{O2}} \right)^{1/3} \frac{D_{O2}}{d_b} \tag{3}$$

where:

d_b = bubble diameter (l)
ρ_{H2O} = density of water (m/l^3)
ρ_{air} = density of air (m/l^3)
g = gravitational constant (l/t^2)
μ_{H2O} = viscosity of water ($m/l \cdot t$)

If a measured value of D_y is not available, then it can be calculated from the Hayduk and Laudie correlation (Lyman *et al.*, 1982):

$$D_y (cm^2/\text{sec}) = \frac{13.26 x10^{-5}}{\mu_{H2O}^{1.14} \; V_m^{0.589}} \tag{4}$$

where:

V_m = molar volume of solute (cm^3/mol)
μ_{H2O} = viscosity of water (centipoise)

The mass transfer coefficient can be corrected for the bath temperature (°C) as follows (Tschabanoglous, 1991):

$$K_{OL,y,T} = K_{OL,y,25^{o}C}\ 1.024^{(T-25)} \tag{5}$$

Bailey and Ollis (1977) developed a relationship for the interfacial area per unit volume (a) as a function of the bubble diameter, gas flow rate, and tank geometry:

$$a=\frac{6\ Q_G\ t_b}{V_L\ d_b} \tag{6}$$

where:

h = tank depth (l); and

$$t_b=\frac{18\ h\ \mu_{H2O}}{d_b^2\ (\rho_{H2O}-\rho_{air})g} \tag{7}$$

Values of H_y are often reported at 25ºC. The Henry's constant can be corrected to the bath temperature using the van't Hoff equation:

$$H_{y,T}=H_{y,25^{o}C}\exp\left[\frac{\Delta H_{gas}-\Delta H_{aq}}{R}\left(\frac{1}{298.15}-\frac{1}{273.15+T}\right)\right] \tag{8}$$

where:

$\Delta\eta_{gas}$ = enthalpy of the chemical in the gas phase (cal/mol)
ΔH_{aq} = enthalpy of the chemical in the aqueous phase (cal/mol)
R = gas constant (1.987 cal/mol·K)

Matter-Müller (1981) concluded that surfactants do not significantly alter the rate of volatilization from the water. Some agents did lower the overall mass transfer coefficient, but most showed no appreciable difference. This was attributed to an increase in the specific interfacial area, *a*, when the interfacial energy, or mass transfer coefficient, was decreased. The transfer rate of volatile organic compounds (VOCs) was found to depend heavily upon the type of aerators used, and the degree of saturation of the bubbles rising through the liquid.

III. AEROSOL GENERATION FROM BATHS MIXED BY SPARGING WITH AIR

Aerosols or mists have been identified as a major source of contaminants released by electroplating baths to the atmosphere (Burgess, 1981) and should be investigated as a potential source of contaminants from electroless baths. At least two sources of aerosols exist in electroplating baths: 1) aerosols generated due to liquid dripping from parts as they are removed from the bath (drag-out drips); and 2) aerosols generated due to bursting of the bubbles at the surface. Drag-out drips are insignificant compared to other sources of aerosols (Berglund and Lindh, 1987; Cooper et al., 1993).

Bubbles in electroplating baths can originate from the dissociation of water at the electrode, or mixing of the bath via air sparging. Bubbles in other plating baths (e.g., electroless plating baths) can originate from reactions in the bath or mixing of the bath via air sparging. The rate of aerosol generation per unit bubble volume decreases with increasing bubble size. Bubbles generated by water dissociation are typically smaller than those generated by air sparging; therefore, aerosol generation in electroless plating processes may be less significant than in electroplating operations. The focus of this memo is aerosols generated by air sparging. Except for the conductive polymer and non-formaldehyde electroless alternatives, MHC processes in PWB manufacturing do not use electroplating and therefore would not dissociate water to form gas bubbles. Information collection is continuing to allow prediction of aerosol formation in MHC processes that do have an electroplating step. Importantly, Berglund and Lindh (1987) report that aerosol generation from electroplating tanks is greatly reduced by sparging; the relatively large air bubbles formed during air sparging coalesce the smaller bubbles formed by hydrolysis and electroless plating reactions.

To estimate the emission of contaminants resulting from aerosols, the rate of aerosol generation and the concentration of contaminant in the aerosol are required. Limited information concerning the rate of aerosol formation was found in the literature. The following sources were consulted:

- U.S. EPA (1991). *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments*.
- Chemical Abstracts, 1986 to date.
- Current and past text books in air pollution, chemical engineering, and water and wastewater treatment.
- Perry’s Handbook (1984) related to entrainment in distillation trays.
- The last five years of *Water Environment Research* and *ASCE Journal of the Environmental Engineering Division*.
- A title key-word search of holdings in the library of the University of Tennessee.
- The ASPEN model commonly used for modeling chemical manufacturing processes. (It was found that any aerosol formation routines within ASPEN would be relevant to entrainment in devices such as distillation trays and not relevant to sparging of tanks.)
- The manager of the US EPA Center for Environmental Assessment Modeling in Athens, Georgia, as well as an expert in the Air and Energy Lab - Emission Modeling Branch in North Carolina.

In this work, the aerosol formation rates will be predicted based upon limited measurements of aerosol generation in electroplating (Berglund and Lindh, 1987) and other air-sparged baths (Wangwongwatana et al., 1988; Wangwongwatana et al., 1990) found in the literature.

Berglund and Lindh (1987) developed several graphs relating aerosol generation to air sparging rate (Figure 1a), bath temperature (Figure 1b), air flow rate above the bath (Figure 1c), and distance between bath surface and the tank rim (Figure 1d). Using Figures 1a-1d, the following relationship may be developed:

$$R_A = \left[5.5x10^{-5}\left(Q_G \;/\; A\right) + 0.01\right] F_T \; F_A \; F_D \tag{9}$$

where:

R_A = aerosol generation rate (ml/min/m^2)
Q_G/A = air sparging rate per unit bath area (l/min/m^2)
F_T = temperature correction factor
F_A = air velocity correction factor
F_D = distance between the bath surface and tank rim correction factor

Wangwongwatana et al. (1988) presented figures relating the number of aerosol droplets generated as a function of air flow rate, bubble rise distance, bubble size, and colloid concentration (Figure 2). Droplet size distribution measurements by these researchers indicate volume mean diameters of 5 to 10 µm. The aerosol generation rate can be calculated using the following equation:

$$R_A = \frac{Q_G C_d V_d}{A} \tag{10}$$

where:

C_d = droplet concentration (l^{-3})
V_d = droplet volume (l)
A = bath area (l^2)

Contaminants may be present in aerosols at elevated concentration relative to the bath concentration. Colloidal contaminants may be collected on the bubble surface as it rises through the bath. As the bubble bursts, the contaminants on the bubble surface are incorporated into aerosols. Wangwongwatana et al. (1990) report that in their experiments about one in two aerosols contain polystyrene latex spheres, compared to about one in 250 expected based upon the concentration of latex sphere in the bath. Organic contaminants may also partition at the air-water interface. A correlation for the water-interface partitioning coefficient for nonpolar compounds, k_{IW}, defined as the ratio of the mass of contaminant per unit area of interface to the mass of contaminant per unit volume of water is given by Hoff et al. (1993):

$$\log \; k_{IW} = -8.58 \; - 0.769 \; \log \; C_W^S \tag{11}$$

where:

C^S_W = saturated aqueous solubility of the contaminant.

For more polar compounds a more complicated relationship is required:

$$\log\ k_{IW} = -7.508 + \log\ \gamma_w + a_s(\sigma_{wa} - \sigma_{sa} - 1.35\sigma_{sw})/2.303RT \tag{12}$$

where:

γ_w = activity coefficient of the contaminant in water (dimensionless)
a_s = molar area of the solute (cm^2/mol)
R = gas constant ($8.314x10^{7}$ erg/mol K)
σ_{WA} = surface tension of the water-air interface (dyne/cm)
σ_{SA} = surface tension of the solute-air interface (dyne/cm)
σ_{SW} = surface tension of the solute-water interface (dyne/cm)

Hoff et al. (1993) also present a relationship for the ratio of the mass of contaminant sorbed at the air-water interface to the mass of contaminant in the gas volume of the bubble:

$$\frac{M_I}{M_b} = \frac{k_{IW}}{H_y(d_b\ /\ 6)} \tag{13}$$

where:

M_I = mass of contaminant at the interface
M_b = mass of contaminant in gas bubble

Only a small fraction of the bubble interface will be ejected as aerosols. It may be calculated from the following equation:

$$f_{IE} = \frac{R_A\ \ A\ d_b}{6\ Q_G\ l_b} \tag{14}$$

where:

f_{IE} = fraction of bubble interface ejected as aerosols (dimensionless)
l_b = thickness of bubble film (l)

The rate of mass transfer from the tank to the atmosphere by aerosols, $F_{y,a}$ (m/t) is given by:

$$F_{y,a} = \frac{M_I}{M_b}\ f_{IE}\ F_{y,s} \tag{15}$$

IV. VOLATILIZATION OF CHEMICALS FROM THE OPEN SURFACE OF MHC TANKS

Most plating tanks have a free liquid surface from which chemicals can volatilize into the workplace air. Air currents across the tank will accelerate the rate of volatilization. The model presented in the Chemical Engineering Branch Manual for the Preparation of Engineering Assessments (CEBMPEA) (US EPA, 1991) has potential application in this case. Some limitations of the model should be pointed out. The model was developed to predict the rate of volatilization of pure chemicals, not aqueous solutions. The model was also validated using pure chemicals. As a result, the model implicitly assumes that mass transfer resistance on the gas side is limiting. The model may fail in describing volatilization of chemicals from solutions when liquid-side mass transfer controls.

CEBMPEA models the evaporation of chemicals from open surfaces using the following model:

$$F_{y,o} = 2\, c_{L,y}\, H_y\, A\, [D_{y,air} v_z/(\pi z)]^{0.5} \tag{16}$$

where:

$F_{y,o}$ = volatilization rate of chemical *y* from open tanks (m/t)
$D_{y,air}$ = molecular diffusion coefficient of chemical *y* in air (l^2/t)
v_z = air velocity (l/t)
z = distance along the pool surface (l)

The value of v_z recommended by CEBMPEA is 100 $ft \cdot min^{-1}$. The value of $D_{y,air}$ can be estimated by the following formula (US EPA, 1991):

$$D_{y,air} = 4.09\text{x}10^{-5}\, T^{1.9}\, (1/29 + 1/M)^{0.5}\, M^{-0.33}/P_t \tag{17}$$

where:

$D_{y,air}$ = molecular diffusion coefficient of chemical *y* in air (cm^2/s)
T = air temperature (K)
M = molecular weight (g/mol)
P_t = total pressure (atm)

This equation is based on kinetic theory and generally gives values of $D_{y,air}$ that agree closely with experimental data.

V. CALCULATION OF CHEMICAL CONCENTRATION IN WORKPLACE AIR FROM EMISSION RATES

The indoor air concentration will be estimated from the following equation (US EPA, 1991):

$$C_y = F_{y,T}/(V_R\, R_V\, k) \tag{18}$$

where:

C_y = workplace contaminant concentration (m/l^3)
$F_{y,T}$ = total emission rate of chemical from all sources (m/t)
V_R = room volume (l^3/t)
R_V = room ventilation rate (t^{-1})
k = dimensionless mixing factor

The mixing factor accounts for slow and incomplete mixing of ventilation air with room air. CEBMPEA sets this factor to 0.5 for the typical case and 0.1 for the worst case. CEBMPEA commonly uses values of the ventilation rate Q from 500 ft^3/min to 3,500 ft^3/min. Appropriate ventilation rates for MHC lines will be chosen from facility data and typical industrial recommendations.

VI. EXAMPLE MODELING OF FORMALDEHYDE RELEASE TO ATMOSPHERE FROM AIR-SPARGED ELECTROLESS COPPER BATH

In the examples below, the values of some parameters are based upon a site visit to SM Corporation in Asheville, NC. Except where stated otherwise, final values of the various parameters used in the models will be chosen based on the results of the Workplace Practices Questionnaire, chemical suppliers information, site visits, and performance demonstrations. All parameter values are based on preliminary information and are subject to change.

Values of site-specific parameters assumed in the example

Tank volume = 242 L	Site visit to SM Co., Asheville, NC
Tank depth = 71 cm	Assumed
Tank width = 48 cm	Assumed
Tank length = 71 cm	Assumed
Air sparging rate = 53.80 L/min	Midpoint of values given in Perry's Handbook, 1985, pg 19.13
Tank temperature = 51.67°C	Site visit to SM Co., Asheville, NC
H2CO Concentration in tank = 7,000 mg/L	Product data sheets
Bubble diameter at tank surface = 2.00 mm	Assumed
Room length = 20 m	Assumed
Room width = 20 m	Assumed
Room height = 5 m	Assumed
Air turnovers/hour = 4 hr^{-1}	Assumed
Air velocity across tank surface = 0.508 m/s	Default recommended by US EPA, 1991
Dimensionless mixing factor = 0.5	Default recommended by US EPA, 1991

Volatilization induced by air sparging

Calculating overall mass transfer coefficient for oxygen in water:

$$K_{OL,O_2} = 0.31 * \left(\frac{d_b^3 (\rho_{H2O} - \rho_{air}) g}{\mu_{H2O} D_{O2}} \right)^{1/3} \frac{D_{O2}}{d_b}$$

$$= 0.0113 \text{ cm/sec}$$
$$= 0.678 \text{ cm/min}$$

where:

d_b = 0.2 cm
ρ_{H2O} = 0.997 g/cm^3 (Dean, 1985)
ρ_{gas} = 0.00118 g/cm^3 (Dean, 1985)
g = 980 cm/sec^2

μ_{H2O} = 0.0089 (g/cm·sec) (Dean, 1985)
D_{O2} = $2.1\text{x}10^{-5}$ cm^2/sec (Cussler, 1984)

Calculating molecular diffusion coefficient of formaldehyde in water:

$$D_y = \frac{13.26x10^{-5}}{\mu_{H2O}^{1.14}\ V_m^{0.589}}$$

$= 1.81\text{x}10^{-5}\ \text{cm}^2\text{/sec}$

where:
V_m = 36.8 cm^3/mol
μ_{H2O} = 0.89 centipoise

Calculating mass transfer coefficient of formaldehyde in water:

$$K_{OL,y} = \left(\frac{D_y}{D_{O2}}\right) K_{OL,O2} = \left(\frac{1.81x10^{-5}}{2.10x10^{-5}}\right) * 0.678$$

= 0.584 cm/min

Correcting mass transfer coefficient for temperature:

$K_{OL,y,\ 51.67} = K_{OL,y,25^{o}C}\ 1.024^{(T-25)} = 0.584 * 1.024^{(51.67-25)} = 1.10$ cm/min

Calculating t_b:

$$t_b = \frac{18\ \ h\ \mu_{H2O}}{d_b^2\ (\rho_{H2O} - \rho_{air}) g}$$

= 0.291 sec
$= 4.85\text{x}10^{-3}$ min

where:
h = 71 cm

Calculating interfacial area per unit volume:

$$a = \frac{6\ Q_G\ t_b}{V_L\ d_b}$$

$= 0.0323\ \text{cm}^2\text{/cm}^3$

where:

Q_G = 53,800 cm^3/min
V_L = 242,000 cm^3

Correcting Henry's constant for temperature:

$$H_{y,51.67} = H_{y,25^oC} \exp\left[\frac{\Delta H_{gas} - \Delta H_{aq}}{R}\left(\frac{1}{298.15} - \frac{1}{273.15+T}\right)\right]$$

= 1.99x10^{-5} (dimensionless)

where:

$H_{y,25}$°C = 1.7x10^{-7} atm·m^3/mol (Risk Assistant, 1995)
= 6.38x10^{-6} (dimensionless)
DH_{gas} = -27,700 cal/mol
DH_{aq} = -35,900 cal/mol
R = 1.987 cal/mol·K

Calculating mass transfer rate of formaldehyde by air sparging:

$$F_{y,v} = Q_G \; H_y \; c_{L,y} \left[1 - \exp\left(-\frac{K_{OL,y} a V_L}{H_y Q_G}\right)\right]$$

= 7.49 mg/min

The argument of the exponential function is -8031. This indicates that the formaldehyde concentration in the air bubbles is essentially in equilibrium with the bath concentration.

Transport in aerosols

The aerosol generation rate will be estimated using data presented by both Berglund and Lindh (1987) and Wangwongwatana et al. (1988).

Calculating aerosol generation rate using Berglund and Lindh (1987) data:

$$R_A = \left[5.5x10^{-5}\left(Q_G/A\right) + 0.01\right] F_T \; F_A \; F_D$$

= 0.0187 mL/min/m^2

where:

Q_G/A = (53.8*10,000)/(71*48) = 158 (L/min/m^2)
F_T = 0.95 @ 51.67°C (Figure 1b)
F_A = 1.2 @ 0.508 m/s (Figure 1c)
F_D = 1.0 assumed (Figure 1d)

Calculating aerosol generation rate using Wangwongwatana et al. (1988) data:

The air sparging rate used in the example (53.8 L/min) must be converted to an equivalent rate in the experimental apparatus using the ratio of the area of the example bath (0.341 m^2) to the area of the experimental apparatus (0.123 m^2). The equivalent rate is 19.4 L/min. The bubble rise distance would be approximately 0.6 m. From Figure 2, it can be inferred that the droplet concentration is not much greater than 100 droplets/cm^3. The aerosol generation rate can now be calculated:

$$R_A = \frac{Q_G C_d V_d}{A}$$

$$= 8.27\text{x}10^{-3} \text{ ml/m}^2\text{/min}$$

where:

Q_G = 53800 cm^3/min
C_d = 100 droplets/cm^3
V_d = (p/6) d_d^3 = 5.24x10^{-10} cm^3
d_d = 0.001 cm (upper end of range reported by Wangwongwatana et al., 1988)
A = 0.341 m^2

The aerosol generation rates calculated by the two methods agree quite well. The model of Berglund and Lindh (1987) will be used because it gives a slightly greater generation rate and is easier to use.

Emission rate from bath. If it is assumed that the formaldehyde concentration in the aerosols is equal to the bath concentration (7 mg/mL) then the formaldehyde emission rate is:

$$F_{y,a} = (7 \text{ mg/mL}) \cdot (0.0187 \text{ mL/m}^2\text{/min}) \cdot (0.341 \text{ m}^2) = 4.46\text{x}10^{-2} \text{ mg/min}$$

To determine if accumulation of the contaminant at the air-water interface is significant, k_{IW} must be estimated using Equation 11. Since formaldehyde is a gas at the temperatures of interest, interfacial tension data are not available; however, average values of other aldehydes may be used (Hoff et al., 1993). Calculation of k_{IW} @25^{o}C is summarized below; information was not available for calculating k_{IW} at other temperatures.

$$\log\ k_{IW} = -7.508 + \log\ \gamma_w + a_s(\sigma_{wa} - \sigma_{sa} - 1.35\sigma_{sw})\ /\ 2.303RT$$

$$= -6.848$$

where:

γ_w = 1.452 Method 1, page 11-10 in Lyman et al. (1982)
a_s = 9.35x10^8 cm^2/mol Calculated from: a_s = 8.45x10^7 $V_m^{2/3}$
R = 8.314x10^7 erg/mol K
σ_{WA} = 72 dyne/cm Hoff et al. (1993)
σ_{SA} = 21.9 dyne/cm Value for acetaldehyde, Weast, 1980
σ_{SW} = 14.6 dyne/cm Average value for n-heptaldehyde and benzaldehyde, Girfalco and Good, 1957
k_{IW} = 1.418x10^{-7} cm

Formaldehyde emissions due to aerosols can now be calculated:

Calculating the ratio of contaminant mass sorbed at the air-water interface to mass in gas volume of bubble:

$$\frac{M_I}{M_b} = \frac{k_{IW}}{H_y(d_b/6)}$$

$$= 0.2138$$

Calculating fraction of bubble interface ejected as aerosols:

$$f_{IE} = \frac{R_A \ A \ d_b}{6 \ Q_G \ l_b}$$

$$= 4.35\text{x}10^{-3}$$

where:

l_b = $5\text{x}10^{-7}$ cm (Rosen, 1978)

Calculating formaldehyde mass transfer rate via aerosols from tank to the atmosphere:

$$F_{y,a} = \frac{M_I}{M_b} f_{IE} F_{y,s}$$

$$= 0.00697 \text{ mg/min}$$

Volatilization from open tanks

Calculating molecular diffusion coefficient of formaldehyde in air:

$$D_{y,air} = 4.09\text{x}10^{-5}\ T^{1.9}\ (1/29 + 1/M)^{0.5}\ M^{-0.33} / P_t$$

$$= 0.174 \text{ cm}^2\text{/sec}$$

where:

T = 298.15 K
M = 30.03 g/mol
P_t = 1 atm

Calculating volatilization rate of formaldehyde from open tanks:

$$F_{y,o} = 2\ c_{L,y}\ H_y\ A\ [D_{y,air} v_z/(pz)]^{0.5}$$

$$= 13.8 \text{ mg/min}$$

where:

$D_{y,air}$ = molecular diffusion coefficient of chemical in air (l^2/t)
V_z = 0.508 m/sec
z = 0.48 m (shortest tank dimension gives highest mass transfer rate)

The gas side mass transfer coefficient (k_g) in the above model is:

$$k_g = 2[D_{y,air} v_z/(pz)]^{0.5}$$

= 0.484 cm/sec

Thibodeaux (1979) reports a value of the liquid side mass transfer coefficient (k_l) in large water bodies of about $6x10^{-4}$ cm/sec for wind speeds of 0.5 m/sec. Although not directly applicable to the current situation, it can be used as a first estimate to determine the potential for liquid film resistance to control the mass transfer rate.

Liquid side resistance = $H_y / k_l = 3.3x10^{-2}$ sec/cm

Gas side resistance = $1/k_g$ = 2.1 sec/cm

It can be concluded that formaldehyde volatilization from open tanks is controlled by gas-side mass transfer resistance; therefore, the CEBMPEA equation appears to be valid. It should be noted that it may be necessary to consider liquid-side mass transfer resistance for chemicals with larger Henry's constants. In this case the CEBMPEA model would not be valid.

Surprisingly, volatilization due to air sparging is less significant than that from open tanks. Although the concentration of formaldehyde in the bubbles is high (virtually at equilibrium with the formaldehyde concentration in the bath), the volume of air sparged is small compared to the volume of room air flowing over the top of the tanks.

Concentration of formaldehyde in workplace air

C_y = $F_{y,T}/(V_R R_V k)$
= 0.326 mg/m^3
= 0.265 ppmv

where: $F_{y,T}$ = 7.49 mg/min + 0.421 mg/min + 13.8 mg/min = 21.71 mg/min
V_R = 20 m · 20 m · 5 m = 2000 m^3
R_V = 4 hr-1 = 0.0667 min^{-1}
k = 0.5

VII. COMPARISON OF PREDICTED FORMALDEHYDE CONCENTRATIONS IN WORKPLACE AIR TO MONITORING DATA

In this section, the concentrations of formaldehyde in the workplace air predicted by the model are compared to available monitoring data. The purpose of the comparison is not to validate the model but to determine if the modeling approach gives reasonable values of formaldehyde concentration. Model validation would require calculation of formaldehyde concentrations using the conditions specific to the monitoring sites. Such data are not available.

The results of an OSHA database (OCIS) search of monitoring data for formaldehyde (provided by OPPT) include 43 measured air concentrations for 10 facilities in Standard Industrial Classification (SIC) 3672 (printed circuit boards). The concentrations range from not detected to 4.65 ppmv. Most of the concentrations (37/42) range from ≤ 0.04 to 0.6 ppmv, with all but one less than 1.55 ppmv. Cooper et al. reports formaldehyde concentrations from three electroless plating operations measured over a two day period. The mean concentrations ranged from 0.088 to 0.199 ppmv. The predicted concentration of formaldehyde in the workplace air was 0.263 ppmv. Thus the predicted value is within the range of concentrations determined by monitoring, and less than the OSHA time-weighted-average concentration of 0.75 ppmv. The authors conclude that the results are reasonable.

REFERENCES

Bailey and Ollis. *Biochemical Engineering Fundamentals.* New York: McGraw-Hill, Inc., 1977.

Berglund, R. and E. Lindh. “Prediction of the Mist Emission Rate from Plating Baths.” *Proc. Am. Electroplaters and Surface Finishers Soc. Annu. Tech. Conf.,* 1987.

Burgess, W.H. *Recognition of Health Hazards in Industry: A Review of Materials and Processes.* New York: John Wiley and Sons, 1981.

Cohen, Y. and W. Cocchio. Laboratory Study of Liquid-Phase Controlled Volatilization Rates in Presence of Wind Waves. *Environ. Sci. Technol.*, **12**:553, 1978.

Cooper, C.D., R.L. Wayson, J.D. Dietz, D. Bauman, K. Cheze and P.J. Sutch. *Atmospheric Releases of Formaldehyde from Electroless Copper Plating Operations.* Proceedings of the 80th AESF Annual Technical Conference, Anaheim, CA. 1993.

Cussler, E.L. *Diffusion: Mass Transfer in Fluid Systems.* Cambridge: Cambridge University Press, 1984.

Dean, J.A. (Ed). *Lange’s Handbook of Chemistry,* 13th ed. New York: McGraw Hill, 1985.

Girifalco, L.A. and R.J. Good. “A Theory for the Estimation of Surface and Interfacial Energies: I. Derivation and Application to Interfacial Tension.” *J. Phys. Chem.,* **61**(7):904-909, 1957.

Hoff, J.T., D. Mackay, R. Gillham and W.Y. Shiu. “Partitioning of Organic Chemicals at the Air-Water Interface in Environmental Systems.” *Environ. Sci. Technol.,* **27**(10):2174-2180, 1993.

Hsieh, C., R. Babcock and M. Strenstrom. Estimating Semivolatile Organic Compound Emission Rates and Oxygen Transfer Coefficients in Diffused Aeration. *Water Environ. Research*, **66**:206, 1994.

Liss, P.S. and P.G. Slater. Flux of Gases Across the Air-Sea Interface. *Nature,* **247**:181, 1974.

Lyman, W.J., W.F. Reehl and D.H. Rosenblatt. *Handbook of Chemical Property Estimation Methods,* Washington DC: American Chemical Society, 1982.

Mackay, D. and P.J. Leinonen. Rate of Evaporation of Low Solubility Contaminants from Water Bodies to Atmosphere. *Environ. Sci. Technol.,* **9**:1178, 1975.

Matter-Müller, C., W. Gujer and W. Giger. *Transfer of Volatile Substances from the Water to the Atmosphere*. Institute for Water Resources and Water Pollution Control (EAWAG), Swiss Federal Institute of Technol., CH-8600 Dubendorf, Switzerland, **15**:1271, 1981.

Parker, W., D. Thompson and J. Bell. Fate of Volatile Organic Compounds in Municipal Activated Sludge Plants. *Water Environ. Research*, **65**:58, 1993.

Peng, J., J.K. Bewtra and N. Biswas. Transport of High-Volatility Chemicals from Water into Air. *Proceeding of 1993 Joint CSCE-ASCE National Conf. on Environmental Eng.*, **120**:662, 1993.

Peng, J., J. Bewtra and N. Biswas. Effect of Turbulence on Volatilization of Selected Organic Compounds from Water, *Water Environ. Research*, **67**:000, 1995.

Perry, R.H., D.W. Green and J.O. Maloney (Eds). *Perry's Chemical Engineers' Handbook,* New York: McGraw-Hill Book Company, 1984.

Risk Assistant Software. Alexandria, VA: Thistle Publishing, 1995.

Roberts, P.V., P. Dandliker and C. Matter-Müller. *Volatilization of Organic Pollutants in Wastewater Treatment-Model Studies*, EPA-R-806631. U.S. EPA, Munic. Environ. Res. Lab., Cincinnati, Ohio, 1983.

Rosen, M.J. *Surfactants and Interfacial Phenomena.* New York: John Wiley & Sons, 1978.

Smith, J. H., D.C. Bomberger and D.L. Haynes. Prediction of the Volatilization Rates of High-Volatility Chemicals from Natural Water Bodies, *Environ. Sci. Technol.*, **14**:1332, 1980.

Thibodeaux, L.J. *Chemodynamics: Environmental Movement of Chemicals in Air, Water and Soil.* New York: John Wiley & Sons, 1979.

Tschabanoglous, G. and F.L. Burton. *Wastewater Engineering: Treatment, Disposal, and Reuse*. New York: McGraw-Hill, Inc., 1991.

U.S. Environmental Protection Agency. *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments*. Washington, DC: U.S. EPA Office of Toxic Substances. February 28, 1991.

Wangwongwatana, S., P.V. Scarpino and K. Willeke. "Liquid-to-Air Transmission of Aerosols from a Bubbling Liquid Surface." *J. Aerosol Sci.*, **19**(7):947-951, 1988.

Wangwongwatana, S., P.V. Scarpino, K. Willeke and P.A . Baron. "System for Characterizing Aerosols from Bubbling Liquids." *Aerosol Sci. Technol.*, **13**(3):297-307, 1990.

Weast, R.C. (Ed.) *CRC Handbook of Chemistry and Physics*, 61st ed. Boca Raton, FL: CRC Press, 1980.

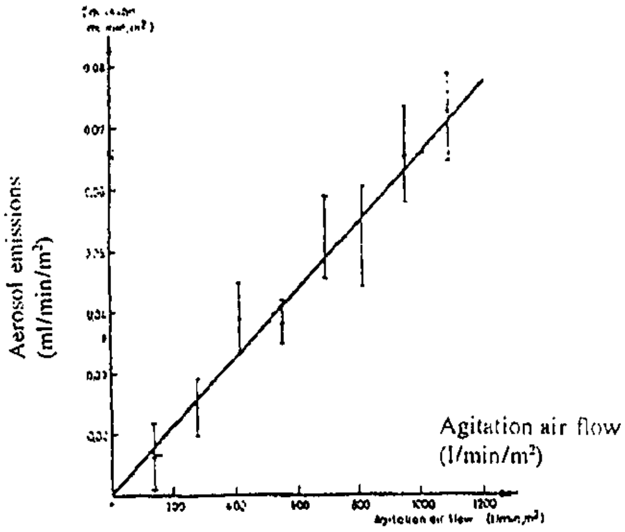


Figure 1a. Mist generation caused by air agitation.

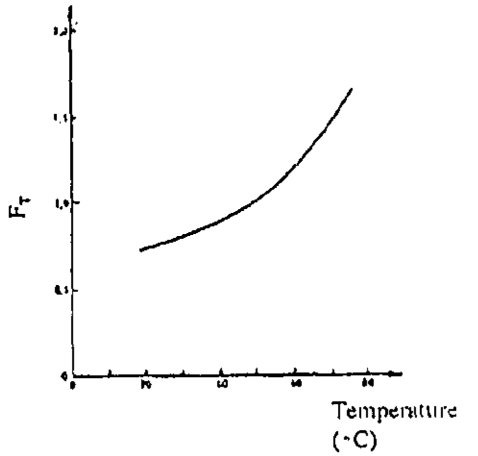


Figure 1b. Influence of bath temperature.

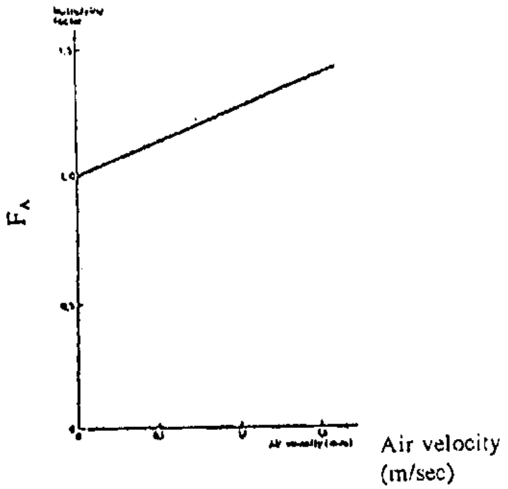


Figure 1c. Influence of air velocity across the bath surface.

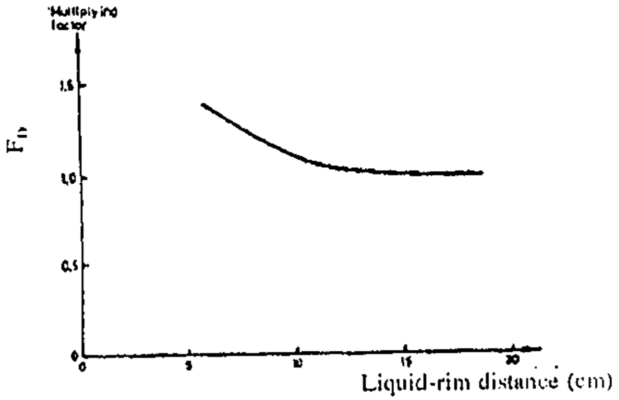


Figure 1d. Influence of the distance from the liquid to the bath rim.

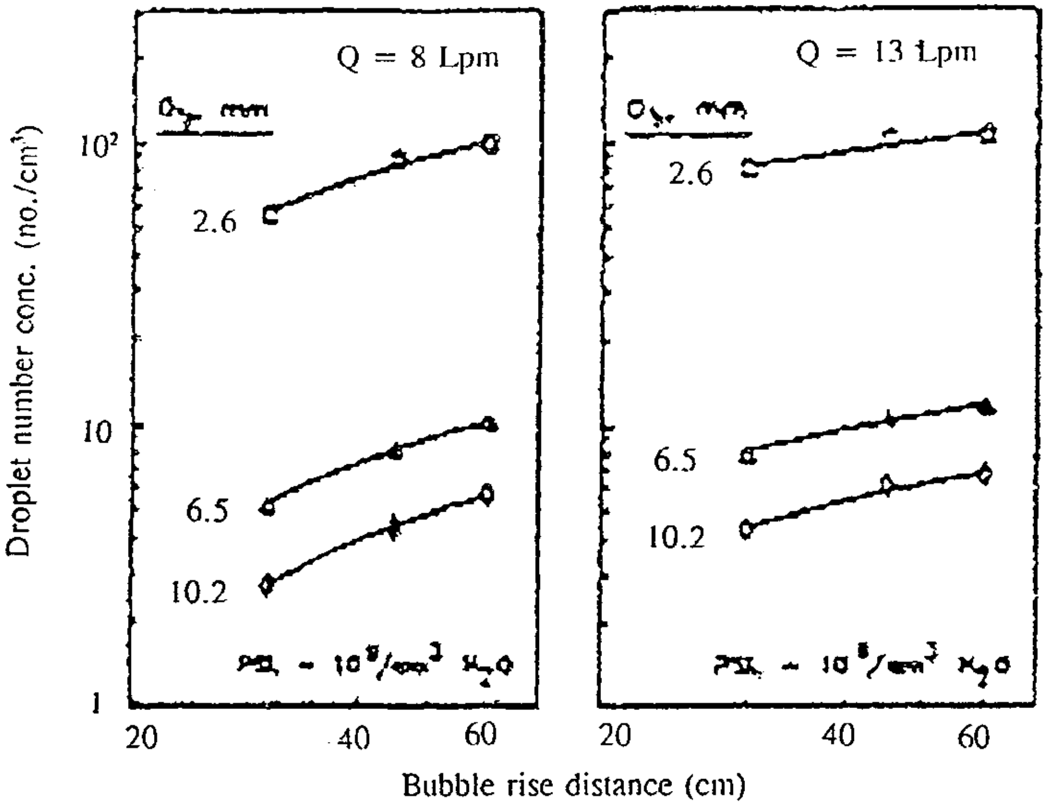


Figure 2. Effect of bubble rise distance on droplets number concentration. (From Wangwongwatana et al., 1990)

D.2 Technical Memorandum RE: Sensitivity and Uncertainty Analysis of Workplace Air Concentration Models Used in the PWB Exposure Assessment

TECHNICAL MEMORANDUM

TO: Kathy Hart / EPA DfE
PWB Project File (Project # X823-941)

cc: Lori Kincaid

FROM Nick Jackson, Mary Swanson, Bruce Robinson, Chris Cox

DATE: July 18, 1996 (revised August 8, 1996 and December 5, 1997)

RE: **SENSITIVITY AND UNCERTAINTY ANALYSIS OF WORKPLACE AIR CONCENTRATION MODELS USED IN THE PWB EXPOSURE ASSESSMENT**

I. INTRODUCTION

This technical memorandum is submitted to the RM2 Work Group for review and comment. Sensitivity and uncertainty analyses of the fate and transport models used in predicting workplace air concentrations of MHC chemicals were performed. (These air concentrations are used in the exposure assessment to estimate worker inhalation exposures.) The model parameters having the greatest effect on chemical air concentrations in the workplace are identified. A quantitative uncertainty analysis was also performed. These analyses serve to pinpoint and validate key parameter assumptions.

II. METHODS AND RESULTS

Sensitivity Analysis

The first step in this analysis was to determine the parameters in the air transport models that had the largest impact on the workplace chemical air concentrations regardless of parameter variability. This was done by independently varying each parameter in the model by a specific amount and observing the effect on chemical air concentration. This allows a comparison to be made between parameter importance in terms of model sensitivity because their effects on chemical air concentration were obtained independently of the other parameters.

Table 1 lists the parameters that had the greatest effect on workplace air concentration. Small changes in some parameters caused the model results to vary widely, indicating a need to determine the uncertainty associated with these variables. For sparged baths the example chemical was formaldehyde, and fluoboric acid was used for the unsparged bath analysis. Other chemicals were observed in the sensitivity analysis to learn whether the effects per chemical would vary with these parameters. This means that every chemical will not be affected in exactly the same way when varying parameters, but will exhibit close behavior. This initial sensitivity analysis was used primarily to select the important parameters for the Monte Carlo Analysis to follow, and as a check for that analysis.

Table 1. Model Sensitivity to Parameters

Parameters (x)	Δ x [1] (%)	Effects on Sparged Volatiles[2] (%)	Effects on Sparged Non-Volatiles[3] (%)	Effects on Un-Sparged Volatiles[4] (%)
Enthalpy (Aqueous or Gas)	10	-23.6	NA	-4.4
Bath Temperature	10	16.2	4.8	19.3
Henry's Law Constant (H_C)	10	10.0	NA	10.0
Bath Concentration of Chemical	10	10.0	10.0	10.0
Process Room Volume	10	-9.1	-9.1	-9.1
Air Turnover Rate	10	-9.1	-9.1	-9.1
Bath Surface Area	10	5.9	2.3	7.4
Air Sparging Rate	10	2.1	7.7	NA
Air Velocity Across Tank Surface	10	3.7	1.2	4.9
Molecular Weight	10	-2.0	NA	-2.1

1: Percentage increase in each parameter that produces corresponding percentage change in chemical room air concentration as shown in columns 2, 3, and 4.
2: Percentage increase or decrease in room air concentration of air-sparged volatiles due to parameter variation (Δ x) of 10 percent.
3: Percent increase or decrease in room air concentration of air-sparged nonvolatile (i.e., vapor pressure < $1x10^{-3}$ torr) due to parameter variation (Δ x) of 10 percent.
4: Percent increase or decrease in room air concentration of unsparged volatiles due to parameter variation (Δ x) of 10 percent.

For example, a 10% increase in bath surface area increases a sparged volatiles' workplace air concentration by 5.9%, while only increasing a sparged non-volatile or salt air concentration by 2.3%. Each parameter listed was also increased by 20% to determine if its relationship to air concentration was highly nonlinear, but none exhibited a significant trend in this area. Parameters not listed in Table 1 exhibited negligible effects on the model (<0.001 percent change in air concentration). These negligible parameters are:

- Bath volume;
- Surface tension coefficients;
- Molecular volume;
- Water densities and viscosities (due to variation of temperature in baths);
- Sparged bubble diameter; and
- Correction factors in the Berglund and Lindh model (see Exposure Assessment Draft, 1996).

Monte Carlo Analysis

Overview and Approach. After evaluating the sensitivity of the model to each parameter the next step was to examine model sensitivity and uncertainty using Monte Carlo Analysis. This was done with a Monte Carlo software package (Crystal Ball, Decisioneering, Inc.) in conjunction with a spreadsheet program (Lotus 1-2-3). The air transport equations outlined in the Exposure Assessment Draft (May 15, 1996) were used with the distributions for each parameter from the Workplace Practices Survey to perform this Monte Carlo Analysis.

Many different methods are available to propagate parameter distributions through a model and analyze the results. However, the difficult task of correlating complex nonlinear models and their parameters with some kind of regression algorithm severely limits the available techniques. The Latin Hypercube modification of the Monte Carlo method is agreed upon by many researchers to be the best way to perform a sensitivity/uncertainty analysis of contaminant transport models. In Latin Hypercube sampling, a probability distribution is divided into intervals of equal probability, thereby allowing for a more precise sampling routine because the entire probability range is more consistently represented (Decisioneering, Inc.). This probabilistic approach was used to generate a distribution of possible workplace air concentrations in contrast to a single point estimate.

Table 2 lists the assumptions used for the parameter distributions for the two bath type examples and describes the sources of information.

Crystal Ball was used to produce two independent Monte Carlo simulations, one for volatiles in air-sparged baths and one for unsparged baths. The number of iterations used for each simulation was 15,000. This was chosen to ensure adequate convergence and stabilization of the tails on output distributions (based on McKone and Bogen, 1991). The mass flux contribution from nonvolatiles in sparged baths is largely negligible and is not included to simplify the Monte Carlo simulations.

In addition to probability distributions, Crystal Ball calculates the percent contribution each parameter makes to overall model variance by computing Spearman rank correlation coefficients between every assumption and model result while the simulation is running. Spearman rank correlation coefficients differ from traditional linear regressions because ranks are assigned to observations and then substituted for the actual numerical values in the correlation formula. This correlation has distinct advantages over a simple linear regression. The relationship between variables is no longer assumed to be linear, and no assumptions of normality are made concerning the distributions of the variables as the relationship is nonparametric (Walpole and Myers, 1993). This parameter analysis combines model sensitivity and variable uncertainty.

Table 2. Parameter Assumptions Used in Monte Carlo Forecast

Parameters	Sparged Bath	Unsparged Bath	Source of Data
Process Room Volume	Lognormal Dist. based on survey data[a]	Lognormal Dist. based on survey data[b]	Workplace Practices Survey Data
Process Area Air Turnover Rate	Lognormal Dist. based on survey data[a]	Lognormal Dist. based on survey data[b]	Workplace Practices Survey Data
k (EPA, 1991) dimensionless mixing factor	Point estimate 1.0	Point estimate 1.0	Comments, G. Froiman /EPA RM2 Workgroup; June 16, 1996
Henry's Law Constant (H_C)	Normal Dist. based on avail. data[a]	Normal Dist. based on avail. data[b]	ORNL and other chemical info sources
Chemical Conc. in Bath	Triangular Dist.[a]	Triangular Dist.[b]	MSDS and Supplier info
Bath Surface Area	Lognormal Dist. based on survey data[a]	Lognormal Dist. based on survey data[b]	Workplace Practices Survey Data
Bath Temperature	Normal Dist. based on survey data[a]	Normal Dist. based on survey data[b]	Workplace Practices Survey Data
Bath Volume	Normal Dist. based on survey data[a]	Normal Dist. based on survey data[b]	Workplace Practices Survey Data
Air Sparging Rate	Point estimate 53.8 L/min	Point estimate 53.8 L/min	Midpoint of avail. values - chosen after model sensitivity seen to be small
Bubble Diameter	Lognormal Dist. based on avail. information[a]	Lognormal Dist. based on avail. information[b]	allowed to vary largely with little effect
Air Velocity across Bath Surface	Point estimate 0.508 m/s	Point estimate 0.508 m/s	recommended by EPA
Distance across pool Surface	Square root of bath area from survey data	Square root of bath area from survey data	directly correlated with area Dist.
Enthalpies, Gas and Aqueous States	Point estimate -35.9 kcal/mol & -27.7 kcal/mol	Point estimate -35.9 kcal/mol & -27.7 kcal/mol	ORNL and other chemical info sources
Activity Coeff.	Point estimate 1.45	Point estimate 25	ORNL and other chemical info sources
Surface Tension Coefficients	Point estimate 72, 21.92, &14.6 dynes/cm^2	Point estimate 72, 28.85, & 35 dynes/cm^2	ORNL and other chemical info sources

a: Attachment A shows these parameter distribution functions.
b: Attachment B shows these parameter distribution functions.

Results. Two types of results are presented: probability distributions for modeled air concentrations and the Spearman Rank Correlation results. The probabilistic chemical air concentration curves for each type of bath are presented in Figures 1 and 2. An uncertainty chart for each bath identifies the parameters that contribute most to model variance (Figures 3 and 4).

The parameter that contributes most to model variance for both bath types is air turnover rate in the process area. The range and standard deviation of reported air turnover rates from the Workplace Survey is very high. This causes it to contribute more to model variance than the process room volume. The variability of the room volume data is low and keeps it from even appearing on this list, despite the model being equally sensitive to changes in volume or turnover rate (as shown by Table 1). The chemical concentration in the bath is also high on the uncertainty charts because of the models' relative sensitivity to concentration and its variability.

Another important variable that appears on the sensitivity/uncertainty charts is bath temperature. This parameter is used to correct Henry's Law Constant (H_C) for temperature by an exponential relationship, but does not have much variability. H_C can also have a great effect on model outcome, depending upon the variability of the data. The distributions of H_C used here may not be entirely representative of the variation that can sometimes be encountered with this constant. For instance, Mackay (1991) has observed that a great deal of variation occurs with H_C when hydrophobic chemicals associate with the air-water interface and electrolytes or sorbents affect solubility in water. These variations are very difficult to characterize in a study unless H_C is measured under the conditions in question, which is not feasible here. Most chemical flux from sparged baths comes from the open surface volatilization equation (CEB, 1991), and will cause it to behave similarly to the unsparged bath equation as seen by results.

Comparison to Point Estimates. The probability distribution of formaldehyde air concentrations calculated by Monte Carlo Analysis were lower than expected from previously calculated point estimates. The 90th percentile from the frequency distribution is 0.61 mg/m^3, compared to 1.55 mg/m^3 calculated as a "high-end" point estimate (in the May, 1996, Exposure Assessment Draft). This suggests that the use of current point estimates results in a much more conservative air concentration than the 90th percentile. The point estimates in the exposure assessment use the 10th percentile air turnover rate, which controls air concentration because of its large variability shown in the uncertainty analysis.

A Monte Carlo distribution-based air turnover rate was determined using point estimates for all parameters and setting the air concentration equal to the 90th percentile probability frequency distribution from Crystal Ball. This was done for several chemicals in sparged and unsparged baths. This distribution-based air turnover rate was calculated as follows (from 3.3.1 in Exposure Assessment):

$$R_V = \frac{F_{Y,TOT}}{Conc \cdot V_R \cdot k}$$

where:

Rv = distribution-based air turnover rate (min^{-1})
Fy,tot = total emissions from all air transport mechanisms (mg/min)
Vr = room volume (m^3)
k = dimensionless mixing factor (a default value of 1.0 was used)
Conc = 90th percentile workplace air concentration from Monte Carlo Analysis (mg/m^3) determined using complete distributions for all parameters

This calculated air turnover rate was 0.0211 min^{-1} for formaldehyde in a sparged bath compared to the 10th percentile air turnover rate of 0.0083 min^{-1}. To ascertain the dependence of this distribution-based air turnover rate on chemical and bath type (sparged or unsparged) this calculation was repeated several times. These calculated (distribution-based) air turnover rates were:

- 0.0210 min^{-1} for copper chloride in a sparged bath; and
- 0.0206 min^{-1} for fluoboric acid in an unsparged bath.

Because air concentration estimates become more conservative as air turnover rates decrease, the value of 0.021 min^{-1} is recommended for estimating air concentrations for all chemicals to best approximate 90th percentile air concentrations with the available data.

The results of this sensitivity analysis are consistent with those obtained by Fehrenbacher and Hummel (1996). They suggest default air turnover rates of 14 m^3/min for a bounding, or maximum, estimate of exposure with this equation. The default input value of ventilation rate for obtaining “what-if”, or average estimates is 85 m^3/min (this value lies in the central portion of the range for the parameter). An air turnover rate of 0.021 min^{-1} corresponds to a ventilation rate of 23 m^3/min, when combined with room volume.

IV. CONCLUSIONS

It is evident that a few parameters are key to modeling chemical flux from PWB tanks. These key parameters are:

- Air turnover rate;
- Bath temperature;
- Chemical concentration in bath; and
- Henry’s Law Constant (H_C).

The air models’ sensitivity to these parameters and their uncertainty provides a means of isolating them from less important variables. Isolating these variables allows for additional scrutiny to be placed upon the point estimate assumptions used for them in the volatilization models.

The air turnover rate assumption contributes most to overall model variance. The chemical bath concentration and bath temperature also contribute variance to the model, but are less important than air turnover rate. This statement is fortified by the fact that relatively accurate information is available on their distributions. H_C appears to be least important of the four, but may have more variability associated with it. The models appear to be largely indifferent to small changes in most other parameters.

A comparison of point estimates with the 90th percentile from Monte Carlo Analysis suggests that using the 10th percentile value for air turnover rate yields a point estimate that is highly conservative, and that an increased air turnover estimate of 0.021 min^{-1} would provide air concentration results closer to the 90th percentile.

V. REFERENCES

Decisioneering, Inc. 1993. *Crystal Ball Software*.

Fehrenbacher, M.C. and A.A. Hummel. 1996. "Evaluation of the Mass Balance Model Used by the Environmental Protection Agency for Estimating Inhalation Exposure to New Chemical Substances." *American Industrial Hygiene Association*, **57**:526-536.

Mackay, D. 1991. *Multimedia Environmental Models: The Fugacity Approach*, Lewis Publishers, Inc.

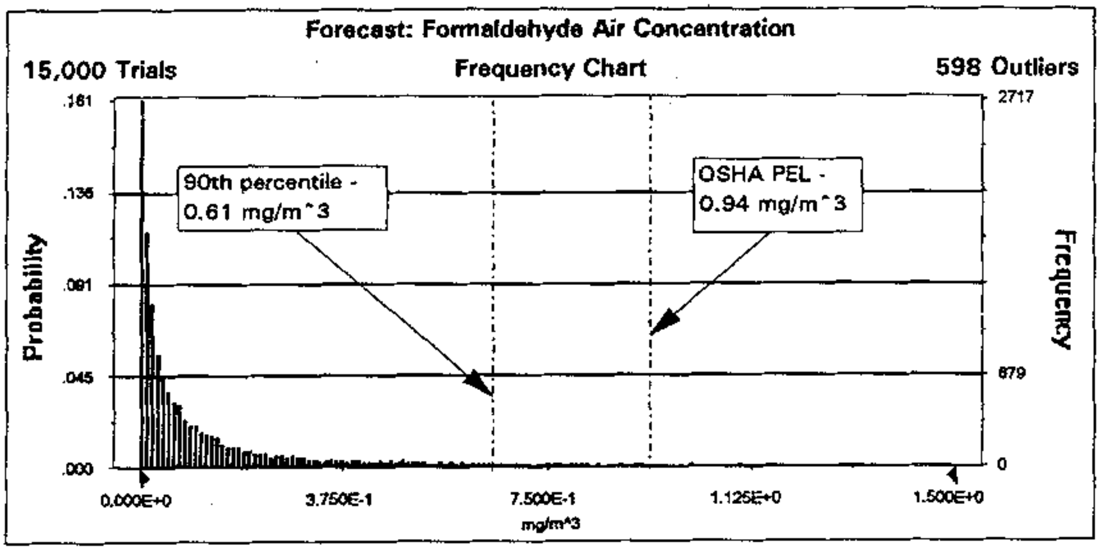
McKone, T.E. and K.T. Bogen. 1991. "Predicting the Uncertainties in Risk Assessment: A California Groundwater Case Stud.," *Environmental Science & Technology*, **25**(10): 1674-1681.

U.S. Environmental Protection Agency. 1991. *Chemical Engineering Branch Manual for the Preparation of Engineering Assessments*. Washington, DC: U.S. EPA Office of Toxic Substances, February 28.

Walpole, R.E. and R.H. Myers. 1993. *Probability and Statistics for Engineers and Scientists*, New York: MacMillan Publishing Company.

Figure 1.

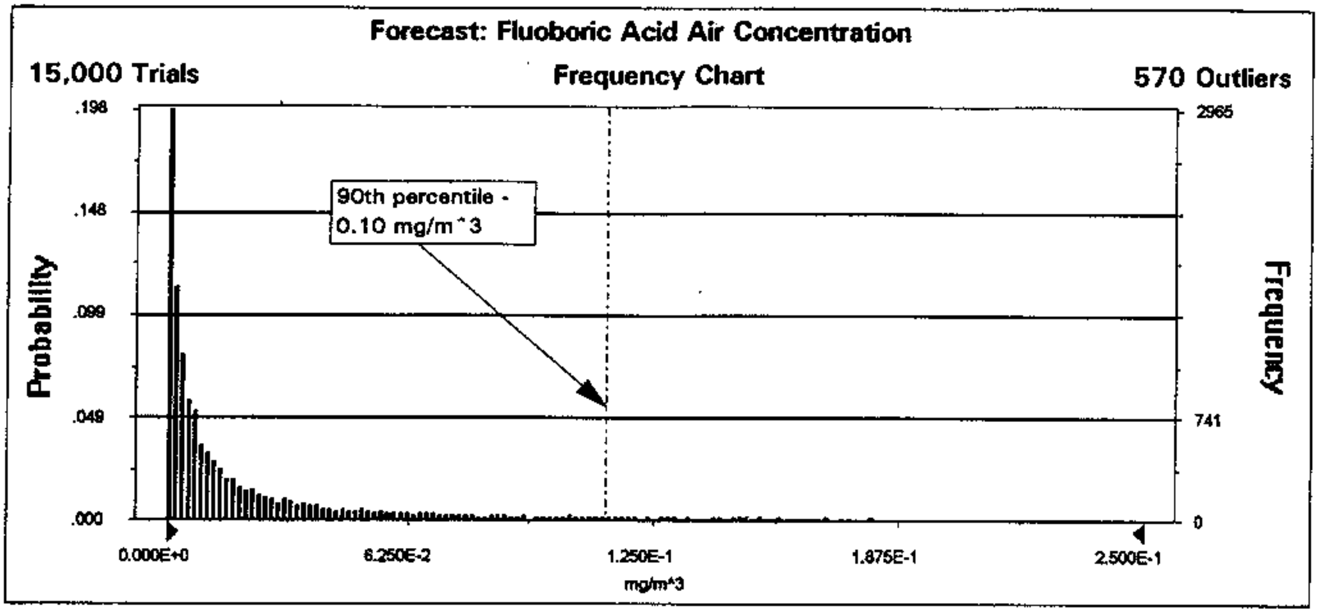
Forecast Probability Distribution from Monte Carlo Analysis for Sparged Bath Chemical Workplace Air Concentration in mg/m^ 3 (Formaldehyde)



Percentiles:

Percentile	mg/m^3
0%	9.569E-05
10%	4.977E-03
20%	1.131E-02
30%	2.026E-02
40%	3.363E-02
50%	5.478E-02
60%	8.814E-02
70%	1.446E-01
80%	2.633E-01
90%	**6.107E-01**
100%	5.969E+01

Figure 2.
Forecast Probability Distribution from Monte Carlo Analysis for Unsparged Bath Chemical Workplace Air Concentration in mg/m^ 3 (Fluoroboric Acid)



Percentiles:

Percentile	mg/m^3
0%	1.600E-05
10%	7.568E-04
20%	1.689E-03
30%	3.146E-03
40%	5.288E-03
50%	8.389E-03
60%	1.368E-02
70%	2.294E-02
80%	4.206E-02
90%	1.004E-01
100%	1.265E+01

Figure 3.
Sensitivity Chart for Sparged Bath Chemical Parameters Spearman Rank Correlation

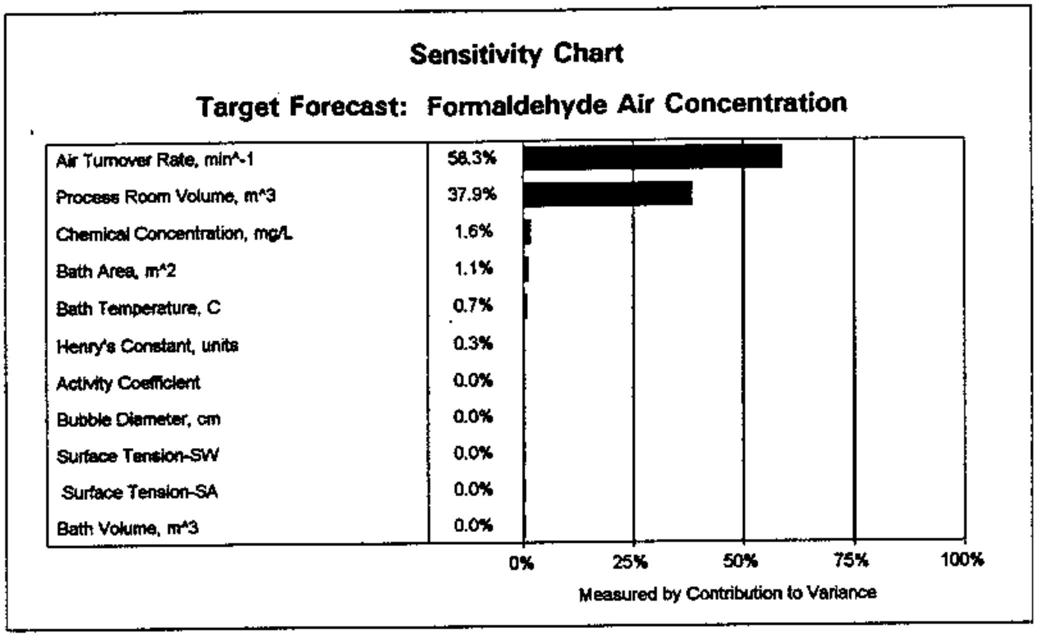


Figure 4.
Sensitivity Chart for Unsparged Bath Chemical Parameters Spearman Rank Correlation

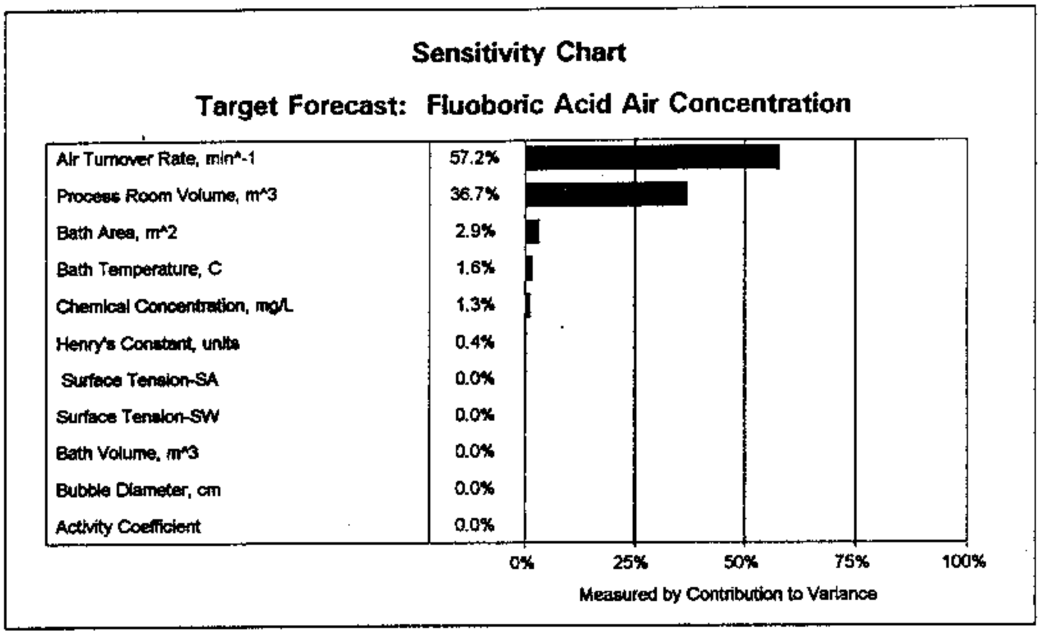


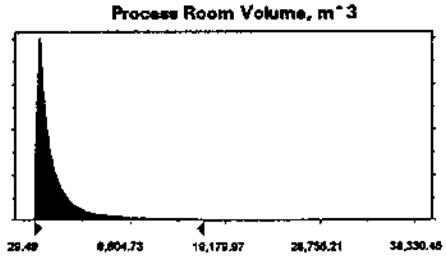
Figure 5.
Parameter Assumptions for Sparged Bath Monte Carlo Analysis - PDFs

Parameter: Process Room Volume, m^3

Lognormal distribution with parameters:

Geometric Mean	1,063.16
Geometric Std. Dev.	3.30

Selected range is from 33.00 to 17,000.00
Mean value in simulation was 1,911.23

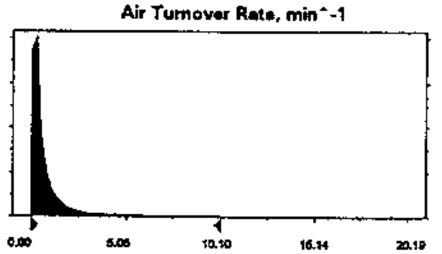


Parameter: Air Turnover Rate, min^-1

Lognormal distribution with parameters:

Mean	0.74
Standard Dev.	2.00

Selected range is from 0.00 to 10.10
Mean value in simulation was 0.64

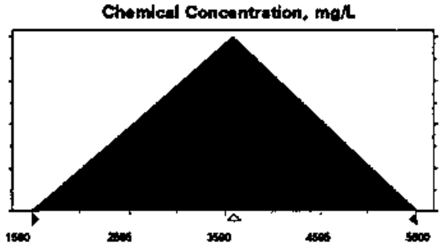


Parameter: Chemical Concentration in Bath, mg/L

Triangular distribution with parameters:

Minimum	1580
Likeliest	3680
Maximum	5600

Selected range is from 1580 to 5600
Mean value in simulation was 3620

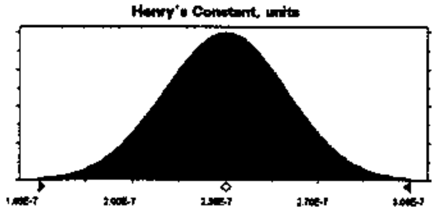


Parameter: Henry's Constant, atm*m^3/mol

Normal distribution with parameters:

Mean	2.35E-07
Standard Dev.	2.35E-08

Selected range is from -Infinity to +Infinity
Mean value in simulation was 2.35E-7

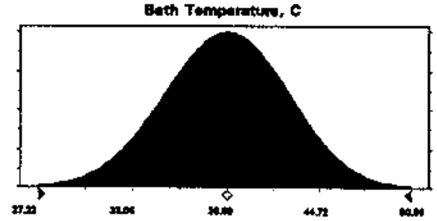


Parameter: Bath Temperature, degrees C

Normal distribution with parameters:

Mean	38.89
Standard Dev.	3.89

Selected range is from 20.00 to 58.00
Mean value in simulation was 38.89



Parameter: Bath Surface Area, m^2

Lognormal distribution with parameters:

Log Mean	-0.11
Log Std. Dev.	0.33

Selected range is from 0.00 to 3.72
Mean value in simulation was 0.94

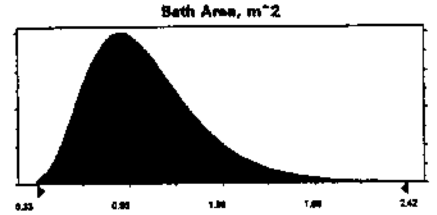


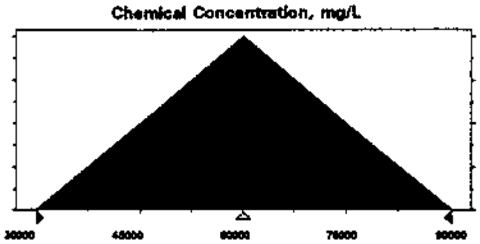
Figure 6.
Parameter Assumptions for Unsparged Bath Monte Carlo Analysis - PDFs

Parameter: Chemical Concentration in Bath, mg/L

Triangular distribution with parameters:

Minimum	30000
Likeliest	60000
Maximum	90000

Selected range is from 30000 to 90000
Mean value in simulation was 60000

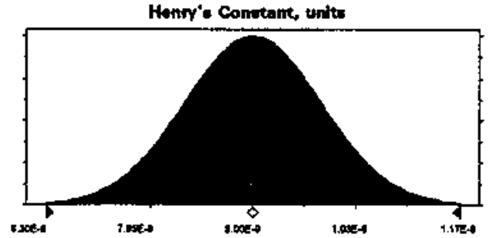


Parameter: Henry's Constant, atm*m^3/mol

Normal distribution with parameters:

Mean	9.00E-09
Standard Dev.	9.00E-10

Selected range is from 5.40E-9 to 1.26E-8
Mean value in simulation was 9.00E-9

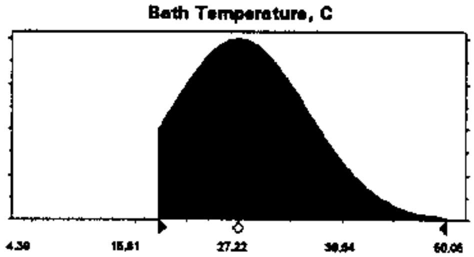


Parameter: Bath Temperature, degrees C

Normal distribution with parameters:

Mean	27.22
Standard Dev.	7.61

Selected range is from 18.39 to 50.39
Mean value in simulation was 28.95

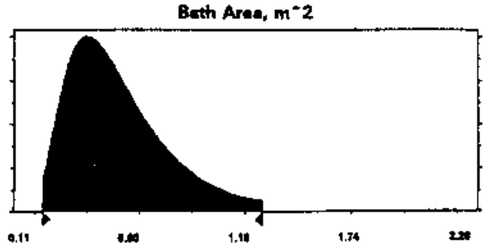


Parameter: Bath Surface Area, m^2

Lognormal distribution with parameters:

Geometric Mean	0.49
Geometric Std. Dev.	1.67

Selected range is from 0.15 to 1.28
Mean value in simulation was 0.53



Note: Process room volume and process room air turnover rate assumptions are the same as for formaldehyde (Figure 5).

Appendix E

Comprehensive Exposure Assessment and Risk Characterization Results

E.1 Risk Characterization Results for Electroless Copper, Non-Conveyorized, Line Operator Scenario

E.2 Risk Characterization Results for Electroless Copper, Non-Conveyorized, Laboratory Technician Scenario

E.3 Risk Characterization Results for Electroless Copper, Non-Conveyorized, Surrounding Population Scenario

E.4 Risk Characterization Results for Electroless Copper, Conveyorized, Line Operator Scenario

E.5 Risk Characterization Results for Electroless Copper, Conveyorized, Laboratory Technician Scenario

E.6 Risk Characterization Results for Electroless Copper, Conveyorized, Surrounding Population Scenario

E.7 Risk Characterization Results for Carbon, Conveyorized, Line Operator Scenario

E.8 Risk Characterization Results for Carbon, Conveyorized, Laboratory Technician Scenario

E.9 Risk Characterization Results for Carbon, Conveyorized, Surrounding Population Scenario

E.10 Risk Characterization Results for Conductive Polymer, Conveyorized, Line Operator Scenario

E.11 Risk Characterization Results for Conductive Polymer, Conveyorized, Laboratory Technician Scenario

E.12 Risk Characterization Results for Conductive Polymer, Conveyorized, Surrounding Population Scenario

E.13 Risk Characterization Results for Graphite, Conveyorized, Line Operator Scenario

E.14 Risk Characterization Results for Graphite, Conveyorized, Laboratory Technician Scenario

E.15 Risk Characterization Results for Graphite, Conveyorized, Surrounding Population Scenario

E.16 Risk Characterization Results for Non-Formaldehyde Electroless Copper, Non-Conveyorized, Line Operator Scenario

E.17 Risk Characterization Results for Non-Formaldehyde Electroless Copper, Non-Conveyorized, Laboratory Technician Scenario

Table E 1. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	NA	NA	1640		0.0E+00	NE (2)	NE (2)	8.4E-02	NE (1)	1.9E+04
BENZOTRIAZOLE	NA	NA	NA	21.8		6.6E-04	NE (1)	NE (1)	2.5E-03	NE (1)	8.8E+03
BORIC ACID	NA	NA	NA	56.2		9.2E-04	NE (1)	NE (1)	3.3E-02	NE (1)	1.7E+03
COPPER (I) CHLORIDE	NA	0.6	NA	0.042		4.0E-04	NE (1)	4.2E+02	4.4E-02	NE (1)	9.6E-01
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA	NA	NA		4.4E-04	NE (1)	NE (1)	4.9E-02	NE (1)	NE (1)
DIMETHYLAMINOBORANE	NA	NA	NA	NA	H	1.0E-02	NE (1)	NE (1)	3.9E-03	NE (1)	NE (1)
DIMETHYLFORMAMIDE	0.03	NA	NA	25		7.6E-03	8.8E-01	NE (3)	1.1E-03	NE (1)	2.2E+04
ETHANOLAMINE	NA	12.7	NA	64		5.3E-02	NE (1)	6.8E+01	1.0E-02	NE (1)	6.3E+03
2-ETHOXYETHANOL	0.2	NA	0.4	NA		7.8E+00	1.4E+02	NE (3)	1.4E-01	3.4E-01	NE (3)
ETHYLENE GLYCOL	NA	31	2	NA		1.8E-02	NE (1)	5.0E+02	2.5E-03	1.2E-03	NE (3)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA	NA	NA	NA	NA	LM	2.7E-03	NE (1)	NE (1)	1.7E-05	NE (1)	NE (1)
FLUOROBORIC ACID	NA	NA	NA	0.77	H	1.2E-02	NE (1)	NE (1)	3.9E-01	NE (1)	2.0E+00
FORMALDEHYDE	NA	100	0.002	NA		7.4E-02	NE (1)	4.8E-01	1.1E-02	1.5E+01	NE (3)
FORMIC ACID	NA	59.2	NA	NA		1.9E-01	NE (1)	1.0E+02	3.5E-02	NE (1)	NE (1)
HYDROCHLORIC ACID	0.007	15	NA	NA		2.9E-05	1.4E-02	NE (3)	9.0E-01	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	79	NA	31.5		8.9E-04	NE (1)	2.5E+04	1.3E-01	NE (1)	2.4E+02
HYDROXYACETIC ACID	NA	NA	NA	50		1.7E-04	NE (1)	NE (1)	2.4E-02	NE (1)	2.1E+03
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980	NA	20		2.8E+00	NE (1)	1.0E+02	3.1E-02	NE (1)	6.4E+02
M-NITROBENZENE SULFONIC ACID	NA	NA	NA	NA	M	4.9E-06	NE (1)	NE (1)	8.8E-07	NE (1)	NE (1)
MAGNESIUM CARBONATE	NA	NA	NA	NA	LM	5.4E-05	NE (1)	NE (1)	7.8E-03	NE (1)	NE (1)
METHANOL	NA	1596	0.5	NA		1.2E+00	NE (1)	3.7E+02	1.1E-02	2.3E-02	NE (3)
p-TOLUENE SULFONIC ACID	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	4.0E-03	NE (1)	NE (1)
PALLADIUM	NA	NA	NA	0.0475		0.0E+00	NE (2)	NE (2)	2.4E-03	NE (1)	2.0E+01
PEROXYMONOSULFURIC ACID; OR POTASSIUM	NA	NA	NA	NA	M	1.2E-03	NE (1)	NE (1)	1.7E-01	NE (1)	NE (1)
POTASSIUM BISULFATE	NA	NA	NA	NA	M	6.2E-04	NE (1)	NE (1)	9.0E-02	NE (1)	NE (1)
POTASSIUM CYANIDE	NA	NA	0.0025	NA		1.4E-05	NE (1)	NE (1)	1.5E-03	5.8E-01	NE (3)
POTASSIUM HYDROXIDE	NA	7.1	NA	NA		1.2E-05	NE (1)	1.6E+05	5.4E-03	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	NA	NA	M	4.4E-04	NE (1)	NE (1)	6.4E-02	NE (1)	NE (1)
POTASSIUM SULFATE	NA	15	NA	NA	L	8.6E-04	NE (1)	5.0E+03	1.3E-01	NE (1)	NE (1)
POTASSIUM-SODIUM TARTRATE	NA	NA	NA	NA		1.9E-03	NE (1)	NE (1)	2.1E-01	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	4.6E-01	NE (1)	NE (1)
SODIUM CARBONATE	NA	10	NA	NA		3.0E-06	NE (1)	9.4E+05	3.3E-04	NE (1)	NE (1)
SODIUM CHLORITE	NA	NA	NA	0.5		0.0E+00	NE (2)	NE (2)	3.0E-02	NE (1)	1.7E+01
SODIUM CYANIDE	NA	NA	0.002	NA		1.4E-05	NE (1)	NE (1)	1.5E-03	7.6E-01	NE (3)
SODIUM HYDROXIDE	NA	2	NA	NA		6.3E-04	NE (1)	9.1E+02	8.5E-02	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	5.6E-02	NE (1)	NE (1)
SODIUM SULFATE	NA	NA	NA	420		0.0E+00	NE (2)	NE (2)	8.3E-02	NE (1)	5.1E+03
STANNOUS CHLORIDE	NA	NA	0.0186	NA		0.0E+00	NE (2)	NE (2)	6.7E-02	3.6E+00	NE (3)
SULFURIC ACID	NA	0.066	NA	NA		5.6E-02	NE (1)	2.8E+00	1.2E+00	NE (1)	NE (1)
TARTARIC ACID	NA	NA	NA	1.74		6.2E-05	NE (1)	NE (1)	5.7E-05	NE (1)	3.0E+04
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETH	NA	NA	NA	32		0.0E+00	NE (2)	NE (2)	3.5E-03	NE (1)	9.3E+03

Table E 1. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Line Operator Scenario

Notes and Abbreviations
RfC: Reference Concentration
NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level
RfD: reference dose
SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.
ADD: average daily dose
HQ: hazard quotient (unitless ratio)
MOE: margin of exposure (unitless ratio)
NA: data not available
NE: risk indicator not evaluated for the following reasons:
(1) toxicity data not available
(2) exposure expected to be negligible
(3) HQ could be calculated

Table E 2. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	1640		2.1E-03	NE (1)	7.9E+05
BENZOTRIAZOLE	NA	21.8		6.1E-05	NE (1)	3.6E+05
BORIC ACID	NA	56.2		8.0E-04	NE (1)	7.0E+04
COPPER (I) CHLORIDE	NA	0.042		1.1E-03	NE (1)	3.9E+01
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		1.2E-03	NE (1)	NE (1)
DIMETHYLAMINOBORANE	NA	NA	H	9.6E-05	NE (1)	NE (1)
DIMETHYLFORMAMIDE	NA	25		2.8E-05	NE (1)	9.0E+05
ETHANOLAMINE	NA	64		2.5E-04	NE (1)	2.6E+05
2-ETHOXYETHANOL	0.4	NA		3.4E-03	8.4E-03	NE (3)
ETHYLENE GLYCOL	2	NA		6.0E-05	3.0E-05	NE (3)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA)	NA	NA	LM	4.1E-07	NE (1)	NE (1)
FLUOROBORIC ACID	NA	0.77	H	9.6E-03	NE (1)	8.0E+01
FORMALDEHYDE	0.002	NA		2.6E-04	3.7E-01	NE (3)
FORMIC ACID	NA	NA		8.5E-04	NE (1)	NE (1)
HYDROCHLORIC ACID	NA	NA		2.2E-02	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	31.5		3.2E-03	NE (1)	9.8E+03
HYDROXYACETIC ACID	NA	50		5.9E-04	NE (1)	8.4E+04
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	20		7.7E-04	NE (1)	2.6E+04
MAGNESIUM CARBONATE	NA	NA	LM	1.9E-04	NE (1)	NE (1)
METHANOL	0.5	NA		2.8E-04	5.6E-04	NE (3)
p-TOLUENE SULFONIC ACID	NA	NA	LM	9.8E-05	NE (1)	NE (1)
PALLADIUM	NA	0.0475		5.8E-05	NE (1)	8.2E+02
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	4.2E-03	NE (1)	NE (1)
POTASSIUM BISULFATE	NA	NA	M	2.2E-03	NE (1)	NE (1)
POTASSIUM CYANIDE	0.0025	NA		3.6E-05	1.4E-02	NE (3)
POTASSIUM HYDROXIDE	NA	NA		1.3E-04	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	M	1.6E-03	NE (1)	NE (1)
POTASSIUM SULFATE	NA	NA	L	3.1E-03	NE (1)	NE (1)
POTASSIUM-SODIUM TARTRATE	NA	NA		5.1E-03	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	M	1.1E-02	NE (1)	NE (1)
SODIUM CARBONATE	NA	NA		8.0E-06	NE (1)	NE (1)
SODIUM CHLORITE	NA	0.5		7.3E-04	NE (1)	6.9E+02
SODIUM CYANIDE	0.002	NA		3.7E-05	1.9E-02	NE (3)
SODIUM HYDROXIDE	NA	NA		2.1E-03	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	LM	1.4E-03	NE (1)	NE (1)
M-NITROBENZENE SULFONIC ACID	NA	NA	M	2.2E-08	NE (1)	NE (1)
SODIUM SULFATE	NA	420		2.0E-03	NE (1)	2.1E+05
STANNOUS CHLORIDE	0.0186	NA		1.6E-03	8.9E-02	NE (3)

Table E 2. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
SULFURIC ACID	NA	NA		2.9E-02	NE (1)	NE (1)
TARTARIC ACID	NA	1.74		1.4E-06	NE (1)	1.2E+06
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	32		8.5E-05	NE (1)	3.8E+05

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

(3) HQ could be calculated

Table E 3. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
BENZOTRIAZOLE	NA	NA		NE (2)	NE (2)	NE (2)
BORIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
COPPER CHLORIDE(I)	NA	0.6		NE (2)	NE (2)	NE (2)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
DIMETHYLAMINOBORANE	NA	NA	H	NE (2)	NE (2)	NE (2)
DIMETHYLFORMAMIDE	0.03	NA		NE (2)	NE (2)	NE (2)
ETHANOLAMINE	NA	12.7		NE (2)	NE (2)	NE (2)
2-ETHOXYETHANOL	0.2	NA		6.5E-04	1.1E-02	NE (3)
ETHYLENE GLYCOL	NA	31		NE (2)	NE (2)	NE (2)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA)	NA	NA	LM	NE (2)	NE (2)	NE (2)
FLUOROBORIC ACID	NA	NA	H	NE (2)	NE (2)	NE (2)
FORMALDEHYDE	NA	100		7.4E-06	NE (1)	2.8E+06
FORMIC ACID	NA	59.2		NE (2)	NE (2)	NE (2)
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
HYDROGEN PEROXIDE	NA	79		NE (2)	NE (2)	NE (2)
HYDROXYACETIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980		2.4E-04	NE (1)	1.2E+06
MAGNESIUM CARBONATE	NA	NA	LM	NE (2)	NE (2)	NE (2)
METHANOL	NA	1596		1.0E-04	NE (1)	4.4E+06
p-TOLUENE SULFONIC ACID	NA	NA	LM	NE (2)	NE (2)	NE (2)
PALLADIUM	NA	NA		NE (2)	NE (2)	NE (2)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM CYANIDE	NA	NA		NE (2)	NE (2)	NE (2)
POTASSIUM HYDROXIDE	NA	7.1		NE (2)	NE (2)	NE (2)
POTASSIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM SULFATE	NA	15	L	NE (2)	NE (2)	NE (2)
POTASSIUM-SODIUM TARTRATE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CARBONATE	NA	10		NE (2)	NE (2)	NE (2)
SODIUM CHLORITE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM CYANIDE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
SODIUM HYPOPHOSPHITE	NA	NA	LM	NE (2)	NE (2)	NE (2)
M-NITROBENZENE SULFONIC ACID	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
STANNOUS CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)

Table E 3. Risk Characterization Results for Electroless Copper, Non-Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)
TARTARIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

(3) HQ could be calculated

Table E 4. Risk Characterization Results for Electroless Copper, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	NA	NA	1640		0.0E+00	NE (2)	NE (2)	2.1E-02	NE (1)	7.8E+04
BENZOTRIAZOLE	NA	NA	NA	21.8		0.0E+00	NE (2)	NE (2)	6.3E-04	NE (1)	3.5E+04
BORIC ACID	NA	NA	NA	56.2		0.0E+00	NE (2)	NE (2)	9.2E-03	NE (1)	6.1E+03
COPPER (I) CHLORIDE	NA	0.6	NA	0.042		0.0E+00	NE (2)	NE (2)	9.8E-03	NE (1)	4.3E+00
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	1.1E-02	NE (1)	NE (1)
DIMETHYLAMINOBORANE	NA	NA	NA	NA	H	0.0E+00	NE (2)	NE (2)	1.1E-03	NE (1)	NE (1)
DIMETHYLFORMAMIDE	0.03	NA	NA	25		0.0E+00	NE (2)	NE (2)	2.8E-04	NE (1)	8.9E+04
ETHANOLAMINE	NA	12.7	NA	64		0.0E+00	NE (2)	NE (2)	2.5E-03	NE (1)	2.5E+04
2-ETHOXYETHANOL	0.2	NA	0.4	NA		0.0E+00	NE (2)	NE (2)	3.5E-02	8.7E-02	NE (3)
ETHYLENE GLYCOL	NA	31	2	NA		0.0E+00	NE (2)	NE (2)	6.5E-04	3.2E-04	NE (3)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	3.8E-06	NE (1)	NE (1)
FLUOROBORIC ACID	NA	NA	NA	0.77	H	0.0E+00	NE (2)	NE (2)	9.4E-02	NE (1)	8.2E+00
FORMALDEHYDE	NA	100	0.002	NA		0.0E+00	NE (2)	NE (2)	2.4E-03	3.4E+00	NE (3)
FORMIC ACID	NA	59.2	NA	NA		0.0E+00	NE (2)	NE (2)	8.6E-03	NE (1)	NE (1)
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	2.1E-01	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	79	NA	31.5		0.0E+00	NE (2)	NE (2)	3.7E-02	NE (1)	8.6E+02
HYDROXYACETIC ACID	NA	NA	NA	50		0.0E+00	NE (2)	NE (2)	6.0E-03	NE (1)	8.3E+03
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980	NA	20		0.0E+00	NE (2)	NE (2)	7.8E-03	NE (1)	2.6E+03
MAGNESIUM CARBONATE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	2.2E-03	NE (1)	NE (1)
METHANOL	NA	1596	0.5	NA		0.0E+00	NE (2)	NE (2)	2.6E-03	5.2E-03	NE (3)
p-TOLUENE SULFONIC ACID	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	9.9E-04	NE (1)	NE (1)
PALLADIUM	NA	NA	NA	0.0475		0.0E+00	NE (2)	NE (2)	5.2E-04	NE (1)	9.2E+01
PEROXYMONOSULFURIC ACID; OR POTASSIUM	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	4.7E-02	NE (1)	NE (1)
POTASSIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	2.5E-02	NE (1)	NE (1)
POTASSIUM CYANIDE	NA	NA	0.0025	NA		0.0E+00	NE (2)	NE (2)	3.3E-04	1.3E-01	NE (3)
POTASSIUM HYDROXIDE	NA	7.1	NA	NA		0.0E+00	NE (2)	NE (2)	1.4E-03	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.8E-02	NE (1)	NE (1)
POTASSIUM SULFATE	NA	15	NA	NA	L	0.0E+00	NE (2)	NE (2)	3.5E-02	NE (1)	NE (1)
POTASSIUM-SODIUM TARTRATE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	4.6E-02	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.0E-01	NE (1)	NE (1)
SODIUM CARBONATE	NA	10	NA	NA		0.0E+00	NE (2)	NE (2)	7.3E-05	NE (1)	NE (1)
SODIUM CHLORITE	NA	NA	NA	0.5		0.0E+00	NE (2)	NE (2)	7.0E-03	NE (1)	7.1E+01
SODIUM CYANIDE	NA	NA	0.002	NA		0.0E+00	NE (2)	NE (2)	3.4E-04	1.7E-01	NE (3)
SODIUM HYDROXIDE	NA	2	NA	NA		0.0E+00	NE (2)	NE (2)	1.9E-02	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	1.3E-02	NE (1)	NE (1)
M-NITROBENZENE SULFONIC ACID	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	2.2E-07	NE (1)	NE (1)
SODIUM SULFATE	NA	NA	NA	420		0.0E+00	NE (2)	NE (2)	1.8E-02	NE (1)	2.3E+04
STANNOUS CHLORIDE	NA	NA	0.0186	NA		0.0E+00	NE (2)	NE (2)	1.5E-02	7.9E-01	NE (3)
SULFURIC ACID	NA	0.066	NA	NA		0.0E+00	NE (2)	NE (2)	3.2E-01	NE (1)	NE (1)
TARTARIC ACID	NA	NA	NA	1.74		0.0E+00	NE (2)	NE (2)	1.3E-05	NE (1)	1.4E+05
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETH	NA	NA	NA	32		0.0E+00	NE (2)	NE (2)	8.6E-04	NE (1)	3.7E+04

Table E 4. Risk Characterization Results for Electroless Copper, Conveyorized, Line Operator Scenario

Notes and Abbreviations

RfC: Reference Concentration
NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level
RfD: reference dose
SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.
ADD: average daily dose
HQ: hazard quotient (unitless ratio)
MOE: margin of exposure (unitless ratio)
NA: data not available
NE: risk indicator not evaluated for the following reasons:
(1) toxicity data not available
(2) exposure expected to be negligible
(3) HQ could be calculated

Table E 5. Risk Characterization Results for Electroless Copper, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	1640		2.1E-03	NE (1)	7.9E+05
BENZOTRIAZOLE	NA	21.8		6.1E-05	NE (1)	3.6E+05
BORIC ACID	NA	56.2		8.0E-04	NE (1)	7.0E+04
COPPER (I) CHLORIDE	NA	0.042		1.1E-03	NE (1)	3.9E+01
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		1.2E-03	NE (1)	NE (1)
DIMETHYLAMINOBORANE	NA	NA	H	9.6E-05	NE (1)	NE (1)
DIMETHYLFORMAMIDE	NA	25		2.8E-05	NE (1)	9.0E+05
ETHANOLAMINE	NA	64		2.5E-04	NE (1)	2.6E+05
2-ETHOXYETHANOL	0.4	NA		3.4E-03	8.4E-03	NE (3)
ETHYLENE GLYCOL	2	NA		6.0E-05	3.0E-05	NE (3)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA)	NA	NA	LM	4.1E-07	NE (1)	NE (1)
FLUOROBORIC ACID	NA	0.77	H	9.6E-03	NE (1)	8.0E+01
FORMALDEHYDE	0.002	NA		2.6E-04	3.7E-01	NE (3)
FORMIC ACID	NA	NA		8.5E-04	NE (1)	NE (1)
HYDROCHLORIC ACID	NA	NA		2.2E-02	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	31.5		3.2E-03	NE (1)	9.8E+03
HYDROXYACETIC ACID	NA	50		5.9E-04	NE (1)	8.4E+04
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	20		7.7E-04	NE (1)	2.6E+04
MAGNESIUM CARBONATE	NA	NA	LM	1.9E-04	NE (1)	NE (1)
METHANOL	0.5	NA		2.8E-04	5.6E-04	NE (3)
p-TOLUENE SULFONIC ACID	NA	NA	LM	9.8E-05	NE (1)	NE (1)
PALLADIUM	NA	0.0475		5.8E-05	NE (1)	8.2E+02
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	4.1E-03	NE (1)	NE (1)
POTASSIUM BISULFATE	NA	NA	M	2.2E-03	NE (1)	NE (1)
POTASSIUM CYANIDE	0.0025	NA		3.6E-05	1.4E-02	NE (3)
POTASSIUM HYDROXIDE	NA	NA		1.3E-04	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	M	1.6E-03	NE (1)	NE (1)
POTASSIUM SULFATE	NA	NA	L	3.1E-03	NE (1)	NE (1)
POTASSIUM-SODIUM TARTRATE	NA	NA		5.1E-03	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	M	1.1E-02	NE (1)	NE (1)
SODIUM CARBONATE	NA	NA		8.0E-06	NE (1)	NE (1)
SODIUM CHLORITE	NA	0.5		7.3E-04	NE (1)	6.9E+02
SODIUM CYANIDE	0.002	NA		3.7E-05	1.9E-02	NE (3)
SODIUM HYDROXIDE	NA	NA		2.1E-03	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	LM	1.4E-03	NE (1)	NE (1)
M-NITROBENZENE SULFONIC ACID	NA	NA	M	2.2E-08	NE (1)	NE (1)
SODIUM SULFATE	NA	420		2.0E-03	NE (1)	2.1E+05
STANNOUS CHLORIDE	0.0186	NA		1.6E-03	8.9E-02	NE (3)

Table E 5. Risk Characterization Results for Electroless Copper, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
SULFURIC ACID	NA	NA		2.9E-02	NE (1)	NE (1)
TARTARIC ACID	NA	1.74		1.4E-06	NE (1)	1.2E+06
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	32		8.5E-05	NE (1)	3.8E+05

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

(3) HQ could be calculated

Table E 6. Risk Characterization Results for Electroless Copper, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
AMMONIUM CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
BENZOTRIAZOLE	NA	NA		NE (2)	NE (2)	NE (2)
BORIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
COPPER (I) CHLORIDE	NA	0.6		NE (2)	NE (2)	NE (2)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
DIMETHYLAMINOBORANE	NA	NA	H	NE (2)	NE (2)	NE (2)
DIMETHYLFORMAMIDE	0.03	NA		NE (2)	NE (2)	NE (2)
ETHANOLAMINE	NA	12.7		NE (2)	NE (2)	NE (2)
2-ETHOXYETHANOL	0.2	NA		7.0E-04	1.2E-02	NE (3)
ETHYLENE GLYCOL	NA	31		NE (2)	NE (2)	NE (2)
ETHYLENEDIAMINE-TETRAACETIC ACID (EDTA)	NA	NA	LM	NE (2)	NE (2)	NE (2)
FLUOROBORIC ACID	NA	NA	H	NE (2)	NE (2)	NE (2)
FORMALDEHYDE	NA	100		2.0E-05	NE (1)	1.0E+06
FORMIC ACID	NA	59.2		3.5E-05	NE (1)	4.8E+05
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
HYDROGEN PEROXIDE	NA	79		NE (2)	NE (2)	NE (2)
HYDROXYACETIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980		4.6E-04	NE (1)	6.0E+05
MAGNESIUM CARBONATE	NA	NA	LM	NE (2)	NE (2)	NE (2)
METHANOL	NA	1596		1.9E-04	NE (1)	2.4E+06
p-TOLUENE SULFONIC ACID	NA	NA	LM	NE (2)	NE (2)	NE (2)
PALLADIUM	NA	NA		NE (2)	NE (2)	NE (2)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM CYANIDE	NA	NA		NE (2)	NE (2)	NE (2)
POTASSIUM HYDROXIDE	NA	7.1		NE (2)	NE (2)	NE (2)
POTASSIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
POTASSIUM SULFATE	NA	15	L	NE (2)	NE (2)	NE (2)
POTASSIUM-SODIUM TARTRATE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CARBONATE	NA	10		NE (2)	NE (2)	NE (2)
SODIUM CHLORITE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM CYANIDE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
SODIUM HYPOPHOSPHITE	NA	NA	LM	NE (2)	NE (2)	NE (2)
M-NITROBENZENE SULFONIC ACID	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
STANNOUS CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)

Table E 6. Risk Characterization Results for Electroless Copper, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)
TARTARIC ACID	NA	NA		NE (2)	NE (2)	NE (2)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

(3) HQ could be calculated

Table E 7. Risk Characterization Results for Carbon, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	1.7E-02	NE (1)	NE (1)
ETHANOLAMINE	NA	12.7	NA	64		0.0E+00	NE (2)	NE (2)	9.6E-03	NE (1)	6.7E+03
POTASSIUM HYDROXIDE	NA	7.1	NA	NA		0.0E+00	NE (2)	NE (2)	7.3E-02	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	7.0E-01	NE (1)	NE (1)
SULFURIC ACID	NA	0.066	NA	NA		0.0E+00	NE (2)	NE (2)	6.4E-03	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 8. Risk Characterization Results for Carbon, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		1.4E-04	NE (1)	NE (1)
ETHANOLAMINE	NA	64		1.3E-04	NE (1)	5.0E+05
POTASSIUM HYDROXIDE	NA	NA		1.2E-03	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	M	5.7E-03	NE (1)	NE (1)
SULFURIC ACID	NA	NA		5.3E-05	NE (1)	NE (1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

Table E 9. Risk Characterization Results for Carbon, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
ETHANOLAMINE	NA	12.70		NE (2)	NE (2)	NE (2)
POTASSIUM HYDROXIDE	NA	7.10		NE (2)	NE (2)	NE (2)
SODIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SULFURIC ACID	NA	0.0660		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 10. Risk Characterization Results for Conductive Polymer, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
SODIUM CARBONATE	NA	10	NA	NA		0.0E+00	NE (2)	NE (2)	2.5E-02	NE (1)	NE (1)
PHOSPHORIC ACID	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.0E-01	NE (1)	NE (1)
1H-PYRROLE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	2.6E-02	NE (1)	NE (1)
PEROXYMONOSULFURIC ACID; OR POTASSIUM	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	7.0E-01	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	2	NA	NA		0.0E+00	NE (2)	NE (2)	2.7E-03	NE (1)	NE (1)
SULFURIC ACID	NA	0.066	NA	NA		0.0E+00	NE (2)	NE (2)	1.4E-01	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 11. Risk Characterization Results for Conductive Polymer, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
SODIUM CARBONATE	NA	NA		3.3E-04	NE (1)	NE (1)
PHOSPHORIC ACID	NA	NA	M	1.3E-03	NE (1)	NE (1)
1H-PYRROLE	NA	NA		3.3E-04	NE (1)	NE (1)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	8.8E-03	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	NA		3.9E-05	NE (1)	NE (1)
SULFURIC ACID	NA	NA		1.8E-03	NE (1)	NE (1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:
(1) toxicity data not available

Table E 12. Risk Characterization Results for Conductive Polymer, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
SODIUM CARBONATE	NA	10		NE (2)	NE (2)	NE (2)
PHOSPHORIC ACID	NA	NA	M	NE (2)	NE (2)	NE (2)
1H-PYRROLE	NA	NA		NE (2)	NE (2)	NE (2)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(2) exposure expected to be negligible

Table E 13. Risk Characterization Results for Graphite, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
AMMONIA	0.1	NA	NA	NA		0.0E+00	NE (2)	NE (2)	4.2E-03	NE (1)	NE (1)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	1.1E-02	NE (1)	NE (1)
ETHANOLAMINE	NA	12.7	NA	64		0.0E+00	NE (2)	NE (2)	5.3E-03	NE (1)	1.2E+04
GRAPHITE	NA	56	NA	NA	LM	0.0E+00	NE (2)	NE (2)	9.8E-02	NE (1)	NE (1)
POTASSIUM CARBONATE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	2.1E-02	NE (1)	NE (1)
PEROXYMONOSULFURIC ACID; OR POTAS	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.2E-01	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	2.3E-01	NE (1)	NE (1)
SULFURIC ACID	NA	0.066	NA	NA		0.0E+00	NE (2)	NE (2)	2.4E-01	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:
(1) toxicity data not available
(2) exposure expected to be negligible

Table E 14. Risk Characterization Results for Graphite, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
AMMONIA	NA	NA		3.3E-04	NE (1)	NE (1)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		4.5E-04	NE (1)	NE (1)
ETHANOLAMINE	NA	64		3.2E-04	NE (1)	2.0E+05
GRAPHITE	NA	NA	LM	7.7E-03	NE (1)	NE (1)
POTASSIUM CARBONATE	NA	NA	LM	1.3E-03	NE (1)	NE (1)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	5.1E-03	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	M	9.7E-03	NE (1)	NE (1)
SULFURIC ACID	NA	NA		1.0E-02	NE (1)	NE (1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:
(1) toxicity data not available

Table E 15. Risk Characterization Results for Graphite, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results					
	Inhalation		SAT	Inhalation					
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)		HQ		MOE	
AMMONIA	0.1	NA		NE	(2)	NE	(2)	NE	(2)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE	(2)	NE	(2)	NE	(2)
ETHANOLAMINE	NA	12.7		NE	(2)	NE	(2)	NE	(2)
GRAPHITE	NA	56	LM	NE	(2)	NE	(2)	NE	(2)
POTASSIUM CARBONATE	NA	NA	LM	NE	(2)	NE	(2)	NE	(2)
PEROXYMONOSULFURIC ACID; OR POTASSIUM PEROXYMONOSULFATE	NA	NA	M	NE	(2)	NE	(2)	NE	(2)
SODIUM PERSULFATE	NA	NA	M	NE	(2)	NE	(2)	NE	(2)
SULFURIC ACID	NA	0.066		NE	(2)	NE	(2)	NE	(2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(2) exposure expected to be negligible

Table E 16. Risk Characterization Results for Non-Formaldehyde Electroless Copper, Non-Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA	NA	NA		1.5E-03	NE (1)	NE (1)	1.7E-01	NE (1)	NE (1)
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	2.2E-02	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	79	NA	31.5		5.0E-04	NE (1)	4.5E+04	1.2E-01	NE (1)	2.7E+02
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980	NA	20		3.9E-01	NE (1)	7.1E+02	1.3E-02	NE (1)	1.5E+03
POTASSIUM HYDROXIDE	NA	7.1	NA	NA		8.0E-06	NE (1)	2.5E+05	2.2E-03	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	NA	NA	M	3.0E-04	NE (1)	NE (1)	7.2E-02	NE (1)	NE (1)
SODIUM CHLORITE	NA	NA	NA	0.5		0.0E+00	NE (2)	NE (2)	3.3E-02	NE (1)	1.5E+01
SODIUM HYDROXIDE	NA	2	NA	NA		9.3E-06	NE (1)	6.1E+04	2.2E-03	NE (1)	NE (1)
STANNOUS CHLORIDE	NA	NA	0.0186	NA		0.0E+00	NE (2)	NE (2)	6.9E-02	3.7E+00	NE (3)
SULFURIC ACID	NA	0.066	NA	NA		7.9E-04	NE (1)	2.4E+01	1.7E-01	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

(3) HQ could be calculated

Table E 17. Risk Characterization Results for Non-Formaldehyde Electroless Copper, Non-Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		2.7E-04	NE (1)	NE (1)
HYDROCHLORIC ACID	NA	NA		3.4E-05	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	31.5		1.9E-04	NE (1)	1.7E+05
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	20		2.1E-05	NE (1)	9.6E+05
POTASSIUM HYDROXIDE	NA	NA		3.5E-06	NE (1)	NE (1)
POTASSIUM PERSULFATE	NA	NA	M	1.1E-04	NE (1)	NE (1)
SODIUM CHLORITE	NA	0.5		5.2E-05	NE (1)	9.5E+03
SODIUM HYDROXIDE	NA	NA		3.5E-06	NE (1)	NE (1)
STANNOUS CHLORIDE	0.0186	NA		1.1E-04	5.9E-03	NE (1)
SULFURIC ACID	NA	NA		2.6E-04	NE (1)	NE (1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

Table E 18. Risk Characterization Results for Non-Formaldehyde Electroless Copper, Non-Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
HYDROGEN PEROXIDE	NA	79		NE (2)	NE (2)	NE (2)
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980		3.3E-05	NE (1)	8.5E+06
POTASSIUM HYDROXIDE	NA	7.1		NE (2)	NE (2)	NE (2)
POTASSIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CHLORITE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
STANNOUS CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 19. Risk Characterization Results for Organic-Palladium, Non-Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	6.4E-02	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	7.8E-01	NE (1)	NE (1)
SODIUM CARBONATE	NA	10	NA	NA		0.0E+00	NE (2)	NE (2)	2.3E-01	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	3.2E-02	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	7.8E-01	NE (1)	NE (1)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	6.7E-03	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 20. Risk Characterization Results for Organic-Palladium, Non-Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results				
	Dermal		SAT	Dermal Contact				
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ		MOE	
HYDROCHLORIC ACID	NA	NA		2.2E-04	NE	(1)	NE	(1)
SODIUM BISULFATE	NA	NA	M	2.7E-03	NE	(1)	NE	(1)
SODIUM CARBONATE	NA	NA		7.8E-04	NE	(1)	NE	(1)
SODIUM HYPOPHOSPHITE	NA	NA	LM	1.1E-04	NE	(1)	NE	(1)
SODIUM PERSULFATE	NA	NA	M	2.7E-03	NE	(1)	NE	(1)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM CITRATE	NA	NA		2.3E-05	NE	(1)	NE	(1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

Table E 21. Risk Characterization Results for Organic-Palladium, Non-Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CARBONATE	NA	10		NE (2)	NE (2)	NE (2)
SODIUM HYPOPHOSPHITE	NA	NA	LM	NE (2)	NE (2)	NE (2)
SODIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM CITRATE	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(2) exposure expected to be negligible

Table E 22. Risk Characterization Results for Organic-Palladium, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	1.8E-02	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.5E-01	NE (1)	NE (1)
SODIUM CARBONATE	NA	10	NA	NA		0.0E+00	NE (2)	NE (2)	4.8E-02	NE (1)	NE (1)
SODIUM HYPOPHOSPHITE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	6.1E-03	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	1.5E-01	NE (1)	NE (1)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	1.4E-03	NE (1)	NE (1)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Table E 23. Risk Characterization Results for Organic-Palladium, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results				
	Dermal		SAT	Dermal Contact				
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ		MOE	
HYDROCHLORIC ACID	NA	NA		2.2E-04	NE	(1)	NE	(1)
SODIUM BISULFATE	NA	NA	M	2.7E-03	NE	(1)	NE	(1)
SODIUM CARBONATE	NA	NA		7.8E-04	NE	(1)	NE	(1)
SODIUM HYPOPHOSPHITE	NA	NA	LM	1.1E-04	NE	(1)	NE	(1)
SODIUM PERSULFATE	NA	NA	M	2.7E-03	NE	(1)	NE	(1)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM CITRATE	NA	NA		2.3E-05	NE	(1)	NE	(1)

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:
(1) toxicity data not available

Table E 24. Risk Characterization Results for Organic-Palladium, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CARBONATE	NA	10		NE (2)	NE (2)	NE (2)
SODIUM HYPOPHOSPHITE	NA	NA	LM	NE (2)	NE (2)	NE (2)
SODIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
TRISODIUM CITRATE 5.5-HYDRATE; OR SODIUM CITRATE	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(2) exposure expected to be negligible

Table E 25. Risk Characterization Results for Tin-Palladium, Non-Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	NA	NA	100		0.0E+00	NE (2)	NE (2)	9.7E-03	NE (1)	1.0E+04
COPPER (I) CHLORIDE	NA	0.6	NA	0.042		0.0E+00	NE (2)	NE (2)	2.3E-02	NE (1)	1.9E+00
COPPER SULFATE; OR CUPRIC SULFA	NA	NA	NA	NA		4.0E-04	NE (1)	NE (1)	1.3E-01	NE (1)	NE (1)
ETHANOLAMINE	NA	12.7	NA	64		1.1E-01	NE (1)	3.4E+01	2.7E-02	NE (1)	2.4E+03
FLUOBORIC ACID	NA	NA	NA	0.77	H	9.4E-03	NE (1)	NE (1)	1.7E-01	NE (1)	4.6E+00
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	2.9E-01	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	79	NA	31.5		5.2E-04	NE (1)	4.3E+04	1.6E-01	NE (1)	2.0E+02
ISOPROPYL ALCOHOL; OR 2-PROPAN	NA	980	NA	20		1.6E+00	NE (1)	1.8E+02	1.6E-02	NE (1)	1.2E+03
LITHIUM HYDROXIDE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	1.8E-01	NE (1)	NE (1)
PALLADIUM	NA	NA	NA	0.0475		0.0E+00	NE (2)	NE (2)	8.5E-03	NE (1)	5.6E+00
PALLADIUM CHLORIDE	NA	NA	NA	0.0475	MH	0.0E+00	NE (2)	NE (2)	5.3E-03	NE (1)	8.9E+00
POTASSIUM CARBONATE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	2.9E+00	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	7.9E-01	NE (1)	NE (1)
SODIUM CHLORIDE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	9.0E+00	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	2	NA	NA		0.0E+00	NE (2)	NE (2)	2.6E-01	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	4.5E-03	NE (1)	NE (1)	1.3E+00	NE (1)	NE (1)
STANNOUS CHLORIDE	NA	NA	0.0186	NA		0.0E+00	NE (2)	NE (2)	2.8E-01	1.5E+01	NE (3)
SULFURIC ACID	NA	0.066	NA	NA		6.2E-04	NE (1)	3.0E+01	1.9E+00	NE (1)	NE (1)
TRIETHANOLAMINE; OR 2,2,2-NITRIL	NA	NA	NA	32		0.0E+00	NE (2)	NE (2)	2.4E-03	NE (1)	1.4E+04
VANILLIN	NA	NA	NA	3.84		4.3E-04	NE (1)	NE (1)	3.0E-03	NE (1)	1.3E+03

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:
(1) toxicity data not available
(2) exposure expected to be negligible
(3) HQ could be calculated

Table E 26. Risk Characterization Results for Tin-Palladium, Non-Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	100		9.7E-05	NE (1)	1.0E+06
COPPER (I) CHLORIDE	NA	0.042		2.3E-04	NE (1)	1.9E+02
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		1.2E-03	NE (1)	NE (1)
ETHANOLAMINE	NA	64		2.7E-04	NE (1)	2.4E+05
FLUOBORIC ACID	NA	0.77	H	1.7E-03	NE (1)	4.6E+02
HYDROCHLORIC ACID	NA	NA		2.9E-03	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	31.5		1.5E-03	NE (1)	2.0E+04
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	20		1.6E-04	NE (1)	1.2E+05
LITHIUM HYDROXIDE	NA	NA		1.8E-03	NE (1)	NE (1)
PALLADIUM	NA	0.0475		8.5E-05	NE (1)	5.6E+02
PALLADIUM CHLORIDE	NA	0.0475	MH	5.3E-05	NE (1)	8.9E+02
POTASSIUM CARBONATE	NA	NA	LM	2.9E-02	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	M	7.9E-03	NE (1)	NE (1)
SODIUM CHLORIDE	NA	NA		9.0E-02	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	NA		2.6E-03	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	M	1.3E-02	NE (1)	NE (1)
STANNOUS CHLORIDE	0.0186	NA		2.8E-03	1.5E-01	NE (3)
SULFURIC ACID	NA	NA		1.9E-02	NE (1)	NE (1)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	32		2.4E-05	NE (1)	1.4E+06
VANILLIN	NA	3.84		3.0E-05	NE (1)	1.3E+05

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:

(1) toxicity data not available

(3) HQ could be calculated

Table E 27. Risk Characterization Results for Tin-Palladium, Non-Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	NA		NE (2)	NE (2)	NE (2)
COPPER (I) CHLORIDE	NA	0.6		NE (2)	NE (2)	NE (2)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
ETHANOLAMINE	NA	12.7		NE (2)	NE (2)	NE (2)
FLUOBORIC ACID	NA	NA	H	NE (2)	NE (2)	NE (2)
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
HYDROGEN PEROXIDE	NA	79		NE (2)	NE (2)	NE (2)
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980		1.3E-04	NE (1)	2.1E+06
LITHIUM HYDROXIDE	NA	NA		NE (2)	NE (2)	NE (2)
PALLADIUM	NA	NA		NE (2)	NE (2)	NE (2)
PALLADIUM CHLORIDE	NA	NA	MH	NE (2)	NE (2)	NE (2)
POTASSIUM CARBONATE	NA	NA	LM	NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
SODIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
STANNOUS CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	NA		NE (2)	NE (2)	NE (2)
VANILLIN	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:
(1) toxicity data not available
(2) exposure expected to be negligible

Table E 28. Risk Characterization Results for Tin-Palladium, Conveyorized, Line Operator Scenario

Chemical Name	Human health toxicity data					Exposure and risk indicator results					
	Inhalation		Dermal		SAT	Inhalation			Dermal Contact		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE	ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	NA	NA	100		0.0E+00	NE (2)	NE (2)	2.7E-03	NE (1)	3.7E+04
COPPER (I) CHLORIDE	NA	0.6	NA	0.042		0.0E+00	NE (2)	NE (2)	8.1E-03	NE (1)	5.2E+00
COPPER SULFATE; OR CUPRIC SULFA	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	4.9E-02	NE (1)	NE (1)
ETHANOLAMINE	NA	12.7	NA	64		0.0E+00	NE (2)	NE (2)	1.2E-02	NE (1)	5.2E+03
FLUOROBORIC ACID	NA	NA	NA	0.77	H	0.0E+00	NE (2)	NE (2)	6.0E-02	NE (1)	1.3E+01
HYDROCHLORIC ACID	0.007	15	NA	NA		0.0E+00	NE (2)	NE (2)	1.1E-01	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	79	NA	31.5		0.0E+00	NE (2)	NE (2)	6.1E-02	NE (1)	5.2E+02
ISOPROPYL ALCOHOL; OR 2-PROPAN	NA	980	NA	20		0.0E+00	NE (2)	NE (2)	8.4E-03	NE (1)	2.4E+03
LITHIUM HYDROXIDE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	6.5E-02	NE (1)	NE (1)
PALLADIUM	NA	NA	NA	0.0475		0.0E+00	NE (2)	NE (2)	2.4E-03	NE (1)	2.0E+01
PALLADIUM CHLORIDE	NA	NA	NA	0.0475	MH	0.0E+00	NE (2)	NE (2)	1.5E-03	NE (1)	3.2E+01
POTASSIUM CARBONATE	NA	NA	NA	NA	LM	0.0E+00	NE (2)	NE (2)	1.0E+00	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	3.3E-01	NE (1)	NE (1)
SODIUM CHLORIDE	NA	NA	NA	NA		0.0E+00	NE (2)	NE (2)	3.3E+00	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	2	NA	NA		0.0E+00	NE (2)	NE (2)	9.2E-02	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	NA	NA	M	0.0E+00	NE (2)	NE (2)	5.2E-01	NE (1)	NE (1)
STANNOUS CHLORIDE	NA	NA	0.0186	NA		0.0E+00	NE (2)	NE (2)	7.9E-02	4.2E+00	NE (3)
SULFURIC ACID	NA	0.066	NA	NA		0.0E+00	NE (2)	NE (2)	1.2E+00	NE (1)	NE (1)
TRIETHANOLAMINE; OR 2,2,2-NITRIL	NA	NA	NA	32		0.0E+00	NE (2)	NE (2)	1.2E-03	NE (1)	2.6E+04
VANILLIN	NA	NA	NA	3.84		0.0E+00	NE (2)	NE (2)	8.4E-04	NE (1)	4.6E+03

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

RfD: reference dose

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

(3) HQ could be calculated

Table E 29. Risk Characterization Results for Tin-Palladium, Conveyorized, Laboratory Technician Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Dermal		SAT	Dermal Contact		
	RfD (mg/kg-day)	NOAEL/LOAEL (mg/kg-day)		ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	100		9.7E-05	NE (1)	1.0E+06
COPPER (I) CHLORIDE	NA	0.042		2.3E-04	NE (1)	1.9E+02
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		1.2E-03	NE (1)	NE (1)
ETHANOLAMINE	NA	64		2.7E-04	NE (1)	2.4E+05
FLUOROBORIC ACID	NA	0.77	H	1.7E-03	NE (1)	4.6E+02
HYDROCHLORIC ACID	NA	NA		2.9E-03	NE (1)	NE (1)
HYDROGEN PEROXIDE	NA	31.5		1.5E-03	NE (1)	2.0E+04
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	20		1.6E-04	NE (1)	1.2E+05
LITHIUM HYDROXIDE	NA	NA		1.8E-03	NE (1)	NE (1)
PALLADIUM	NA	0.0475		8.5E-05	NE (1)	5.6E+02
PALLADIUM CHLORIDE	NA	0.0475	MH	5.3E-05	NE (1)	8.9E+02
POTASSIUM CARBONATE	NA	NA	LM	2.9E-02	NE (1)	NE (1)
SODIUM BISULFATE	NA	NA	M	7.9E-03	NE (1)	NE (1)
SODIUM CHLORIDE	NA	NA		9.0E-02	NE (1)	NE (1)
SODIUM HYDROXIDE	NA	NA		2.6E-03	NE (1)	NE (1)
SODIUM PERSULFATE	NA	NA	M	1.3E-02	NE (1)	NE (1)
STANNOUS CHLORIDE	0.0186	NA		2.8E-03	1.5E-01	NE (3)
SULFURIC ACID	NA	NA		1.9E-02	NE (1)	NE (1)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	32		2.4E-05	NE (1)	1.4E+06
VANILLIN	NA	3.84		3.0E-05	NE (1)	1.3E+05

Notes and Abbreviations

RfD: reference dose

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:
L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: risk indicator not evaluated for the following reason:
(1) toxicity data not available
(3) HQ could be calculated

Table E 30. Risk Characterization Results for Tin-Palladium, Conveyorized, Surrounding Population Scenario

Chemical Name	Human health toxicity data			Exposure and risk indicator results		
	Inhalation		SAT	Inhalation		
	RfC (mg/m3)	NOAEL/LOAEL (mg/m3)		ADD (mg/kg-day)	HQ	MOE
1,3-BENZENEDIOL	NA	NA		NE (2)	NE (2)	NE (2)
COPPER (I) CHLORIDE	NA	0.6		NE (2)	NE (2)	NE (2)
COPPER SULFATE; OR CUPRIC SULFATE	NA	NA		NE (2)	NE (2)	NE (2)
ETHANOLAMINE	NA	12.7		2.3E-05	NE (1)	1.6E+05
FLUOROBORIC ACID	NA	NA	H	NE (2)	NE (2)	NE (2)
HYDROCHLORIC ACID	0.007	15		NE (2)	NE (2)	NE (2)
HYDROGEN PEROXIDE	NA	79		NE (2)	NE (2)	NE (2)
ISOPROPYL ALCOHOL; OR 2-PROPANOL	NA	980		1.0E-04	NE (1)	2.7E+06
LITHIUM HYDROXIDE	NA	NA		NE (2)	NE (2)	NE (2)
PALLADIUM	NA	NA		NE (2)	NE (2)	NE (2)
PALLADIUM CHLORIDE	NA	NA	MH	NE (2)	NE (2)	NE (2)
POTASSIUM CARBONATE	NA	NA	LM	NE (2)	NE (2)	NE (2)
SODIUM BISULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
SODIUM CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
SODIUM HYDROXIDE	NA	2		NE (2)	NE (2)	NE (2)
SODIUM PERSULFATE	NA	NA	M	NE (2)	NE (2)	NE (2)
STANNOUS CHLORIDE	NA	NA		NE (2)	NE (2)	NE (2)
SULFURIC ACID	NA	0.066		NE (2)	NE (2)	NE (2)
TRIETHANOLAMINE; OR 2,2,2-NITRILOTRIS ETHANOL	NA	NA		NE (2)	NE (2)	NE (2)
VANILLIN	NA	NA		NE (2)	NE (2)	NE (2)

Notes and Abbreviations

RfC: Reference Concentration

NOAEL/LOAEL: no-observed adverse effect level / lowest-observed adverse effect level

SAT: Structure-Activity Team Rank. Overall concern levels were ranked as follows:

L: Low; LM: Low Moderate; M: Moderate; MH: Moderate High; H: High.

ADD: average daily dose

HQ: hazard quotient (unitless ratio)

MOE: margin of exposure (unitless ratio)

NA: data not available

NE: ADD or risk indicator not evaluated for the following reasons:

(1) toxicity data not available

(2) exposure expected to be negligible

Appendix F

Supplemental Performance Demonstration Information

Appendix F includes:

F.1 Test panel artwork

F.2 Lamination Specifications for DfE Performance Demonstration Panels

F.3 Process Steps for Manufacturing and Drilling DfE Performance Demonstration Panels

F.4 Design for the Environment Printed Wiring Board Project Performance Demonstration Workplan

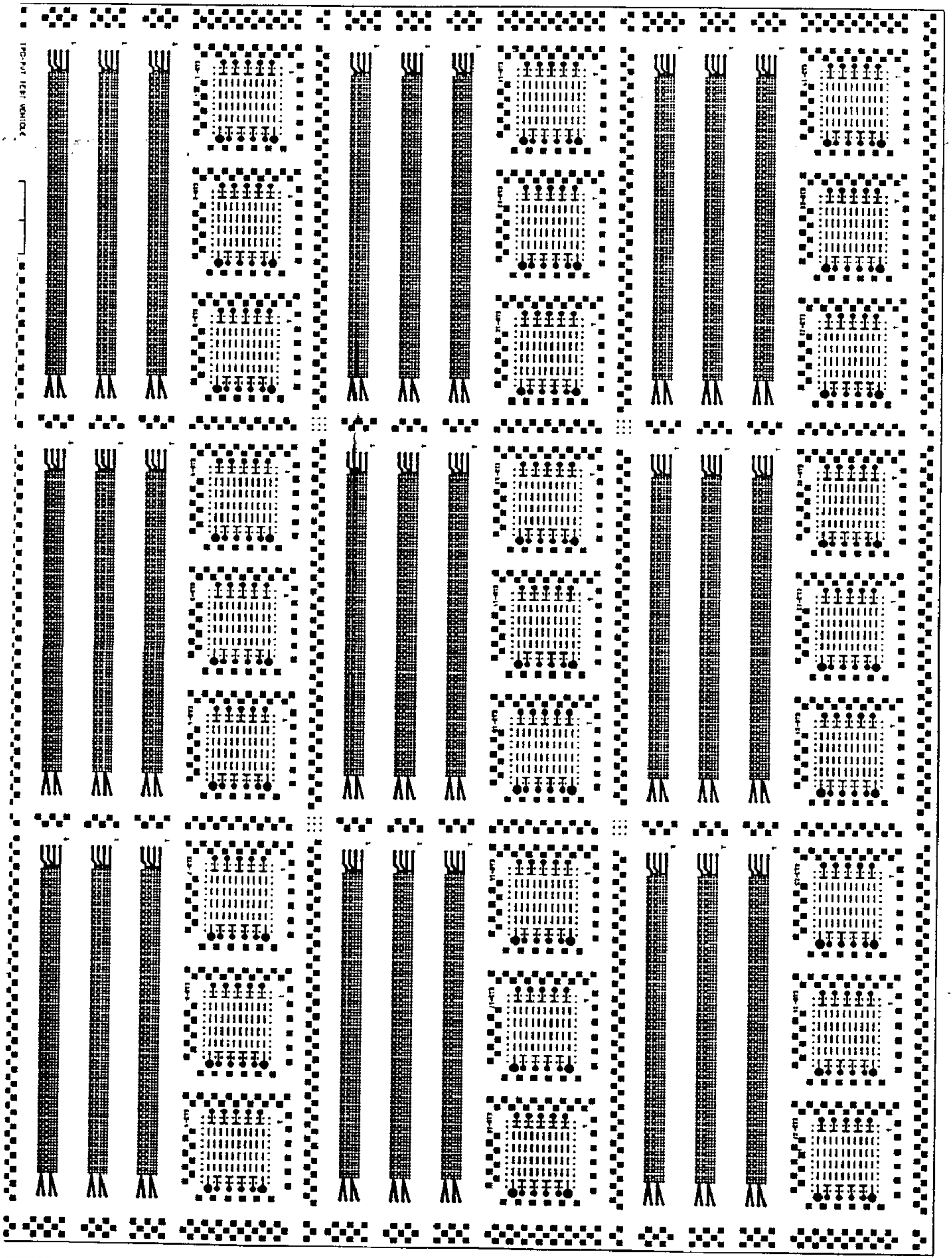
F.5 Process Steps for Electroplating, Etching, HASL, and IR Reflow of DfE Performance Demonstration

F.6 Specifications for IR Reflow of DfE Performance Demonstration Panels

F.7 IPC-TM-650 Test Methods Manual

F.8 IPC TM 650: Protocol for Thermal Stress Test for Plated Through Holes, Number 2.6.8

F.1 Test Panel Artwork



F.2 Lamination Specifications for DfE Performance Demonstration Panels

Layer	Core	Item Description	Copper oz	Material Thickness	Qty Per.
1		Copper Foil 0.5		0.0007	1
		Prepreg 1080		0.0026	2
2/3	1	Standard Core .006	1/1	0.0060	1
		Prepreg 7628		0.0066	2
4/5	2	Standard Core .006	1/1	0.0060	1
		Prepreg 7628		0.0066	2
6/7	3	Standard Core .006	1/1	0.0060	1
		Prepreg 1080		0.0026	2
8		Copper Foil 0.5		0.0007	1
Total Thickness				0.0562	

Board Type:	8 layer multilayer
Board Technology:	Through-hole
Board Dimensions:	15.587" x 20.758"
Material Grade:	FR-4
Panel Size:	18" x 24"
Line Width:	0.0200
Spacing:	0.0140
Overall Calculated Press Thickness:	0.062 +/- 0.009

F.3 Process Steps for Manufacturing and Drilling DfE Performance Demonstration Panels

1. Clean
2. Laminate dry film
3. Over layers
4. Image
5. Develop
6. Etch/Strip
7. Optical inspect
8. Mechanical inspect
9. Black oxide
10. Converter
11. Bake @250° C for one hour
12. Lay-up/press
13. Drill
14. Final inspection
15. Put panels in bags with desiccant
16. Ship panels to individual MHC test sites

F.4 Design for the Environment Printed Wiring Board Project Performance Demonstration Methodology

Note: This workplan provides the general protocol for the Design for the Environment (DfE) Printed Wiring Board (PWB) Project Performance Demonstration, which will generate information for the PWB Cleaner Technologies Substitutes Assessment (CTSA) on the "making holes conductive" step of the PWB manufacturing process. The workplan is based on input from representatives of the PWB industry, industry suppliers, EPA, the University of Tennessee Center for Clean Products and Clean Technologies, and other stakeholders of the DfE PWB Project. There may be slight modifications to the workplan as preparations for the performance demonstration progress.

I. OVERVIEW

A. Goals

The overall goal of this performance demonstration is to obtain specific information about alternative technologies that effectively make holes conductive. Specifically, the goals are the following: 1) to encourage PWB manufacturers to experiment with new products and workpractices that may reduce environmental and human health risk and result in pollution prevention; 2) to standardize existing information about commonly used technologies; and 3) to gain information about technologies not in widespread use, emerging technologies, or technologies that may be applicable to making holes conductive.

B. General Performance Demonstration Plan

The general plan for the performance demonstration is to collect information about alternative technologies at sites where the technologies are already being used. These sites may be customer production facilities, customer testing facilities (beta sites), or supplier testing facilities, in that order of preference. The test vehicle will be a standardized 8-layer multilayer board that has been used by industry to evaluate accelerated board testing methods. Every attempt will be made to limit the variability associated with the boards that is not due to differences in the technologies being tested. The boards will be produced specifically for this performance demonstration. Information will be collected from each demonstration site during the testing.

C. Characteristics of Alternative Technologies to be Reported from Performance Testing

1. Product cost: Cost per square foot of panel processed. This number will be based on information provided by product suppliers, such as purchase price, recommended bath life and treatment/disposal methods, and estimated chemical and equipment costs per square foot panel per day. "Real world" information from PWB manufacturers, such as actual dumping frequencies, treatment/disposal methods, and chemical and equipment costs will be included. The product cost may differ for different shop throughput categories.

2. Product constraints: Types of board shop processes with which the product is compatible. This information will be submitted by the manufacturers and may also be identified as a result of the performance testing.

3. Special storage, safety and disposal requirements: Flammability or volatility of the product, VOCs, TTOs, HAPS, Prop. 65 chemicals. This information will be requested from the manufacturers and will vary according to the chemicals comprising the products. Manufacturers will provide recommendations on disposal or treatment of wastes associated with the use of their products. The storage and disposal costs will be a factor in determining the adjusted cost of the product.

4. Ease of use: Physical effort required to effectively use the product line, convenience. This is a subjective, qualitative measurement based on the judgment of the product user. Specific questions such as the following will be asked: How many hours of training are required to use this product? What process parameters are needed to ensure good performance? What are the ranges of those parameters and is there much flexibility in the process steps?

5. Duration of production cycle: The measured time of the “making holes conductive” process, number of operators. This information will be used to measure the labor costs associated with the use of the products. Labor costs will be based on the time required for making holes conductive with the specific products and at a standard worker wage. The product cycle has been defined as the desmear step through a flash up to 0.1 mil (includes desmear and flash).

6. Effectiveness of technology, product quality: These characteristics will be assessed based on performance standard measurements such as aspect ratio plated, solder float test, thermal cycling, yield, and CpK (process capability).

7. Energy and natural resource data: This information will be used to measure energy consumption and the variability of energy consumption for the use of different technologies. Measurements of duty and load, for example, will be collected. The information will also address materials use rates and how the rates vary with alternative processes.

8. Exposure data: These data will be used to characterize exposures associated with technologies not in widespread use. Exposure information for more commonly used technologies will be collected in the Workplace Practices Survey, conducted separately from this study.

II. PERFORMANCE DEMONSTRATION PROTOCOL

A. Technologies to be Tested

1. Electroless copper
2. Carbon
3. Graphite
4. Palladium
5. Non-formaldehyde electroless
6. Conductive polymer
7. Conductive ink

B. Step One: Identification of Suppliers and Test Sites/Facilities

Workgroup members will identify any additional suppliers of the above product lines and participate actively in soliciting supplier participation in the performance demonstration. Any supplier that wishes to participate will be eligible to submit their technology, provided that they agree to comply with the testing protocol and submit the requested information.

Suppliers will identify sites that are using their product lines/technologies to make holes conductive according to the priority sites listed below.

First preference for testing sites: customer production facilities
Second preference for testing sites: beta sites - customer testing facilities
Third preference for testing sites: supplier testing facilities

Every vendor is guaranteed testing at one site; a submission of a second site will be subject to the review of the performance demonstration workgroup. The workgroup will decide how many submissions are feasible based on time and resource constraints. If a supplier has more than one substantially different product line, it may submit names of test facilities for each of the product lines.

C. Step Two: Test Vehicle Production and Characteristics

In order to minimize the variables associated with panel production, one manufacturer will produce all of the panels. The time and materials to produce the panels will be donated to the project by industry members. The manufacturer will produce enough 18" x 24" 8-layer multilayer panels to send three panels to each test facility. The artwork and detailed characteristics for the panels are being developed separately in IPC’s electroless/electrolytic plating subcommittee. Detailed construction information, when available, will be attached to the performance demonstration workplan. The panels will have the following characteristics:

Material: FR 4 Fiberglass Resin
Laminate thickness: .062 inches
Hole sizes: multiple holes of sizes .013, .018, and .036 inches

The boards will be manufactured at a single shop, stopping before the desmear step. Three panels will be shipped to each test facility to be run through the making holes conductive line, which begins with the desmear step.

D. Step Three: Making Holes Conductive

The panels, once distributed to testing facilities, will be run through the making holes conductive (MHC) process line in operation at the facility. The usual process operator will operate the line in order to minimize error due to unfamiliarity with the technology. The panels will all be processed in the same production run. In order to ensure compatibility with desmear processes, the panels will be desmeared and run through the MHC line at the individual facilities.

Panels that are manufactured with the pattern plate process will be treated slightly differently than panels manufactured with the panel plate process. Panels manufactured with the pattern plate process will first go through the MHC line. Dry film will be applied, and the panels will be developed to remove all resist. The panels will then be flash plated up to 0.1 mil.

Panels that are panel plated will first go through the MHC line, and then be directly flash plated up to 0.1 mil. This process was designed to ensure that resist residues don’t interfere with the through-hole plating process. (Note: the process was not meant to test the adhesion of the resist to the panel or to test resist compatibility with different processes.)

After the holes have been flashed to 0.1 mil of electroplated copper, the individual test facilities will ship all of the panels to a single plating facility, where the panels will be electroplated. This procedure will minimize variability due to variation in electroplating techniques.

E. Step Four: Information Collection at Demonstration Facilities

An independent observer will be present when the panels are run through MHC product lines at demonstration facilities. The observer will record information on an Observer Data Collection Sheet during the test. The information requested on this data collection sheet will be discussed with the operator prior to the test.

F. Step Five: Electroplating and Testing of the Boards

After the panels have been completed (holes made conductive and flashed up to 0.1 mil) at the different testing sites, they will be collected at one facility, where they will be electroplated to a thickness of 1 mil. Once finished, the boards will be electrically tested using Interconnect Stress Test (IST) methodology. In addition, they will be microsectioned, and tests such as solder shock and thermal cycling will be conducted.

III. PERFORMANCE DEMONSTRATION PARTICIPANT REQUIREMENTS

A. From the Facilities/Process Operators:

1. Facility will make their process line/process operators available to run three panels in the designated performance demonstration time frame.

2. The process operator will meet with the independent observer briefly before running the first panel through the line to familiarize him/her with the unique aspects of the line. The process operator will be available to assist the independent observer in collecting information about the line when the panels are run through it.

B. From the Vendors/Suppliers of the Process Line Alternatives:

1. Vendors will identify demonstration sites.

2. Vendors will submit product data sheets, on which they will provide information on product constraints, recommended disposal/ treatment, product formulations, etc. The requested information will be agreed upon prior to testing.

F.5 Process Steps for Electroplating, Etching, HASL, and IR Reflow of DfE Performance Demonstration Panels

1. Drill to create tooling holes
2. Apply plating resist (organic photopolymer) - image and develop
3. Electroplate copper
4. Apply etch resist (tin)
5. Strip plating resist
6. Etch
7. Strip etch resist
8. Solder mask - image and develop
9. Hot air solder leveling (HASL)
10. Rout out AT&T B coupons, place in numbered bags
11. Send AT&T B coupons to Robisan Laboratory Inc.
12. Send panels to simulated assembly process (IR Reflow)
13. IR Reflow
14. Package and ship panels to DEC Canada for electrical testing

F.6 Specifications for IR Reflow of DfE Performance Demonstration Panels

The panels containing only IST coupons were processed through a surface mount technology (SMT) oven with the following specifications:

Oven Model	BTU VIP98 Unit
Oven Profile (top and bottom)	Zone 1 = 200 C Zone 2 = 180 C Zone 3 = 170 C Zone 4 = 180 C Zone 5 = 190 C Zone 6 = 240 C Zone 7 = 240 C
Processing Speed	30 inches/minute
Panel Orientation	#1 edge up and leading; shorter (18") edge leading
Panel Spacing	24 inches or 48 seconds
Oven Passes	Two - first 12/29/95 1540 to 1745 second 12/30/95 0801 to 1015
Oven Carrying Support	Wire conveyor
Cooling Between Passes	Horizontally in metal rack, room temperature

*Note: Only IST coupons were processed through IR Reflow

F.7 IPC-TM-650 Test Methods Manual

The Institute for Interconnecting and Packaging Electronic Circuits
2215 Sanders Road Northbrook IL 60062-6135

IPC-TM-650
Test Methods Manual

1.0 Scope This test measures increases in resistance of plated-through hole barrels and inner layer connections as holes are subjected to thermal cycling. Thermal cycling is produced by the application of a current through a specific coupon configuration. In this technique, a chain of plated-through copper barrels and inner layer interconnects are resistance heated by passing DC current through the post interconnect for 3 minutes to bring the temperature of the copper to a designated temperature (slightly above the Tg of the laminate in the sample). Switching the current on and off creates thermal cycles between room temperature and the designated temperature within the sample. This thermal cycling induces cyclic fatigue strain in the plated-through hole barrels and inner layer interconnects and precipitates any infant mortality or latent defects.

The number of cycles achieved permits a quantitative assessment of the performance of the entire interconnect. Correlation has been achieved between IST, Thermal Ovens, Liquid to Liquid Thermal Shock and Thermal Stress (Solder Float) Testing.

Detailed information regarding the test is found in the NOTES 6.0 section.

2.0 Applicable Documents

2.1 IPC-TM-650, Method 2.1.1

2.2 IPC-TM-650, Method 2.1.1.2

3.0 Test Specimens Daisy chain test coupon. For artwork, see Appendix 1. See note 6.1, “Test Coupon.”

4.0 Apparatus or Material

4.1 Interconnect Stress Test System

4.2 Two (2) Four pin, 2.54 mm (0.1 inch) pitch male connectors (MOLEX 2241-4042 or equivalent)

4.3 Sn60Pb40 or Sn63Pb37 Solder

Number 2.6.X	
Subject **Interconnect Stress Technology (IST)**	
Date **6/96**	Revision **Proposal**
Originating Committee: Test Methods Subcommittee (7-11)	

4.4 Solder Flux

4.5 Soldering Iron

4.6 Multimeter - optional

4.7 Microsectioning equipment - optional

5.0 Procedure

5.1 Sample preparation

5.1.1 Solder two 4 pin male connectors to 0.040 inch holes at left and right edges of side 1.

5.1.2 Allow coupons to come to room temperature (minimum 10 minutes), prior to installation onto IST system.

5.2 IST Procedure

5.2.1 Position coupons at each test head by attaching male to female connectors.

5.2.2 Provide system software with specific test conditions. The available ranges and standard conditions are as follows:

Conditions	IST Range	Standard
No. of samples	1-6	6
Test Temp	50°C to 250°C (122°F to 422°F)	150°C (GF) (302°F)
Max. Res. Chng	1-100%	10%
Max No. Cycles	1-1000	250 (1 day)
Data Coll. Freq.	1-100 cycles	10 cycles
Cooling Ratio	0.5-2X heat time	1:1
Table Selection	system/custom	system

5.2.3 Enter a file name and begin test. The IST system continuously monitors the coupons and records the relative changes in resistance of both the barrel and the inner layer connections. Data is compiled to create graphs of each coupon's performance throughout IST stress testing.

5.3 Microsection Evaluation - Optional If detailed failure analysis is desired to determine exact location of separations and/or cracks, microsection of failed coupons shall be performed in accordance with IPC-TM-650, Method 2.1.1 or 2.1.1.2.

6.0 Notes

6.1 Test Coupon. Certain design rules must be applied to achieve thermal uniformity. Electronic design files for coupon construction are available from the IPC office. The coupon resistance should measure between 150 milliohms and 1.5 ohms when measured at room temperature. Two resistance values (voltage drops) for each coupon are monitored independently, using a four wire measurement technique.

The test coupons are incorporated as part of each panel produced to monitor production or can be step and repeated over a single panel and used to develop processes or process change.

6.2 Instrument Details.

6.2.1 Overview of General Steps of Procedure.

6.2.1.1 Data Entry. Identify and enter the specific test conditions.

6.2.1.2 Pre-cycling. The application of a trial DC current to each coupon, that elevates the individual coupons to a predetermined resistance level, relative to the specific resistance (temperature) required for stress testing. Compensations are applied by the equipment until all coupons achieve their independent resistance in 3 minutes ± 3 seconds.

6.2.1.3 Stress Cycle. The conditions achieved during the pre-cycling stage are repeated continuously (both heating and cooling) until the coupon exceeds one of the rejection criteria or the maximum numbers of cycles has been reached.

6.2.1.4 Graphing. Graphs are automatically generated that depict the performance of all or each coupon under test. Test data can be inputted into various spreadsheet formats for further statistical analysis.

6.2.1.5 Failure Analysis - Optional. Failure site is identified using a multimeter or thermographic system and subsequently microsectioned.

6.2.2 Test Sequence. A description of the equipment sequence is as follows. The sequence described is for an individual coupon, although all installed coupons are processed simultaneously.

6.2.2.1 The auto ranging multimeter measures and displays (on PC monitor) the ambient resistance (voltage drop) of the coupon’s inner layer interconnect circuit.

6.2.2.2 The system software calculates and displays the required “target” resistance (temperature). The available stress testing range is from 50°C - 250°C (122°F - 422°F). The equation used to calculate the target resistance is as follows:

Target Resistance = ([TCRI X R_{rm} X T_h]+ R_{rm})/1.1

where:
TCRI = Thermal coefficient of resistance for the Interconnect
R_{rm} = Resistance of coupon at room temp (25C)
T_h = Specified temperature to be achieved.

6.2.2.3 The system selects and displays a DC current associated to the measured ambient resistance, derived from an internal software library.

NOTE: Additional equations/algorithms used by IST that establish the initial current selection for pre-cycling, relative to the relationship of coupon interconnect resistance TCRI, coupon construction and stress test temperature to be achieved are considered proprietary at this time.

6.2.2.4 The rejection resistance is calculated and displayed. This is adjustable from 1 - 100% increase. If 10% is selected, 10% of the target resistance is calculated and added to the original resistance to establish the rejection criteria.

6.2.2.5 Pre-cycling is initiated by the application of the selected current to the coupon, the computer monitors and records the coupon’s performance throughout this first cycle. If at the end of the 1st pre-cycle, the coupon achieves the specified resistance level in 3 minutes ± 3 seconds, it will be accepted for subsequent stress testing. If the resistance level was not achieved in this time frame, the coupon will automatically be pre-cycled again with a revised/compensated current.

6.2.2.6 Forced air cooling is commenced after each pre-cycle to cool the coupons. (Requires 3.5 minutes)

6.2.2.7 The IST system software will automatically compensate for the difference between what actual resistance was achieved and the target resistance. The system will re-test using revised conditions until all coupons are accepted for stress testing.

NOTE: The equations/algorithms used by IST to compensate the DC current is considered proprietary at this time.

6.2.2.8 The system automatically records and saves all information regarding conditions for subsequent stress testing.

6.2.2.9 The stress test is initiated by re-applying the same DC current level established for each individual coupon during the pre-cycle operation. Three minutes of heating is followed by two to three minutes of cooling. Cooling time is a function of overall thickness and construction of the coupon.

6.2.2.10 Individual coupons are continually recycled using their customized heating and cooling conditions (before failure initiates), until one of the rejection criteria is achieved or the maximum number of cycles is completed.

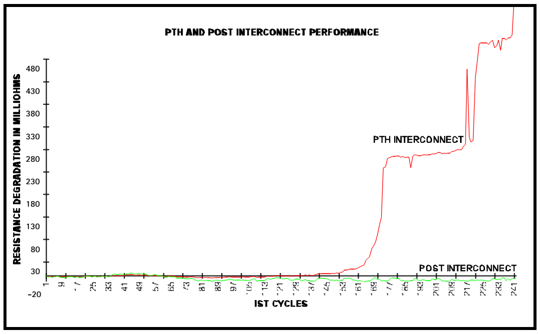
6.2.2.11 The coupon's resistance "delta" (variance from initial calculated resistance) increases (positively) as failure inception occurs. The rate of change in the delta is indicative of the mechanical change (failure) within the interconnects.

6.2.2.12 When each coupon delta reaches the maximum resistance rejection criteria, IST stress testing is stopped. The rejection criteria prevents thermal runaway (burnout) plus allows for early intervention for failure analysis to be completed effectively.

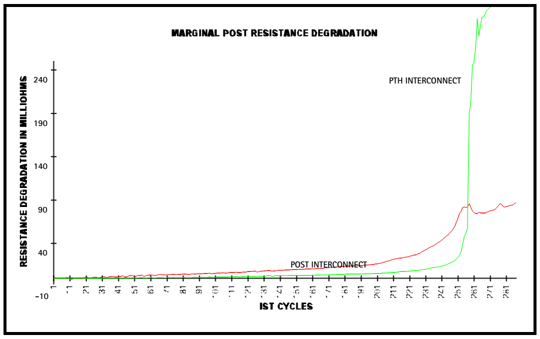
6.2.2.13 The IST system continuously monitors the two independent circuits of each coupon, recording multiple points of each cycle until the coupon exceeds one of the rejection criteria. The data is compiled to create graphs of each or all coupon's performance throughout IST stress testing. The following are typical graphs generated by good and bad coupons.

.

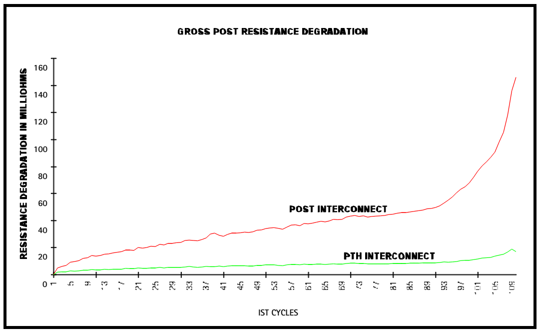
NOTE: The axis are not the same in all three graphs.



This figure shows a plated through hole barrel which begins to fail at 200 cycles while the post remains intact.



This figure shows a post that shows an increase in resistance beginning around 70 cycles while the barrel doesn't completely fail until around 250 cycles.



This figure shows an increase in post resistance at the initial cycle.

6.2.2.14 If rejections are noted, the holes exhibiting the defect can be identified by using a multimeter or thermographic system. These sites can be microsectioned to determine exact location of separations or cracks.

F.8 IPC TM 650: Protocol for Thermal Stress Test for Plated-Through Holes, Number 2.6.8

1. Scope

To standardize the thermal stressing methodology for subsequent evaluation of the copper plating in through holes after exposure to high temperature solder float. The test may be performed on plated-through holes after any stage of plating (e.g., copper, nickel, gold, tin).

2. Applicable Documents

Federal specifications QQ-S-571 and MIL-F-14256, and IPC-TM-650. Test Method 2.1.1.

3. Test Specimen

3.1 Specimen shall be removed from the panel by sawing or equivalent method, 1/4" from the edge of terminal pad area of through holes to be tested.

3.2 Specimens shall be sawed from a printed wiring board or test coupon in such a manner that at least three of the smallest size plated-through holes can be viewed in the finished microsection.

4. Apparatus

4.1 Circulating Air Chamber. Capable of maintaining a uniform temperature of 135°C (275°F) to 149°C (300° F).

4.2 Solder Pot. Electrically heated, thermostatically controlled of sufficient size containing at least 2 pounds of SN63 percent solder conforming to the contaminant level specified in Table II of IPC-S-615.

4.3 Thermocouple indicator. Or other devices to measure the solder temperature 3/4" +/- 1/4" below the surface.

4.4 Desiccator

4.5 Microscope. Range (100x/400x)

4.6 Stop Watch

4.7 Water White Rosin Flux. Type R per MIL-F-14256 or flux agreed upon between customer and vendor.

5. Procedure

5.1 Specimens shall be conditioned by drying in an oven for a minimum of 4 hours at 135°C (275° F) to 149°C (300°F) and cooled to room temperature in a desiccator.

5.2 Remove the specimens from the desiccator using tongs. Flux coat the surface and plated-through holes to ensure solder slugging.

5.3 Remove the dross from the solder pot surface and lay the specimen on the solder maintained at 288° C (550° F) +/-5° C (+/-9° F) for 10 seconds +1. -0 seconds. (The specimens are not to be held against the surface of the molten solder.)

5.4 Using tongs, carefully remove the specimen from the solder and allow to cool to room temperature.

Caution: Do not shock specimens while the solder in the plated-through hole is still liquid.

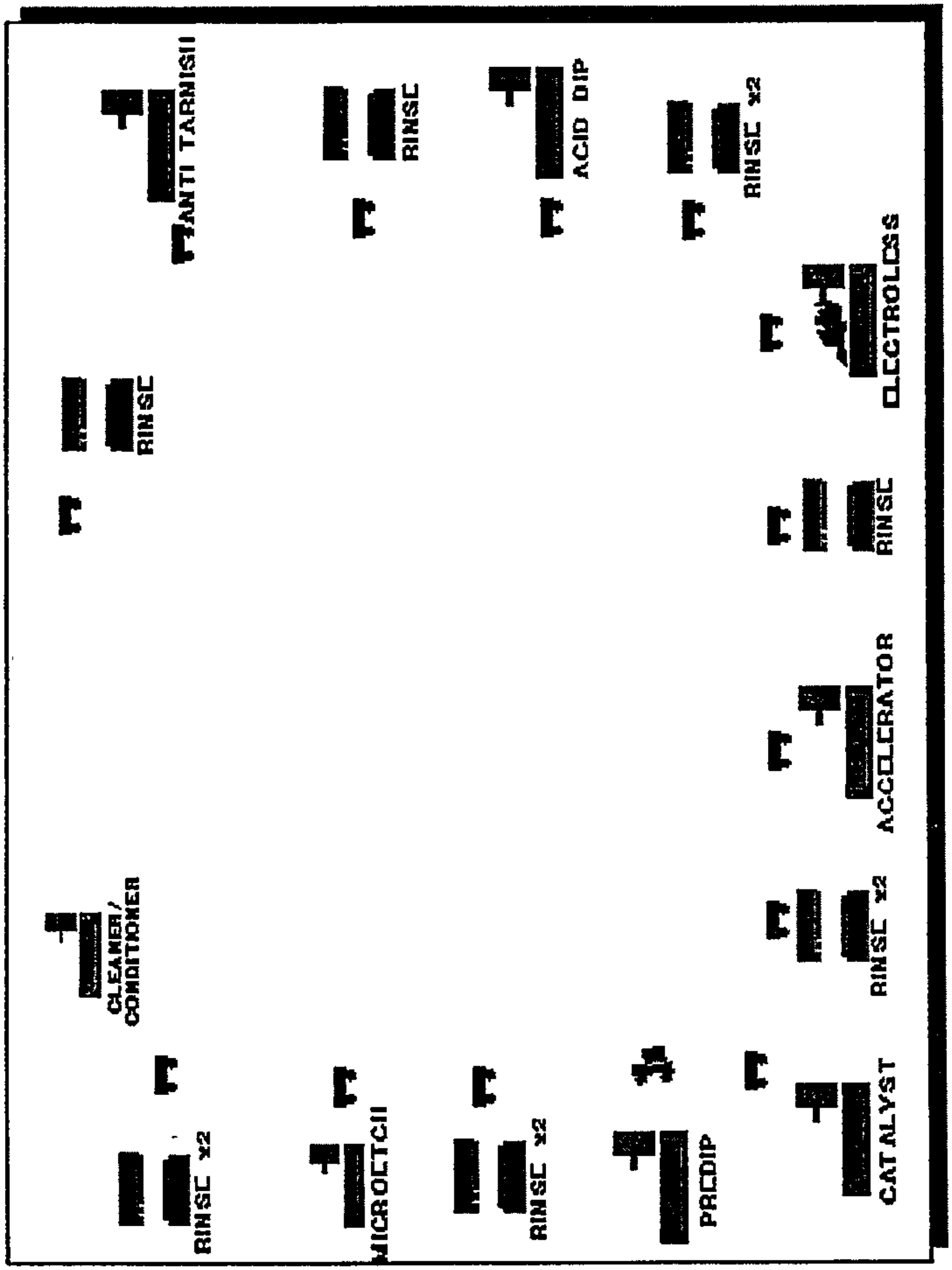
5.5 Microsection as defined in Test Method 2.1.1 of IPC-TM-650 and examine plated-through holes for degradation of the plated metal or the foil.

Appendix G

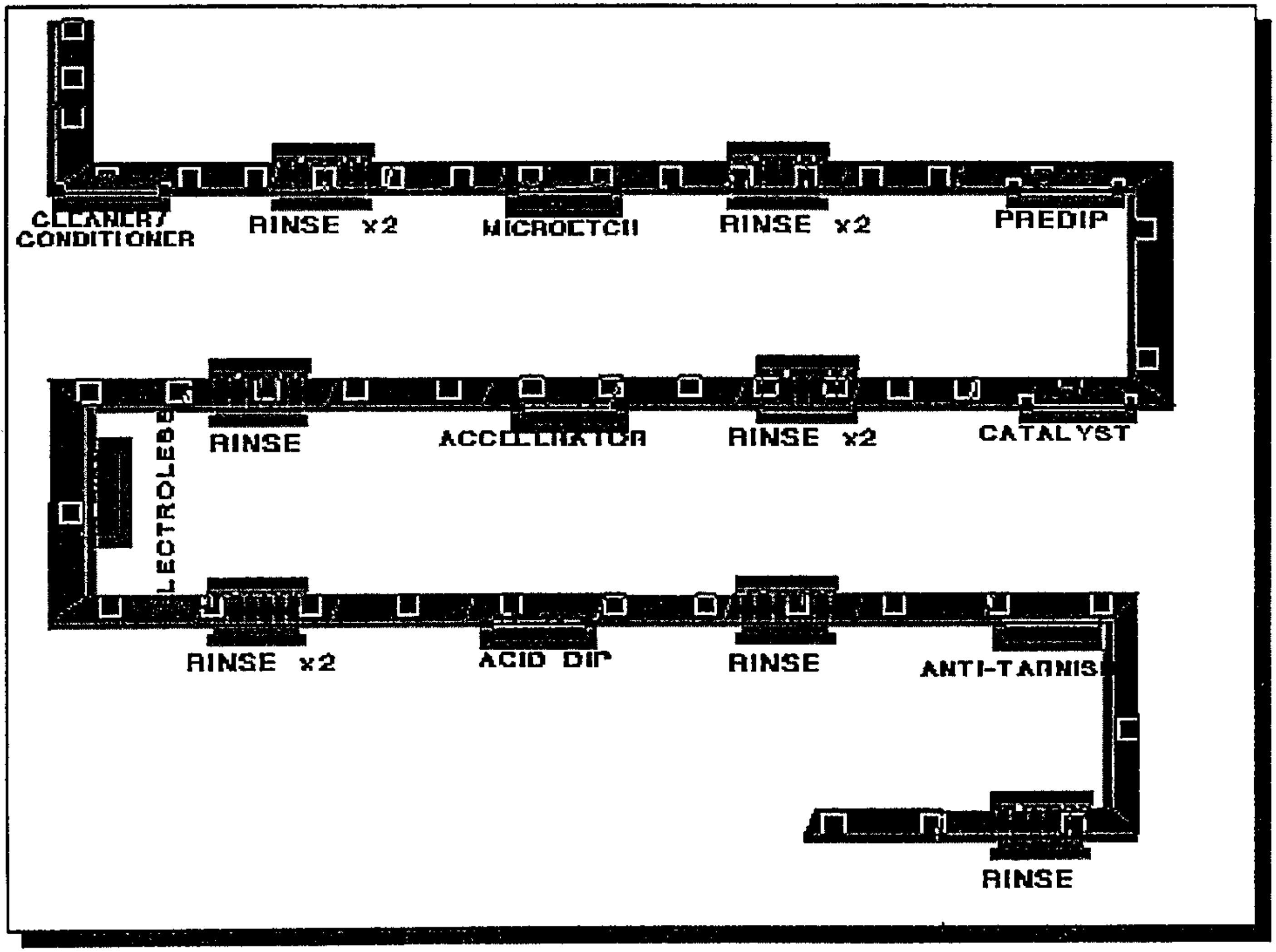
Supplemental Cost Analysis Information

G.1 Graphic Representations of Cost Simulation Models for MHC Alternatives

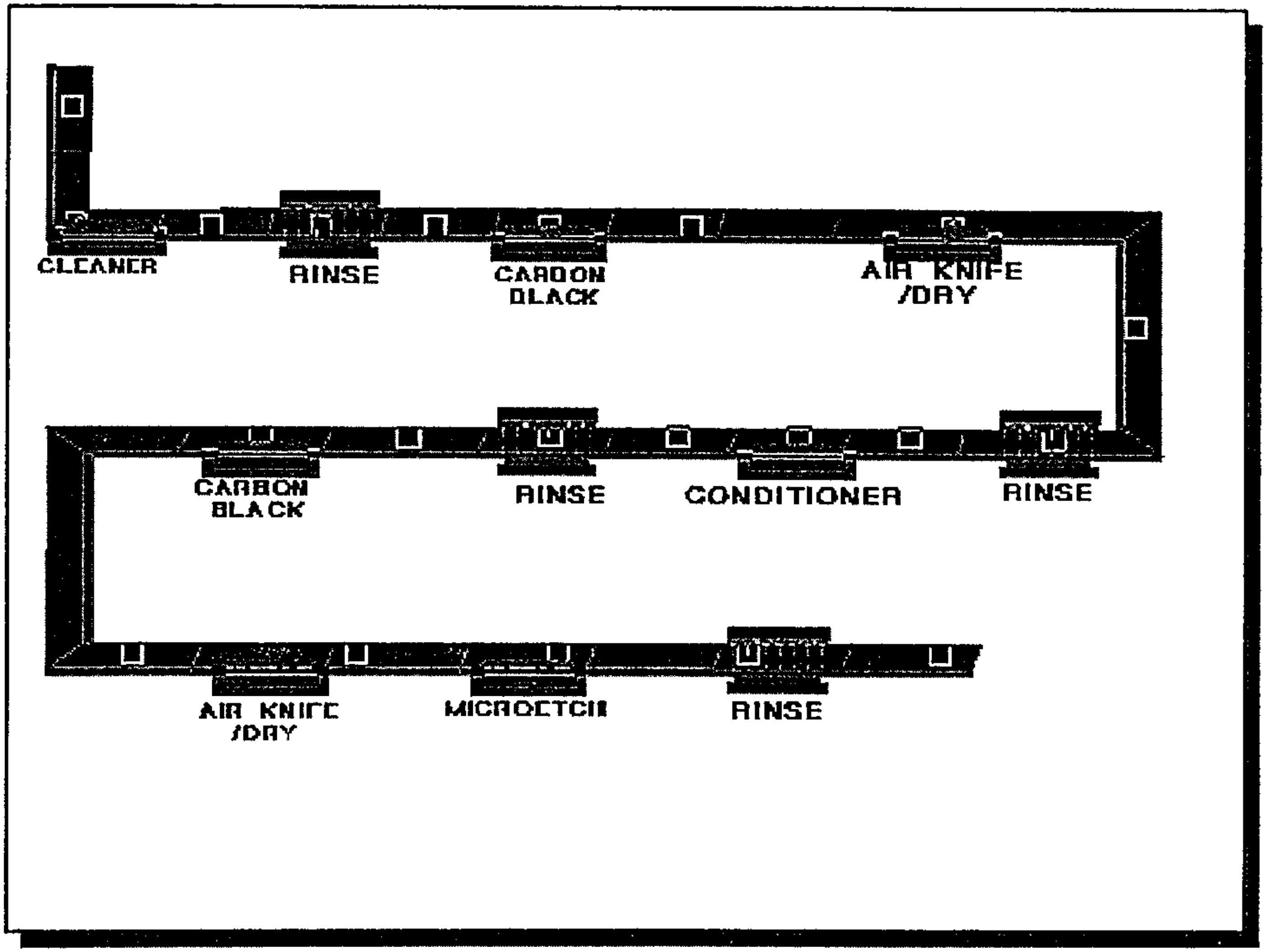
Electroless Copper Process, Non-Conveyorized



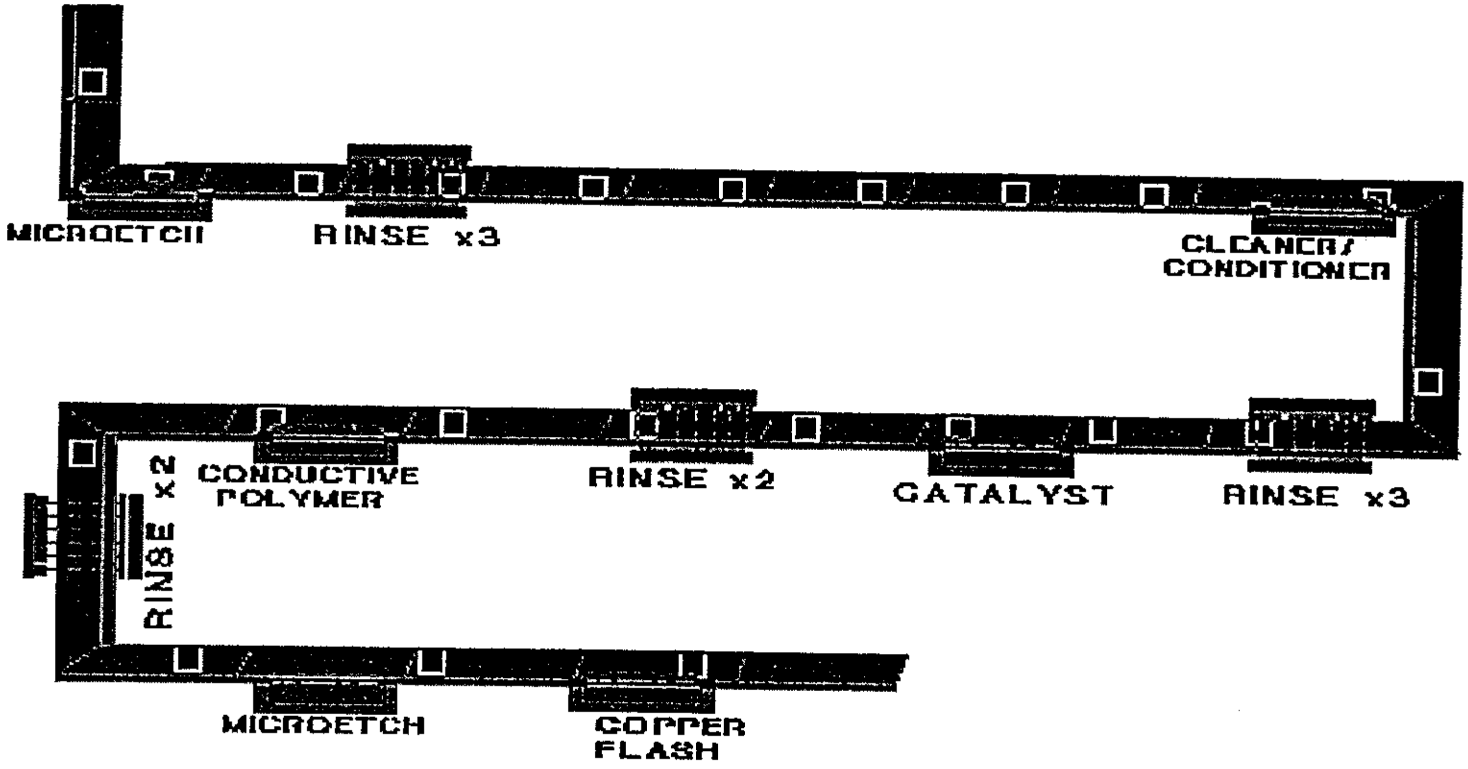
Electroless Copper Process, Conveyorized



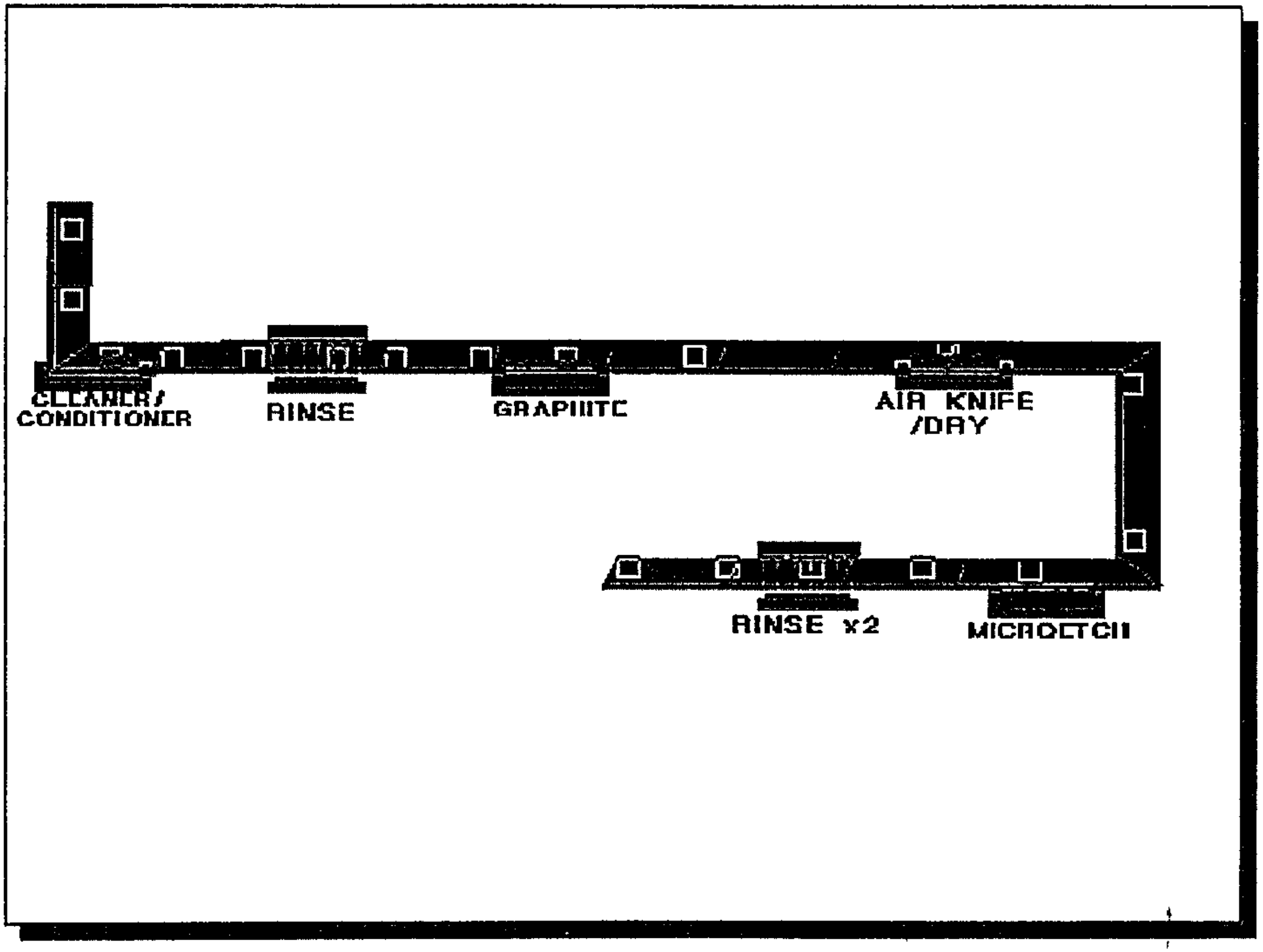
Carbon Process, Conveyorized



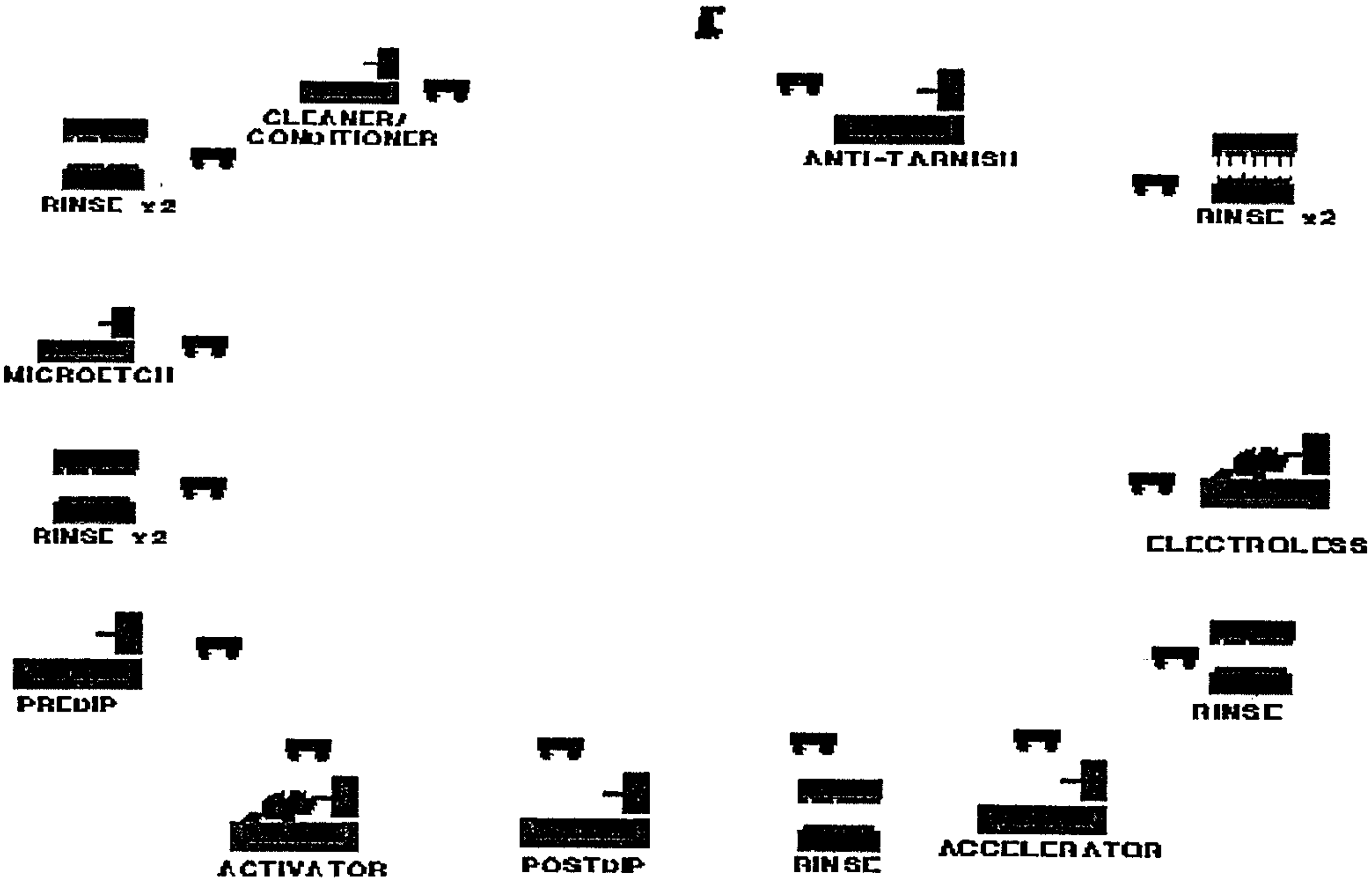
Conductive Polymer Process, Conveyorized



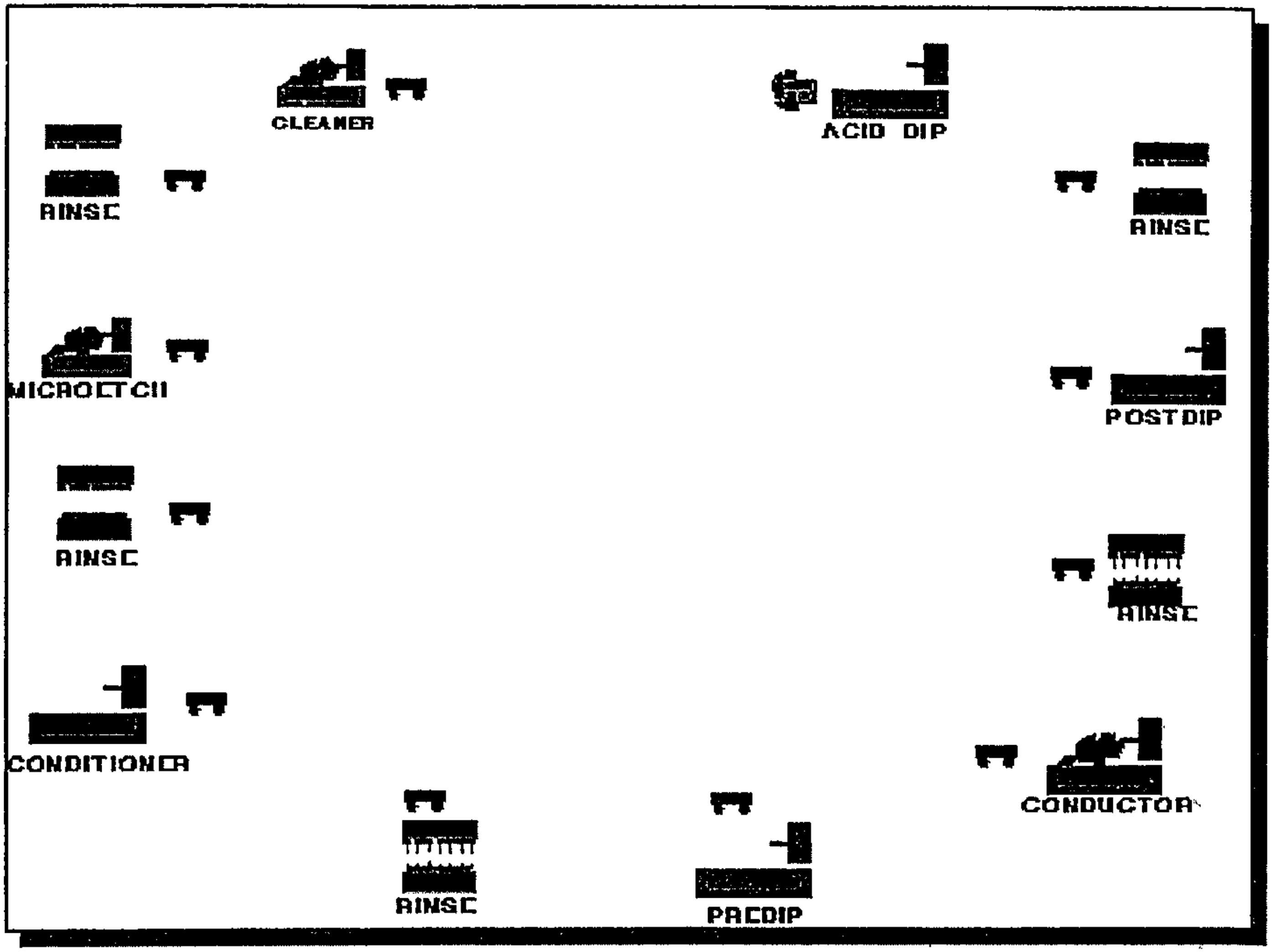
Graphite Process, Conveyorized



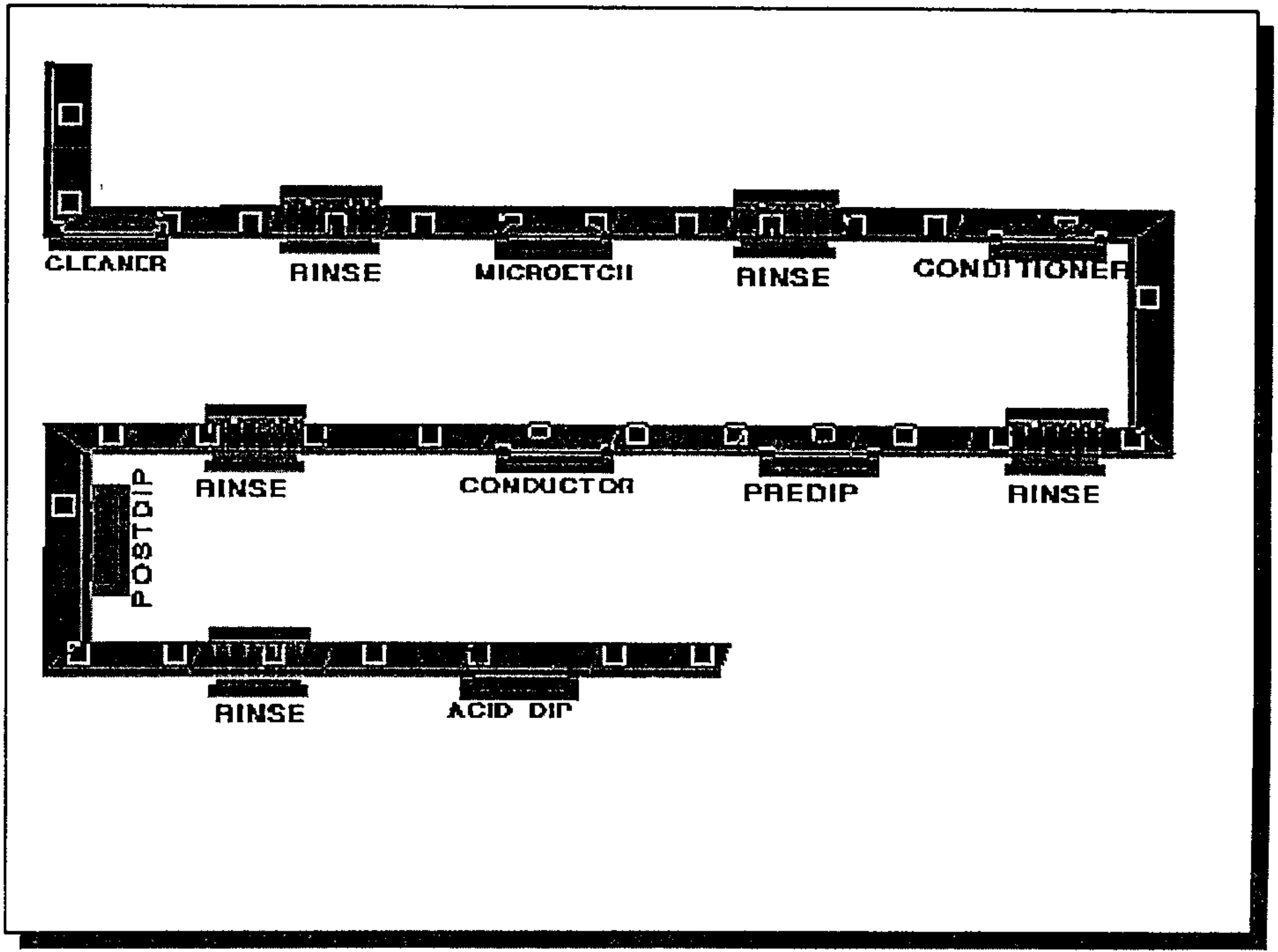
Non-Formaldehyde Electroless Copper Process, Non-Conveyorized



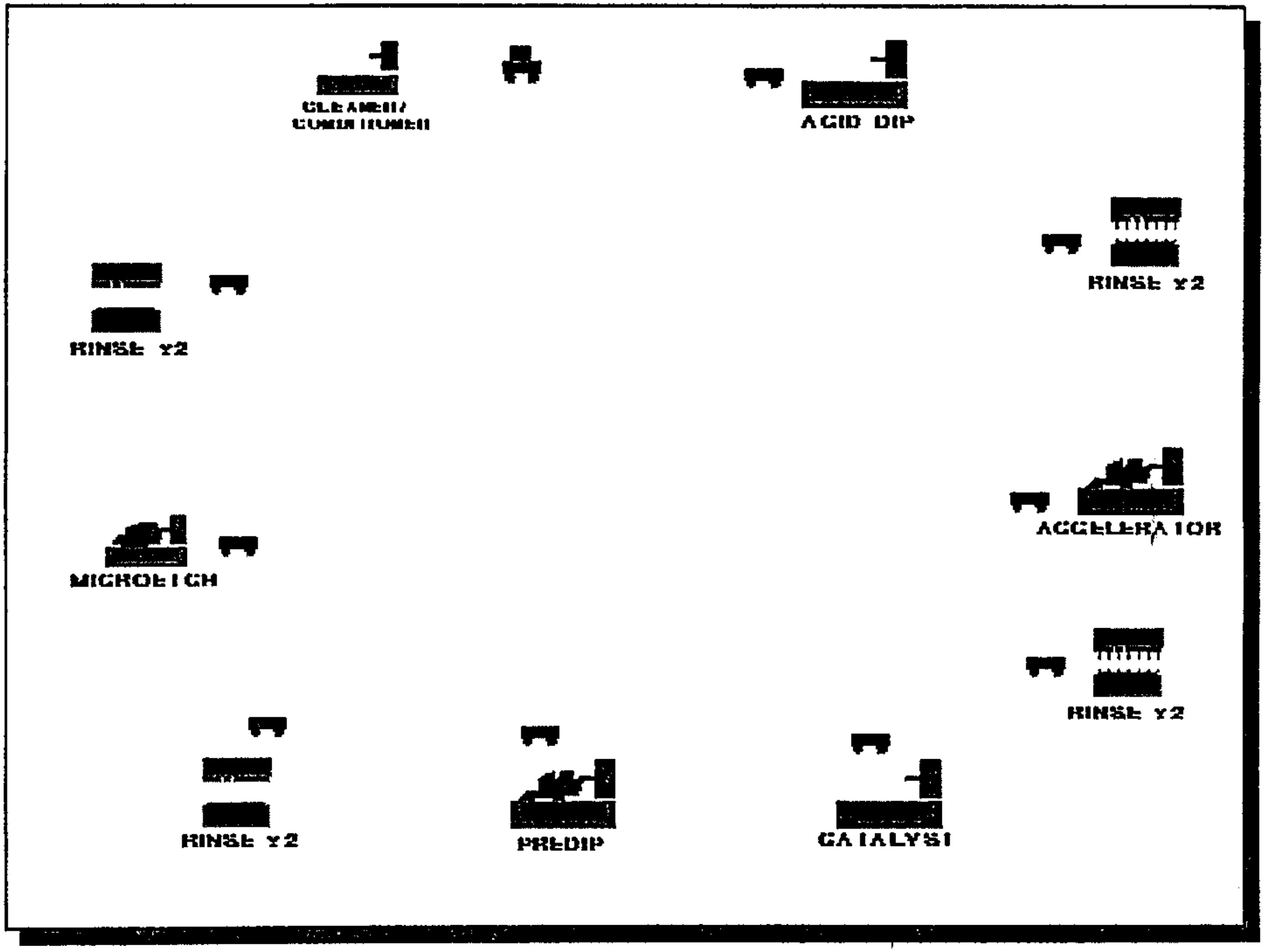
Organic-Palladium Process, Non-Conveyorized



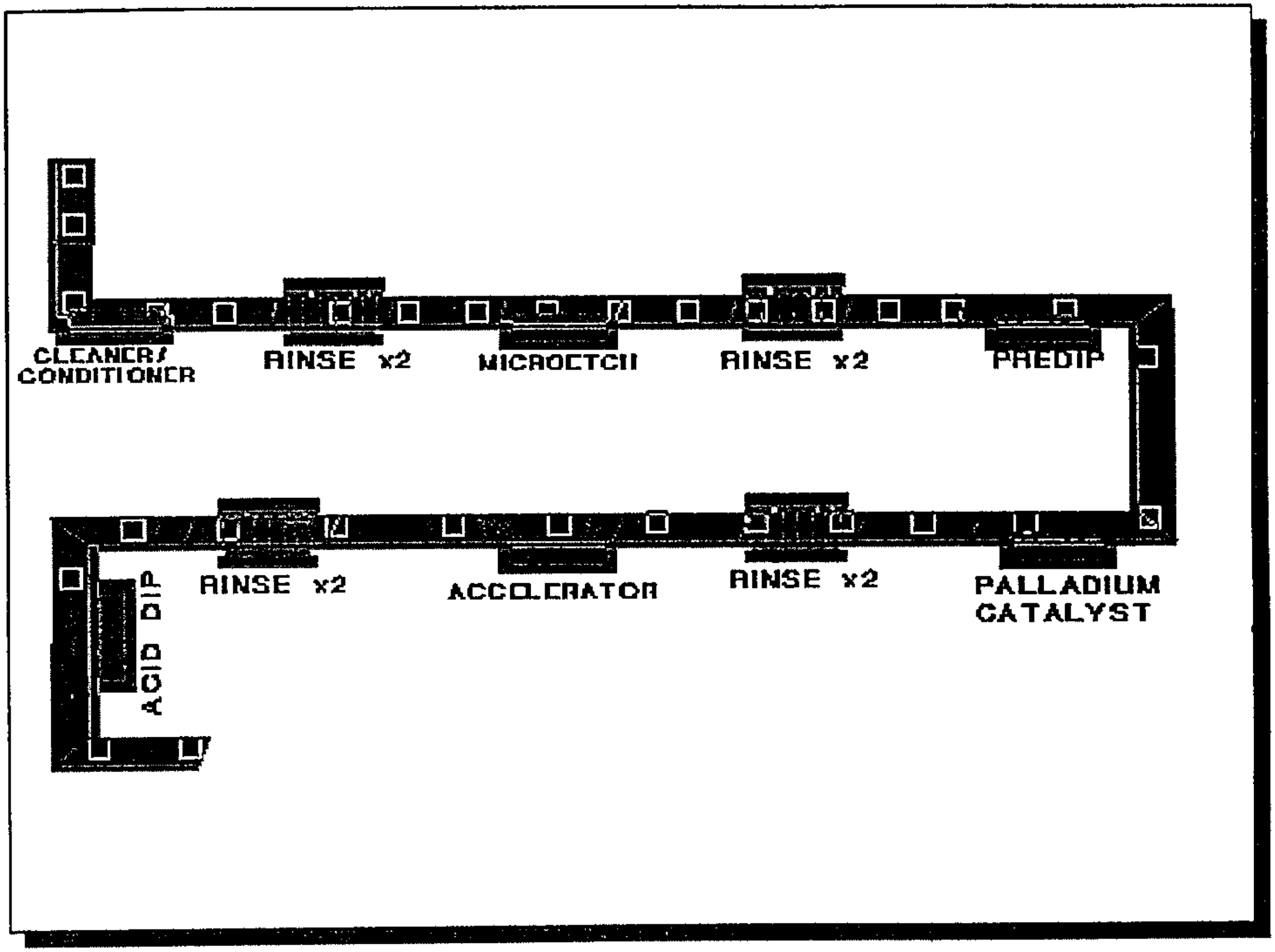
Organic-Palladium Process, Conveyorized



Tin-Palladium Process, Non-Conveyorized



Tin-Palladium Process, Conveyorized



G.2 Bath Replacement Criteria for MHC Alternatives

Electroless Copper - Non-Conveyorized (Baseline)
Electroless Copper - Conveyorized
Non-Formaldehyde Electroless Copper - Non-Conveyorized[A]

Process Step	Bath Replacement Frequencies (ssf/gal) [1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement [2]	Conveyorized (Panels)	Non-Conveyorized (Racks)
Cleaner/Conditioner	Conc.	228	500	300	1,000	510	5,920	396
Micro-Etch	Conc.	ND	250	ND	Conc.	250	2,858	194
Predip	Conc.	228	Conc.	400	1,000	540	4,822	418
Catalyst	300	Conc.	500	6 mos	Conc.	1/year	1/year	1/year
Post Dip/Acid Dip	ND	ND	1,000	ND	350	675	9,523	523
Accelerator	360	160	2,500 *	250	350	280	4,000	217
Electroless Copper	360	Conc.	500	ND	Conc.	430	14,206	334
Anti-Tarnish	200	ND	250	ND	500	325	2,264	252

ND = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g, g/L Cu) so not usable in this analysis.
* - data point considered outlier and thus not included in calculation of average.

[A] Incomplete bath replacement data submitted for non-formaldehyde copper process. Therefore, the process was assumed to be similar to electroless copper for the purposes of bath replacement.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.
To calculate racks per bath replacement, multiply average frequency of replacement by 75 gallons (average bath size) and divide by 96.8 ssf/rack.

Carbon - Conveyorized

Process Step	Bath Replacement Frequencies (ssf/gal) [1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement [2]	Conveyorized (Panels)	Non-Conveyorized (Racks)
Cleaner	300	NA	NA	NA	NA	300	2,340	NA
Carbon Black	1/year	NA	NA	NA	NA	1/year	1/year	NA
Conditioner	300	NA	NA	NA	NA	300	2,961	NA
Carbon Black	1/year	NA	NA	NA	NA	1/year	1/year	NA
Micro-Etch	ND	NA	NA	NA	NA	250**	2,855	NA

NA = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g., g/L Cu) so not usable in this analysis.
** - Due to lack of replacement data, the frequency of replacement of the micro-etch bath was assumed to the same as for electroless copper.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.

Conductive Polymer - Conveyorized

Process Step	Bath Replacement Frequencies (ssf/gal) [1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement [2]	Conveyorized (Panels)	Non-Conveyorized (Racks)
Micro-Etch	ND	NA	NA	NA	NA	250**	2,855	NA
Cleaner/Conditioner	408	NA	NA	NA	NA	410	4,681	NA
Cleaner/Conditioner	408	NA	NA	NA	NA	410	4,681	NA
Catalyst	4,880	NA	NA	NA	NA	4,880	11,985	NA
Conductive Polymer	1,935	NA	NA	NA	NA	1,940	8,918	NA
Micro-Etch	ND	NA	NA	NA	NA	250**	2,855	NA

NA = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g., g/L Cu) so not usable in this analysis.
** - Due to lack of replacement data, the frequency of replacement of the micro-etch bath was assumed to the same as for electroless copper.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.

Organic Palladium - Conveyorized
Organic Palladium - Non-Conveyorized

Process Step	Bath Replacement Frequencies (ssf/gal) [1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement [2]	Conveyorized (Panels)	Non-Conveyorized (Racks)
Cleaner	200	NA	NA	NA	NA	200	1,560	155
Micro-Etch	ND	NA	NA	NA	NA	250**	2,855	194
Conditioner	244	NA	NA	NA	NA	240	2,411	189
Predip	1/week	NA	NA	NA	NA	1/week	1/week	NA
Conductor	2,038	NA	NA	NA	NA	2,040	39,007	1,580
Post Dip	244	NA	NA	NA	NA	240	1,950	189
Acid Dip	200	NA	NA	NA	NA	200	2,801	155

ND = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g, g/L Cu) so not usable in this analysis.
** - Due to lack of replacement data, the frequency of replacement of the micro-etch bath was assumed to be the same as for electroless copper.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.
To calculate racks per bath replacement, multiply average frequency of replacement by 75 gallons (average bath size) and divide by 96.8 ssf/rack.

Graphite - Conveyorized

Process Step	Bath Replacement Frequencies (ssf/gal)[1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement[2]	Conveyorized (Panels)	Non-Conveyorized (Racks)
Cleaner/Conditioner	200	750	NA	NA	NA	475	5,443	NA
Graphite	Conc.	3,000	NA	NA	NA	3,000	19,415	NA
Micro-Etch	Conc.	ND	NA	NA	NA	250**	2,855	NA

ND = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g, g/L Cu) so not usable in this analysis.
** - Due to lack of replacement data, the frequency of replacement of the micro-etch bath was assumed to be the same as for electroless copper.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.

Tin-Palladium - Conveyorized
Tin-Palladium - Non-Conveyorized

Process Step	Bath Replacement Frequencies (ssf/gal) [1]						Frequency of Replacement Cost Simulation Inputs[3]	
	Process # 1	Process # 2	Process # 3	Process # 4	Process # 5	Average Frequency of Replacement 2	Conveyorized (Panels)	Non-Conveyorized (Racks)
Cleaner/Conditioner	350	1,000	500	2 weeks	NA	610	6,879	465
Micro-Etch	Conc.	Conc.	250	Conc.	NA	250**	2,855	194
Predip	400	4,000*	500	Conc.	NA	450	3,972	349
Catalyst	3,000	Conc.	2,500	1,000	NA	1/year	1/year	1/year
Accelerator	500	1,000	500	400	NA	600	8,457	465
Acid Dip	500	ND	1,000	210	NA	570	7,961	442

ND = No Data
NA = Not Applicable
Conc. = Replacement data given in concentration (e.g, g/L Cu) so not usable in this analysis.
** - Due to lack of replacement data, the frequency of replacement of the micro-etch bath was assumed to be the same as for electroless copper.

[1] Bath replacement frequency data for MHC product lines reported on product data sheets provided by chemical supplier of each individual process.

[2] Reported value was calculated by excluding any outlying values and then averaging remaining bath replacement data for each bath.

[3] To calculate panels per bath replacement, multiply average frequency of replacement by bath size in gallons and divide by 5.6 ssf/panel.
To calculate racks per bath replacement, multiply average frequency of replacement by 75 gallons (average bath size) and divide by 96.8 ssf/rack.

G.3 Bills of Activities for the MHC Process

Activities Associated with the Bath Setup

Activity Description	Cost Driver	Cost/Activity
Wear masks, goggles, rubber gloves, and suitable clothing	**$/bath setup**	**$2.50**
Go to storage area	labor	
Locate protective equipment	labor	
Put on protective equipment	labor	
	protective equipment	
Return to tank	labor	
Put in base liquid (usually water)	**$/bath setup**	**$2.60**
Open water valve	labor	
Wait for measured amount	labor	
Close water valve	labor	
Document water amount/level	labor	
Mix the bath solution	**$/bath setup**	**$5.00**
Open the chemical containers	labor	
Add the chemicals to the bath	labor	
Turn on the agitator	labor	
Wait for mixing	labor	
Turn off the agitator	labor	
Titrate sample	labor	
Document	labor	
Repeat as necessary	labor	
Flush containers	**$/bath setup**	**$3.00**
Turn on water valve	labor	
Spray containers	labor	
Turn off water valve	labor	
Place empty container in storage area	**$/bath setup**	**$2.00**
Take container to storage	labor	
Documentation	labor	
Return to tank	labor	
Total =	**$per testing**	**$15.10**

Activities Associated with the Tank Cleanup

Activity Description	Cost Driver	Cost/Activity
Rinse with water	**$/cleanup**	**$25.00**
Obtain spray/rinse equipment	labor	
Turn water on	labor	
Spray equipment	labor	
Turn water off	labor	
Obtain scrubbing and cleaning tools	**$/cleanup**	**$1.00**
Go to storage area	labor	
Find necessary tools	labor	
Return to tank	labor	
Hand scrub tank	**$/cleanup**	**$30.00**
Put on gloves, choose tool	labor	
Scrub tank	labor	
	cleaning supplies	
Return cleaning tools	**$/cleanup**	**$1.25**
Go to the storage area	labor	
Place tools in correct place	labor	
Return to tank	labor	
Spray according to schedule	**$/cleanup**	**$5.00**
Wait for time to elapse before spraying	labor	
Obtain spray equipment	labor	
Turn spray on	labor	
Spray all cleaning solution from tank	labor	
Turn spray off	labor	
Operator opens control valve	**$/cleanup**	**$1.00**
Find correct control valve	labor	
Open valve	labor	
Water goes to treatment facility	**$/cleanup**	**$2.75**
Wait for water to drain	labor	
Operator closes control valve	**$/cleanup**	**$1.00**
Locate correct control valve	labor	
Close valve	labor	
Total =	**$per testing**	**$67.00**

Activities Associated with Sampling and Testing

Activity Description	Cost Driver	Cost/Activity
Get sample	**$/testing**	**$1.35**
Go to the line	labor	
Titrate small sample into flask	labor	
	materials	
Transfer to lab	labor	
Test sample	**$/testing**	**$1.35**
Request testing chemicals	labor	
Document request	labor	
Locate chemicals	labor	
Add chemicals to sample	labor	
	materials	
Mix	labor	
Document the results	labor	
Return testing chemicals	labor	
Relay information to line operator	**$/testing**	**$1.00**
Return to line	labor	
Inform operator of results	labor	
Document	labor	
Total =	**$per testing**	**$3.70**

Activities Associated with Filter Replacement

Activity Description	Cost Driver	Cost/Activity
Check old filter	**$/replacement**	**$1.50**
Pull canister from process	labor	
Inspect filter	labor	
Decide if replacement is necessary	labor	
Get new filer	**$/replacement**	**$1.75**
Go to storage area	labor	
Locate new filters	labor	
Fill out paper work	labor	
Return to tank	labor	
Change filter	**$/replacement**	**$12.25**
Pull old filter from canister	labor	
Replace with new filter	labor	
	filter	
Replace canister	labor	
Fill out paper work	labor	
Dispose of old filter	**$/replacement**	**$2.00**
Take old filter to disposal bin/area	labor	
Dispose of filter	labor	
Return to tank	labor	
Fill out paper work	labor	
Total =	**$per replacement**	**$17.50**

G.4 Simulation Model Outputs for MHC Alternatives

```
                          SIMAN V - License #8810427
                          Systems Modeling Corporation

                        Summary for Replication 1 of 1

Project:  VERTICAL GENERIC ELECTRO              Run execution date :   6/10/1997
Analyst:  CHAD TONEY                            Model revision date:   7/10/1996

Replication ended at time       : 163453.0

                                TALLY VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Observations
_________________________________________________________________________________

TAKT TIME                 45.201     .81575     34.000     306.00       3615
TIME IN SYSTEM            49.271    9.8667E-04 49.116      49.333       3616
TIME STOPPED              80.408     .69205     .00000     271.97        422

                           DISCRETE-CHANGE VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Final Value
________________________________________________________________________________

CARRIER Active            15.000     .00000     15.000     15.000     15.000
CARRIER Busy              .01106     9.4553     .00000     1.0000     .00000
# in ACCELERATOR_Q        .00148     26.015     .00000     1.0000     .00000
# in ACID DIP_Q           .00147     26.019     .00000     1.0000     .00000
# in CATALYST_Q           .00148     26.015     .00000     1.0000     .00000
# in CLEAN_Q              8.3941E-04 34.500     .00000     1.0000     .00000
# in ELECTROLESS_Q        .00192     22.819     .00000     1.0000     .00000
# in MICROETCH_Q          .00148     26.015     .00000     1.0000     .00000
# in PREDIP_Q             .00148     26.015     .00000     1.0000     .00000
# in RINSE1_Q             .00148     26.015     .00000     1.0000     .00000
# in RINSE2_Q             .00148     26.015     .00000     1.0000     .00000
# in RINSE3_Q             .00148     26.015     .00000     1.0000     .00000
# in RINSE4_Q             .00148     25.999     .00000     1.0000     .00000
# in RINSE5_Q             .00147     26.019     .00000     1.0000     .00000
# in RINSE6_Q             .00147     26.019     .00000     1.0000     .00000
# in RINSE7_Q             .00147     26.019     .00000     1.0000     .00000
# in STARTING_Q           .00000        --      .00000     .00000     .00000
# in TARNISH_Q            .00147     26.019     .00000     1.0000     .00000
# in CLEAN1_Q             .00000        --      .00000     .00000     .00000
# in MICROETCH1_Q         .00000        --      .00000     .00000     .00000
# in PREDIP1_Q            .00000        --      .00000     .00000     .00000
# in CATALYST1_Q          .00000        --      .00000     .00000     .00000
# in ACCELERATOR1_Q       .00000        --      .00000     .00000     .00000
# in ELECTROLESS1_Q       .00000        --      .00000     .00000     .00000
# in ACID DIP1_Q          .00000        --      .00000     .00000     .00000
# in TARNISH1_Q           .00000        --      .00000     .00000     .00000

                                   COUNTERS

                    Identifier                 Count   Limit
                    _________________________________________

                    PARTS DONE                  3616  Infinite

                                  FREQUENCIES
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                                          --Occurrences--    Standard   Restricted
Identifier              Category          Number  AvgTime    Percent    Percent
_____________           ______________________________________________________

STATE(CLEAN1_R)         CLEAN BATH        9       138.22       0.76       0.76
                        BUSY              400     92.965      22.75      22.75
                        IDLE              403     310.23      76.49      76.49

STATE(MICROETCH1_R)     MICRO BATH        18      145.66       1.60       1.60
                        BUSY              400     94.395      23.10      23.10
                        IDLE              405     303.88      75.30      75.30

STATE(PREDIP1_R)        PREDIP BATH       8       124.50       0.61       0.61
                        BUSY              400     95.790      23.44      23.44
                        IDLE              402     308.80      75.95      75.95

STATE(CATALYST1_R)      CATAL BATH        1       230.00       0.14       0.14
                        BUSY              400     95.485      23.37      23.37
                        IDLE              401     311.79      76.49      76.49

STATE(ACCELERATOR1_R)   ACCEL BATH        16      129.75       1.27       1.27
                        BUSY              400     97.560      23.87      23.87
                        IDLE              405     302.10      74.86      74.86

STATE(ELECTROLESS1_R)   ELECT BATH        10      113.60       0.70       0.70
                        BUSY              400     98.875      24.20      24.20
                        IDLE              401     306.15      75.11      75.11

STATE(ACID DIP1_R)      ACID BATH         6       146.00       0.54       0.54
                        BUSY              400     99.445      24.34      24.34
                        IDLE              401     306.23      75.13      75.13

STATE(TARNISH1_R)       TARN BATH         13      119.53       0.95       0.95
                        BUSY              400     101.42      24.82      24.82
                        IDLE              404     300.31      74.23      74.23

Execution time: 75.62 minutes.
Simulation run complete.
```

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                              SIMAN V - License #8810427
                              Systems Modeling Corporation

                            Summary for Replication 1 of 1

Project: TYPICAL CARBON CONVEYORIZED                Run execution date :  10/ 4/1996
Analyst:  CHAD TONEY                                Model revision date:   7/11/1996

Replication ended at time        50808.6

                                  TALLY VARIABLES

Identifier               Average    Variation   Minimum     Maximum    Observations
_____________________________________________________________________________________

TAKT TIME                .81854     6.7748      .60608      195.00       62056
TIME IN SYSTEM           47.610     1.0902      12.996      257.69       62057
TIME STOPPED             74.507     1.0634      14.000      208.92         158

                              DISCRETE-CHANGE VARIABLES

Identifier               Average    Variation   Minimum     Maximum    Final Value
_____________________________________________________________________________________

# in TO_CLEANER_Q        .00145     26.200      .00000      1.0000      .00000

                                     COUNTERS

                        Identifier                Count    Limit
                        ___________________________________________

                        parts done                62057   Infinite

                                    FREQUENCIES

                                              --Occurrences--    Standard   Restricted
Identifier                Category            Number   AvgTime    Percent    Percent
_____________________________________________________________________________________

STATE(CLEAN_R)            CLEAN BATH          26       147.01        7.52       7.52
                          BUSY                124      12.460        3.04       3.04
                          IDLE                136      334.12       89.44      89.44

STATE(MICROETCH_R)        MICRO BATH          21       160.66        6.64       6.64
                          BUSY                124      24.645        6.01       6.01
                          IDLE                138      321.58       87.34      87.34

STATE(CARBON_R)           BUSY                124      12.460        3.04       3.04
                          IDLE                125      394.10       96.96      96.96

STATE(CONDITIONER_R)      CONDI BATH          20       142.03        5.59       5.59
                          BUSY                124      19.674        4.80       4.80
                          IDLE                134      339.76       89.61      89.61

STATE(CARBON2_R)          BUSY                124      19.674        4.80       4.80
                          IDLE                125      386.95       95.20      95.20

Execution time:. 32.93 minutes.
```

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                    SIMAN V - License #8810427
                    Systems Modeling Corporation

                  Summary for Replication 1 of 1

Project:  CONVEYORIZED TYPICAL CON          Run execution date :   6/11/1997
Analyst:  CHAD TONEY                        Model revision date:   7/10/1996

Replication ended at time      : 29091.1

                           TALLY VARIABLES

Identifier                Average   Variation  Minimum    Maximum   Observations
--------------------------------------------------------------------------------
TAKT TIME                 .46866    9.1628     .35294     190.00     62056
TIME IN SYSTEM            38.993    1.2748     8.0000     216.01     62057
TIME STOPPED              77.321    .99426     .00000     192.20        92

                      DISCRETE-CHANGE VARIABLES

Identifier                Average   Variation  Minimum    Maximum   Final Value
--------------------------------------------------------------------------------
# in TO_MICROETCHER_Q     .36856    1.3089     .00000     1.0000    1.0000

                              COUNTERS

                     Identifier                Count   Limit
                     ---------------------------------------
                     PARTS DONE                62057  Infinite

                             FREQUENCIES

                                         --Occurrences--   Standard  Restricted
Identifier               Category        Number  AvgTime   Percent   Percent
--------------------------------------------------------------------------------
STATE(CLEAN_R)           CLEAN BATH      13      150.96       6.75      6.75
                         BUSY            71      21.147       5.16      5.16
                         IDLE            78      328.55      88.09     88.09

STATE(MICROETCH_R)       MICRO BATH      21      145.76      10.52     10.52
                         BUSY            71      15.567       3.80      3.80
                         IDLE            82      303.96      85.68     85.68

STATE(CATALYST_R)        BUSY            71      21.147       5.16      5.16
                         IDLE            72      383.18      94.84     94.84

STATE(CONDUCT_R)         CONDUCT BATH    6       135.43       2.79      2.79
                         BUSY            71      24.971       6.09      6.09
                         IDLE            75      353.40      91.11     91.11

STATE(MICROETCH2_R)      MICRO2 BATH     21      145.76      10.52     10.52
                         BUSY            71      24.971       6.09      6.09
                         IDLE            82      295.81      83.38     83.38

STATE(CLEAN2_R)          CLEAN2 BATH     13      150.96       6.75      6.75
                         BUSY            71      21.147       5.16      5.16
                         IDLE            78      328.55      88.09     88.09

Execution time: 25.02 minutes.
Simulation run complete.
```

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                         SIMAN V - License #8810427
                         Systems Modeling Corporation

                       Summary for Replication 1 of 1

Project:  CONVEYORIZED GENERIC ELE           Run execution date :   6/10/1997
Analyst:  CHAD TONEY                         Model revision date:   7/ 9/1996

Replication ended at time       : 36063.0

                              TALLY VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Observations
_________________________________________________________________________________

TAKT TIME                 .58089     11.492     .31433     195.00      62056
TIME IN SYSTEM            52.938     1.1157     14.998     282.95      62057
TIME STOPPED              114.06     .69924     .00000     211.27        143

                         DISCRETE-CHANGE VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Final Value
_________________________________________________________________________________

# in TO_CLEANER_Q         .00259     19.641     .00000     1.0000     .00000

                                  COUNTERS

                    Identifier                Count   Limit
                    _______________________________________

                    PARTS DONE                62057  Infinite

                                FREQUENCIES

                                          --Occurrences--    Standard  Restricted
Identifier               Category        Number   AvgTime    Percent   Percent
_________________________________________________________________________________

STATE(ACCELERATOR_R)     ACCEL BATH       15      160.23        6.66      6.66
                         BUSY             88      29.890        7.29      7.29
                         IDLE             95      326.62       86.04     86.04

STATE(CLEAN_R)           CLEAN BATH       10      168.71        4.68      4.68
                         BUSY             88      11.362        2.77      2.77
                         IDLE             96      347.66       92.55     92.55

STATE(ELECTROLESS_R)     ELECT BATH       4       135.81        1.51      1.51
                         BUSY             88      32.154        7.85      7.85
                         IDLE             91      359.23       90.65     90.65

STATE(ACID DIP_R)        ACID BATH        6       174.40        2.90      2.90
                         BUSY             88      33.135        8.09      8.09
                         IDLE             91      352.75       89.01     89.01

STATE(MICROETCH_R)       MICRO BATH       21      165.74        9.65      9.65
                         BUSY             88      16.644        4.06      4.06
                         IDLE             102     305.07       86.29     86.29
```

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STATE(CATALYST_R)      BUSY              88        25.024        6.11      6.11
                       IDLE              89        380.45       93.89     93.89

STATE(PREDIP_R)        PREDIP BATH       13        126.76        4.57      4.57
                       BUSY              88        25.024        6.11      6.11
                       IDLE              93        346.37       89.32     89.32

STATE(TARNISH_R)       TARN BATH         28        146.91       11.41     11.41
                       BUSY              88        45.458       11.09     11.09
                       IDLE              100       279.48       77.50     77.50

Execution time: 35.08 minutes.
Simulation run complete.
```

```
                     SIMAN V - License #9999999
                     Systems Modeling Corporation

                   Summary for Replication 1 of 1

Project:   GRAPHITE CONVEYORIZED                 Run execution date :  10/ 7/1996
Analyst:   CHAD TONEY                            Model revision date:   7/11/1996

Replication ended at time       : 33441.3

                            TALLY VARIABLES

Identifier              Average   Variation   Minimum    Maximum   Observations
_______________________________________________________________________________

TAKT TIME               .53876    8.2863      .43032     230.00      62056
TIME IN SYSTEM          50.811    1.3392      7.7983     262.99      62057
TIME STOPPED            66.957    1.3307      10.000     230.00         97

                        DISCRETE-CHANGE VARIABLES

Identifier              Average   Variation   Minimum    Maximum   Final Value
_______________________________________________________________________________

KNIFE_R Available       1.0000    .00000      1.0000     1.0000    1.0000
KNIFE_R Busy            .00000      --        .00000     1.0000    .00000
# in TO_CLEANER_Q       .05939    3.9795      .00000     1.0000    .00000

                              COUNTERS

                    Identifier           Count   Limit
                    __________________________________

                    PARTS DONE           62057   Infinite

                             FREQUENCIES

                                        --Occurrences--    Standard   Restricted
Identifier             Category         Number   AvgTime   Percent    Percent
_______________________________________________________________________________

STATE(CLEAN_R)         CLEAN BATH       11       146.08       4.81       4.81
                       BUSY             81       13.067       3.17       3.17
                       IDLE             85       362.06      92.03      92.03

STATE(MICROETCH_R)     MICRO BATH       21       169.72      10.66      10.66
                       BUSY             81       29.377       7.12       7.12
                       IDLE             93       295.67      82.23      82.23

STATE(GRAPHITE_R)      GRAPH BATH       3        171.19       1.54       1.54
                       BUSY             81       14.975       3.63       3.63
                       IDLE             83       382.10      94.84      94.84

Execution time: 19.63 minutes.
Simulation run complete.
```

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                       SIMAN V - License #8810427
                       Systems Modeling Corporation

                     Summary for Replication 1 of 1

Project:   VERTICAL NONFORMALDEHYDE             Run execution date :    7/ 1/1997
Analyst:   CHAD TONEY                           Model revision date:    5/13/1996

Replication ended at time       : 73313.7

                              TALLY VARIABLES

Identifier                 Average   Variation   Minimum    Maximum   Observations
___________________________________________________________________________________

TAKT TIME                  20.266     .81589     15.900     160.00       3615
TIME IN SYSTEM             49.864     .04022     49.600     66.400       3616
TIME STOPPED               62.084     .24716     .00000     127.82        243

                         DISCRETE-CHANGE VARIABLES

Identifier                 Average   Variation   Minimum    Maximum   Final Value
___________________________________________________________________________________

ACCELERATOR_R Availabl     1.0000     .00000     1.0000     1.0000     1.0000
ACCELERATOR_R Busy         .12334     2.6660     .00000     1.0000     .00000
CLEAN_R Available          1.0000     .00000     1.0000     1.0000     1.0000
CLEAN_R Busy               .12340     2.6653     .00000     1.0000     1.0000
ACTIVATOR_R Available      1.0000     .00000     1.0000     1.0000     1.0000
ACTIVATOR_R Busy           .12337     2.6656     .00000     1.0000     .00000
ELECTROLESS_R Availabl     1.0000     .00000     1.0000     1.0000     1.0000
ELECTROLESS_R Busy         .77594     .53736     .00000     1.0000     1.0000
FLASH_R Available          1.0000     .00000     1.0000     1.0000     1.0000
FLASH_R Busy               .12331     2.6664     .00000     1.0000     .00000
MICROETCH_R Available      1.0000     .00000     1.0000     1.0000     1.0000
MICROETCH_R Busy           .12337     2.6656     .00000     1.0000     .00000
POSTDIP_R Available        1.0000     .00000     1.0000     1.0000     1.0000
POSTDIP_R Busy             .12337     2.6656     .00000     1.0000     1.0000
PREDIP_R Available         1.0000     .00000     1.0000     1.0000     1.0000
PREDIP_R Busy              .12337     2.6656     .00000     1.0000     .00000
RINSE1_R Available         1.0000     .00000     1.0000     1.0000     1.0000
RINSE1_R Busy              .12337     2.6656     .00000     1.0000     .00000
RINSE2_R Available         1.0000     .00000     1.0000     1.0000     1.0000
RINSE2_R Busy              .12337     2.6656     .00000     1.0000     .00000
RINSE3_R Available         1.0000     .00000     1.0000     1.0000     1.0000
RINSE3_R Busy              .12334     2.6660     .00000     1.0000     .00000
RINSE4_R Available         1.0000     .00000     1.0000     1.0000     1.0000
RINSE4_R Busy              .12334     2.6660     .00000     1.0000     .00000
TARNISH_R Available        1.0000     .00000     1.0000     1.0000     1.0000
TARNISH_R Busy             .12331     2.6664     .00000     1.0000     .00000
RINSE5_R Available         1.0000     .00000     1.0000     1.0000     1.0000
RINSE5_R Busy              .12331     2.6664     .00000     1.0000     .00000
CARRIER Active             15.000     .00000     15.000     15.000     15.000
CARRIER Busy               .02566     6.1618     .00000     1.0000     .00000
POSTDIP1_R Available       1.0000     .00000     1.0000     1.0000     1.0000
POSTDIP1_R Busy            .00000       --       .00000     1.0000     .00000

                                 COUNTERS
```

```
                         Identifier              Count   Limit
                         ____________________________________________

                         PARTS DONE                3616  Infinite

                                    FREQUENCIES

                                            --Occurrences--    Standard  Restricted
Identifier                 Category         Number  AvgTime    Percent   Percent
___________________________________________________________________________________

STATE(ACCELERATOR1_R)      ACCEL BATH       16      81.000       1.77      1.77
                           BUSY             179     65.391      15.97     15.97
                           IDLE             193     312.50      82.27     82.27

STATE(ACTIVATOR1_R)        BUSY             179     65.391      15.97     15.97
                           IDLE             180     342.27      84.03     84.03

STATE(CLEAN1_R)            CLEAN BATH       9       66.314       0.81      0.81
                           BUSY             179     65.100      15.89     15.89
                           IDLE             186     328.30      83.29     83.29

STATE(ELECTROLESS1_R)      ELECT BATH       10      61.746       0.84      0.84
                           BUSY             179     64.966      15.86     15.86
                           IDLE             186     328.31      83.30     83.30

STATE(FLASH1_R)            FLASH BATH       6       81.000       0.66      0.66
                           BUSY             179     65.491      15.99     15.99
                           IDLE             184     332.09      83.35     83.35

STATE(MICROETCH1_R)        MICRO BATH       18      63.405       1.56      1.56
                           BUSY             179     64.771      15.81     15.81
                           IDLE             190     318.83      82.63     82.63

STATE(PREDIP1_R)           PREDIP BATH      8       64.491       0.70      0.70
                           BUSY             179     65.391      15.97     15.97
                           IDLE             186     328.45      83.33     83.33

STATE(TARNISH1_R)          TARN BATH        14      73.400       1.40      1.40
                           BUSY             179     64.973      15.86     15.86
                           IDLE             191     317.57      82.73     82.73

Execution time: 40.03 minutes.
Simulation run complete.
```

```
                        SIMAN V - License #9999999
                        Systems Modeling Corporation

                      Summary for Replication 1 of 1

Project:  TYPICAL ORGANIC PALLADIUM CONVEYORIZED     Run execution date :   10/ 4/1996
Analyst:  CHAD TONEY                                 Model revision date:    7/11/1996

Replication ended at time       : 45329.2

                              TALLY VARIABLES

Identifier                Average    Variation   Minimum    Maximum    Observations
___________________________________________________________________________________

TAKT TIME                 .73022     7.8793      .43504     232.76     62056
TIME IN SYSTEM            28.353     .92094      14.595     119.50     62057
TIME STOPPED              81.324     .63072      .00000     226.77       221

                                 COUNTERS

                     Identifier                Count   Limit
                     _______________________________________

                     PARTS DONE                62057  Infinite

                                FREQUENCIES

                                          --Occurrences--   Standard  Restricted
Identifier              Category          Number  AvgTime   Percent   Percent
________________________________________________________________________________

STATE(CLEAN_R)          CLEAN BATH        39      103.56      8.91      8.91
                        BUSY              111     21.517      5.27      5.27
                        IDLE              137     283.95     85.82     85.82

STATE(MICROETCH_R)      MICRO BATH        21      103.68      4.80      4.80
                        BUSY              111     24.406      5.98      5.98
                        IDLE              126     320.97     89.22     89.22

STATE(CONDITIONER_R)    CONDI BATH        25      103.31      5.70      5.70
                        BUSY              111     27.955      6.85      6.85
                        IDLE              130     304.94     87.46     87.46

STATE(PREDIP_R)         PREDIP BATH       21      100.53      4.66      4.66
                        BUSY              111     29.498      7.22      7.22
                        IDLE              125     319.54     88.12     88.12

STATE(CONDUCT_R)        CONDUCT BATH      1       123.00      0.27      0.27
                        BUSY              111     30.606      7.49      7.49
                        IDLE              113     369.99     92.23     92.23

STATE(POSTDIP_R)        POSTDIP BATH      31      111.61      7.63      7.63
                        BUSY              111     32.685      8.00      8.00
                        IDLE              133     287.52     84.36     84.36

STATE(ACID DIP_R)       ACID BATH         21      105.90      4.91      4.91
                        BUSY              111     35.369      8.66      8.66
                        IDLE              128     306.08     86.43     86.43

Execution time: 35.07 minutes.
Simulation run complete.
```

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                         SIMAN V - License #9999999
                         Systems Modeling Corporation

                        Summary for Replication 1 of 1

  Project:  TYPICAL ORGANIC PALLADIUM VERTICAL          Run execution date :   9/26/1996
  Analyst:   CHAD TONEY                                Model revision date:   7/11/1996

  Replication ended at time      : 31763.2

                              TALLY VARIABLES

  Identifier              Average    Variation   Minimum    Maximum    Observations
  _________________________________________________________________________________

  TAKT TIME               8.7786     2.1895      2.0750     226.95        3615
  TIME IN SYSTEM          33.349     .44838      27.575     137.57        3616
  TIME STOPPED            77.536     .53042      .02500     187.45         139

                          DISCRETE-CHANGE VARIABLES

  Identifier              Average    Variation   Minimum    Maximum    Final Value
  _________________________________________________________________________________

  CARRIER Active          13.000     .00000      13.000     13.000     13.000
  CARRIER Busy            .12964     2.6342      .00000     2.0000     .00000

                                  COUNTERS

                    Identifier               Count   Limit
                    ______________________________________

                    PARTS DONE                3616  Infinite

                                FREQUENCIES

                                        --Occurrences--     Standard   Restricted
  Identifier             Category       Number  AvgTime     Percent    Percent
  _________________________________________________________________________________

  STATE(CLEAN1_R)        CLEAN BATH       23    91.783        6.65       6.65
                         BUSY             77    40.221        9.75       9.75
                         IDLE             94    282.50       83.60      83.60

  STATE(CONDITIONER1_R)  CONDI BATH       18    89.387        5.07       5.07
                         BUSY             77    41.871       10.15      10.15
                         IDLE             90    299.22       84.78      84.78

  STATE(PREDIP1_R)       PREDIP BATH      14    90.642        4.00       4.00
                         BUSY             77    42.793       10.37      10.37
                         IDLE             88    309.08       85.63      85.63

  STATE(CONDUCTOR1_R)    CONDUCT BATH     2     65.158        0.41       0.41
                         BUSY             77    44.891       10.88      10.88
                         IDLE             79    356.66       88.71      88.71

  STATE(POSTDIP1_R)      POSTDIP BATH     18    101.21        5.74       5.74
                         BUSY             77    43.271       10.49      10.49
                         IDLE             90    295.65       83.77      83.77

  STATE(ACID DIP1_R)     ACID BATH        22    91.494        6.34       6.34
                         BUSY             77    46.718       11.33      11.33
                         IDLE             95    275.29       82.34      82.34

  STATE(MICROETCH1_R)    MICRO BATH       18    91.800        5.20       5.20
                         BUSY             77    40.355        9.78       9.78
                         IDLE             91    296.74       85.01      85.01

  Execution time: 26.28 minutes.
  Simulation run complete.
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                        SIMAN V - License #8810427
                        Systems Modeling Corporation

                      Summary for Replication 1 of 1

Project:  CONVEYORIZED GENERIC TIN           Run execution date :    6/10/1997
Analyst:  CHAD TONEY                         Model revision date:    7/11/1996

Replication ended at time      : 26082.6

                              TALLY VARIABLES

Identifier               Average   Variation   Minimum    Maximum   Observations
________________________________________________________________________________

TAKT TIME                .42017     11.661     .27134     190.00      62056
TIME IN SYSTEM           64.169     1.1194     8.6078     433.99      62057
TIME STOPPED             93.815     .90075     10.000     241.52         96

                         DISCRETE-CHANGE VARIABLES

Identifier               Average   Variation   Minimum    Maximum   Final Value
________________________________________________________________________________

# in TO_CLEANER_Q        .03874     4.9813     .00000     1.0000     .00000

                                  COUNTERS

                    Identifier                Count   Limit
                    _______________________________________

                    PARTS DONE                62057  Infinite

                                FREQUENCIES

                                         --Occurrences--    Standard  Restricted
Identifier              Category          Number  AvgTime    Percent   Percent
________________________________________________________________________________

STATE(CLEAN_R)          CLEAN BATH        9       181.61       6.27      6.27
                        BUSY              63      4.9883       1.20      1.20
                        IDLE              71      339.91      92.53     92.53

STATE(MICROETCH_R)      MICRO BATH        21      129.85      10.45     10.45
                        BUSY              63      23.525       5.68      5.68
                        IDLE              76      287.81      83.86     83.86

STATE(PREDIP_R)         PREDIP BATH       15      149.46       8.60      8.60
                        BUSY              63      32.337       7.81      7.81
                        IDLE              72      302.82      83.59     83.59

STATE(ACID DIP_R)       ACID BATH         7       122.88       3.30      3.30
                        BUSY              63      42.546      10.28     10.28
                        IDLE              64      352.21      86.43     86.43

STATE(CATALYST_R)       BUSY              63      32.337       7.81      7.81
                        IDLE              64      375.70      92.19     92.19

STATE(ACCELERATOR_R)    ACCEL BATH        7       153.10       4.11      4.11
                        BUSY              63      35.931       8.68      8.68
                        IDLE              68      334.51      87.21     87.21

Execution time: 23.80 minutes.
Simulation run complete.
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                         SIMAN V - License #8810427
                         Systems Modeling Corporation

                       Summary for Replication 1 of 1

Project:   VERTICAL GENERIC TIN STA              Run execution date :    6/10/1997
Analyst:   CHAD TONEY                            Model revision date:    7/11/1996

Replication ended at time       : 48525.4

                             TALLY VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Observations
_________________________________________________________________________________

TAKT TIME                 13.409    1.9911      9.2750     294.97      3615
TIME IN SYSTEM            52.839    .08080      50.000     65.625      3616
TIME STOPPED              102.49    .73478      .00000     286.32       133

                         DISCRETE-CHANGE VARIABLES

Identifier                Average   Variation   Minimum    Maximum   Final Value
_________________________________________________________________________________

CARRIER Active            11.000    .00000      11.000     11.000    11.000
CARRIER Busy              .06573    3.8295      .00000     2.0000    .00000

                                 COUNTERS

                 Identifier                Count    Limit
                 ________________________________________

                 PARTS DONE                3616   Infinite

                                FREQUENCIES

                                        --Occurrences--    Standard   Restricted
Identifier                Category      Number  AvgTime    Percent    Percent
_________________________________________________________________________________

STATE(CLEAN1_R)           CLEAN BATH    7       170.93       2.47       2.47
                          BUSY          119     63.565      15.59      15.59
                          IDLE          121     328.63      81.95      81.95

STATE(MICROETCH1_R)       MICRO BATH    18      202.66       7.52       7.52
                          BUSY          119     63.707      15.62      15.62
                          IDLE          127     293.67      76.86      76.86

STATE(PREDIP1_R)          PREDIP BATH   10      67.055       1.38       1.38
                          BUSY          119     75.149      18.43      18.43
                          IDLE          120     324.26      80.19      80.19

STATE(CATALYST1_R)        BUSY          119     75.149      18.43      18.43
                          IDLE          119     332.62      81.57      81.57

STATE(ACCELERATOR1_R)     ACCEL BATH    7       107.83       1.56       1.56
                          BUSY          119     74.082      18.17      18.17
                          IDLE          125     311.63      80.28      80.28

STATE(ACID DIP1_R)        ACID BATH     8       159.12       2.62       2.62
                          BUSY          119     77.569      19.02      19.02
                          IDLE          121     314.22      78.35      78.35

Execution time: 36.25 minutes.
Simulation run complete.
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G.5 Chemical Costs by Bath for Individual MHC Processes

Total Materials Cost by MHC Alternative

Process: Electroless Copper
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	6	$25.45/gal	$98.79	$114.98
Microetch	64.3	75.3	B	13.8 g/l	$2.57/lb	$50.27	$58.87
			C	2.5	7.62/gal		
			D	18.5	$1.60/gal		
Predip	49.8	75.3	E	31.725 g/l	$1.31/lb	$14.65	$22.15
			F	1.5	$2.00/gal		
Catalyst	138.5	75.3	G	4	$391.80/gal	$2,180.53	$1,185.52
			H	0.176 g/l	$1.31/lb		
			I	3.5	$2.00/gal		
Accelerator	79.5	75.3	J	20	$18.10/gal	$287.79	$272.59
Electroless Copper	185	75.3	K	7	$27.60/gal	$617.92	$251.51
			L	8.5	$16.45/gal		
			M	0.22	$4.50/gal		
Neutralizer	57	75.3	N	100	$1.60/gal	$91.20	$120.48
Anti-Tarnish	38.6	75.3	O	0.25	$39.00/gal	$3.76	$7.33

Process: Electroless Copper
Supplier #2

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	6	$25.45/gal	$98.79	$114.98
Microetch	64.3	75.3	B	13.8 g/l	$2.57/lb	$50.27	$58.87
			C	2.5	7.62/gal		
			D	18.5	$1.60/gal		
Predip	49.8	75.3	E	31.725 g/l	$1.31/lb	$14.65	$22.15
			F	1.5	$2.00/gal		
Catalyst	138.5	75.3	G	4	$391.80/gal	$2,180.53	$1,185.52
			H	0.176 g/l	$1.31/lb		
			I	3.5	$2.00/gal		
Accelerator	79.5	75.3	J	20	$18.10/gal	$287.79	$272.59
Electroless Copper	185	75.3	K	2.75	$27.60/gal	$623.45	$253.76
			L	1.75	$12.90/gal		
			M	14.5	$16.45/gal		
Neutralizer	57	75.3	N	100	$1.60/gal	$91.20	$120.48
Anti-Tarnish	38.6	75.3	O	0.25	$39.00/gal	$3.76	$7.33

Process: Electroless Copper
Supplier #3

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	10	$36.68/gal	$356.00	$414.32
			B	5	$28.78/gal		
			C	2.5	$15.81/gal		
Microetch	64.3	75.3	D	9.8 g/l	$2.62/lb	$16.32	$19.11
			E	2.5	$1.60/gal		
Predip	49.8	75.3	F	75	$5.39/gal	$201.32	$304.41
Activator/Palladium	57	75.3	G	1	$497.71/gal	$514.12	$679.18
			H	75	$5.39/gal		
Accelerator	79.5	75.3	I	8.96 g/l	$497.71/lb	$3,013.94	$2,854.71
			J	1	$77.71/gal		
Electroless Copper	185	75.3	K	4	$11.51/gal	$433.14	$176.30
			L	10	$15.44		
			M	0.2	$19.36/gal		
			N	3	$9.19/gal		
			O	0.5	$4.50/gal		
Anti-Tarnish	38.6	75.3	P	1	$28.26/gal	$10.90	$21.26

Process: Electroless Copper
Supplier #4

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	12.5	$10.30/gal	$83.30	$96.95
Microetch	64.3	75.3	B	5	$12.32/gal	$84.68	$95.65
			C	3	$13.81/gal		
			D	15	$1.60/gal		
Predip	49.8	75.3	E	75	$2.79/gal	$104.21	$157.57
Activator/Palladium	57	75.3	F	3.8	$211.35/gal	$638.35	$843.29
			G	1	$128.59/gal		
			H	579.5 g/l	$0.39/lb		
Accelerator	79.5	75.3	I	5	$16.47/gal	$144.65	$137.01
			J	15	$6.64/gal		
Electroless Copper	185	75.3	K	5	$9.57/gal	$393.16	$160.03
			L	1.5	$9.22/gal		
			M	12	$12.57/gal		
Acid Dip	78.8	75.3	N				
Anti-Tarnish	38.6	75.3	O	0.25	$14.07	$1.36	$2.65

Process: Electroless Copper
Supplier #5

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	15	$26.50/gal	$257.18	$299.31
Microetch	64.3	75.3	B	60 g/l	$2.57/lb	$83.59	$97.89
			C	1	$1.60/gal		
Predip	49.8	75.3	D	1165 g/l	$1.59/gal	$768.14	$1,161.46
Palladium Catalyst	138.5	75.3	E	3	$497/gal	$2,280.00	$1,239.60
			F	97	$1.59/lb		
Electroless Copper	185	75.3	G	4.2	$19.29/gal	$1,834.31	$746.61
			H	10	$29.37/gal		
			I	12	$51.40/gal		
Anti-Tarnish	38.6	75.3	J	2.5	$20.50/gal	$21.63	$42.20
			K	3	$1.60/gal		

Process: Electroless Copper
Supplier #6

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	0.5	$22.70/gal	$77.87	$90.63
			B	4	$26.88/gal		
			C	2.5	$0.594/g		
Predip	49.8	75.3	D	5	$99.29/gal	$247.22	$373.81
Activator	57	75.3	E	25	$147.5/gal	$2,101.89	$2,776.71
			F	0.5	$0.0594/g		
Reducer	57	75.3	G	0.5	$147.5/gal	$42.03	$55.52
			H	5 g/l	$.795/lb		
Electroless Copper	185	75.3	I	1.4	No data		
			J	8	No data		
			K	0.15	No data		
			L	3	No data		

Process: Formaldehyde-Free Electroless Copper
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	No data	75.3	A	10	$36.68/gal	No data	$384.56
			B	5	$28.78/gal		
Microetch	No data	75.3	C	9.8 g/l	$2.62/lb	No data	$19.11
			D	2.5	$1.60/gal		
Predip	No data	75.3	E	75	$6.38/gal	No data	$360.31
Activator	No data	75.3	F	1.5	$497.71/gal	No data	$562.17
			G	75	$6.38/gal		
Accelerator	No data	75.3	H	8.96 g/l	$497.71/gal	No data	$2,854.70
			I	1	$77.71/gal		
Electroless Copper	No data	75.3	J	11	$92.96/gal	No data	$1,633.84
			K	5.5	$14.18/gal		
			L	32	$24.99/gal		
			M	25 g/l	$5.49/lb		
			N	15 g/l	$12.43/lb		
Anti-Tarnish	No data	75.3	O	1	$28.61/gal	No data	$21.54

Process: Organic-Palladium
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner	44	75.3	A	5	$36.38/gal	$104.95	$180.45
			B	5	$11.55/gal		
Microetch	64.3	75.3	C	75 g/l	$16.20/gal	$650.54	$761.83
Predip	49.8	75.3	D	100	No data	No data	No data
Conductor	108	75.3	E	10	$36.38/gal	$534.6	$372.74
			F	10	$13.12/gal		
Post-Dip	45	75.3	G	20	$17.42/gal	$156.78	$262.35
Acid Dip Bath	78.8	75.3	H	No data	No data	No data	No data
Conditioner	56	75.3	I	5	$36.38/gal	$133.58	$180.45
			J	5	$11.55/gal		

Process: Tin-Palladium
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	75.3	A	25	$22.90/gal	$370.41	$431.10
Microetch	64.3	75.3	B	149.8 g/l	$3/lb	$241.14	$282.39
			C	0.5	$1.60/gal		
Predip	49.8	75.3	D	100	$12.75/gal	$634.95	$960.08
Activator	138.5	75.3	E	95	$12.75/gal	$6,871.33	$3,735.82
			F	5	$750/gal		
Accelerator	79.5	75.3	G	25	$13.20/gal	$724.44	$686.17
			H	25	$23.25/gal		
Acid Dip Bath	78.8	75.3	I	10	$1.60/gal	$12.61	$12.05

Process: Tin-Palladium
Supplier #2

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Conditioner	55.7	75.3	A	15	$31.38/gal	$292.13	$394.93
			B	2.5	$21.58/gal		
Predip	49.8	75.3	C	100	$5.94/gal	$295.18	$447.28
Palladium Catalyst	138.5	75.3	D	92	$5.94/gal	$5,411.36	$2,942.06
			E	8	$420.80/gal		
Accelerator	79.5	75.3	F	20	$68.75/gal	$1,093.12	$1,035.37
Enhancer	57	75.3	G	2	$5.14/gal	$25.81	$34.10
			H	2	$17.50/gal		
Stabilizer	57	75.3	I	2	$17.50/gal	$19.95	$26.36
Microetch	64.3		J	7	$25.79/gal	$318.13	$372.55
			K	2.5	$104.29/gal		
			L	10	$1.60/gal		
			M	5	$7.50/gal		

Process: Tin-Palladium
Supplier #3

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Conditioner	55.7	75.3	A	1	$83.30/gal	$46.40	$62.73
Microetch	64.3	75.3	B	175 g/l	$1.50/lb	$140.55	$164.59
Predip	49.8	75.3	C	100	$2.95/gal	$209.35	$316.55
Catalyst	138.5	75.3	D	95	$5.95/gal	$6,634	$3,607.00
			E	5	$845/gal		
Accelerator	79.5	75.3	F	0.045 g/l	No data	No data	No data
			G	1.2			
Acid Stabilizer	78.8	75.3	H	10	$1.60/gal	$12.61	$12.05

Process: Carbon
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner	44	No data	A	5	$90.43/gal	$198.94	No data
Conditioner	55.7	No data	B	2.5	$192.17/lb	$267.60	No data
Carbon Black	128	No data	C	100	$153.98/gal	$19,709.44	No data
Microetch	64.3	No data	D	200 g/l	$1.17/lb	$126.03	No data
			E	1	$1.60/gal		

Process: Graphite
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Cleaner/Conditioner	64.7	No data	A	25	$47.83/gal	$773.66	No data
Graphite	36.5	No data	B	60	$675/gal	$14,782.50	No data
Fixer	57	No data	C	10	$16.50/gal	$94.05	No data
Microetch	64.3	No data	D	55	$9.32/gal	$331.66	No data
			E	2	$1.60/gal		

Process: Conductive Polymer
Supplier #1

Bath	Volume in Bath (in gallons) Horizontal	Volume in Bath (in gallons) Vertical	Chemical Name	Percentage of Chemical in Bath	Cost of Chemicals	Total Cost of the Bath (Horizontal)	Total Cost of the Bath (Vertical)
Microetch	64.3	No data	A	2	$1.60/gal	$27.64	No data
		No data	B	7.5 Kg	$3.41/Kg		No data
Cleaner/Conditioner	64.7	No data	C	10	$21.90/gal	$140.82	No data
Catalyst	138.5	No data	D	81.5	$36.90/gal	$4,183.90	No data
		No data	E	0.3	$4.00/gal		No data
		No data	F	0.5	$24.60/gal		No data
Conductive Polymer	26	No data	G	15	$90.30/gal	$460.70	No data
		No data	H	23	$17.40/gal		No data
		No data	I	0.7	$24.60/gal		No data

Summary average cost per bath

Process: Electroless Copper

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner/ Conditioner	$161.99	10	$1,619.90	$188.53	9	$1,696.77
Microetch	$57.03	21	$1,197.63	$66.08	18	$1,189.44
Predip	$225.03	13	$2,925.39	$340.26	8	$2,722.08
Catalyst	$1,649.24	1	$1,649.24	$1,318.30	1	$1,318.30
Accelerator	$755.24	15	$11,328.60	$718.48	16	$11,495.68
Electroless Copper	$779.29	4	$3,117.16	$317.19	10	$3,171.90
Neutralizer	$91.20	6	$547.20	$120.48	6	$722.88
Anti-Tarnish	$9.41	28	$263.48	$16.15	13	$209.95
Total			$22,648.60			$22,527.00

Process: Formaldehyde-Free Electroless Copper

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner/ Conditioner	NA	NA	NA	$384.56	9	$3,461.04
Microetch	NA	NA	NA	$19.11	18	$343.98
Predip	NA	NA	NA	$360.31	8	$2,882.48
Activator	NA	NA	NA	$562.17	1	$562.17
Accelerator	NA	NA	NA	$2,854.70	16	$45,675.20
Electroless Copper	NA	NA	NA	$1,633.84	10	$16,338.40
Anti-Tarnish	NA	NA	NA	$21.54	14	$301.56
Total						$69,564.83

Process: Organic Palladium

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner	$155.05	39	$6,046.95	$180.45	23	$4,150.35
Microetch	$650.54	21	$13,661.34	$761.83	18	$13,714.74
Conditioner	$133.58	25	$3,339.50	$180.45	18	$3,248.10
Predip	-	21	-	-	14	-
Conductor	$534.60	1	$534.60	$372.74	2	$745.48
Post Dip	$156.78	31	$4,860.18	$262.35	18	$4,722.30
Acid Dip Bath	$19.95	21	$418.95	$19.02	22	$418.34
Total			$28,861.52			$26,999.31

*Acid Dip assumed to be similar in price to acid dip for tin palladium.

Process: Tin-Palladium

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner/ Conditioner	$236.31	9	$2,126.79	$296.25	7	$2,073.75
Microetch	$233.27	21	$4,898.67	$273.18	18	$4,917.24
Predip	$380.04	15	$5,700.60	$574.61	10	$5,746.10
Catalyst	$6,305.56	1	$6,305.56	$3,428.29	1	$3,428.29
Accelerator	$908.78	7	$6,361.46	$860.77	7	$6,025.39
Acid Dip Bath	$15.06	7	$105.42	$16.82	8	$134.56
Total			$25,498.50			$22,325.33

* Some processes included an enhancer bath that will not be included in analysis.

Process: Carbon

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner	$198.94	26	$5,172.44	NA	NA	NA
Conditioner	$267.60	20	$5,352.00	NA	NA	NA
Carbon Black[1]	$19,709.44	1	$19,709.44	NA	NA	NA
Microetch	$126.03	21	$2,646.63	NA	NA	NA
Total			$32,880.51	NA	NA	NA

[1] Carbon had no bath replacements in the simulation, however, at least one bath out of two would more than likely have been replaced.

Process: Graphite

Bath	Total Bath Cost (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Cleaner/ Conditioner	**$773.66**	**11**	**$8,510.26**	**NA**	**NA**	**NA**
Graphite	**$14,782.50**	**3**	**$44,347.50**	**NA**	**NA**	**NA**
Fixer	**$94.05**	**NA**	**NA**	**NA**	**NA**	**NA**
Microetch	**$331.66**	**21**	**$6,964.86**	**NA**	**NA**	**NA**
Total			**$59,822.62**	**NA**	**NA**	**NA**

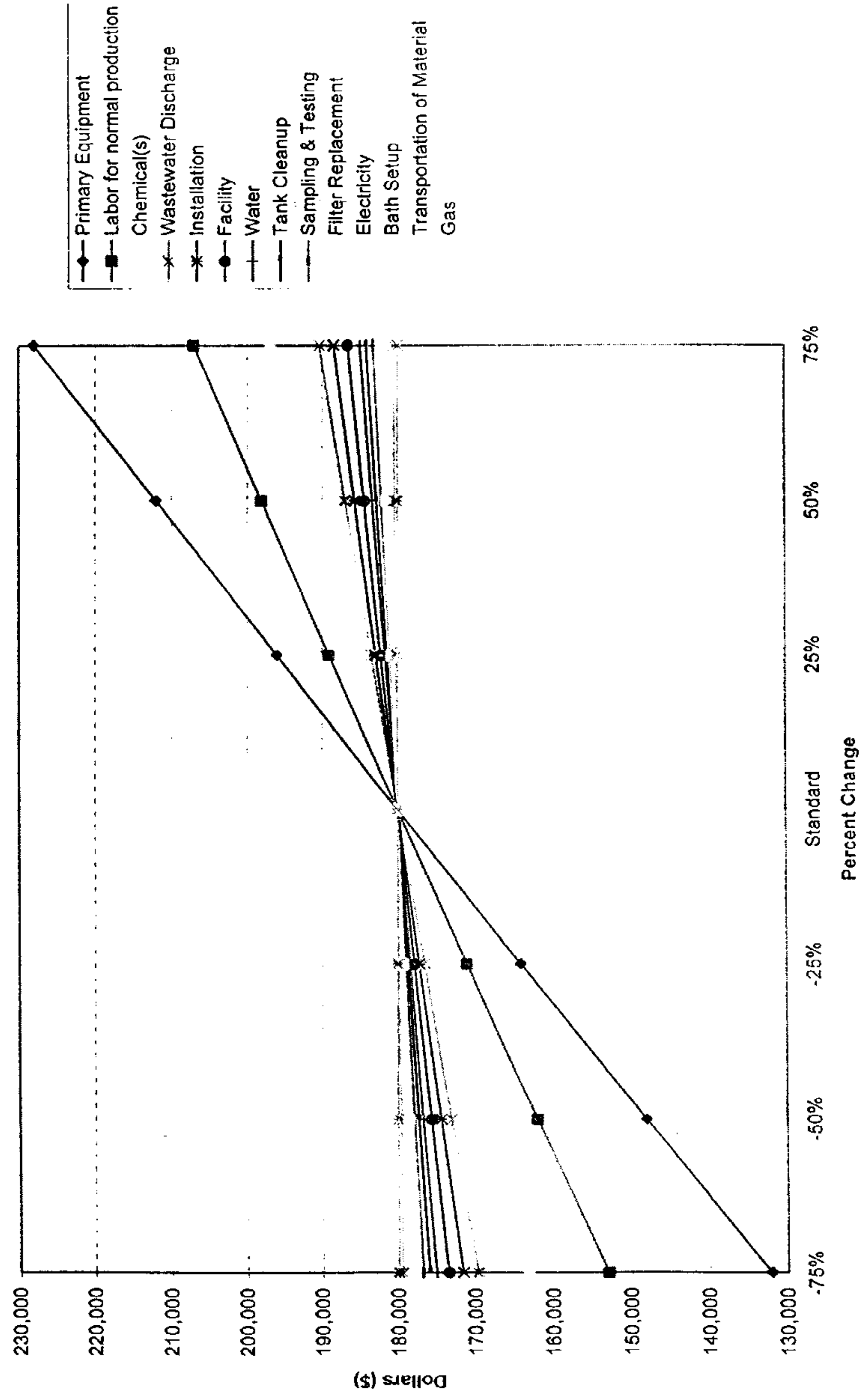
Process: Conductive Polymer[1]

Bath	Total Bath Coat (Conveyorized)	Replacement Frequency (Conveyorized)	Annual Cost (Conveyorized)	Total Bath Cost (Non-Conveyorized)	Replacement Frequency (Non-Conveyorized)	Annual Cost (Non-Conveyorized)
Microetch		**21**		**Not Avail.**	**NA**	**NA**
Cleaner/ Conditioner		**13**		**Not Avail.**	**NA**	**NA**
Catalyst		**1**		**Not Avail.**	**NA**	**NA**
Conductive Polymer		**6**		**Not Avail.**	**NA**	**NA**
Total						

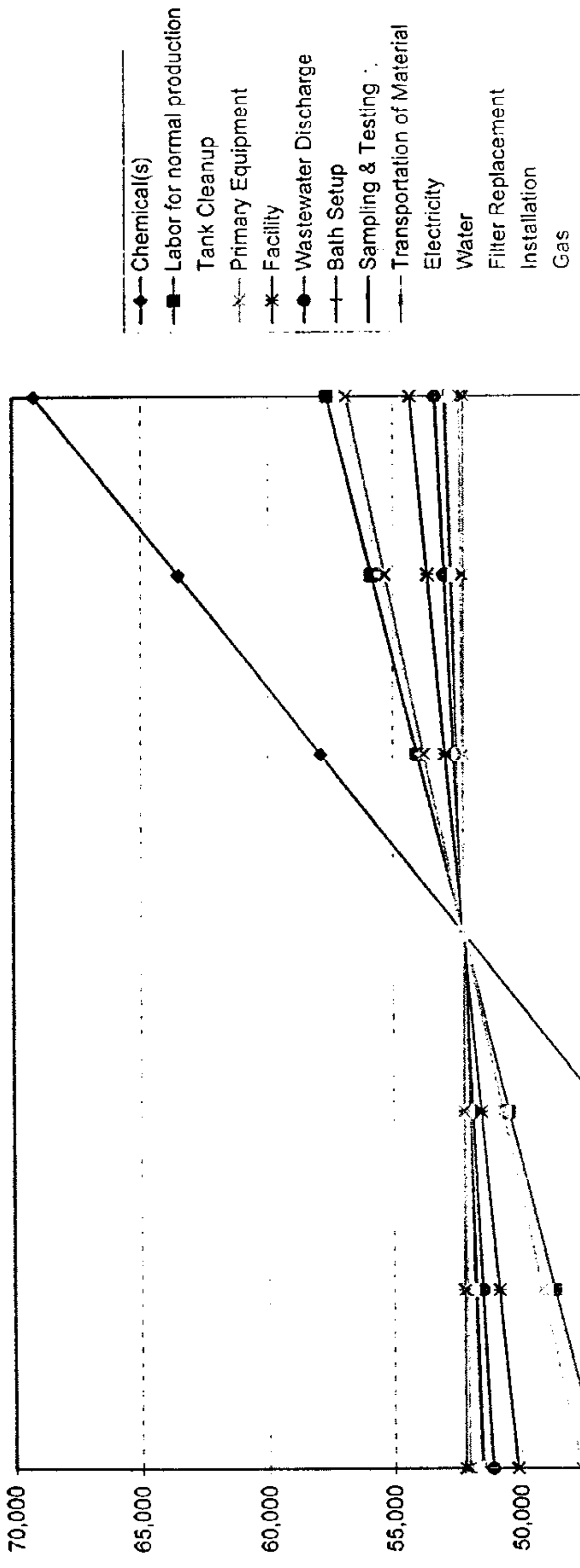
[1] Cost data were not available for all chemical products when this analysis was completed. These costs will be included in the final analysis.

G.6 Sensitivity Analyses

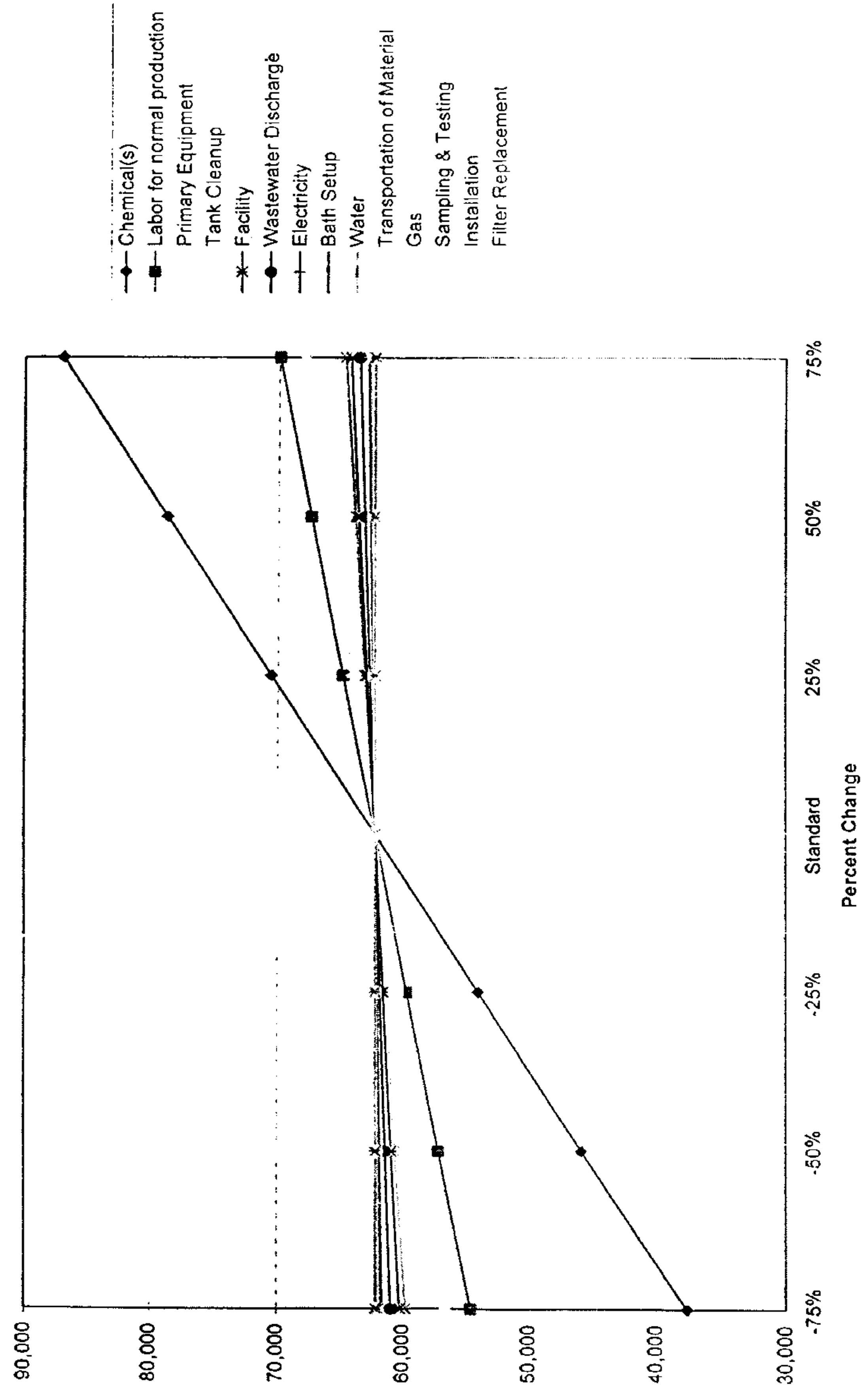
Sensitivity Analysis for the Non-Conveyorized Electroless Copper Process



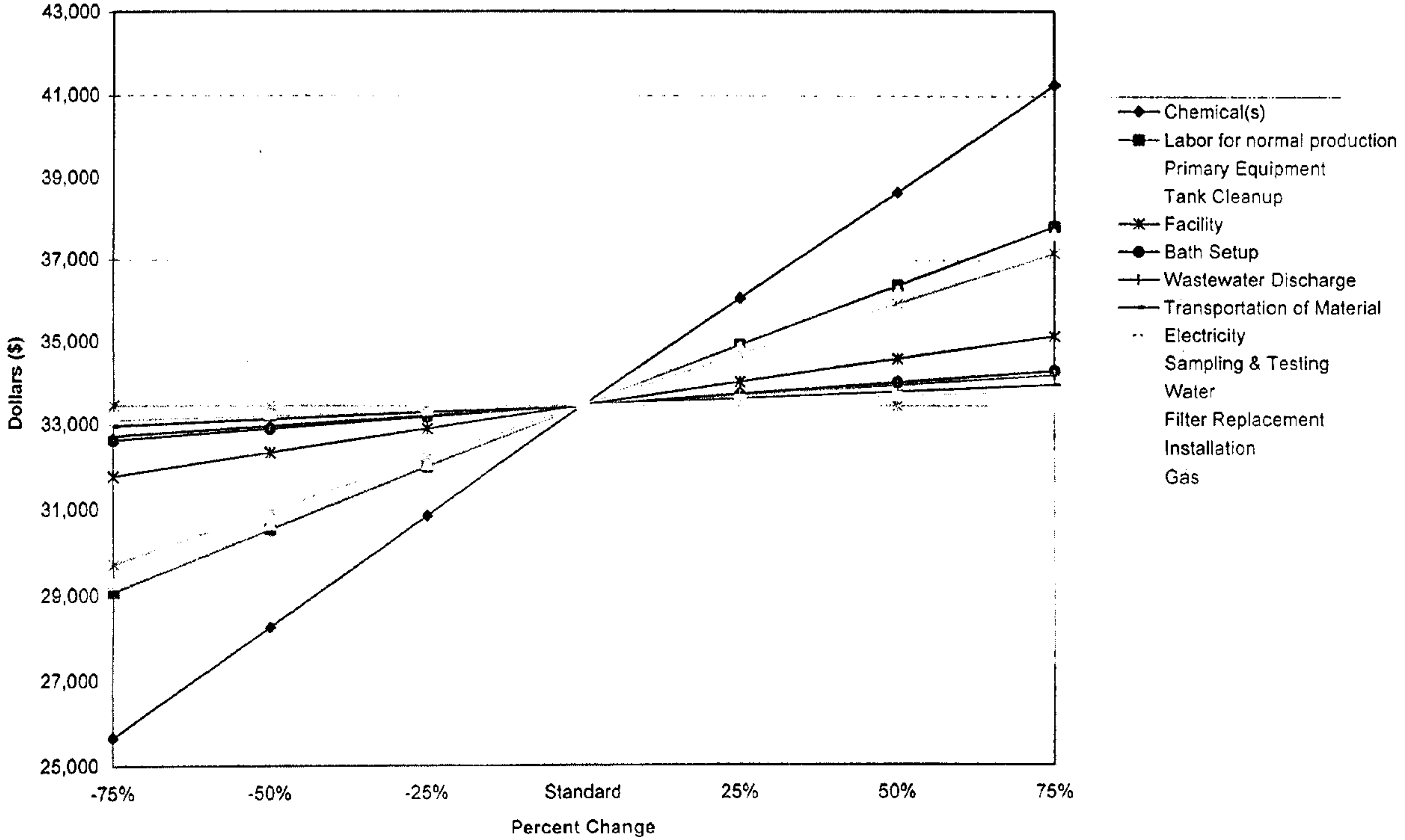
Sensitivity Analysis for the Conveyorized Electroless Copper Process



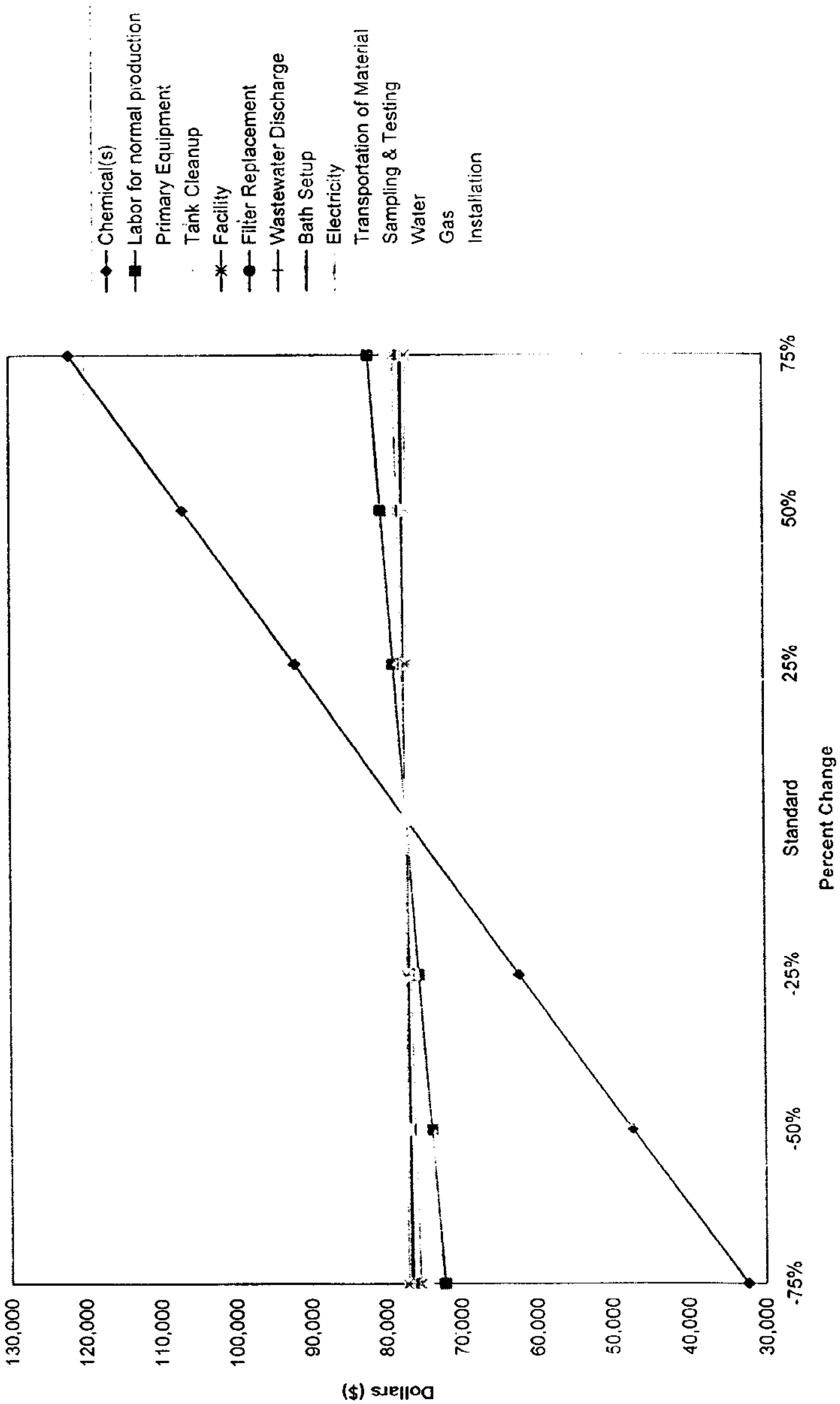
Sensitivity Analysis for the Conveyorized Carbon Process



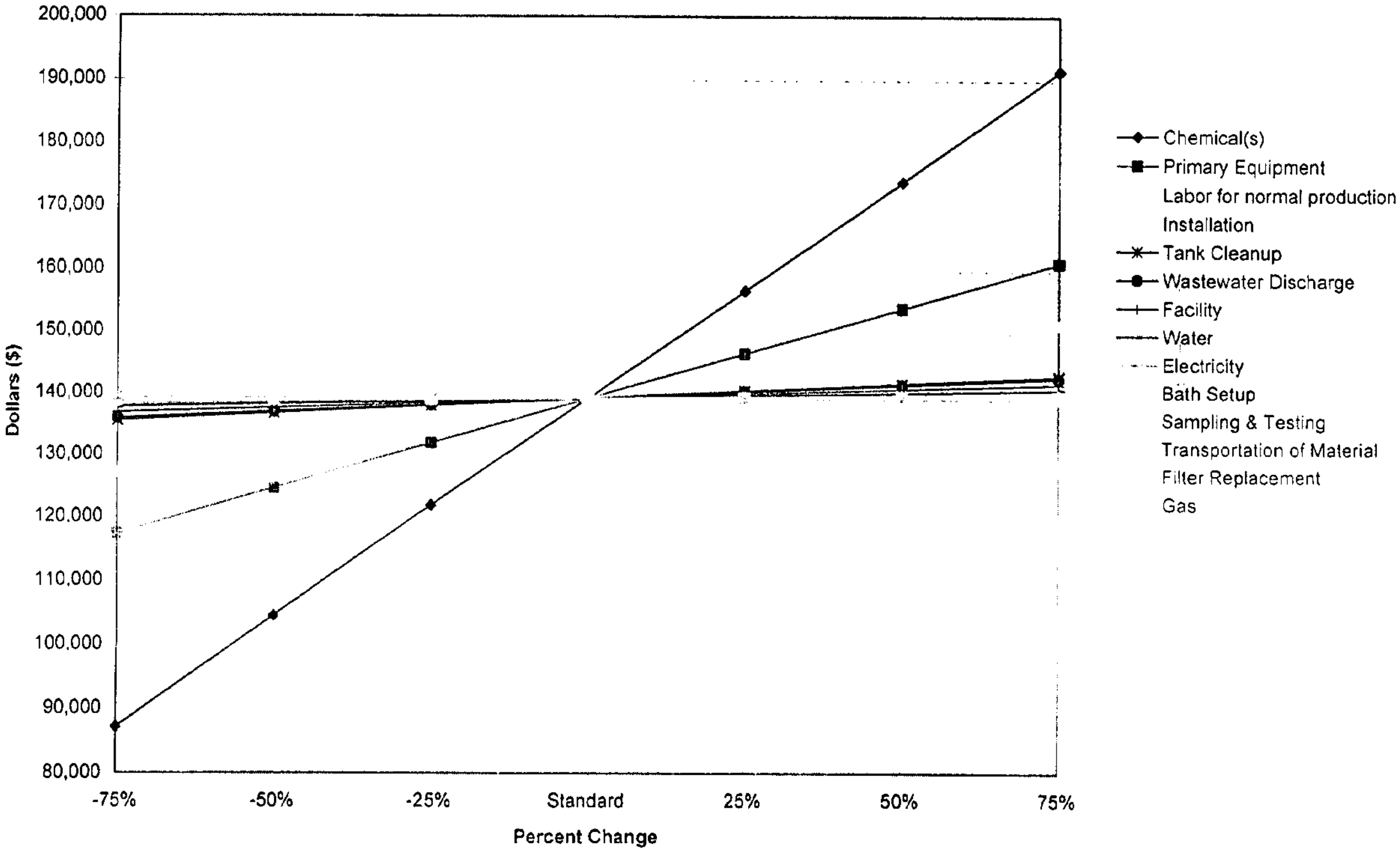
Sensitivity Analysis for the Conveyorized Conductive Polymer Process



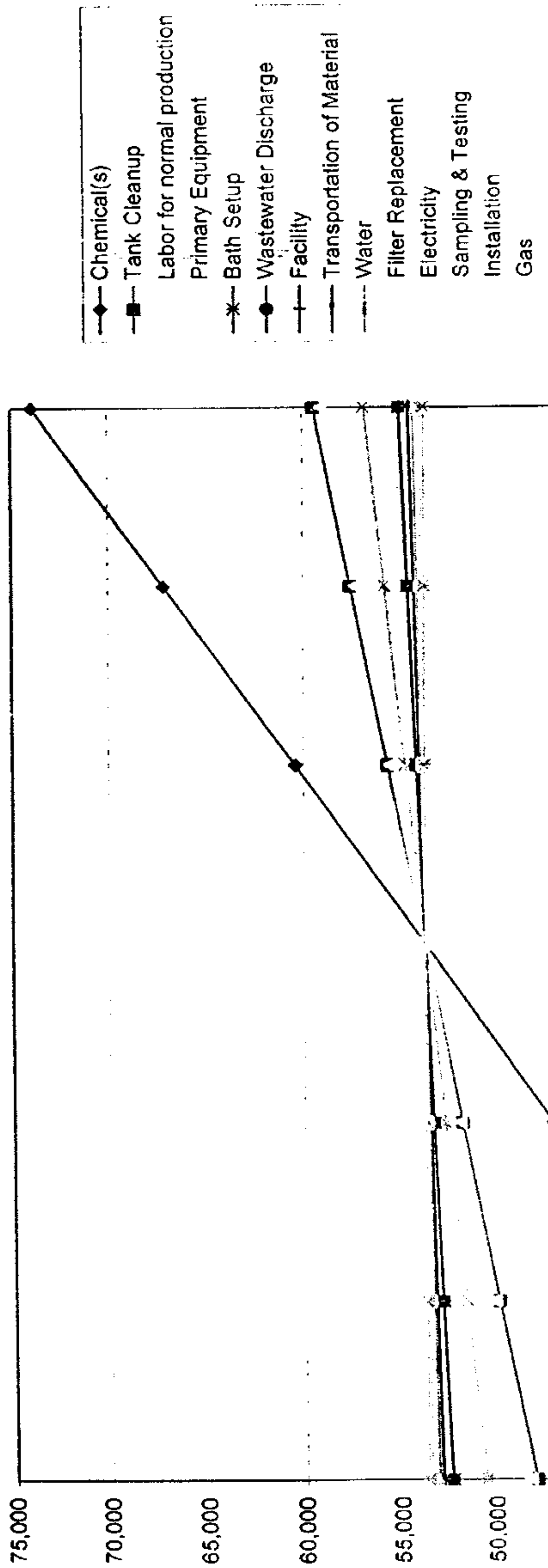
Sensitivity Analysis for the Conveyorized Graphite Process



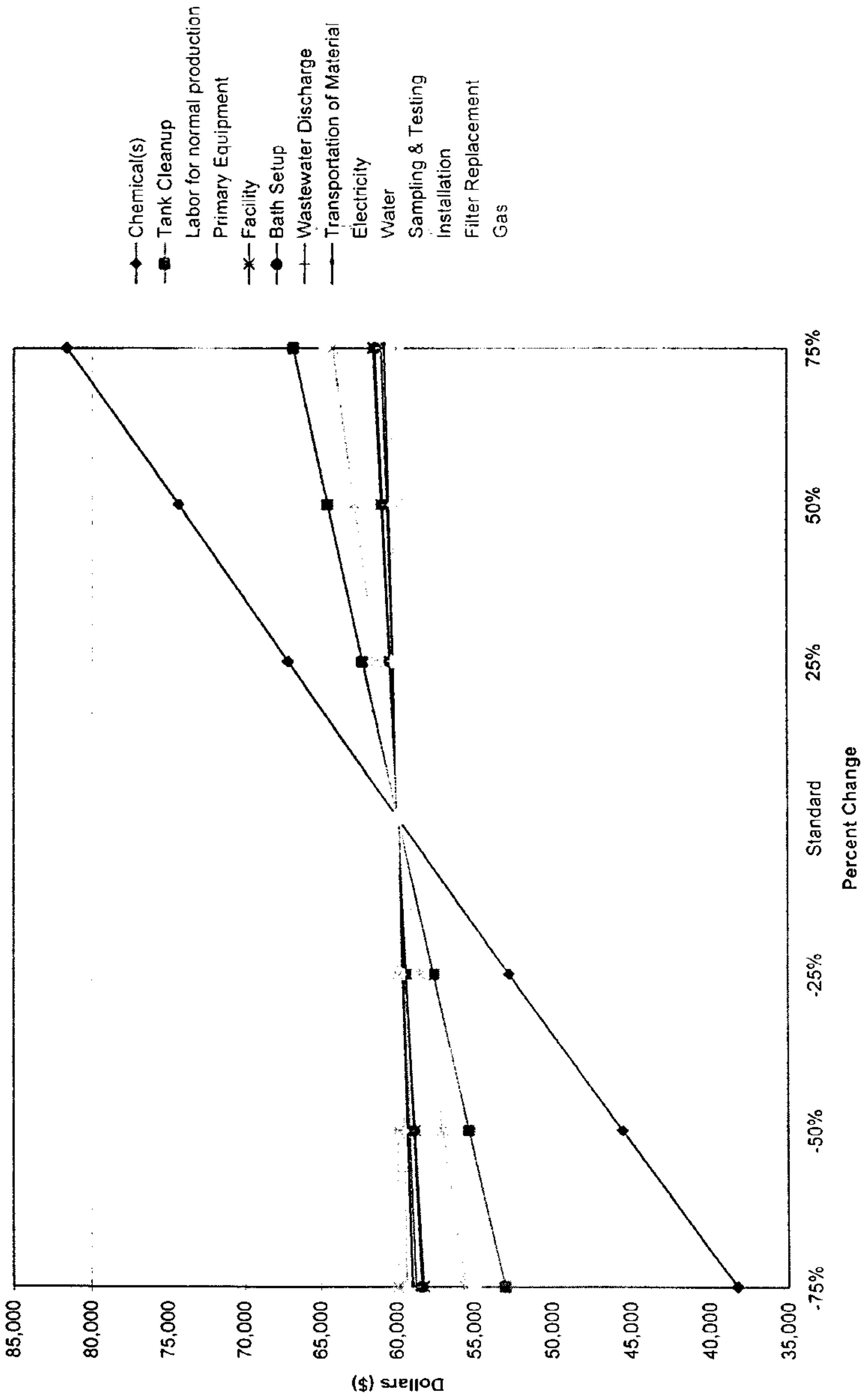
Sensitivity Analysis for the Non-Conveyorized Non-Formaldehyde Electroless Copper Process



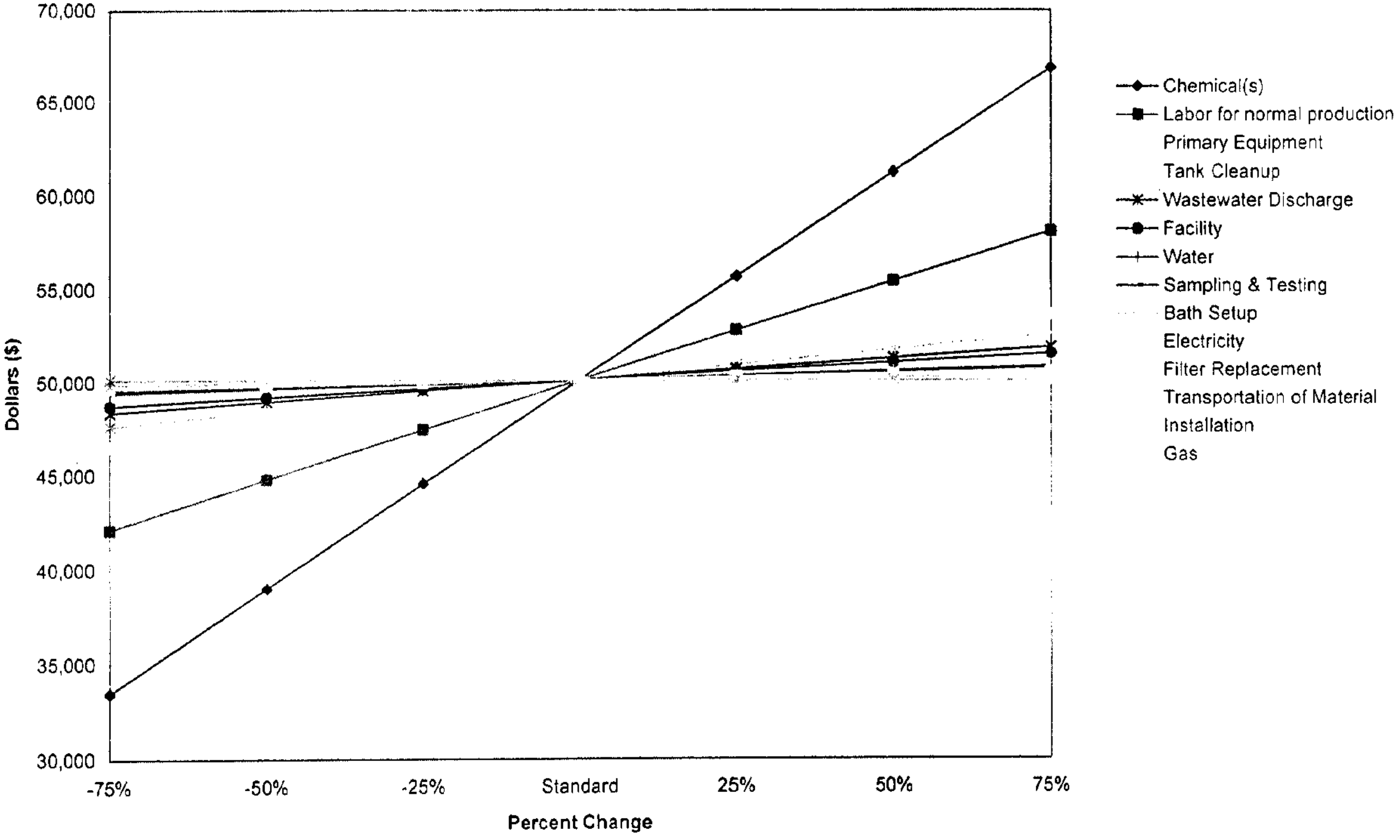
Sensitivity Analysis for the Non-Conveyorized Organic-Palladium Process



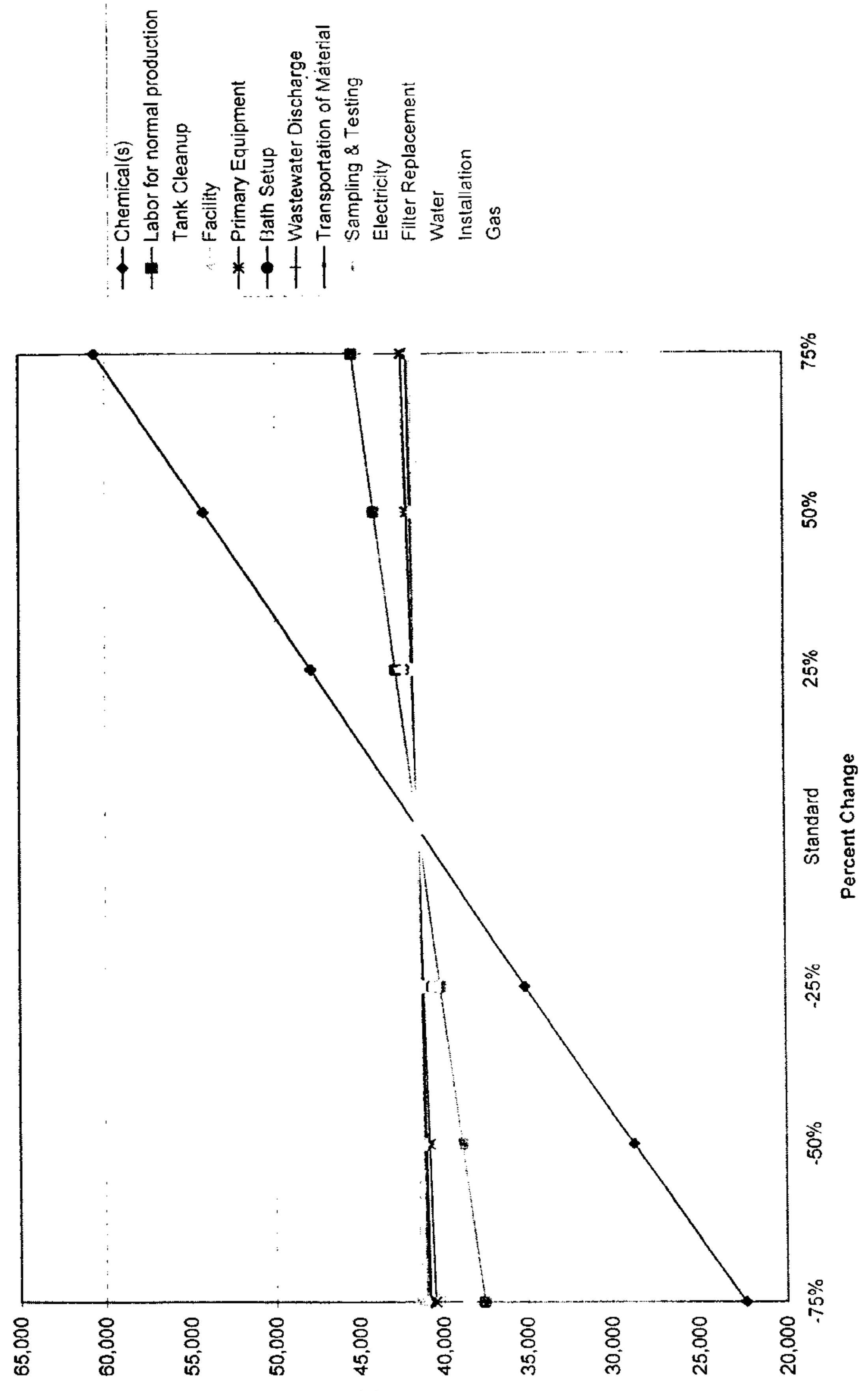
Sensitivity Analysis for the Conveyorized Organic-Palladium Process



Sensitivity Analysis for the Non-Conveyorized Tin-Palladium Process



Sensitivity Analysis for the Conveyorized Tin-Palladium Process



Appendix H

P2P Computer Printouts: Pollutants Generated by Energy Production

```
                 POLLUTION GENERATED--SUMMARY REPORT FOR
                    All Previously Selected Stage(s)

Product:                  Carbon
Unit-of-Use:              per ssf of board produced
Product Life:             1 year

==============================================================================

           3. Pollution Generated per Unit-of-Use of product--
  by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution  |    Pollutant        Amount   |                             Amount
 Category  |      Class         Prevented |       Pollutant            Prevented
            ----------------    -------   | --------------------       -------
          /Toxic Inorganics      0.50  g  |
  Human   |                               |Nitrogen oxides (NOx)      0.18  g
  health  |                               |Sulfur oxides (SOx)        0.32  g
 impacts  |Toxic Organics       59.   mg  |
          \                               |Carbon monoxide           59.   mg

          /Acid Rain Precursors  0.50  g  |
          |                               |Nitrogen oxides (NOx)      0.18  g
          |                               |Sulfur oxides (SOx)        0.32  g
          | Corrosives           0.53  g  |
          |                               |Nitrogen oxides (NOx)      0.18  g
          |                               |Sulfur oxides (SOx)        0.32  g
          |                               |Sulfuric acid             26.   mg
          | Dissolved Solids    34.   mg  |
          |                               |Dissolved solids           8.4  mg
   Use    |                               |Sulfuric acid             26.   mg
impairment| Global Warmers      56.    g  |
 impacts  |                               |Carbon dioxide            56.    g
          |                               |Nitrogen oxides (NOx)      0.18  g
          | Odorants             0.26  g  |
          |                               |Hydrocarbons               0.26  g
          | Particulates        60.   mg  |
          |                               |Particulates              60.   mg
          | Smog Formers         0.50  g  |
          |                               |Carbon monoxide           59.   mg
          |                               |Hydrocarbons               0.26  g
          \                               |Nitrogen oxides (NOx)      0.18  g

Disposal  /Solid Wastes          4.3   g  |
capacity  |                               |Solid wastes               4.3   g
 impacts  \                               |
                                          |
==============================================================================

     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
              POLLUTION.GENERATED--SUMMARY REPORT FOR
                 All Previously Selected Stage(s)


Product:            Carbon
Unit-of-Use:        per ssf of board produced
Product Life:       1 year

==========================================================================

          2. Pollution Generated per Unit-of-Use of product--
           by Pollution Category, by Pollutant and by Medium

                          | All     |            | Soil/     |          (  Indoor
Pollution prevented for:  | Media   |  Water     | Grdwater  |  Air     (   Air
                          |-------- | --------   | --------  | -------- ( --------
*Overall environment      | 61.    g| 34.    mg  |  4.3    g | 57.     g(
Carbon dioxide            | 56.    g|            |           | 56.     g(
Carbon monoxide           | 59.   mg|            |           | 59.    mg(
Dissolved solids          |  8.4  mg|  8.4   mg  |           |          (
Hydrocarbons              |  0.26  g|            |           |  0.26   g(
Nitrogen oxides (NOx)     |  0.18  g|            |           |  0.18   g(
Particulates              | 60.   mg|            |           | 60.    mg(
Solid wastes              |  4.3   g|            |  4.3    g |          (
Sulfur oxides (SOx)       |  0.32  g|            |           |  0.32   g(
Sulfuric acid             | 26.   mg| 26.    mg  |           |          (
                          |         |            |           |          (
*Human health impacts     |  0.56  g|            |           |  0.56   g(
Carbon monoxide           | 59.   mg|            |           | 59.    mg(
Nitrogen oxides (NOx)     |  0.18  g|            |           |  0.18   g(
Sulfur oxides (SOx)       |  0.32  g|            |           |  0.32   g(
                          |         |            |           |          (
*Use impairment impacts   | 57.    g| 34.    mg  |           | 57.     g(
Carbon dioxide            | 56.    g|            |           | 56.     g(
Carbon monoxide           | 59.   mg|            |           | 59.    mg(
Dissolved solids          |  8.4  mg|  8.4   mg  |           |          (
Hydrocarbons              |  0.26  g|            |           |  0.26   g(
Nitrogen oxides (NOx)     |  0.18  g|            |           |  0.18   g(
Particulates              | 60.   mg|            |           | 60.    mg(
Sulfur oxides (SOx)       |  0.32  g|            |           |  0.32   g(
Sulfuric acid             | 26.   mg| 26.    mg  |           |          (
                          |         |            |           |          (
*Disposal cap'cty impacts |  4.3   g|            |  4.3    g |          (
Solid wastes              |  4.3   g|            |  4.3    g |          (
                          |         |            |           |          (
==========================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
               POLLUTION GENERATED--SUMMARY REPORT FOR
                  All Previously Selected Stage(s)

Product:               Electroless V
Unit-of-Use:           per ssf of board produced
Product Life:          1 year

=============================================================================

           2. Pollution Generated per Unit-of-Use of product--
            by Pollution Category, by Pollutant and by Medium

                         | All                        Soil/              (  Indoor
Pollution prevented for: | Media   |   Water   |  Grdwater  |   Air     (   Air
                          --------   --------    --------    -------- ( --------
*Overall environment     | 130.   g|  0.11  g |  14.     g | 120.    g(
Carbon dioxide           | 120.   g|          |            | 120.    g(
Carbon monoxide          |   0.16 g|          |            |   0.16  g(
Dissolved solids         |  22.  mg|  22.  mg |            |          (
Hydrocarbons             |   0.14 g|          |            |   0.14  g(
Nitrogen oxides (NOx)    |   0.51 g|          |            |   0.51  g(
Particulates             |   0.19 g|          |            |   0.19  g(
Solid wastes             |  14.   g|          |  14.     g |          (
Sulfur oxides (SOx)      |   1.0  g|          |            |   1.0   g(
Sulfuric acid            |  86.  mg|  86.  mg |            |          (
                         |         |          |            |          (
*Human health impacts    |   1.7  g|          |            |   1.7   g(
Carbon monoxide          |   0.16 g|          |            |   0.16  g(
Nitrogen oxides (NOx)    |   0.51 g|          |            |   0.51  g(
Sulfur oxides (SOx)      |   1.0  g|          |            |   1.0   g(
                         |         |          |            |          (
*Use impairment impacts  | 120.   g|  0.11  g |            | 120.    g(
Carbon dioxide           | 120.   g|          |            | 120.    g(
Carbon monoxide          |   0.16 g|          |            |   0.16  g(
Dissolved solids         |  22.  mg|  22.  mg |            |          (
Hydrocarbons             |   0.14 g|          |            |   0.14  g(
Nitrogen oxides (NOx)    |   0.51 g|          |            |   0.51  g(
Particulates             |   0.19 g|          |            |   0.19  g(
Sulfur oxides (SOx)      |   1.0  g|          |            |   1.0   g(
Sulfuric acid            |  86.  mg|  86.  mg |            |          (
                         |         |          |            |          (
*Disposal cap'cty impacts|  14.   g|          |  14.     g |          (
Solid wastes             |  14.   g|          |  14.     g |          (
                         |         |          |            |          (

=============================================================================

      NOTE: Some totals in these reports may appear incorrect since all
      numbers displayed have been rounded to two significant figures.
```

```
              POLLUTION GENERATED--SUMMARY REPORT FOR
                  All Previously Selected Stage(s)

Product:                 Electroless V
Unit-of-Use:             per ssf of board produced
Product Life:            1 year

=============================================================================

          3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |    Pollutant       Amount  |                            Amount
 Category |      Class       Prevented |        Pollutant         Prevented
             ----------------  ------- | ----------------------    -------
         /Toxic Inorganics     1.5   g |
 Human   |                             |Nitrogen oxides (NOx)      0.51  g
 health  |                             |Sulfur oxides (SOx)        1.0   g
 impacts |Toxic Organics       0.16  g |
         \                             |Carbon monoxide            0.16  g

         /Acid Rain Precursors 1.5   g |
         |                             |Nitrogen oxides (NOx)      0.51  g
         |                             |Sulfur oxides (SOx)        1.0   g
         |Corrosives           1.6   g |
         |                             |Nitrogen oxides (NOx)      0.51  g
         |                             |Sulfur oxides (SOx)        1.0   g
         |                             |Sulfuric acid              86.   mg
         |Dissolved Solids     0.11  g |
         |                             |Dissolved solids           22.   mg
   Use   |                             |Sulfuric acid              86.   mg
impairment|Global Warmers      120.    g |
 impacts |                             |Carbon dioxide            120.    g
         |                             |Nitrogen oxides (NOx)      0.51  g
         |Odorants             0.14  g |
         |                             |Hydrocarbons               0.14  g
         |Particulates         0.19  g |
         |                             |Particulates               0.19  g
         |Smog Formers         0.82  g |
         |                             |Carbon monoxide            0.16  g
         |                             |Hydrocarbons               0.14  g
         \                             |Nitrogen oxides (NOx)      0.51  g

Disposal /Solid Wastes         14.   g |
capacity |                             |Solid wastes               14.   g
impacts  \                             |
                                       |
=============================================================================

   NOTE: Some totals in these reports may appear incorrect since all
   numbers displayed have been rounded to two significant figures.
```

POLLUTION GENERATED--SUMMARY REPORT FOR
All Previously Selected Stage(s)

Product:	Electroless Copper C
Unit-of-Use:	per ssf of board produced
Product Life:	1 year

2. Pollution Generated per Unit-of-Use of product--
by Pollution Category, by Pollutant and by Medium

Pollution prevented for:	All Media	Water	Soil/ Grdwater	Air	Indoor Air
***Overall environment**	32. g	26. mg	3.4 g	29. g	
Carbon dioxide	28. g			28. g	
Carbon monoxide	40. mg			40. mg	
Dissolved solids	5.4 mg	5.4 mg			
Hydrocarbons	34. mg			34. mg	
Nitrogen oxides (NOx)	0.12 g			0.12 g	
Particulates	47. mg			47. mg	
Solid wastes	3.4 g		3.4 g		
Sulfur oxides (SOx)	0.25 g			0.25 g	
Sulfuric acid	21. mg	21. mg			
***Human health impacts**	0.41 g			0.41 g	
Carbon monoxide	40. mg			40. mg	
Nitrogen oxides (NOx)	0.12 g			0.12 g	
Sulfur oxides (SOx)	0.25 g			0.25 g	
***Use impairment impacts**	29. g	26. mg		29. g	
Carbon dioxide	28. g			28. g	
Carbon monoxide	40. mg			40. mg	
Dissolved solids	5.4 mg	5.4 mg			
Hydrocarbons	34. mg			34. mg	
Nitrogen oxides (NOx)	0.12 g			0.12 g	
Particulates	47. mg			47. mg	
Sulfur oxides (SOx)	0.25 g			0.25 g	
Sulfuric acid	21. mg	21. mg			
***Disposal cap'cty impacts**	3.4 g		3.4 g		
Solid wastes	3.4 g		3.4 g		

NOTE: Some totals in these reports may appear incorrect since all numbers displayed have been rounded to two significant figures.

```
                  POLLUTION GENERATED--SUMMARY REPORT FOR
                      All Previously Selected Stage(s)

Product:              Electroless Copper C
Unit-of-Use:          per ssf of board produced
Product Life:         1 year

================================================================================

              3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |    Pollutant        Amount                                    Amount
 Category |      Class         Prevented|        Pollutant               Prevented
            ----------------    -------   ---------------------           -------
          /Toxic Inorganics     0.37  g |
  Human   |                             |Nitrogen oxides (NOx)          0.12  g
  health  |                             |Sulfur oxides (SOx)            0.25  g
 impacts  |Toxic Organics      40.    mg|
          \                             |Carbon monoxide               40.    mg

          /Acid Rain Precursors 0.37  g |
          |                             |Nitrogen oxides (NOx)          0.12  g
          |                             |Sulfur oxides (SOx)            0.25  g
          |Corrosives           0.39  g |
          |                             |Nitrogen oxides (NOx)          0.12  g
          |                             |Sulfur oxides (SOx)            0.25  g
          |                             |Sulfuric acid                 21.    mg
          |Dissolved Solids    26.    mg|
          |                             |Dissolved solids               5.4  mg
   Use    |                             |Sulfuric acid                 21.    mg
impairment|Global Warmers      28.     g|
 impacts  |                             |Carbon dioxide                28.     g
          |                             |Nitrogen oxides (NOx)          0.12  g
          |Odorants            34.    mg|
          |                             |Hydrocarbons                  34.    mg
          |Particulates        47.    mg|
          |                             |Particulates                  47.    mg
          |Smog Formers         0.20  g |
          |                             |Carbon monoxide               40.    mg
          |                             |Hydrocarbons                  34.    mg
          \                             |Nitrogen oxides (NOx)          0.12  g

 Disposal /Solid Wastes         3.4   g |
 capacity |                             |Solid wastes                   3.4   g
 impacts  \                             |
                                        |

================================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
              POLLUTION GENERATED--SUMMARY REPORT FOR
                 All Previously Selected Stage(s)

Product:             Graphite
Unit-of-Use:         per ssf of board produced
Product Life:        1 year

    ================================================================    ==========

          2. Pollution Generated per Unit-of-Use of product--
            by Pollution Category, by Pollutant and by Medium

                          |   All     |           |  Soil/    |           (  Indoor
Pollution prevented for:  |  Media    |   Water   | Grdwater  |    Air    (   Air
                          | --------  | --------  | --------  | --------  (  --------
*Overall environment      | 29.     g | 19.    mg |  2.4    g | 27.     g(
Carbon dioxide            | 27.     g |           |           | 27.     g(
Carbon monoxide           | 31.    mg |           |           | 31.    mg(
Dissolved solids          |  4.3   mg |  4.3   mg |           |           (
Hydrocarbons              | 98.    mg |           |           | 98.    mg(
Nitrogen oxides (NOx)     | 94.    mg |           |           | 94.    mg(
Particulates              | 33.    mg |           |           | 33.    mg(
Solid wastes              |  2.4    g |           |  2.4    g |           (
Sulfur oxides (SOx)       |  0.18   g |           |           |  0.18   g(
Sulfuric acid             | 14.    mg | 14.    mg |           |           (
                          |           |           |           |           (
*Human health impacts     |  0.30   g |           |           |  0.30   g(
Carbon monoxide           | 31.    mg |           |           | 31.    mg(
Nitrogen oxides (NOx)     | 94.    mg |           |           | 94.    mg(
Sulfur oxides (SOx)       |  0.18   g |           |           |  0.18   g(
                          |           |           |           |           (
*Use impairment impacts   | 27.     g | 19.    mg |           | 27.     g(
Carbon dioxide            | 27.     g |           |           | 27.     g(
Carbon monoxide           | 31.    mg |           |           | 31.    mg(
Dissolved solids          |  4.3   mg |  4.3   mg |           |           (
Hydrocarbons              | 98.    mg |           |           | 98.    mg(
Nitrogen oxides (NOx)     | 94.    mg |           |           | 94.    mg(
Particulates              | 33.    mg |           |           | 33.    mg(
Sulfur oxides (SOx)       |  0.18   g |           |           |  0.18   g(
Sulfuric acid             | 14.    mg | 14.    mg |           |           (
                          |           |           |           |           (
*Disposal cap'cty impacts |  2.4    g |           |  2.4    g |           (
Solid wastes              |  2.4    g |           |  2.4    g |           (
                          |           |           |           |           (
==================================================================================

     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                 POLLUTION GENERATED--SUMMARY REPORT FOR
                    All Previously Selected Stage(s)


Product:                Graphite
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

==============================================================================

            3. Pollution Generated per Unit-of-Use of product--
  by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |      Pollutant        Amount  |                             Amount
 Category |        Class       Prevented |          Pollutant        Prevented
           ----------------    -------   | ---------------------     -------
          /Toxic Inorganics      0.27  g |
  Human   |                              |Nitrogen oxides (NOx)      94.   mg
  health  |                              |Sulfur oxides (SOx)         0.18  g
 impacts  |Toxic Organics       31.    mg|
          \                              |Carbon monoxide            31.   mg
                                         |
          /Acid Rain Precursors  0.27  g |
          |                              |Nitrogen oxides (NOx)      94.   mg
          |                              |Sulfur oxides (SOx)         0.18  g
          |Corrosives            0.28  g |
          |                              |Nitrogen oxides (NOx)      94.   mg
          |                              |Sulfur oxides (SOx)         0.18  g
          |                              |Sulfuric acid              14.   mg
          |Dissolved Solids     19.    mg|
          |                              |Dissolved solids            4.3  mg
   Use    |                              |Sulfuric acid              14.   mg
impairment|Global Warmers       27.    g |
 impacts  |                              |Carbon dioxide             27.    g
          |                              |Nitrogen oxides (NOx)      94.   mg
          |Odorants             98.    mg|
          |                              |Hydrocarbons               98.   mg
          |Particulates         33.    mg|
          |                              |Particulates               33.   mg
          |Smog Formers          0.22  g |
          |                              |Carbon monoxide            31.   mg
          |                              |Hydrocarbons               98.   mg
          \                              |Nitrogen oxides (NOx)      94.   mg
                                         |
 Disposal /Solid Wastes          2.4   g |
 capacity |                              |Solid wastes                2.4   g
 impacts  \                              |
                                         |
==============================================================================
```

NOTE: Some totals in these reports may appear incorrect since all numbers displayed have been rounded to two significant figures.

```
                     POLLUTION GENERATED--SUMMARY REPORT FOR
                       All Previously Selected Stage(s)

Product:                 Conductive Polymer
Unit-of-Use:             per ssf of board produced
Product Life:            1 year

================================================================================

              2. Pollution Generated per Unit-of-Use of product--
               by Pollution Category, by Pollutant and by Medium

                           | All        |            | Soil/      |            (  Indoor
Pollution prevented for:   | Media      |   Water    | Grdwater   |    Air     (   Air
                           | --------   | --------   | --------   | --------   ( --------
*Overall environment       | 22.     g  | 18.    mg  |  2.3    g  | 20.      g(
Carbon dioxide             | 19.     g  |            |            | 19.      g(
Carbon monoxide            | 27.     mg |            |            | 27.     mg(
Dissolved solids           |  3.7    mg |  3.7   mg  |            |           (
Hydrocarbons               | 24.     mg |            |            | 24.     mg(
Nitrogen oxides (NOx)      | 84.     mg |            |            | 84.     mg(
Particulates               | 32.     mg |            |            | 32.     mg(
Solid wastes               |  2.3    g  |            |  2.3    g  |           (
Sulfur oxides (SOx)        |  0.17   g  |            |            |  0.17    g(
Sulfuric acid              | 14.     mg | 14.    mg  |            |           (
                           |            |            |            |           (
*Human health impacts      |  0.28   g  |            |            |  0.28    g(
Carbon monoxide            | 27.     mg |            |            | 27.     mg(
Nitrogen oxides (NOx)      | 84.     mg |            |            | 84.     mg(
Sulfur oxides (SOx)        |  0.17   g  |            |            |  0.17    g(
                           |            |            |            |           (
*Use impairment impacts    | 20.     g  | 18.    mg  |            | 20.      g(
Carbon dioxide             | 19.     g  |            |            | 19.      g(
Carbon monoxide            | 27.     mg |            |            | 27.     mg(
Dissolved solids           |  3.7    mg |  3.7   mg  |            |           (
Hydrocarbons               | 24.     mg |            |            | 24.     mg(
Nitrogen oxides (NOx)      | 84.     mg |            |            | 84.     mg(
Particulates               | 32.     mg |            |            | 32.     mg(
Sulfur oxides (SOx)        |  0.17   g  |            |            |  0.17    g(
Sulfuric acid              | 14.     mg | 14.    mg  |            |           (
                           |            |            |            |           (
*Disposal cap'cty impacts  |  2.3    g  |            |  2.3    g  |           (
Solid wastes               |  2.3    g  |            |  2.3    g  |           (
                           |            |            |            |           (

================================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                 POLLUTION GENERATED--SUMMARY REPORT FOR
                    All Previously Selected Stage(s)


Product:                Conductive Polymer
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

==============================================================================

          3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution  |     Pollutant        Amount  |                             Amount
 Category  |       Class          Prevented|        Pollutant           Prevented
           ----------------     -------  | ---------------------      -------
          /Toxic Inorganics       0.25  g |
  Human   |                               |Nitrogen oxides (NOx)      84.   mg
  health  |                               |Sulfur oxides (SOx)         0.17  g
 impacts  |Toxic Organics        27.    mg|
          \                               |Carbon monoxide            27.   mg

          /Acid Rain Precursors   0.25  g |
          |                               |Nitrogen oxides (NOx)      84.   mg
          |                               |Sulfur oxides (SOx)         0.17  g
          | Corrosives            0.27  g |
          |                               |Nitrogen oxides (NOx)      84.   mg
          |                               |Sulfur oxides (SOx)         0.17  g
          |                               |Sulfuric acid              14.   mg
          | Dissolved Solids     18.    mg|
          |                               |Dissolved solids            3.7  mg
   Use    |                               |Sulfuric acid              14.   mg
impairment|Global Warmers        19.    g |
 impacts  |                               |Carbon dioxide             19.    g
          |                               |Nitrogen oxides (NOx)      84.   mg
          |Odorants              24.    mg|
          |                               |Hydrocarbons               24.   mg
          |Particulates          32.    mg|
          |                               |Particulates               32.   mg
          |Smog Formers           0.14  g |
          |                               |Carbon monoxide            27.   mg
          |                               |Hydrocarbons               24.   mg
          \                               |Nitrogen oxides (NOx)      84.   mg

 Disposal /Solid Wastes           2.3   g |
 capacity |                               |Solid wastes                2.3   g
 impacts  \                               |
                                          |
==============================================================================
```

NOTE: Some totals in these reports may appear incorrect since all numbers displayed have been rounded to two significant figures.

```
                POLLUTION GENERATED--SUMMARY REPORT FOR
                    All Previously Selected Stage(s)


Product:               Tin Palladium V
Unit-of-Use:           per ssf of board produced
Product Life:          1 year

 ================================================================================

             2. Pollution Generated per Unit-of-Use of product--
               by Pollution Category, by Pollutant and by Medium

                          |  All      |           | Soil/     |           (  Indoor
Pollution prevented for:  | Media     |   Water   | Grdwater  |   Air     (   Air
                          | --------  | --------  | --------  | --------  ( --------
*Overall environment      | 30.     g | 25.    mg |  3.2    g | 27.     g(
Carbon dioxide            | 27.     g |           |           | 27.     g(
Carbon monoxide           | 38.    mg |           |           | 38.    mg(
Dissolved solids          |  5.1   mg |  5.1   mg |           |           (
Hydrocarbons              | 33.    mg |           |           | 33.    mg(
Nitrogen oxides (NOx)     |  0.12   g |           |           |  0.12   g(
Particulates              | 45.    mg |           |           | 45.    mg(
Solid wastes              |  3.2    g |           |  3.2    g |           (
Sulfur oxides (SOx)       |  0.23   g |           |           |  0.23   g(
Sulfuric acid             | 20.    mg | 20.    mg |           |           (
                          |           |           |           |           (
*Human health impacts     |  0.39   g |           |           |  0.39   g(
Carbon monoxide           | 38.    mg |           |           | 38.    mg(
Nitrogen oxides (NOx)     |  0.12   g |           |           |  0.12   g(
Sulfur oxides (SOx)       |  0.23   g |           |           |  0.23   g(
                          |           |           |           |           (
*Use impairment impacts   | 27.     g | 25.    mg |           | 27.     g(
Carbon dioxide            | 27.     g |           |           | 27.     g(
Carbon monoxide           | 38.    mg |           |           | 38.    mg(
Dissolved solids          |  5.1   mg |  5.1   mg |           |           (
Hydrocarbons              | 33.    mg |           |           | 33.    mg(
Nitrogen oxides (NOx)     |  0.12   g |           |           |  0.12   g(
Particulates              | 45.    mg |           |           | 45.    mg(
Sulfur oxides (SOx)       |  0.23   g |           |           |  0.23   g(
Sulfuric acid             | 20.    mg | 20.    mg |           |           (
                          |           |           |           |           (
*Disposal cap'cty impacts |  3.2    g |           |  3.2    g |           (
Solid wastes              |  3.2    g |           |  3.2    g |           (
                          |           |           |           |           (

================================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                  POLLUTION GENERATED--SUMMARY REPORT FOR
                     All Previously Selected Stage(s)

Product:              Tin Palladium V
Unit-of-Use:          per ssf of board produced
Product Life:         1 year

==================================================================================

          3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |    Pollutant        Amount  |                              Amount
 Category |      Class        Prevented |        Pollutant            Prevented
           ----------------    -------  | --------------------         -------
         /Toxic Inorganics      0.35  g |
  Human  |                              |Nitrogen oxides (NOx)         0.12  g
  health |                              |Sulfur oxides (SOx)           0.23  g
 impacts |Toxic Organics       38.    mg|
         \                              |Carbon monoxide              38.    mg

         /Acid Rain Precursors  0.35  g |
         |                              |Nitrogen oxides (NOx)         0.12  g
         |                              |Sulfur oxides (SOx)           0.23  g
         | Corrosives           0.37  g |
         |                              |Nitrogen oxides (NOx)         0.12  g
         |                              |Sulfur oxides (SOx)           0.23  g
         |                              |Sulfuric acid                20.    mg
         | Dissolved Solids    25.    mg|
         |                              |Dissolved solids              5.1  mg
   Use   |                              |Sulfuric acid                20.    mg
impairment|Global Warmers      27.     g|
  impacts|                              |Carbon dioxide               27.     g
         |                              |Nitrogen oxides (NOx)         0.12  g
         |Odorants             33.    mg|
         |                              |Hydrocarbons                 33.    mg
         |Particulates         45.    mg|
         |                              |Particulates                 45.    mg
         |Smog Formers          0.19  g |
         |                              |Carbon monoxide              38.    mg
         |                              |Hydrocarbons                 33.    mg
         \                              |Nitrogen oxides (NOx)         0.12  g

Disposal /Solid Wastes          3.2   g |
capacity |                              |Solid wastes                  3.2   g
impacts  \                              |
                                        |
==================================================================================

   NOTE: Some totals in these reports may appear incorrect since all
   numbers displayed have been rounded to two significant figures.
```

```
                 POLLUTION GENERATED--SUMMARY REPORT FOR
                    All Previously Selected Stage(s)

Product:                Tin Palladium C
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

================================================================================

             2. Pollution Generated per Unit-of-Use of product--
              by Pollution Category, by Pollutant and by Medium

                           |   All     |           |  Soil/    |          (  Indoor
Pollution prevented for:   |  Media    |   Water   | Grdwater  |   Air    (   Air
                           | --------  | --------  | --------  | -------- ( --------
*Overall environment       |  23.    g | 18.    mg |  2.4    g | 20.     g(
Carbon dioxide             |  20.    g |           |           | 20.     g(
Carbon monoxide            |  28.   mg |           |           | 28.    mg(
Dissolved solids           |   3.7  mg |  3.7   mg |           |          (
Hydrocarbons               |  24.   mg |           |           | 24.    mg(
Nitrogen oxides (NOx)      |  86.   mg |           |           | 86.    mg(
Particulates               |  33.   mg |           |           | 33.    mg(
Solid wastes               |   2.4   g |           |  2.4    g |          (
Sulfur oxides (SOx)        |   0.17  g |           |           |  0.17   g(
Sulfuric acid              |  15.   mg | 15.    mg |           |          (
                           |           |           |           |          (
*Human health impacts      |   0.29  g |           |           |  0.29   g(
Carbon monoxide            |  28.   mg |           |           | 28.    mg(
Nitrogen oxides (NOx)      |  86.   mg |           |           | 86.    mg(
Sulfur oxides (SOx)        |   0.17  g |           |           |  0.17   g(
                           |           |           |           |          (
*Use impairment impacts    |  20.    g | 18.    mg |           | 20.     g(
Carbon dioxide             |  20.    g |           |           | 20.     g(
Carbon monoxide            |  28.   mg |           |           | 28.    mg(
Dissolved solids           |   3.7  mg |  3.7   mg |           |          (
Hydrocarbons               |  24.   mg |           |           | 24.    mg(
Nitrogen oxides (NOx)      |  86.   mg |           |           | 86.    mg(
Particulates               |  33.   mg |           |           | 33.    mg(
Sulfur oxides (SOx)        |   0.17  g |           |           |  0.17   g(
Sulfuric acid              |  15.   mg | 15.    mg |           |          (
                           |           |           |           |          (
*Disposal cap'cty impacts  |   2.4   g |           |  2.4    g |          (
Solid wastes               |   2.4   g |           |  2.4    g |          (
                           |           |           |           |          (
================================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                  POLLUTION GENERATED--SUMMARY REPORT FOR
                     All Previously Selected Stage(s)


Product:                Tin Palladium C
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

=========================================================================

               3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |     Pollutant        Amount  |                            Amount
 Category |       Class        Prevented |         Pollutant         Prevented
            ----------------    -------  |  ----------------------   -------
         /Toxic Inorganics      0.26  g  |
  Human  |                               |Nitrogen oxides (NOx)      86.   mg
  health |                               |Sulfur oxides (SOx)         0.17  g
 impacts |Toxic Organics       28.    mg |
         \                               |Carbon monoxide            28.   mg

         /Acid Rain Precursors  0.26  g  |
         |                               |Nitrogen oxides (NOx)      86.   mg
         |                               |Sulfur oxides (SOx)         0.17  g
         |Corrosives            0.27  g  |
         |                               |Nitrogen oxides (NOx)      86.   mg
         |                               |Sulfur oxides (SOx)         0.17  g
         |                               |Sulfuric acid              15.   mg
         |Dissolved Solids     18.    mg |
         |                               |Dissolved solids            3.7  mg
   Use   |                               |Sulfuric acid              15.   mg
impairment Global Warmers      20.     g |
 impacts |                               |Carbon dioxide             20.    g
         |                               |Nitrogen oxides (NOx)      86.   mg
         |Odorants             24.    mg |
         |                               |Hydrocarbons               24.   mg
         |Particulates         33.    mg |
         |                               |Particulates               33.   mg
         |Smog Formers          0.14  g  |
         |                               |Carbon monoxide            28.   mg
         |                               |Hydrocarbons               24.   mg
         \                               |Nitrogen oxides (NOx)      86.   mg

 Disposal /Solid Wastes         2.4   g  |
 capacity |                              |Solid wastes                2.4   g
 impacts  \                              |

=========================================================================


    NOTE: Some totals in these reports may appear incorrect since all
    numbers displayed have been rounded to two significant figures.
```

```
                    POLLUTION GENERATED--SUMMARY REPORT FOR
                       All Previously Selected Stage(s)


Product:                Organic Palladium V
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

=====================================================================

              2. Pollution Generated per Unit-of-Use of product--
               by Pollution Category, by Pollutant and by Medium

                         | All                     Soil/               (  Indoor
Pollution prevented for: | Media   |   Water   | Grdwater  |   Air     (   Air
                          --------   --------    --------    -------- (  --------
*Overall environment      16.    g | 13.   mg | 1.7     g | 14.     g(
Carbon dioxide            14.    g |          |           | 14.     g(
Carbon monoxide           19.   mg |          |           | 19.    mg(
Dissolved solids           2.6  mg |  2.6  mg |           |           (
Hydrocarbons              17.   mg |          |           | 17.    mg(
Nitrogen oxides (NOx)     60.   mg |          |           | 60.    mg(
Particulates              23.   mg |          |           | 23.    mg(
Solid wastes               1.7   g |          | 1.7     g |           (
Sulfur oxides (SOx)        0.12  g |          |           |  0.12   g(
Sulfuric acid             10.   mg | 10.   mg |           |           (
                                   |          |           |           (
*Human health impacts      0.20  g |          |           |  0.20   g(
Carbon monoxide           19.   mg |          |           | 19.    mg(
Nitrogen oxides (NOx)     60.   mg |          |           | 60.    mg(
Sulfur oxides (SOx)        0.12  g |          |           |  0.12   g(
                                   |          |           |           (
*Use impairment impacts   14.    g | 13.   mg |           | 14.     g(
Carbon dioxide            14.    g |          |           | 14.     g(
Carbon monoxide           19.   mg |          |           | 19.    mg(
Dissolved solids           2.6  mg |  2.6  mg |           |           (
Hydrocarbons              17.   mg |          |           | 17.    mg(
Nitrogen oxides (NOx)     60.   mg |          |           | 60.    mg(
Particulates              23.   mg |          |           | 23.    mg(
Sulfur oxides (SOx)        0.12  g |          |           |  0.12   g(
Sulfuric acid             10.   mg | 10.   mg |           |           (
                                   |          |           |           (
*Disposal cap'cty impacts  1.7   g |          | 1.7     g |           (
Solid wastes               1.7   g |          | 1.7     g |           (
                                   |          |           |           (

=====================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                    POLLUTION GENERATED--SUMMARY REPORT FOR
                       All Previously Selected Stage(s)


Product:                Organic Palladium V
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

==============================================================================

              3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |     Pollutant       Amount  |                              Amount
 Category |       Class        Prevented|          Pollutant          Prevented
           ----------------     ------- | ---------------------        -------
          /Toxic Inorganics     0.18  g |
  Human   |                             |Nitrogen oxides (NOx)        60.   mg
  health  |                             |Sulfur oxides (SOx)           0.12  g
 impacts  |Toxic Organics      19.    mg|
          \                             |Carbon monoxide              19.   mg

          /Acid Rain Precursors 0.18  g |
          |                             |Nitrogen oxides (NOx)        60.   mg
          |                             |Sulfur oxides (SOx)           0.12  g
          | Corrosives          0.19  g |
          |                             |Nitrogen oxides (NOx)        60.   mg
          |                             |Sulfur oxides (SOx)           0.12  g
          |                             |Sulfuric acid                10.   mg
          | Dissolved Solids   13.    mg|
          |                             |Dissolved solids              2.6  mg
   Use    |                             |Sulfuric acid                10.   mg
impairment| Global Warmers     14.     g|
 impacts  |                             |Carbon dioxide               14.    g
          |                             |Nitrogen oxides (NOx)        60.   mg
          | Odorants           17.    mg|
          |                             |Hydrocarbons                 17.   mg
          | Particulates       23.    mg|
          |                             |Particulates                 23.   mg
          | Smog Formers       96.    mg|
          |                             |Carbon monoxide              19.   mg
          |                             |Hydrocarbons                 17.   mg
          \                             |Nitrogen oxides (NOx)        60.   mg

 Disposal /Solid Wastes         1.7   g |
 capacity |                             |Solid wastes                  1.7   g
 impacts  \                             |
                                        |
==============================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                POLLUTION GENERATED--SUMMARY REPORT FOR
                   All Previously Selected Stage(s)

Product:                 Organic Palladium C
Unit-of-Use:             per ssf of board produced
Product Life:            1 year

===============================================================================

         2. Pollution Generated per Unit-of-Use of product--
            by Pollution Category, by Pollutant and by Medium

                         |   All     |           |  Soil/    |           (  Indoor
Pollution prevented for: |  Media    |  Water    | Grdwater  |   Air     (   Air
                         | --------  | --------  | --------  | --------  ( --------
                         |           |           |           |           (
*Overall environment     | 35.     g | 28.    mg |  3.7    g | 31.     g (
Carbon dioxide           | 30.     g |           |           | 30.     g (
Carbon monoxide          | 43.    mg |           |           | 43.    mg (
Dissolved solids         |  5.8   mg |  5.8   mg |           |           (
Hydrocarbons             | 37.    mg |           |           | 37.    mg (
Nitrogen oxides (NOx)    |  0.13   g |           |           |  0.13   g (
Particulates             | 51.    mg |           |           | 51.    mg (
Solid wastes             |  3.7    g |           |  3.7    g |           (
Sulfur oxides (SOx)      |  0.27   g |           |           |  0.27   g (
Sulfuric acid            | 22.    mg | 22.    mg |           |           (
                         |           |           |           |           (
*Human health impacts    |  0.44   g |           |           |  0.44   g (
Carbon monoxide          | 43.    mg |           |           | 43.    mg (
Nitrogen oxides (NOx)    |  0.13   g |           |           |  0.13   g (
Sulfur oxides (SOx)      |  0.27   g |           |           |  0.27   g (
                         |           |           |           |           (
*Use impairment impacts  | 31.     g | 28.    mg |           | 31.     g (
Carbon dioxide           | 30.     g |           |           | 30.     g (
Carbon monoxide          | 43.    mg |           |           | 43.    mg (
Dissolved solids         |  5.8   mg |  5.8   mg |           |           (
Hydrocarbons             | 37.    mg |           |           | 37.    mg (
Nitrogen oxides (NOx)    |  0.13   g |           |           |  0.13   g (
Particulates             | 51.    mg |           |           | 51.    mg (
Sulfur oxides (SOx)      |  0.27   g |           |           |  0.27   g (
Sulfuric acid            | 22.    mg | 22.    mg |           |           (
                         |           |           |           |           (
*Disposal cap'cty impacts|  3.7    g |           |  3.7    g |           (
Solid wastes             |  3.7    g |           |  3.7    g |           (
                         |           |           |           |           (

===============================================================================
```

NOTE: Some totals in these reports may appear incorrect since all numbers displayed have been rounded to two significant figures.

POLLUTION GENERATED--SUMMARY REPORT FOR
All Previously Selected Stage(s)

Product:	Organic Palladium C
Unit-of-Use:	per ssf of board produced
Product Life:	1 year

3. Pollution Generated per Unit-of-Use of product--
by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution Category	Pollutant Class	Amount Prevented	Pollutant	Amount Prevented
Human health impacts	Toxic Inorganics	0.40 g	Nitrogen oxides (NOx)	0.13 g
			Sulfur oxides (SOx)	0.27 g
	Toxic Organics	43. mg	Carbon monoxide	43. mg
Use impairment impacts	Acid Rain Precursors	0.40 g	Nitrogen oxides (NOx)	0.13 g
			Sulfur oxides (SOx)	0.27 g
	Corrosives	0.42 g	Nitrogen oxides (NOx)	0.13 g
			Sulfur oxides (SOx)	0.27 g
			Sulfuric acid	22. mg
	Dissolved Solids	28. mg	Dissolved solids	5.8 mg
			Sulfuric acid	22. mg
	Global Warmers	31. g	Carbon dioxide	30. g
			Nitrogen oxides (NOx)	0.13 g
	Odorants	37. mg	Hydrocarbons	37. mg
	Particulates	51. mg	Particulates	51. mg
	Smog Formers	0.21 g	Carbon monoxide	43. mg
			Hydrocarbons	37. mg
			Nitrogen oxides (NOx)	0.13 g
Disposal capacity impacts	Solid Wastes	3.7 g	Solid wastes	3.7 g

NOTE: Some totals in these reports may appear incorrect since all numbers displayed have been rounded to two significant figures.

```
              POLLUTION GENERATED--SUMMARY REPORT FOR
                 All Previously Selected Stage(s)

Product:                NonFormaldehyde Elect V
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

========================================================================

         2. Pollution Generated per Unit-of-Use of product--
           by Pollution Category, by Pollutant and by Medium

                        | All      |          | Soil/    |          (  Indoor
Pollution prevented for:| Media    | Water    | Grdwater |  Air     (   Air
                        | -------- | -------- | -------- | -------- ( --------
*Overall environment    | 63.    g | 51.   mg | 6.7    g | 56.    g (
Carbon dioxide          | 55.    g |          |          | 55.    g (
Carbon monoxide         | 78.   mg |          |          | 78.   mg (
Dissolved solids        | 10.   mg | 10.   mg |          |          (
Hydrocarbons            | 67.   mg |          |          | 67.   mg (
Nitrogen oxides (NOx)   |  0.24  g |          |          |  0.24  g (
Particulates            | 92.   mg |          |          | 92.   mg (
Solid wastes            |  6.7   g |          | 6.7    g |          (
Sulfur oxides (SOx)     |  0.48  g |          |          |  0.48  g (
Sulfuric acid           | 41.   mg | 41.   mg |          |          (
                        |          |          |          |          (
*Human health impacts   |  0.80  g |          |          |  0.80  g (
Carbon monoxide         | 78.   mg |          |          | 78.   mg (
Nitrogen oxides (NOx)   |  0.24  g |          |          |  0.24  g (
Sulfur oxides (SOx)     |  0.48  g |          |          |  0.48  g (
                        |          |          |          |          (
*Use impairment impacts | 56.    g | 51.   mg |          | 56.    g (
Carbon dioxide          | 55.    g |          |          | 55.    g (
Carbon monoxide         | 78.   mg |          |          | 78.   mg (
Dissolved solids        | 10.   mg | 10.   mg |          |          (
Hydrocarbons            | 67.   mg |          |          | 67.   mg (
Nitrogen oxides (NOx)   |  0.24  g |          |          |  0.24  g (
Particulates            | 92.   mg |          |          | 92.   mg (
Sulfur oxides (SOx)     |  0.48  g |          |          |  0.48  g (
Sulfuric acid           | 41.   mg | 41.   mg |          |          (
                        |          |          |          |          (
*Disposal cap'cty impacts|  6.7  g |          | 6.7    g |          (
Solid wastes            |  6.7   g |          | 6.7    g |          (
                        |          |          |          |          (
========================================================================

     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```

```
                    POLLUTION GENERATED--SUMMARY REPORT FOR
                       All Previously Selected Stage(s)


Product:                NonFormaldehyde Elect V
Unit-of-Use:            per ssf of board produced
Product Life:           1 year

================================================================================

               3. Pollution Generated per Unit-of-Use of product--
 by Pollution Category, Pollutant Class, and Pollutant for Overall Environment

Pollution |     Pollutant        Amount  |                              Amount
 Category |       Class         Prevented|          Pollutant          Prevented
           -----------------     ------- |  ---------------------       -------
         /Toxic Inorganics       0.73  g |
  Human  |                               |Nitrogen oxides (NOx)         0.24  g
  health |                               |Sulfur oxides (SOx)           0.48  g
 impacts |Toxic Organics        78.    mg|
         \                               |Carbon monoxide              78.   mg

         /Acid Rain Precursors   0.73  g |
         |                               |Nitrogen oxides (NOx)         0.24  g
         |                               |Sulfur oxides (SOx)           0.48  g
         |Corrosives             0.77  g |
         |                               |Nitrogen oxides (NOx)         0.24  g
         |                               |Sulfur oxides (SOx)           0.48  g
         |                               |Sulfuric acid                41.   mg
         |Dissolved Solids      51.    mg|
   Use   |                               |Dissolved solids             10.   mg
impairment Global Warmers       55.    g |Sulfuric acid                41.   mg
 impacts |                               |
         |                               |Carbon dioxide               55.    g
         |                               |Nitrogen oxides (NOx)         0.24  g
         |Odorants              67.    mg|
         |                               |Hydrocarbons                 67.   mg
         |Particulates          92.    mg|
         |                               |Particulates                 92.   mg
         |Smog Formers           0.39  g |
         |                               |Carbon monoxide              78.   mg
         |                               |Hydrocarbons                 67.   mg
         \                               |Nitrogen oxides (NOx)         0.24  g

Disposal /Solid Wastes           6.7   g |
capacity |                               |Solid wastes                  6.7   g
impacts  \                               |
                                         |
================================================================================


     NOTE: Some totals in these reports may appear incorrect since all
     numbers displayed have been rounded to two significant figures.
```