

**Point-of-Use (POU) Control Systems
for Semiconductor Process
Emissions (ESH003)**

SEMATECH and the **SEMATECH logo** are registered service marks of SEMATECH, Inc.

Product names and company names used in this publication are for identification purposes only and may be trademarks or service marks of their respective companies

Point-of-Use (POU) Control Systems for Semiconductor Process

Emissions (ESH003)

Technology Transfer # 97093364A-XFR

SEMATECH

October 31, 1997

Abstract: This report documents the results of a study of point-of-use (POU) control systems used primarily for corrosive gases (hydrogen chloride, chlorine, etc.), ammonia, silane, arsine, diborane, and phosphine. Perfluorocompounds (PFC) and volatile organic compounds (VOCs) were not included. Three member company facilities and four POU control system suppliers were visited to gather information for creating supplier and member company surveys and to review the different types of POU control system technologies and sampling/analytical techniques used for demonstrating compound removal efficiencies. Because only a few member company surveys were returned, their data are not presented. A suggested list of POU technologies for each of 14 semiconductor process applications is included.

Keywords: Point of Use Abatement, Control Systems, Processes

Authors: J. Michael Sherer, P.E.

Approvals: Walter Worth, Program Manager
Avtar S. Jassal, Project Manager
Bob Duffin, Director
Laurie Modrey, Technical Information Transfer Team Leader

Table of Contents

1	EXECUTIVE SUMMARY	1
2	PURPOSES OF POU CONTROL SYSTEMS	2
3	TECHNOLOGY TYPES FOR POU CONTROL SYSTEMS	2
4	MEMBER COMPANY SITE REVIEWS	4
5	POU CONTROL SYSTEM SUPPLIER VISITS.....	4
6	SUPPLIER POU CONTROL SYSTEM SURVEY	5
7	MEMBER COMPANY POU CONTROL SYSTEM SURVEY	5
8	SUGGESTED TECHNOLOGIES FOR EACH APPLICATION.....	5
APPENDIX A	POU Control System Supplier Survey.....	7
APPENDIX B	POU Control System Member Company Survey	15
APPENDIX C	POU Technology Supplier Survey Results.....	25

Acknowledgements

There are many people to thank for their contribution to the success of this project. Some of these people include the following:

- Bill Cummins, Texas Instruments
- Mark Kohler and Tom Tamayo, IBM
- Paul Thomas Brown, Motorola
- Jim Dietz and Steve Hardwick, Ecosys
- Greg Cuti and James Getty, Delatech
- Peter Mawle and Bob Smith, Edwards
- Jim Huelster, Gradient Point
- Chris Thomas, Misonix
- Don Sanservino, ETC
- Jim Sutherland, Eastern Digital
- Karl Markert, Clean Systems
- Catita Edward, Centrotherm

1 EXECUTIVE SUMMARY

This study was done for the point-of-use (POU) control systems used primarily for corrosive gases (hydrogen chloride, chlorine, etc.), ammonia, silane, arsine, diborane, and phosphine. Perfluorocompounds (PFC) and volatile organic compounds (VOC) were not included. Three member company facilities and four POU control system suppliers were visited to gather more information for creating supplier and member company surveys and to review the different types of POU control system technologies and sampling/analytical techniques used for demonstrating compound removal efficiencies. Nine out of the ten suppliers responded to the survey. Because only a few member company surveys were returned, their data are not considered representative and, therefore, are not reported. Data from the supplier surveys were summarized for 14 different semiconductor processes. Table 1 lists suggested POU technologies for each of these 14 applications.

Table 1 Suggested POU Technologies for Each Application

APPLICATION	POU CONTROL SYSTEM TECHNOLOGIES
1. Wet clean hood with NH ₄ OH/H ₂ O ₂ bath	1. Wet scrubbing (with chemical addition)
2. Wet spray etcher with aqua regia	2. Wet scrubbing (with chemical addition)
3. Silicon EPI with hydrogen vented	3. Wet scrubbing (without chemical addition)
4. Silicon EPI with hydrogen abated	4. Oxidation with hydrogen present/wet scrubbing
5. Ion implant	5. Cold bed
6. Poly deposition; non-PFC clean (Note: The POU technologies for Application #6 need to have a safety review to determine the effects of chlorine trifluoride mass flow to POU control system selected.)	6. Oxidation using electric/wet scrubbing; or oxidation using fuel/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing
7. Doped poly deposition; PFC clean	7. Oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing
8. Metal etch (aluminum)	8. Cold bed; or hot chemical bed; or wet scrubbing (high pH control with chemical addition)
9. Nitride deposition with silane; PFC clean	9. Oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing
10. Nitride deposition with dichlorosilane; PFC clean	10. Hot chemical bed/ammonia control system; or oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing (with low pH control with chemical addition)
11. Oxide deposition; PFC clean	11. Cold bed; or hot chemical bed; or oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing
12. Tungsten deposition; PFC clean	12. Cold bed; or hot chemical bed; or oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing; or wet scrubbing only (if low silane removal is acceptable)
13. Poly etch	13. Cold bed; or hot chemical bed; or wet scrubbing
14. BPSG oxide deposition; PFC clean	14. Hot chemical bed; or oxidation using electric/wet scrubbing; or pre-pump reactor and post-pump wet scrubbing

Note: This table is intended to help member companies select POU control system technologies; that selection is at the discretion of the member company personnel. This suggestion list does not include the direct destruction and/or removal of PFC gases.

2 PURPOSES OF POU CONTROL SYSTEMS

POU control systems are designed for treating air emissions from the outlet of the semiconductor process to remove the compounds of interest before entering the main exhaust ductwork. Historically, POU control systems have been installed for reducing production downtime and for health and safety reasons. Recently, air emissions reduction has been another reason for using POU control systems. Typically, POU control systems are interlocked with the process equipment (i.e., when the POU control system fails, the process equipment is shut down). The main reasons for the use of POU control systems are as follows:

1. Exhaust restrictions (blocked ductwork): reactions between gases, solids from the process, or condensation of vapors produce solid build-up in ductwork. This build-up can cause production downtime to clean ductwork, ductwork collapsing, etc. An additional issue is the handling and disposal of these solids during and after removal.
2. Ductwork fires/explosions: flammable (hydrogen, etc.) and pyrophoric (silane, etc.) gases are used in semiconductor equipment. These gases can cause a fire and/or explosion in the ductwork, possibly resulting in major facility damage and personnel injury.
3. Duct corrosion: etching gases (chlorine, etc.) and byproducts (i.e., hydrogen chloride from boron trichloride) can corrode metal ductwork and other materials of construction. This results in production downtime and possible personnel exposure to these gases in the area outside of ductwork.
4. Exposure to personnel: toxic gases (hydrides, chlorine, etc.) are controlled near the semiconductor equipment outlet to reduce the likelihood that any toxic gases can migrate into the area outside ductwork where personnel are located.
5. Ammonium compounds formation: ammonia will react with acid compounds (hydrogen chloride, nitric acid, etc.) to form ammonium compounds (ammonium chloride, ammonium nitrate, etc.). These ammonium compounds will aggregate in the ductwork (see #1 previously) and possibly generate a sub-micron particle visible opacity at the stack outlet (generally at 1 ppmv or greater at stack outlet).
6. Air regulatory requirements: emissions limits may need to be met in specific regulatory jurisdictions that require POU control systems to be used. Some of this need is due to the lower removal efficiencies for compounds of interest at the centralized (“end-of-pipe”) scrubbers (e.g., chlorine).

3 TECHNOLOGY TYPES FOR POU CONTROL SYSTEMS

The selection of the appropriate POU control system depends primarily upon the following:

1. Type of semiconductor equipment used (including pumps)
2. Compounds emitted from the semiconductor equipment during all of its processes
3. Company philosophy
4. Cost of ownership

Items #1, #2, and #4 were included in the supplier POU control system survey. Item #3 includes company production standardization; company/supplier partnerships; environment; safety, and health (ESH) policies, etc.

The categories for technology types for POU control systems are listed below. It is common to purchase POU control systems that use more than one of these technologies (i.e., flame oxidation with wet scrubbing).

1. Wet scrubbing systems: exhaust gas passes through a liquid in which the compound(s) mass transfer and dissolve in the liquid. In some cases, the compound scrubbed will react with chemical in scrubbing liquid (i.e., chlorine in sodium hydroxide solution). The typical liquid is water, with chemicals added for removing certain compounds (chlorine, ammonia, etc.) more efficiently. Examples of scrubber types are packed bed, venturi, and spray towers.
2. Recycle or reclaim systems: these POU control systems are not widespread for non-PFC compounds. An example would be recycling hydrogen from several EPI reactors.
3. Oxidation systems: four primary systems are used to oxidize compound(s) of interest:
 - a. Oxidation boxes: these systems are primarily designed for silane oxidation in exhaust gas. The silane (pyrophoric above approximately 1.5% by volume) self-reacts with oxygen to silicon dioxide and water, with the silicon dioxide depositing in the box.
 - b. Flame oxidation: compounds in exhaust gas are oxidized by using a flame (typically hydrogen or natural gas with air).
 - c. Hot chamber oxidation: the exhaust gas flows through an electrically heated chamber, where air is added for oxidation. Oxygen can also be used for oxidation.
 - d. Non-flame oxidation: this system uses an incandescent porous wall for oxidation, typically with air, without a flame. Fuel, air, and process gas are mixed and passed through the porous wall matrix.
4. Cold bed systems (adsorber/chemisorber): there are three primary system types:
 - a. Adsorption: exhaust gas flows through a container (canister, drum, etc.) filled with adsorbent material (i.e., activated carbon). The compounds are physically adsorbed into the adsorbent material.
 - b. Chemisorption: this system is a container usually comprised of adsorbent material coated with reactive chemical, reactive porous media, or resin matrix coated with reactive chemical. The compounds are adsorbed into the material (media) and react either with the material itself or with the coating.
 - c. Adsorption with air oxidation: compounds (typically hydride gases) in the exhaust gas are adsorbed (i.e., carbon bed) and then air is fed at a given rate to oxidize the adsorbed compound into oxide compounds that remain in adsorbent material.
5. Hot chemical bed systems: there are three primary system types:
 - a. Hot bed reactors: exhaust gas flows through a container filled with reactive material that is at an elevated temperature. The compounds of interest react with the bed material and are converted into inorganic salts that remain in the bed material. The containers can have one or more zones of bed material.
 - b. Hot catalytic bed: this system uses catalyst in a container, at an elevated temperature, to catalytically convert compounds to less hazardous compounds (i.e., ammonia to hydrogen and nitrogen).

- c. Hot reactor beds with gas inputs: exhaust gas flows through a hot bed (like 5 (a) above) concurrently with another gas (i.e., air). The compounds react with other gas, and possibly the bed material, forming solid salts that stay in the bed material and less hazardous gases (i.e., carbon dioxide) that are exhausted.
6. Reactor systems (e.g., plasma, microwave): exhaust gases from the semiconductor equipment, before the vacuum pump, are treated by flowing them through a reaction chamber containing a plasma energized with low frequency radio frequency (RF) power to enhance reaction, typically into solid particles, which drop out or attach to the chamber walls. In some applications, a blower is placed between semiconductor equipment and reactor system to ensure that the process is not affected. Microwave energies are also being investigated. Hydrogen is a byproduct of the reaction of silane and phosphine in a non-oxygen environment, which could be a concern for the lower explosive limit for hydrogen; therefore, oxygen can be added to oxidize hydrogen to water.
7. Particulate removal systems (traps/filters/cyclones/precipitators): these are installed to remove solid particles and condensable vapors, when needed.

4 MEMBER COMPANY SITE REVIEWS

Three member company facilities were visited in October 1996 to physically review their POU control system technologies and to discuss typical operation concerns. The information gathered was very beneficial in developing the member company and supplier POU control system surveys.

5 POU CONTROL SYSTEM SUPPLIER VISITS

Four POU control system suppliers (Ecosys, Delatech, Edwards, and Gradient Point) were visited in October and November 1996 to review their respective POU control system technologies, observe sampling/analytical techniques, and gather information that would be beneficial to member company personnel and would be included in the member company and supplier surveys. Three of the suppliers have in-house sampling/analytical capabilities. The fourth supplier hires contractors to conduct sampling/analysis.

The POU control system supplier personnel communicated the following information that could benefit member companies:

- Provide detailed specifications to the POU control system supplier, so they can best serve the member company needs. Clearly state what the process exhaust management requirements are. Most supplier companies have forms that can be filled out with process type, process emissions information (type and concentration), gas flow rate, special needs, etc. The suppliers appreciate it when these forms are completely filled out. Other important information can include floor space, frontal access, and height available; utilities available (natural gas, hydrogen, DI water, etc.); wastewater discharge requirements (upward); secondary containment requirements; chemicals available (sodium hydroxide solution, sulfuric acid, etc.) as additives; and required maximum pressure drop across the POU control system. Flowcharts of the process equipment, pump, ancillary valves and traps, and POU control system including gas flow rates, compound concentrations, pressures, temperatures, etc., are also helpful.

- Provide good process and process emissions information. This may include asking the process equipment manufacturer to provide better data. Make sure that all compounds are included (process gases, chamber clean gases, compounds formed by reaction, particulates, etc.).
- Properly install the POU control system before system start-up.
- Perform supplier-recommended preventive maintenance on POU control systems. Preventive maintenance significantly increases process up-time and reduces repair costs. Member company personnel should review the supplier-recommended preventive maintenance before POU control system start-up to ensure that it is appropriate for their process operation and process emissions. Proper training of personnel is required to conduct preventive maintenance (contractor or in-house).
- Stock ample spare parts for the POU control system.
- Purchase appropriate POU control system technology for the process application. This can be different depending on which supplier you communicate with. Discussions between personnel from member company, POU control system supplier, pump supplier, and process equipment manufacturer early in the POU control system selection process is recommended.

6 SUPPLIER POU CONTROL SYSTEM SURVEY

The supplier POU control system survey was sent out to 10 suppliers on January 22, 1997, requesting responses back by February 28, 1997. A copy of the survey is in Appendix A. Additional information was added since the survey was issued: use 1.0 liter per minute of hydrogen fluoride (includes silicon tetrafluoride) assuming 10% process utilization (60 minutes per hour, 876 hours per year) from reaction of PFCs in the process chamber for Applications #7, #9, #10, #11, #12, and #14. The heights of post-pump POU control systems are typically between 6 and 8 feet; heights of pre-pump reactors are typically between 2 and 4 feet.

The survey responses were reviewed to ensure similar comparisons between the POU control system technologies. The results are in Appendix C.

7 MEMBER COMPANY POU CONTROL SYSTEM SURVEY

A member company survey (Appendix B) was issued on February 20, 1997. Because only a few member company surveys were completed, that data are not presented in this report.

8 SUGGESTED TECHNOLOGIES FOR EACH APPLICATION

Table 1 in the Executive Summary lists suggested POU technologies for each of the 14 semiconductor process applications specified in the supplier and member company surveys. This table is intended to assist member company personnel in selecting POU control system technologies, but that selection is at the discretion of the member company personnel. This list does not include the direct destruction and/or removal of PFC gases.

APPENDIX A
POU Control System Supplier Survey

January 22, 1997

To Whom It May Concern:

SEMATECH (Mike Sherer as member company project leader) is conducting a confidential point-of-use (POU) air control system supplier survey as part of a SEMATECH project documenting detailed information on POU control system technologies, not supplier-specific documentation. Perfluorocompounds (PFC) and volatile organic compounds (VOC) are not included in this survey. This information (original survey information provided by your company) will be eventually sent to Avtar Jassal, SEMATECH, so that it is kept SEMATECH confidential in their files (i.e. not in Mike Sherer's Motorola files). Please place "SEMATECH Confidential" on the top of each page you send to Mike Sherer. The extracted technology information will be included in a SEMATECH report available to SEMATECH member companies' personnel (note: technologies will be suggested for a specific semiconductor process operation). Please send written approval for use of your company name and a current list of your POU technologies in the SEMATECH report, so that member company personnel know what technologies you supply in regards to suggested technologies listed.

Please notify Mike Sherer as soon as possible on who your company's contact is for this survey, with phone number and fax number. All revisions and answers to questions will be faxed to contact name. This survey needs to be completed by Friday, February 28, 1997. Please send the finalized survey to: Motorola, 5005 East McDowell Road, Mail Drop D016, Phoenix, Arizona, 85008, Attention: Mike Sherer. My phone number is 602-244-3952; fax number is 602-244-6658. Your company name will be acknowledged in the SEMATECH report for contributing information. Please call Mike Sherer with any questions or assistance. We appreciate your work and time on this survey!!

cc: Laurie Beu, Motorola
Bill Cummins, Texas Instruments
Avtar Jassal, SEMATECH

SEMATECH POU TECHNOLOGY SURVEY

PART 1: SUPPLIER EQUIPMENT INFORMATION

Please list all of the POU control systems that you provide to semiconductor companies that reduce contaminants from the exit of semiconductor equipment. For each type of POU control system (i.e. wet scrubber, dry adsorption, etc.), provide a short paragraph description of your specific technology. Also, state whether a SEMI S2 Safety Hazard Evaluation has been performed on each POU control system you provide.

PART 2: INPUT FROM SUPPLIERS TO SEMICONDUCTOR COMPANY PERSONNEL

Please list, in detail, items which you would like to communicate to semiconductor member company personnel that would help you in interactions with them (e.g. better emissions information from semiconductor processes, Preventive maintenance, etc.).

PART 3: POU SPECIFIC INFORMATION BY SEMICONDUCTOR PROCESS/GASES

Please determine the information listed below for each semiconductor process (application) listed in Attachment 1. Assume that it is one chamber exhaust (if applicable) per POU control system. All costs should be reported in U.S. dollars. Each POU control system would be installed in a sub-fab (semiconductor processes in level above). The vacuum pump supporting the semiconductor equipment is not to be provided by you. Assume the following; all utilities (water, electric, chemicals, etc.) are 10 feet away (you will be responsible in installation cost to connect utilities to POU control system from 10 feet away). Wastewater piping is also 10 feet away upward (e.g. you will need to supply a mechanism to pump wastewater upward 10 feet). Any cooling fluid other than plant cooling water (around 44 degrees F) will need to be provided by you. No operating cost is needed for floor space cost; there is not agreement on “universal” cost per square foot in sub-fab. In addition, most POU control systems have similar foot-prints. Please include the fact that PFCs are used in some of these applications, since it will impact materials of construction, etc. (e.g. hydrogen fluoride produced in process and POU control system because of PFC breakdown).

1. Your recommended POU control system(s) for each application. You can list more than one; however, please provide all information requested for each POU control system for each application. Specify any special changes you would make to a POU control system that would not on a “standard model.”
2. For each POU control system per application, provide the following.
 - a. Purchase cost. The purchase cost must include everything for the POU control system. Include costs for all recommended spare parts (also supply this list), training for two days of semiconductor company personnel and three copies of operation & maintenance manuals.
 - b. Shipping cost from your location to SEMATECH in Austin, Texas.
 - c. Installation cost in the sub-fab of everything required. Assume bare concrete floor with no secondary containment (which is required for any POU control systems containing any liquid) and utility location provided above. Use \$50 per person-hour as labor rate. Please show details on how installation cost was determined, including what costs you assumed for parts used in installation.

- d. Operating cost. Please see Attachment 2 for costs to be used in determining operating costs. Operating costs for POU control system, supporting equipment you supplied, etc. need to be included. All waste disposal costs, wastewater treatment, etc. need to be included. For Preventive maintenance costs, use \$50 per person-hour as labor rate. Please show details on how operating cost was calculated.
- e. Floor space (in square feet) required for all of your POU and ancillary equipment you provide. Do not include frontal access in floor space. Provide maximum height of POU control system in feet.
- f. Percent POU control system uptime on a yearly basis, based on 24 hours per day, 365 days per year. Include Preventive maintenance down time.
- g. Preventive maintenance required for a year. Include how often and number of hours per each episode (note: include time to bring down from normal operation and start-up to normal operation of POU control system).
- h. POU control system removal efficiency (with corresponding inlet concentrations) for each compound listed (and any other compounds you can identify). Describe in detail how the removal efficiency was determined (e.g. removal efficiency determined from POU inlet and outlet concentration measurements in our company laboratory, with similar compound concentration as this application). List any compounds (oxides of nitrogen, hydrogen fluoride, carbon monoxide, etc.) that the POU control system generates and the emissions (in pounds per year) of each compound.
- i. Pressure drop across POU control system.
- j. Number of the same applications that can be safely connected to the one POU control system specified for this application (e.g. four metal etchers can be connected to). Please ensure that incompatible gases, etc. are reviewed before stating that more than one application can be exhausted to one POU control system. State if removal efficiency for each compound presented in (h) above will change (to what removal efficiency) if more than one application is flowing to one POU control system.
- k. Any additional information that would be helpful to member company personnel.

ATTACHMENT 1: SEMICONDUCTOR APPLICATION LIST**Application #1:**

Process: wet clean hood with bath containing heated ammonium hydroxide/hydrogen peroxide solution.

Process utilization: 100%.

Total air flow: 350 CFM.

Exhaust to POU: ammonia at 1000 ppmv maximum, 300 ppmv average.

Other possible compounds emitted by process for you to consider: none.

Application #2:

Process: wet spray etcher (metal) using heated aqua regia solution.

Process utilization: 100%.

Total air flow: 300 CFM.

Exhaust to POU: (1) hydrogen chloride at 10,000 ppmv maximum, 1000 ppmv average; (2) chlorine at 1000 ppmv maximum, 300 ppmv average; (3) nitric acid at 300 ppmv maximum, 50 ppmv average.

Other possible compounds emitted by process for you to consider: none.

Application #3:

Process: silicon EPI with dopants. Hydrogen can be vented safely uncontrolled (e.g. without destruction to below lower explosion limit (LEL) level).

Process utilization: EPI deposition: 30%; clean: 12%.

Total gas flow: EPI deposition: 211 standard liters per minute (slm); clean: 300 slm.

Gases/flows fed into EPI process: EPI deposition: 200 slm hydrogen, 5 slm dichlorosilane; 5 slm hydrogen containing 20 ppmv diborane; 1.0 slm hydrogen with 1.5% phosphine. Clean: 240 slm hydrogen; 60 slm hydrogen chloride.

Other possible compounds emitted by process for you to consider: none.

Application #4:

Process: Same as Application #3 above except the hydrogen must be controlled (destroyed) to below LEL level before entering fiberglass ductwork.

Application #5:

Process: ion implant.

Process utilization: phosphine: 10%; arsine: 10%; boron trifluoride: 20%.

Total gas flow (post-pump, using nitrogen purge): 150 slm.

Gases/flows fed into semiconductor process: 0.005 slm containing 1% phosphine; 0.005 slm containing 100 ppmv arsine; 0.005 slm boron trifluoride.

Other possible compounds emitted by process for you to consider: hydrogen fluoride.

Application #6:

Process: poly deposition; non-PFC clean.

Process utilization: deposition: 10%; clean: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: deposition: 0.5 slm silane; chamber clean: 1.0 slm chlorine trifluoride (ClF₃).

Other possible compounds emitted by process for you to consider: hydrogen fluoride, hydrogen chloride, silicon tetrachloride, and silicon tetrafluoride.

Application #7:

Process: doped poly deposition; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.5 slm silane; 0.35 slm nitrogen containing 1% phosphine.

Other possible compounds emitted by process for you to consider: hydrogen fluoride and silicon tetrafluoride.

Application #8:

Process: metal etch (aluminum).

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.040 slm chlorine; 0.15 slm boron trichloride; 0.070 slm hydrogen bromide.

Other possible compounds emitted by process for you to consider: Aluminum chloride and aluminum bromide.

Application #9:

Process: nitride deposition with silane; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 lpm.

Gases/flows fed into semiconductor process: 0.27 slm silane; 1.8 slm ammonia.

Other possible compounds emitted by process for you to consider: silicon tetrafluoride and hydrogen fluoride.

Application #10:

Process: nitride deposition with dichlorosilane; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 2.5 slm ammonia; 0.30 slm dichlorosilane.

Other possible compounds emitted by process for you to consider: ammonium chloride, silicon tetrafluoride and hydrogen fluoride.

Application #11:

Process: oxide deposition; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.24 slm silane; 4.0 slm nitrous oxide (no laughing allowed!).

Other possible compounds emitted by process for you to consider: silicon tetrafluoride, nitric oxide and hydrogen fluoride.

Application #12:

Process: tungsten deposition; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.35 slm tungsten hexafluoride; 0.015 slm silane.

Other possible compounds emitted by process for you to consider: silicon tetrafluoride and hydrogen fluoride.

Application #13:

Process: poly etch.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.10 slm hydrogen bromide; 0.20 slm chlorine.

Other possible compounds emitted by process for you to consider: hydrogen chloride, silicon tetrachloride and silicon tetrabromide.

Application #14:

Process: BPSG oxide deposition; PFC clean.

Process utilization: 10%.

Total gas flow (post-pump, using nitrogen purge): 50 slm.

Gases/flows fed into semiconductor process: 0.10 slm silane; 0.020 slm diborane; 0.030 slm phosphine; 5.0 slm nitrous oxide (again, no laughing).

Other possible compounds emitted by process for you to consider: silicon tetrafluoride, nitric oxide and hydrogen fluoride.

ATTACHMENT #2

Costs to be used in survey (note: if there is a cost not listed or you significantly disagree with stated cost below, please contact Mike Sherer to develop agreed upon cost for everyone):

Raw water: \$0.002 per gallon

DI water: \$0.02 per gallon

Soft water: \$0.004 per gallon

Cooling water: \$0.005 per gallon

Clean dry air: \$0.015 per cubic foot

Compressed air: \$0.0002 per cubic foot

Air-conditioned load: \$0.0000090 per BTU

Exhaust air: \$0.0000025 per cubic foot

Oxygen: \$0.02 per cubic foot

Nitrogen: \$0.002 per cubic foot

Electricity: \$0.06 per kw-hr

Natural gas: \$0.0021 per cubic foot

Hydrogen: \$0.012 per cubic foot

50% sodium hydroxide solution: \$1.50 per gallon

93% sulfuric acid: \$1.00 per gallon

Wastewater treatment: \$0.004 per gallon

Waste disposal (e.g. canisters) cost, including packaging for shipment: non-hazardous waste: \$0.40 per pound; hazardous waste: \$3.00 per pound. Use \$0.35 per pound if recycled.

Labor cost: \$50 per person-hour

APPENDIX B
POU Control System Member Company Survey

Date: February 20, 1997

From: Mike Sherer, Motorola

To: SEMATECH S66 PTAB Members
Paul Thomas Brown, Motorola
Dave Yost, Motorola

Phone: 602-244-3952

cc: Avtar Jassal, SEMATECH

RE: Attached Member Company Application-specific Point-of-use (POU) Survey

Attached is a survey to determine what POU air control systems your company (site) currently installs on specific semiconductor process applications and the reason(s) why. There are 14 specific semiconductor process applications listed with specific gases and chemicals. If you install a particular POU air control system to also control perfluorocompound (PFC) emissions, please note that as a reason why. A blank is provided for you to provide any experiences you have had (including actual test data) for each POU air control system chosen for each semiconductor process application that would assist me in reviewing supplier provided information.

This information will be kept SEMATECH confidential. The surveys you submit will eventually be sent to SEMATECH (Avtar Jassal) for filing.

Please fax responses to me at 602-244-6658 by Wednesday, 3/26/97. Please call me at 602-244-3952 with any questions. Thanks for your assistance!

APPLICATION-SPECIFIC POU SURVEY COVER SHEET

Company name: _____

Survey contact name: _____

Contact phone number: _____

Contact fax number: _____

Contact Email address: _____

Contact mailing address: _____

APPLICATION-SPECIFIC POU SURVEY

Application #1:

Process: wet clean hood with bath containing heated ammonium hydroxide/hydrogen peroxide solution.

Exhaust to POU: ammonia

Other possible compounds emitted by process: none.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #2:

Process: wet spray etcher (metal) using heated aqua regia solution.

Exhaust to POU: hydrogen chloride, chlorine, and nitric acid

Other possible compounds emitted by process: none.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #3:

Process: silicon EPI with dopants. Hydrogen can be vented safely uncontrolled (e.g. without destruction to below lower explosion limit (LEL) level).

Gases fed into EPI process: hydrogen, dichlorosilane (or trichlorosilane), dopants (diborane, arsine and/or phosphine), and hydrogen chloride.

Other possible compounds emitted by process: silicon tetrachloride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #4:

Process: Same as Application #3 above except the hydrogen must be controlled (destroyed) to below LEL level before entering fiberglass ductwork.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #5:

Process: ion implant.

Gases fed into semiconductor process: phosphine, arsine, and boron trifluoride.

Other possible compounds emitted by process: hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #6:

Process: poly deposition; non-PFC clean.

Gases fed into semiconductor process: deposition: silane; chamber clean: chlorine trifluoride (ClF₃).

Other possible compounds emitted by process: hydrogen fluoride, hydrogen chloride, silicon tetrachloride, and silicon tetrafluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #7:

Process: doped poly deposition; PFC clean.

Gases fed into semiconductor process: silane and phosphine.

Other possible compounds emitted by process for you to consider: hydrogen fluoride and silicon tetrafluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #8:

Process: metal dry etcher (aluminum).

Gases fed into semiconductor process: chlorine, boron trichloride, and hydrogen bromide.

Other possible compounds emitted by process for you to consider: Aluminum chloride and aluminum bromide.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #9:

Process: nitride deposition with silane; PFC clean.

Gases fed into semiconductor process: silane and ammonia.

Other possible compounds emitted by process for you to consider: silicon tetrafluoride and hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #10:

Process: nitride deposition with dichlorosilane; PFC clean.

Gases fed into semiconductor process: ammonia and dichlorosilane.

Other possible compounds emitted by process for you to consider: ammonium chloride, silicon tetrafluoride, and hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #11:

Process: oxide deposition; PFC clean.

Gases fed into semiconductor process: silane and nitrous oxide (no laughing allowed!).

Other possible compounds emitted by process for you to consider: silicon tetrafluoride, nitric oxide, and hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #12:

Process: tungsten deposition; PFC clean.

Gases fed into semiconductor process: tungsten hexafluoride and silane.

Other possible compounds emitted by process for you to consider: silicon tetrafluoride and hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #13:

Process: poly dry etcher.

Gases fed into semiconductor process: hydrogen bromide and chlorine.

Other possible compounds emitted by process for you to consider: hydrogen chloride, silicon tetrachloride, and silicon tetrabromide.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

Application #14:

Process: BPSG oxide deposition; PFC clean.

Gases fed into semiconductor process: silane, diborane, phosphine, and nitrous oxide (again, no laughing).

Other possible compounds emitted by process for you to consider: silicon tetrafluoride, nitric oxide, and hydrogen fluoride.

What POU air control system(s) does your company (site) currently install on this application?

Why does your company (site) choose each of the POU technologies above, listing each one separately (e.g. safety, reduce emissions, eliminate duct plugging, etc.)?

Any experiences you would like to share about the POU(s) selected for this application?

APPENDIX C
POU Technology Supplier Survey Results

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #1: Wet Clean Hood with NH₄OH/H₂O₂ Bath

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Wet scrubbing (with chemical addition)	15–45	0.3–12	3–18	5–16	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #1: Wet Clean Hood with NH₄OH/H₂O₂ Bath

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Wet scrubbing (with chemical addition)	10–20	6–25	1–12

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #1: Wet Clean Hood with NH₄OH/H₂O₂ Bath

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Wet scrubbing (with chemical addition)	1	Ammonia	99 - >99.9

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #2: Wet Spray Etcher with Aqua Regia

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Wet scrubbing (with chemical addition)	15 - 45	0.3 - 12	3 - 18	12 - 44	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #2: Wet Spray Etcher with Aqua Regia

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Wet scrubbing (with chemical addition)	10–20	6–25	1–12

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #2: Wet Spray Etcher with Aqua Regia

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Wet scrubbing (with chemical addition)	1	Hydrogen Chloride	99 - >99.9
		Chlorine	>80
		Nitric Acid	>95

POU Supplier Survey Results – Estimated Costs

APPLICATION #3: Silicon EPI with Hydrogen Vented

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Wet scrubbing (without chemical addition)	22–45	0.3–12	3–18	6–10*	>99

* can be as high as \$46,000 if chemical addition is used.

POU Technology Supplier Survey Results – Additional Information

APPLICATION #3: Silicon EPI with Hydrogen Vented

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Wet scrubbing (without chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #3: Silicon EPI with Hydrogen Vented

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Wet scrubbing (without chemical addition)	1–2	Diborane	>98
		Dichlorosilane	>99.9
		Hydrogen	0
		Hydrogen chloride	>99.99
		Phosphine	0–96*

* The removal efficiency of phosphine of 96% was reported by one supplier; however, no back-up information provided. Note: phosphine is only slightly soluble in water; therefore, minimal removal efficiency would be expected.

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #4: Silicon EPI with Hydrogen Abated

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Oxidation with hydrogen present/wet scrubbing	160–210	0.8–12	10–35	16–25	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #4: Silicon EPI with Hydrogen Abated

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Oxidation with hydrogen present/wet scrubbing	11–22	16–40	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #4: Silicon EPI with Hydrogen Abated

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Oxidation with hydrogen present/wet scrubbing	1–2	Diborane	>99
		Dichlorosilane	>99.9
		Hydrogen	>99.99
		Hydrogen chloride	>99.99
		Phosphine	>99
		Oxides of nitrogen	Not detected

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #5: Ion Implant

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	53–105	0.5–12	3–18	5–11	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	19–24	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–12	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #5: Ion Implant

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Oxidation using fuel/wet scrubbing	6–22	16–40	<1–4
Pre-pump reactor	3–4	12–24	<1

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #5: Ion Implant

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1-4	Arsine	>99
		Boron trifluoride	>97
		Hydrogen fluoride	>97
		Phosphine	>99
Oxidation using fuel/ wet scrubbing	1	Arsine	>99
		Boron trifluoride	>99
		Hydrogen fluoride	>99
		Phosphine	>99
		Oxides of nitrogen	No information provided
Pre-pump reactor	1	Arsine	>99
		Boron trifluoride	>99*
		Hydrogen fluoride	0
		Phosphine	>99

* Hydrogen fluoride will also be emitted from boron trifluoride reaction in pre-pump reactor.

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #6: Poly Deposition; non-PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	112–223	1–24	6–36	62–115	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	16–20	>99
Oxidation using fuel (for dep. only); cold bed (for clean only)	95–120	1.8–36	13–53	145–170	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–10	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–12	>99
Wet scrubbing (with chemical addition)	25–60	0.3–12	3–18	6–20	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #6: Poly Deposition; non-PFC Clean

Technology	Floor Space (ft²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H₂O)
Cold bed	8–32	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel (for dep. only); cold bed (for clean only)	8–12	50–60	3–4
Oxidation using fuel/wet scrubbing	6–22	16–40	<1–4
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #6: Poly Deposition; non-PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–2	Chlorine trifluoride	>99
		Hydrogen chloride	>99
		Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrachloride	>99
		Silicon tetrafluoride	>99
Oxidation using electric/wet scrubbing	1–2	Chlorine trifluoride	>99
		Hydrogen chloride	>99
		Hydrogen fluoride	>99
		Silane	>99.9
		Silicon tetrachloride	>99
		Silicon tetrafluoride	>99
Oxidation using fuel (for dep. only); cold bed (for clean only)	1–4	Chlorine trifluoride	>99
		Hydrogen chloride	>99
		Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrachloride	>99
		Silicon tetrafluoride	>99
Oxidation using fuel/wet scrubbing	1–4	Chlorine trifluoride	>99.9
		Hydrogen chloride	>99
		Hydrogen fluoride	>99
		Silane	>99.9
		Silicon tetrachloride	>99
		Silicon tetrafluoride	>99
		Carbon monoxide	<1 lbs/year created
		Oxides of nitrogen	<3 lbs/year created
Pre-pump reactor	1	Chlorine trifluoride	0
		Hydrogen chloride	0
		Hydrogen fluoride	0
		Silane	>99
		Silicon tetrachloride	0
		Silicon tetrafluoride	0
Wet scrubbing (with chemical addition)	1–4	Chlorine trifluoride	>99
		Hydrogen chloride	>99
		Hydrogen fluoride	>99
		Silane	80
		Silicon tetrachloride	>99
		Silicon tetrafluoride	>99

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #7: Doped Poly Deposition; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	56–111	0.5–12	3–18	37–138	>99
Oxidation using electric/wet scrubbing	70–85	0.5–12	10–35	10–15	>99
Oxidation using fuel	40–60	0.8–12	10–35	6–10	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–10	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–12	>99
Wet scrubbing (with chemical addition)	25–50	0.3–12	3–18	6–10	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #7: Doped Poly Deposition; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel	4–6	30–40	3–4
Oxidation using fuel/wet scrubbing	6–22	16–40	<1–4
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #7: Doped Poly Deposition; PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–4	Hydrogen fluoride	>99
		Phosphine	>99
		Silane	>99
		Silicon tetrafluoride	>99
Oxidation using electric/wet scrubbing	1–2	Hydrogen fluoride	>99
		Phosphine	>99
		Silane	>99.9
		Silicon tetrafluoride	>99
Oxidation using fuel	1–4	Hydrogen fluoride	0
		Phosphine	>99
		Silane	>99
		Silicon tetrafluoride	0
Oxidation using fuel/wet scrubbing	1–4	Hydrogen fluoride	>99
		Phosphine	>99.9
		Silane	>99.9
		Silicon tetrafluoride	>99
		Carbon monoxide	<1 lbs/year created
		Oxides of nitrogen	<3 lbs/year created
Pre-pump reactor	1	Hydrogen fluoride	0
		Phosphine	>99
		Silane	>99
		Silicon tetrafluoride	0
Wet scrubbing (with chemical addition)	1–4	Hydrogen fluoride	>99
		Phosphine	0
		Silane	80
		Silicon tetrafluoride	>99

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #8: Metal Etch (Aluminum)

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	52–103	0.5–12	3–18	13–34	>99
Hot chemical bed	50–70	0.5–12	3–18	8–12	>99
Oxidation using electric/wet scrubbing	54–70	0.5–12	10–35	14–20	>99
Wet scrubbing (with or without chemical addition)	25–60	0.3–12	3–18	5–12	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #8: Metal Etch (Aluminum)

Technology	Floor Space (ft²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H₂O)
Cold bed	4–16	6–40	2–6
Hot chemical bed	3–5	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	16–60	<1–2
Wet scrubbing (with or without chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #8: Metal Etch (Aluminum)

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–4	Aluminum bromide	>99
		Aluminum chloride	>99
		Boron trichloride	>99
		Chlorine	>99
		Hydrogen bromide	>99
		Hydrogen chloride	>99
Hot chemical bed	1–2	Aluminum bromide	>99
		Aluminum chloride	>99
		Boron trichloride	>99.9
		Chlorine	>99.9
		Hydrogen bromide	>99
		Hydrogen chloride	>99.9
Oxidation using electric/wet scrubbing	1–2	Aluminum bromide	>99
		Aluminum chloride	>99
		Boron trichloride	>99.9
		Chlorine	>90
		Hydrogen bromide	>99
		Hydrogen chloride	>99
Wet scrubbing (with or without chemical addition)	1–4	Aluminum bromide	>99
		Aluminum chloride	>99
		Boron trichloride	>99.9
		Chlorine	>97*
		Hydrogen bromide	>99
		Hydrogen chloride	>99.9

* higher chlorine removal efficiency can be realized if pH of scrubber solution is keep above 10.

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #9: Nitride Deposition with Silane; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	54–107	0.5–12	3–18	92–180	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	10–16	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–18	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–12	>99
Wet scrubbing (with chemical addition)	25–60	0.3–12	3–18	3–10	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #9: Nitride Deposition with Silane; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel/wet scrubbing	6–22	16–52	<1–4
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #9: Nitride Deposition with Silane; PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1-4	Ammonia	>99
		Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrafluoride	>99
Oxidation using electric/wet scrubbing	1-2	Ammonia	>99.9
		Hydrogen fluoride	>99
		Silane	>99.9
		Silicon tetrafluoride	>99
		Oxides of nitrogen	<20 lbs/year created
Oxidation using fuel/wet scrubbing	1-4	Ammonia	>99
		Hydrogen fluoride	>99
		Silane	>98
		Silicon tetrafluoride	>99
		Carbon monoxide	<3 lbs/year created
		Oxides of nitrogen	<7 lbs/year created
Pre-pump reactor	1	Ammonia	55 - 99
		Hydrogen fluoride	0
		Silane	>99
		Silicon tetrafluoride	0
		Oxides of nitrogen	0
Wet scrubbing (with chemical addition)	1-4	Ammonia	>99
		Hydrogen fluoride	>99
		Silane	80
		Silicon tetrafluoride	>99

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #10: Nitride Deposition with Dichlorosilane; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	54–106	0.5–12	3–18	120–231	>99
Hot chemical bed/ ammonia control system	58–78	0.5–12	3–18	7–12	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	10–16	>99
Pre-pump reactor	46–50	0.4–12	2–18	12–18	>99
Wet scrubbing (with or without chemical addition)	25–60	0.3–12	3–18	4–13	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #10: Nitride Deposition with Dichlorosilane; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Hot chemical bed/ ammonia control system	3–5	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with or without chemical addition)	5–11	6–44	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #10: Nitride Deposition with Dichlorosilane; PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–2	Ammonia	>99
		Ammonium chloride	>99
		Dichlorosilane	>99
		Hydrogen fluoride	>99
		Silicon tetrafluoride	>99
Hot chemical bed/ ammonia control system	1	Ammonia	>99.9
		Ammonium chloride	>99
		Dichlorosilane	>99.9
		Hydrogen fluoride	>99
		Silicon tetrafluoride	>99
Oxidation using electric/wet scrubbing	1–2	Ammonia	>99.9
		Ammonium chloride	>99
		Dichlorosilane	>99
		Hydrogen fluoride	>99
		Silicon tetrafluoride	>99
		Oxides of nitrogen	<25 lbs/year created
Pre-pump reactor	1	Ammonia	55 - 99
		Ammonium chloride	55 - 99
		Dichlorosilane	>99
		Hydrogen fluoride	0
		Silicon tetrafluoride	0
		Hydrogen chloride	Generated from dichlorosilane in pre-pump reactor
Wet scrubbing (with or without chemical addition)	1–4	Ammonia	>99*
		Ammonium chloride	>99
		Dichlorosilane	>99.9
		Hydrogen fluoride	>99
		Silicon tetrafluoride	>99

* higher ammonia removal efficiency can be realized if pH of scrubber solution is kept below 5.

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #11: Oxide Deposition; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	55–109	0.5–12	3–18	27–94	>99
Hot chemical bed	50–70	0.5–12	3–18	3–10	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	10–16	>99
Oxidation using fuel	40–60	0.8–12	10–35	5–10	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–10	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–12	>99
Wet scrubbing (with chemical addition)	25–60	0.3–12	3–18	3–8	>99

APPLICATION #11: Oxide Deposition; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Hot chemical bed	3–5	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel	4–6	30–40	3–4
Oxidation using fuel/wet scrubbing	6–22	16–40	<1–4
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #11: Oxide Deposition; PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–4	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	>99 No information provided No information provided >99 >99
Hot chemical bed	1	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	>99 No information provided 0 >99.9 >99
Oxidation using electric/wet scrubbing	1–2	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	>99 >50 Not detected >99.9 >99
Oxidation using fuel	1–4	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	0 No information provided No information provided >98 0
Oxidation using fuel/wet scrubbing	1–4	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride Carbon monoxide	>99 >99 <3 lbs/year created >99.9 >99 <3 lbs/year created
Pre-pump reactor	1	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	0 28 0 >99 0
Wet scrubbing (with chemical addition)	1–4	Hydrogen fluoride Nitrous oxide Oxides of nitrogen Silane Silicon tetrafluoride	>99 0 0 80 >99

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #12: Tungsten Deposition; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	53–104	0.5–12	3–18	25–82	>99
Hot chemical bed	50–70	0.5–12	3–18	25–82	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	10–16	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–17	>99
Pre-pump reactor	50–72	0.4–12	2–18	38–50	>99
Wet scrubbing (with or without chemical addition)	25–60	0.3–12	3–18	3–10	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #12: Tungsten Deposition; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Hot chemical bed	3–5	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel/wet scrubbing	6–22	16–66	<1–4
Pre-pump reactor	3–4	24–48	<1
Wet scrubbing (with or without chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #12: Tungsten Deposition; PFC Clean

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–4	Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrafluoride	>99
		Tungsten hexafluoride	>99
Hot chemical bed	1	Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrafluoride	>99
		Tungsten hexafluoride	>99.9
Oxidation using electric/wet scrubbing	1–2	Hydrogen fluoride	>99
		Silane	>95
		Silicon tetrafluoride	<99
		Tungsten hexafluoride	>99.9
Oxidation using fuel/wet scrubbing	1–4	Hydrogen fluoride	>99
		Silane	>99
		Silicon tetrafluoride	>99
		Tungsten hexafluoride	>99
		Carbon monoxide	<3 lbs/year created
		Oxides or nitrogen	<3 lbs/year created
Pre-pump reactor	1	Hydrogen fluoride	0
		Silane	>99
		Silicon tetrafluoride	0
		Tungsten hexafluoride	99
Wet scrubbing (with or without chemical addition)	1–4	Hydrogen fluoride	>99
		Silane	80
		Silicon tetrafluoride	>99
		Tungsten hexafluoride	99

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #13: Poly Etch

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	52–103	0.5–12	3–18	15–49	>99
Hot chemical bed	50–70	0.5–12	3–18	7–12	>99
Wet scrubbing (with or without chemical addition)	25–60	0.3–12	3–18	4–12	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #13: Poly Etch

Technology	Floor Space (ft²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H₂O)
Cold bed	4–16	6–40	2–6
Hot chemical bed	3–5	6–40	2–6
Wet scrubbing (with or without chemical addition)	5–11	6–44	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #13: Poly Etch

Technology	Number of Applications per POU	Compound	% Removal Efficiency
Cold bed	1-4	Chlorine	>99
		Hydrogen bromide	>99
		Hydrogen chloride	>99
		Silicon tetrabromide	>99
		Silicon tetrachloride	>99
Hot chemical bed	1-2	Chlorine	>99.9
		Hydrogen bromide	>99.9
		Hydrogen chloride	>99.9
		Silicon tetrabromide	>99
		Silicon tetrachloride	>99
Wet scrubbing (with or without chemical addition)	1-4	Chlorine	>97*
		Hydrogen bromide	>99.9
		Hydrogen chloride	>99.9
		Silicon tetrabromide	>99
		Silicon tetrachloride	>99

* higher chlorine removal efficiency can be realized if pH of scrubber solution is keep above 10.

POU Technology Supplier Survey Results – Estimated Costs

APPLICATION #14: BPSG Oxide Deposition; PFC Clean

Technology	Estimated Purchase Cost (\$K)	Estimated Shipping Cost (\$K)	Estimated Installation Cost (\$K)	Est. Annual Operating Cost (\$K)	% Uptime
Cold bed	55–108	0.5–12	3–18	25–45	>99
Hot chemical bed	50–70	0.5–12	3–18	4–10	>99
Oxidation using electric/wet scrubbing	68–80	0.5–12	10–35	10–16	>99
Oxidation using fuel	40–60	0.8–12	10–35	6–10	>99
Oxidation using fuel/wet scrubbing	80–170	0.8–12	10–35	5–10	>99
Pre-pump reactor	40–50	0.4–12	2–18	2–10	>99
Wet scrubbing (with chemical addition)	25–60	0.3–12	3–18	3–10	>99

POU Technology Supplier Survey Results – Additional Information

APPLICATION #14: BPSG Oxide Deposition; PFC Clean

Technology	Floor Space (ft ²)	Preventive Maintenance (PM) Number of hours/year	Pressure Drop (in. H ₂ O)
Cold bed	4–16	6–40	2–6
Hot chemical bed	3–5	6–40	2–6
Oxidation using electric/wet scrubbing	6–11	48–60	<1–2
Oxidation using fuel	4–6	30–40	3–4
Oxidation using fuel/wet scrubbing	6–22	16–40	<1–4
Pre-pump reactor	3–4	12–24	<1
Wet scrubbing (with chemical addition)	5–11	6–25	<1–4

POU Technology Supplier Survey Results – Compound Removal Efficiencies

APPLICATION #14: BPSG Oxide Deposition; PFC Clean

Technology	# of Applications per POU	Compound	% Removal Efficiency
Cold bed	1–2	Diborane	>99
		Hydrogen fluoride	>99
		Nitrous oxide	No information provided
		Oxides of nitrogen	No information provided
		Phosphine	>99
		Silane	>99
		Silicon tetrafluoride	>99
Hot chemical bed	1	Diborane	>99.9
		Hydrogen fluoride	>99
		Nitrous oxide	No information provided
		Oxides of nitrogen	0
		Phosphine	>99.9
		Silane	>99.9
		Silicon tetrafluoride	>99
Oxidation using electric/wet scrubbing	1–2	Diborane	>99
		Hydrogen fluoride	>99
		Nitrous oxide	>41
		Oxides of nitrogen	Not detected
		Phosphine	>99
		Silane	>99.9
		Silicon tetrafluoride	>99
Oxidation using fuel	1–4	Diborane	>96
		Hydrogen fluoride	0
		Nitrous oxide	No information provided
		Oxides of nitrogen	No information provided
		Phosphine	>92
		Silane	>95
		Silicon tetrafluoride	0
Oxidation using fuel/wet scrubbing	1–4	Diborane	>99
		Hydrogen fluoride	>99
		Nitrous oxide	>99
		Oxides of nitrogen	<3 lbs/year created
		Phosphine	>99
		Silane	>99.9
		Silicon tetrafluoride	>99
		Carbon monoxide	<3 lbs/year created
Pre-pump reactor	1–4	Diborane	>99
		Hydrogen fluoride	0
		Nitrous oxide	28
		Oxides of nitrogen	0
		Phosphine	>99
		Silane	>99
		Silicon tetrafluoride	0
Wet scrubbing (with chemical addition)	1–4	Diborane	99
		Hydrogen fluoride	>99
		Nitrous oxide	0
		Oxides of nitrogen	0
		Phosphine	0
		Silane	80
		Silicon tetrafluoride	>99

**SEMATECH Technology Transfer
2706 Montopolis Drive
Austin, TX 78741**

<http://www.sematech.org>