

IBM's ECOL - Enhanced Emission Calculation Methodologies – Case Study

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Bruce Tripp, Tuan Vo and Steven Hawkins

IBM, Building 325, Route 52, Hopewell Junction, NY 12533

John F. Takacs and Paula J. Olsson

HighPoint Software Services, Inc., P.O. Box 874, Westminister, MA 01473

Lisa Schaefer, Robert Fromme, Anastasia Howard and Jeffrey Stringer

CDI Corporation, 2345 Route 52, Hopewell Junction, NY 12533

ABSTRACT

IBM's Environmental Control of the Line (“ECOL”) management system is used to track the air, water and waste emissions for all of the manufacturing tools used at the East Fishkill Facility. A recent upgrade to the ECOL system has added enhanced air emission calculation methodologies for Title V real-time continuous compliance.

The IBM East Fishkill plant manufactures semiconductor devices (chips) and substrate packaging. The substrate packaging is used to mount the "chips" for installation into the computers. The semiconductor and substrate packaging manufacturing processes consists of hundreds of chemical using steps. ECOL uses a variety of methods to determine the air emissions for semiconductor and substrate packaging manufacturing and supporting activities:

Materials balance is employed for tools that use gases to perform processes such as chemical vapor deposition and etching.

Wet tools operation includes: chemical baths, spray cleaning and application of organic slurries.

Supporting activities at the plant include chemical /waste handling, wastewater treatment and fuel combustion for generating high temperature hot water.

Incorporating the most accurate emission methodologies available into the ECOL system, has provided IBM with a comprehensive Title V compliance tool which is able to produce highly accurate emission reports.

INTRODUCTION

The IBM Plant located in The Town of East Fishkill, New York, manufactures semiconductor devices (chips) and substrate packaging. The substrate packaging is used to mount the “chips” for installation into the computers. The semiconductor and substrate packaging manufacturing processes consist of hundreds of chemical steps. In order to manage environmental aspects related to the manufacturing of semiconductor and substrate packaging, IBM created the Environmental Control of the Line System (ECOL).

The ECOL system is a Windows-based system used to track and report material/chemical usage at a production tool and the emissions to air, water and solid waste. The ECOL system has evolved at IBM East Fishkill from a mainframe program initiated in the 1970’s to its current version as a Windows-based, Title V continuous compliance tool.

- ECOL is a cradle to grave tracking system with the following capabilities:
- Import information about chemicals delivered to a tool,
- check the authorization for chemical usage limits,
- track chemical usage amounts,
- determine the emission fate and rate of the chemicals used at a tool

To determine the air emissions for semiconductor, substrate packaging manufacturing and supporting activities ECOL uses a variety of emission estimation methods:

Materials balance is employed for tools using gases to perform processes such as chemical vapor deposition and etching.

Emission calculations for wet tools operation includes three types of installations: chemical baths, spray cleaning and application of organic slurries.

Supporting activities at the facility that require air emission calculations include chemical/waste handling, waste water treatment and fuel combustion for generating high temperature hot water.

ECOL SYSTEM

The ECOL system is a Windows-based program written in Microsoft’s Visual Basic. The modules in the system consist of data entry for tool information, reports and support databases. The Support Tables contain information that is used throughout the system in drop down lists for the following:

- Exhaust Fans
- Part Numbers
- Chemical constituents
- Tool/equipment owners

- Buildings
- Control Devices
- Disposal Codes
- Fan Types
- Supply Systems
- Emission Units
- Regulatory Citations
- Calculation Types

An example of the Support Tables for Exhaust Fans are shown in Figures 1 and 2. The exhaust fans table includes information on fan type, manufacturer, location and physical parameters.

Figure 1. Support Table – Exhaust Fans

Environmental Control of the Line System (ECL) - [Exhaust Fans - [300CC14]]

File Edit Options Admin Audits Window Help

Tools Reports Exhaust Fans Part Numbers Constituents Owners Buildings Control Devices Disposal Codes
Fan Types Supply Systems Control Types Emission Units Citations Calc Types Other Tables Exit

Exhaust Fans - [300CC14]

Fan Specifications

Exhaust Fan

Fan ID: 300CC14 Building Name: 300C Floor: 1 State Fan #: KC14 In Use

Fan Model: 30AX5 Fan Type: AXIAL Status: Running Not Running Remove

Manufacturer: DEBOTHEZAT

Control Device: Control Type: Control Efficiency:

UTM X (Meters): 597961 UTM Y (Meters): 4599690 Elevation (Feet): 317.94 Export To AQ-Calc

Update Log

| Date Entered | Entered By | Last Updated | Updated By | Deleted |
|--------------|------------|--------------|------------|--------------------------|
| 9/1/2002 | ECCL3 | 4/11/2003 | PJO | <input type="checkbox"/> |

PJO ADMIN Record 222 Of 4478 4/11/2003 9:21 AM

Figure 2. Support Table – Exhaust Fan Table specifications.

Each tool used at the facility is given a specific number (Brass Tag Number). Note that the term “ tool” is used to describe all equipment on-site. This can be a production tool, boiler, chemical hood, etc. The ECOL system contains records for all tools on-site and tracks if they are in-service or if the record is for a new tool that is pending and not yet in operation. The ECOL system archives historical data which can be retrieved. Figure 3 shows the specific information stored for each tool.

Figure 3. Tool input screen

The screenshot displays the 'Tools - [JK02] - [PECVD SIN/S102 (51.8)]' input screen within the 'Environmental Control of the Line System (ECL)' application. The interface is organized into several sections:

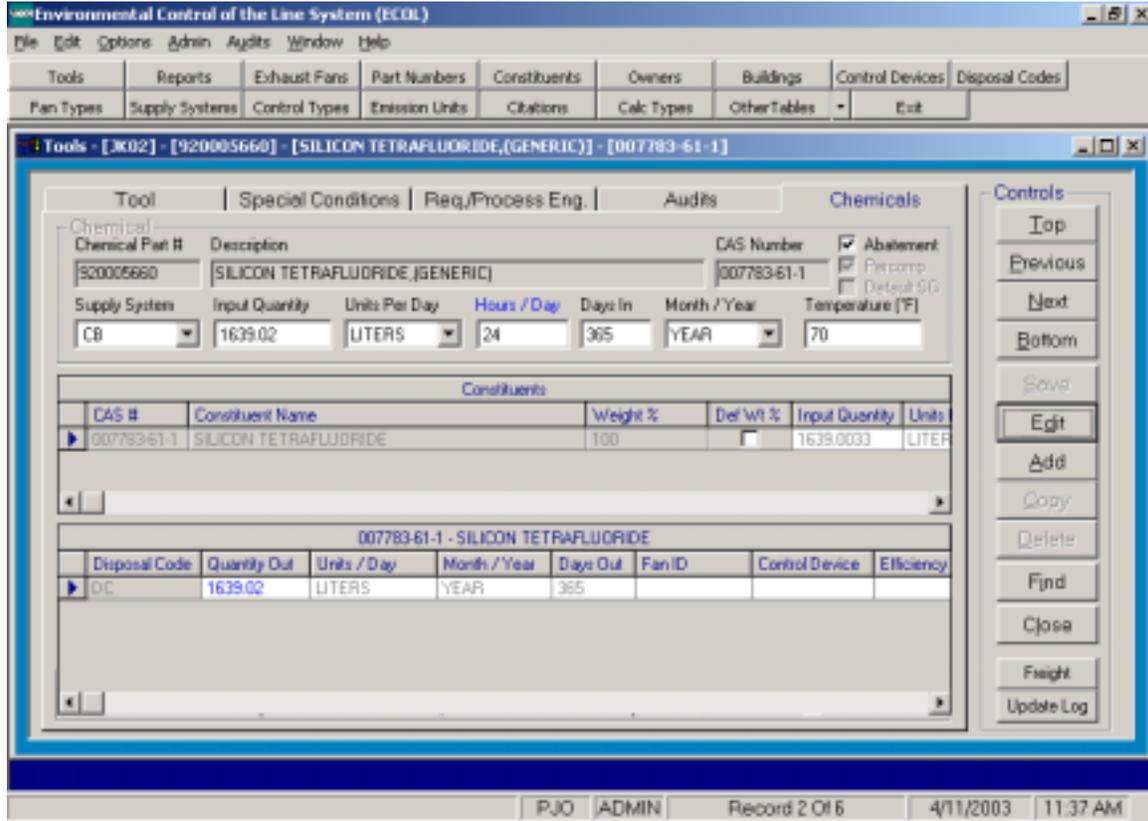
- Tool Information:** Fields for Brass Tag # (JK02), Description (PECVD SIN/S102 (51.8)), and Building Name (323).
- Location and Identification:** Fields for Column (F11), Floor (2), Department (323), Shift Usage (A), EIA Number (323), and Hes Number (JK02).
- Configuration and Status:** Radio buttons for Type (Manufacturing selected), Permit/Exempt/Trivial status (Permit selected), and Calc. Type (STOICHIOMETRIC MATERIALS BALANCE).
- Reporting and Output:** Checkboxes for 'Input to Reports' and 'Output to Reports', and a 'Validated' checkbox.
- Tables:**
 - Fans Table:**

| Fan ID | Actual CFM | Design CFM | C |
|------------|------------|------------|---|
| 323 GENEX1 | 1013 | | |
 - Control Devices Table:**

| Control Device | Deleted |
|----------------|---------|
| | |
- Controls Panel:** A vertical stack of buttons including Top, Previous, Next, Bottom, Save, Edit, Add, Copy, Delete, Find, Close, Print, and Update Log.
- Status Bar:** Displays 'PJO ADMIN Record 3374 Of 4197 (4197) 4/11/2003 11:35 AM'.

The main screen provides location information about a tool as well as any exhaust fans or control devices associated with the tool. The Chemicals flipcard contains information on the chemicals used by the tool (Figure 4). Each chemical used at a tool is identified by a specific IBM chemical part number and the common chemical name. This screen gives information on the amount of chemical supplied to the tool as well as the method of arrival to the tool – i.e. Supply System. The grid at the bottom of the screen details the environmental fate and amount of chemical that is disposed or emitted. This chemical can become part of a product, be disposed down a specific chemical drain, become solid waste or be emitted as an air emission.

Figure 4. Chemical usage and disposal for a tool.



The disposal code, (DC) indicates an air emission from the tool, the emission rate has been calculated using various methodologies built into ECOL to achieve the final emission rate.

AIR EMISSION CALCULATION METHODOLOGIES

Air Emissions in ECOL for semiconductor, substrate packaging manufacturing and supporting activities are estimated using a variety of methods¹.

Materials Balance

Materials balance is typically employed for tools using gases to perform processes such as chemical vapor deposition and etching. For these processes the stoichiometry is known and defines the output chemicals. Any input chemicals used in excess of the “limiting factor” will be discharged with the reactants. Therefore, by “programming” the recipe and the designed flow rates for each tool, the ECOL system calculates the emission.

Material balance calculations for semiconductor fabrication processes are all based upon *process recipes*. A process recipe is the “cookbook” for a given process, a well defined system of operating parameters that provides the process engineer with the results he/she

is seeking. Process and tool engineers at the East Fishkill Site are required to provide the environmental team with the portion of the process recipe that environmental engineering has a need to know. This includes parameters such as, process chemical flow rates, operating temperature and pressures, chamber sizes, and freeboard height to list a few. An example of a process recipe provided to ECOL is shown below in Figure 5. Note that there are many process recipes for this tool, of which only one is shown¹.

After securing process recipes from process and tool engineers, a member of the ECOL team will “roll-up” all of the recipes into an ECOL form. The ECOL form will be a listing of all chemicals used on that particular tool, with flow rates and hours of utilization. A sample ECOL form for a gas phase tool is shown below in Figure 6. The completed ECOL form is the core information that allows the environmental engineer to calculate accurate air, water, and waste disposal masses.

At IBM East Fishkill’s new state of the art 300mm fabrication facility, most gas phase tools have been coupled with a Point of Use abatement system. This system cracks harmful perfluorinated compounds that contribute to global warming into more benign compounds that can be transported into the aqueous phase and subsequently treated. Engineers at IBM East Fishkill have developed models to easily and accurately calculate air, water, and waste emissions using aforementioned recipes, stoichiometry, and gas phase absorption efficiencies. A typical model is shown and described below.

¹Actual process recipe data has been changed for this model.

Figure 5. Sample Process Recipe Provided by Equipment or Process Engineer

| PARAMETERS | | |
|--------------------|--------|---------|
| Thickness of Layer | 4500 | Å |
| Throughput | 80 | WPH |
| Accumulation Limit | 180000 | Å |
| Deposition Rate | 7200 | Å/min |
| Etch Rate | 8000 | Å/min |
| Hours of use/day | 16.8 | hrs/day |
| Number of showers | 4 | heads |

| FLOWS | | |
|---------------|-------|--------|
| SiH4 | 740 | sccm |
| NH3 | | sccm |
| N2O | 16000 | sccm |
| SiF4 | | sccm |
| TEOS | | ml/min |
| NF3 (etchant) | 2500 | sccm |
| O2 | | sccm |
| H2 | | sccm |
| He | 15600 | sccm |
| N2 | 18360 | sccm |
| Ar | | sccm |

OXIDE

calculated columns show "ERR" and if
parameters and flows are entered

| | | |
|--------------------|------|--------|
| Real Thickness | 1125 | Å |
| Wafers before etch | 160 | wafers |
| Cycles/Day | 8.23 | cycles |

| USAGE | | |
|-------|-------|---------|
| SiH4 | 13.71 | hrs/day |
| NH3 | | hrs/day |
| N2O | 13.71 | hrs/day |
| SiF4 | | hrs/day |
| TEOS | | hrs/day |
| NF3 | 3.09 | hrs/day |
| O2 | | hrs/day |
| H2 | | hrs/day |
| He | 13.71 | hrs/day |
| N2 | 16.8 | hrs/day |
| Ar | | hrs/day |

Figure 6: Sample ECOL Form (Sum of Tool's Process Recipes)

IBM

ECOL II

- Please complete all boxes
- Reference the Chemical Management and Environmental Manual On-Line
- List all chemicals (see Chemical Management and Environmental Manual for exceptions)

Date: 7/6/01
 New: _____
 Update: _____

| REQUESTER NAME (PRINT) JOHN SMITH | | PHONE 2-1234 | | BLDG S10 | | DEPT 9XCA | |
|---|-----------------------|-----------------|-----------------|-----------------|-----------------|------------------|---------------|
| PROCESS ENGINEER NAME JANE DOE | | DEPT 28QA | | PHONE 2-4567 | | | |
| TOOL DATA | | | | | | EANO | |
| FRAGS TAG/TOOL NUMBER CRM-51.00 | | | | | | | |
| TOOL DESCRIPTION Vector Single Chamber 50/50 SiO2/SiN + TEOS capability+ FSG | | | | | | HEX NO. JK02 | |
| DEPT. USING | | BLOG 323 | | COLUMN | | FLOOR 1 | |
| CHEMICAL NO. | CHEMICAL NAME | QTY | UNIT OF MEASURE | TEMP | USAGE HRS./ DAY | USED DAYS/ MONTH | TYPE OF DRAIN |
| 920-007-500 | SILANE | 773.333333 | sccm | RT | 10.7 | 30 | NA |
| 925-860-060 | AMMONIA | 7500 | sccm | RT | 3.9 | 30 | NA |
| 929-076-300 | NITROUS OXIDE | 18000 | sccm | RT | 6.8 | 30 | NA |
| 920-005-660 | SILICON TETRAFLUORIDE | 2000 | sccm | RT | 13.66 | 30 | NA |
| 910-025-420 | TEOS | 5 | ml/min | RT | 3.79 | 30 | NA |
| 920-044-130 | NITROGEN TRIFLUORIDE | 2500 | sccm | RT | 2.3 | 30 | NA |
| 921-080-000 | OXYGEN | 9805 | sccm | RT | 3.79 | 30 | NA |
| 921-010-020 | HYDROGEN | 0 | sccm | RT | 0 | 30 | NA |
| 921-020-060 | HELIUM | 14244 | sccm | RT | 14.5 | 30 | NA |
| 921-070-030 | NITROGEN | 11786.6667 | sccm | RT | 12.6 | 30 | NA |
| 921-180-000 | ARGON | 9000 | sccm | RT | 16.8 | 30 | NA |
| 929-000-010 | Reclaim H2O | 0.5 | GPM | RT | 24 | 30 | DF |
| FAN NO. 1 | | CFM NO. 1 | | FAN NO. 2 | | CFM NO. 2 | |
| FAN NO. 3 | | CFM NO. 3 | | FAN NO. 4 | | CFM NO. 4 | |

COMMENTS:

Gas Phase Tool Emission Model:

Step I: Transfer ECOL Data into Emission Model

The first step in generating an emission model is to import the ECOL data, and thus the tool's process recipes, into the model's base table. A sample base table is shown below in Figure 7. From left to right, this table has CRM and HEX which are internal IBM tool identifiers, followed by calculation dates for audit purposes, abatement model, number of tools in this model, chemicals used in the tool, daily usage rates, units of usage, total usage (number of tools multiplied by usage/tool), and total usage converted to moles/day using the ideal gas law.

Figure 7. Emission Model Base Table

| CRM# | HEX | Date of Most Recent Calc. | Abatement | Qty Tools | Chemicals | Usage/ Tool | Unit | Total Usage | Total Usage (mol/Day) |
|-------------|------------|----------------------------------|------------------|------------------|------------------|--------------------|-------------|--------------------|------------------------------|
| 51.80 | JK02 | 01-May-02 | TPU | 1 | N2O | 7390.66 | SLD | 7390.66 | 329.940 |
| 51.80 | JK02 | 01-May-02 | TPU | 1 | NF3 | 341.53 | SLD | 341.53 | 15.247 |
| 51.80 | JK02 | 01-May-02 | TPU | 1 | NH3 | 1752.32 | SLD | 1752.32 | 78.228 |
| 51.80 | JK02 | 01-May-02 | TPU | 1 | SiF4 | 1639.02 | SLD | 1639.02 | 73.171 |
| 51.80 | JK02 | 01-May-02 | TPU | 1 | SiH4 | 498.21 | SLD | 498.21 | 22.241 |
| 51.80 | JK02 | 01-May-02 | TPU | 1 | TEOS | 1135.77 | mLD | 1135.77 | 5.092 |

Step II: Tabulate System Input & Convert to Mass Quantities

Once the model's base information has been imported, we can begin to develop the mass balance through the system for each chemical. The total mass of all inputs must be tabulated and entered into an *Inputs Table* shown below in Figure 8. First, each chemical usage must be converted from molar units into mass in grams. Second, in order for the mass quantities to balance throughout the system we must calculate the *theoretical quantity of oxygen* and methane required to oxidize the influent stream. Next we add in the mass of reclaimed water that is necessary to transport the gaseous stream into the water stream. Each point of use abatement system uses approximately 0.5 GPM on average over a 24-hour period. This calculated quantity is entered into the model as *stream 7*. After calculating the mass quantities of specialty chemicals into the system, oxygen and natural gas for combustion, and scrubber water, we can add across columns, and then down rows to arrive at a total mass quantity entering the system.

Figure 8. Emission Model Inputs Table.

| Inputs to System (GM/DAY) | | | | | |
|---------------------------|---------------------|-----------------------------------|---------------------------|-------------|-------------|
| | Stream 1 | Stream 3 | Stream 4 | Stream 7 | |
| Chemicals | Specialty Chemicals | O2 necessary to Oxidize Chemicals | CH4 for Combustion of NF3 | Reclaim H2O | Total In |
| N2O | 14521.595 | 0.000 | 0.000 | ↓ | 14521.595 |
| NF3 | 1082.544 | 447.197 | 183.438 | | 1713.179 |
| NH3 | 1332.262 | 1877.225 | 0.000 | | 3209.488 |
| SiF4 | 7615.580 | 4682.283 | 1173.731 | | 13471.595 |
| SiH4 | 714.342 | 1423.256 | 0.000 | | 2137.598 |
| TEOS | 1060.81 | 1955.253 | 0.000 | | 3016.067 |
| | 26327.137 | 10385.215 | 1357.170 | 2726179.200 | 2764248.721 |

Step III: Stoichiometry

The third step in the development of an emission model is the most critical. This is where balanced chemical reactions must be written, and accurate destruction and transport efficiencies must be obtained from abatement equipment vendors. There are six columns in the *Reaction & RXN Efficiencies Table* (Figure 9). In order from left to right are chemical species, destruction efficiency in the point of use abatement burn unit, transport efficiency, stoichiometric oxygen and methane to combust each chemical, and balanced destruction reactions.

Figure 9. Reaction and RXN Efficiencies Table

| Reactions & RXN Efficiencies | | | | | |
|------------------------------|---------|-------|-----------|------------|--|
| Chemicals | DRE | SE | Stoich O2 | Stoich CH4 | Destruction RXN |
| N2O | 1 | 0 | 0 | 0 | 2N2O -> O2 + 2N2 |
| NF3 | 0.99995 | 0.999 | 0.92 | 0.75 | 12NF3 + 9CH4 + 11O2 -> 4N2 + 4NO + 36HF + 9CO2 |
| NH3 | 0.9999 | 0 | 0.75 | 0 | 4NH3 + 3O2 -> 2N2 + 6H2O |
| SiF4 | 0.9999 | 0.999 | 2.00 | 1 | SiF4 + CH4 + 2O2 -> SiO2 + 4HF + CO2 |
| SiH4 | 0.9999 | 0.99 | 2 | 0 | SiH4 + 2O2 -> SiO2 + 2H2O |
| TEOS | 1 | 1 | 12 | 0 | Si(OC2H5)4 + 12O2 -> SiO2 + 8CO2 + 10H2O |

These balanced reactions will be converted in step IV to *Stoichiometric Coefficients* that will allow automatic calculation of mass quantities of breakdown products.

Step IV: Stoichiometric Coefficients Tabulation

The fourth step in the emission model is to translate a written balanced equation into a format recognized by common spreadsheet programs that will lend itself to automatic calculation of breakdown products and their associated mass quantities. For example, from Figure 9 above, we can see that 12 moles of NF₃, plus 9 moles of methane, plus 11 moles of NF₃, can be combusted into 4 moles of N₂, 4 moles NO, 36 moles HF, and 9 moles CO₂. To translate this into a usable format each breakdown product must be ratioed to the limiting reactant, here NF₃, in order to derive stoichiometric coefficients (Figure 10).

Figure 10. Mole Ratios by Chemical Input

| Mole Ratios | | | | | | | | |
|------------------|------------------|------------------|----------------|------|------|-----------------|----------------|----------------|
| Burner RXNS | | | | | | | | |
| Chemicals | SiO ₂ | H ₂ O | N ₂ | NO | HF | CO ₂ | W ₃ | O ₂ |
| N ₂ O | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 |
| NF ₃ | 0.00 | 0.00 | 0.33 | 0.33 | 3.00 | 0.75 | 0.00 | 0.00 |
| NH ₃ | 0.00 | 1.50 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SiF ₄ | 1.00 | 0.00 | 0.00 | 0.00 | 4.00 | 1.00 | 0.00 | 0.00 |
| SiH ₄ | 1.00 | 2.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TEOS | 1.00 | 10.00 | 0.00 | 0.00 | 0.00 | 8.00 | 0.00 | 0.00 |

Step V: Calculation of Output Streams

The calculation of mass quantities of each constituent in each output stream is the most rigorous part in developing an air emission model. To this point the model has essentially been accounting and trivial calculation. Here in step 5 is where the stoichiometry is performed, and the output streams are divided into air and wastewater streams.

After completion of step V accurate drain and exhaust output tables will have been completed as shown below in Figures 11 and 12.

Figure 11. Drain Output Table

| System Output (GM/DAY) | | | | | | |
|------------------------------|----------|----------|----------|----------|-------------|-------------|
| Stream 8 - DF Drain (GM/DAY) | | | | | | |
| Chemicals | HF | CO2 | H2O | SiO2 | Reclaim | Total |
| N2O | 0.000 | 0.000 | 0.000 | 0.000 | ↓ | 0.00 |
| NF3 | 914.129 | 502.724 | 0.000 | 0.000 | | 1416.85 |
| NH3 | 0.000 | 0.000 | 2113.741 | 0.000 | | 2113.74 |
| SiF4 | 5849.062 | 3216.687 | 0.000 | 4391.613 | | 13457.36 |
| SiH4 | 0.000 | 0.000 | 801.288 | 1322.876 | | 2124.16 |
| TEOS | 0.000 | 1792.782 | 917.333 | 305.952 | | 3016.07 |
| | 6763.191 | 5512.194 | 3832.362 | 6020.441 | 2726179.200 | 2748307.388 |

Figure 12. Exhaust Output Table

| System Output (GM/DAY) | | | | | | | | | | | | |
|-------------------------------------|-------|-------|--------|-----------|---------|----------|-------|-------|-------|-------|-------|-----------|
| Stream 6 - General Exhaust (GM/DAY) | | | | | | | | | | | | |
| Chemicals | HF | CO2 | SiO2 | N2 | NO | O2 | NF3 | NH3 | SiF4 | SiH4 | TEOS | Total |
| N2O | 0.000 | 0.000 | 0.000 | 9242.749 | 0.000 | 5278.846 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 14521.60 |
| NF3 | 0.915 | 0.503 | 0.000 | 142.363 | 152.490 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 | 0.000 | 296.33 |
| NH3 | 0.000 | 0.000 | 0.000 | 1095.613 | 0.000 | 0.000 | 0.000 | 0.133 | 0.000 | 0.000 | 0.000 | 1095.75 |
| SiF4 | 5.855 | 3.220 | 4.396 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.762 | 0.000 | 0.000 | 14.23 |
| SiH4 | 0.000 | 0.000 | 13.362 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.071 | 0.000 | 13.43 |
| TEOS | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 |
| | 6.770 | 3.723 | 17.758 | 10480.725 | 152.490 | 5278.846 | 0.054 | 0.133 | 0.762 | 0.071 | 0.000 | 15941.334 |

These two output tables (Figure 11 and 12) represent the usable information that will be used in ECOL for emission and wastewater reporting. These two tables detail one tool's, and thus its many recipes', contribution to the total emission and waste stream exiting the East Fishkill Site. When similar models are developed for other semiconductor fabrication tools, this system allows accurate emission calculation by process, building, or Site.

Wet Tool Operation

Wet tool operations include three types of installations: chemical baths, spray cleaning and application of organic slurries (including photoresist).

Emissions from chemical bath operations are estimated using the Ideal Gas Law. For each tool, data is recorded for bath dimensions, temperature, sparging, volume of exhaust, and total number of product cycles the tool runs in an hour. Emissions of spray tools are estimated using empirical data collected on similar applications and scaling for chamber size, adjusting for vapor pressure of the chemical at the temperature used in the tool. Emission for slurry/resist applications are calculated by determining the total volume of slurry/resist applied and assuming that all volatile compounds evaporate.

Chemical bath

Chemical bath operations are estimated by using a spreadsheet model, developed by ENSR, for IBM and is based on Antoine's equation and the ideal gas law. Vapor pressure is the $(\log(P_{\text{vap}}) = A - B/(T - C))$. Where A, B, and C are Antoine's coefficients.

After obtaining the required information about the tool from the process and equipment engineers the spreadsheet in Figure 13 is completed in order to calculate the emissions based on the maximum production throughput of the tool.

Figure 13. Chemical Bath Emissions Estimation Model.

| | | | |
|---|---|-------------|----------------|
| IBM Corporation | | | |
| SOLVENT AND ACID BATH EMISSIONS ESTIMATING MODEL | | | |
| OUTPUT | Calculation results and input data verification | | |
| 0 | | | |
| Print date: | 28-Jan-03 | Print time: | 03:27 PM |
| A. Input data. | | | |
| Most similar hood type is: | Plain multiple slot opening, 2 or more slots | | |
| Exhaust flow (cfm): | | | 185.6 |
| Hood opening length (L, in): | | | 4 |
| Hood opening width (W, in): | | | 4 |
| Average distance of tank from hood opening (in): | | | -8 |
| Dip tank length (in): | | | 13.9 |
| Dip tank width (in): | | | 12.4 |
| Dip tank uncovered area (sq.in.): | | | 172.36 |
| Average surface area of dipped parts and basket (sq.ft.): | | | 86.5 |
| Average number of parts dipped (parts/hr): | | | 1 |
| Maximum number of parts dipped (parts/hr): | | | 1 |
| Annual bath operating hours: | | | 365 |
| Bath is NOT sparged | | | No |
| - | | | - |
| - | | | - |
| Bath is covered | | | Yes |
| Average number of times cover is lifted per hour: | | | 2 |
| Maximum number of times cover is lifted per hour: | | | 2 |
| Average percentage of time uncovered: | | | 5 |
| Maximum percentage of time uncovered: | | | 10 |
| Bath temperature (oC): | | | 40 |
| Bath solution is: | Hydrogen peroxide | | 100.00% |

Based on the input entered in Figure 13, the following emission results are calculated (Figure 14).

Figure 14. Chemical Bath Emissions.

| B. Model calculation results. | | |
|--------------------------------------|--|------------------|
| 1. Average hourly emissions (lb/hr): | | |
| Evaporative (covered) | | 0.0221949 |
| Evaporative (uncovered) | | 0.0011682 |
| Dragout | | 0.0357708 |
| Sparging | | 0 |
| Uncovering | | 0.0020535 |
| TOTAL | | 0.061187 |
| 2. Peak hourly emissions (lb/hr): | | |
| Evaporative (covered) | | 0.0210267 |
| Evaporative (uncovered) | | 0.0023363 |
| Dragout | | 0.0357708 |
| Sparging | | 0 |
| Uncovering | | 0.0020535 |
| TOTAL | | 0.0611873 |
| 3. Annual emissions (tpy): | | |
| Evaporative (covered) | | 0.0040506 |
| Evaporative (uncovered) | | 0.0002132 |
| Dragout | | 0.0065282 |
| Sparging | | 0 |
| Uncovering | | 0.0003748 |
| TOTAL | | 0.0111667 |

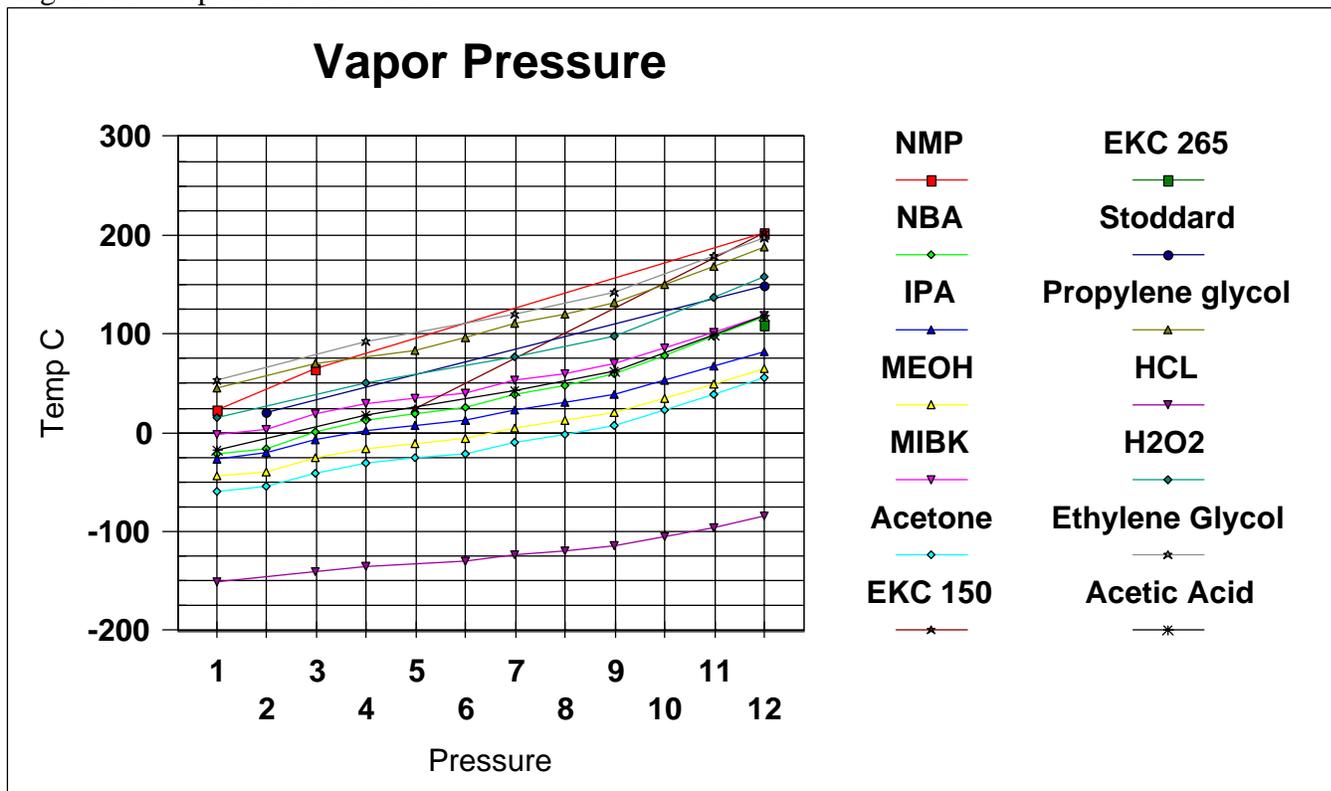
Spray cleaning tools

Emissions of spray cleaning tools are estimated by using empirical data collected from similar applications, scaling for chamber size, and adjusting for vapor pressure and temperature.

To estimate the emission of a spray tool, we first calculate the volume of the process chamber for which we need to estimate the emission. A surrogate tool is selected from the library of stack test data which has similar spray characteristics. We calculate the volume of the process chamber for the surrogate tool. The estimate of emissions for the new tool is made by adjusting the emission rate from the surrogate tool based on the equivalent difference of process chamber volume. For example, if new tool “A” has a chamber volume of 29.5 cubic feet and the surrogate tool “B”, for which empirical data is available, has a process chamber volume of 13.1 cubic feet, the estimated emission of tool “A” would be the known emission rate of surrogate tool “B” X 2.25.

By comparing the vapor pressures of the chemical at the temperature planned for use in the new tool (assuming similar spray characteristics), we can adjust emission rates by selecting a surrogate chemical for which empirical data is available and adjusting for difference in vapor pressure. (See figure 15).

Figure 15. Vapor Pressure Curves ².



Organic Slurry/Photoresist Application

Emissions from tools which apply organic slurries or photoresist are estimated using a materials balance approach. First “shot” or “Job” size is determined for a specific material to be applied. The specific chemical components and concentrations of the material to be applied are available in the ECOL system. Surface areas of both the product and receiving vessels are calculated. The process engineer provides the depth of thickness of the applied material and a total volume is calculated. From this volume and the specific chemical data we can then assume that the emission is equal to 100 percent of volatile chemical components present.

Supporting Activities

Supporting activities at the plant include chemical /waste handling, waste water treatment and fuel combustion for generating high temperature hot water. Calculation methods for these activities are readily available from USEPA and include:

- *Combustion source emissions* are calculated by inputting the appropriate fuel use into the ECOL system. ECOL uses AP-42 to calculate the appropriate emission data.
- *Emissions from Storage Tanks* are calculated by entering dimensional and turnover data into the ECOL system. ECOL uses USEPA Tanks 4 to calculate emissions.

COMPARISON OF CALCULATED EMISSIONS TO STACK TEST DATA

Actual hourly emissions data were calculated in ECOL for several of the emission units on-site using the methodologies described in this paper. Stack tests for the same set of tools and time frames were also performed. Figure 16 is a comparison of the calculated emissions in ECOL and actual stack test data. The results show that the detailed calculated emission estimates are reasonably close to stack test data. Note that the data estimated by ECOL is intended to be conservative and generally over states actual emissions.

Figure 16. Stack Test Emission Data versus ECOL Calculated Emissions.

| Source | chemical | stack test | ECOL |
|--------|--------------|------------|------|
| B/334 | ammonia | 0.18 | 0.28 |
| B/650 | ammonia | 0.24 | 0.49 |
| B/650 | ammonia | 0.29 | 0.29 |
| B/323 | NMP | 0.00 | 0.01 |
| B/334 | NMP | 0.50 | 0.85 |
| B/650 | NMP | 0.08 | 0.09 |
| B/334 | IPA | 1.65 | 1.93 |
| B/650 | IPA | 0.79 | 1.43 |
| B/323 | IPA | 0.05 | 0.02 |
| B/320 | IPA | 0.24 | 0.13 |
| B/323 | Ethyl Lactat | 0.00 | 0.00 |
| B/650 | Ethyl Lactat | 0.08 | 0.06 |
| B/650 | Gama butly | 0.01 | 0.03 |

CONCLUSION

IBM's Environmental Control of the Line (ECOL) management system is used to track the air, water and waste emissions for all of the manufacturing tools used at the facility. Recent additions to the ECOL system have improved and standardized emission calculation methodologies. By incorporating the most accurate emission methodologies available into the ECOL system, IBM has a comprehensive Title V compliance tool, which is able to produce very accurate emission reports. These reports are currently used for planning purposes and reporting to the regulating agency.

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KEY WORDS

Title V Continuous Compliance, Environmental Data Management, Emission Calculation, Environmental Software