

# Emission Factors 101

Intel

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# What Role do Emission Factors Play?

What is an emission factor?

- “An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.” <http://www.epa.gov/ttn/chief/ap42/index.html>

Emission factors have been used by EPA since EPA's beginning as a way to estimate emissions and have been an integral part of their program

CHIEF is EPA's overall compilation of emission factors in various areas

- CHIEF stands for "Clearinghouse for Inventories and Emission Factors" -<http://www.epa.gov/ttn/chief/efpac/index.html>

Early emission factors were primarily for traditional heavy industries and combustion devices like boilers and generators

In the 1990s EPA attempted to expand the emission factor program to cover more industries

- Intel integral to developing semiconductor emission factors
- Only one EPA emission factor document specific to semiconductor manufacturing - <http://www.epa.gov/ttn/chief/eiip/techreport/volume02/ii06.pdf>



# Emission Factors and Intel

Intel NM permit requires quarterly reporting of:

- Nitrogen dioxide (NO<sub>x</sub>)
- Carbon monoxide (CO)
- Volatile organic compounds (VOCs)
- Hazardous air pollutants (HAPs)
- Toxic Air Pollutants (TAPs)
- Total suspended particulates (TSP) from hexamethyldisilazane (HMDS)

Methods to calculate emissions set in permit

Use:

Chemical Use

Fuel Use

x

Emission Factor

=

Emissions

Hours Operated



Source of Emissions	Emissions	Source of Emissions Factors?
Combustion Sources (Boilers, Thermal Oxidizers, Emergency Generators)	NOx/CO  SO2, TSP/PM10, VOC	<ul style="list-style-type: none"> <li>• On-site emissions testing and operational data</li> <li>• Manufacture's data for emergency generators</li> <li>• Manufacture's data and EPA AP-42 emission factors</li> </ul>
Manufacturing Process (exhausted to scrubbers and thermal oxidizers)	VOCs/HAPs  VOCs/HAPs – untreated emissions  TAPs	<ul style="list-style-type: none"> <li>• Tool testing and process recipes</li> <li>• EPA sink equation</li> <li>• No emission factors, ie. chemical use = emissions</li> <li>• No emissions factors, i.e. chemical use = emissions</li> <li>• EPA sink equation</li> </ul>
Tanks	VOCs/HAPs	<ul style="list-style-type: none"> <li>• EPA tank equation</li> </ul>

# Boiler Emission Factors

## NOx/CO

### Boilers

- Used for temperature and humidity control of factories
- Operate at 10 different lever positions – similar to gears in a vehicle
- Primary fuel is natural gas – diesel as back-up fuel

Permit requires annual update to emission factors – Condition C.ii.f details requirements

Emission factors based on 3 years operating and testing data:

- Average firing rate for each lever position
- Maximum stack testing data at each position

Permit requires annual compliance testing

- NMED typically observes
- NMED performed spot check with their equipment during 2004 inspection – used to validate compliance testing

# Thermal Oxidizer Emission Factors NO<sub>x</sub>/CO

## Thermal Oxidizers

- Used to abate VOC emissions from factories
- Only run on natural gas

Emission factors similar to boilers

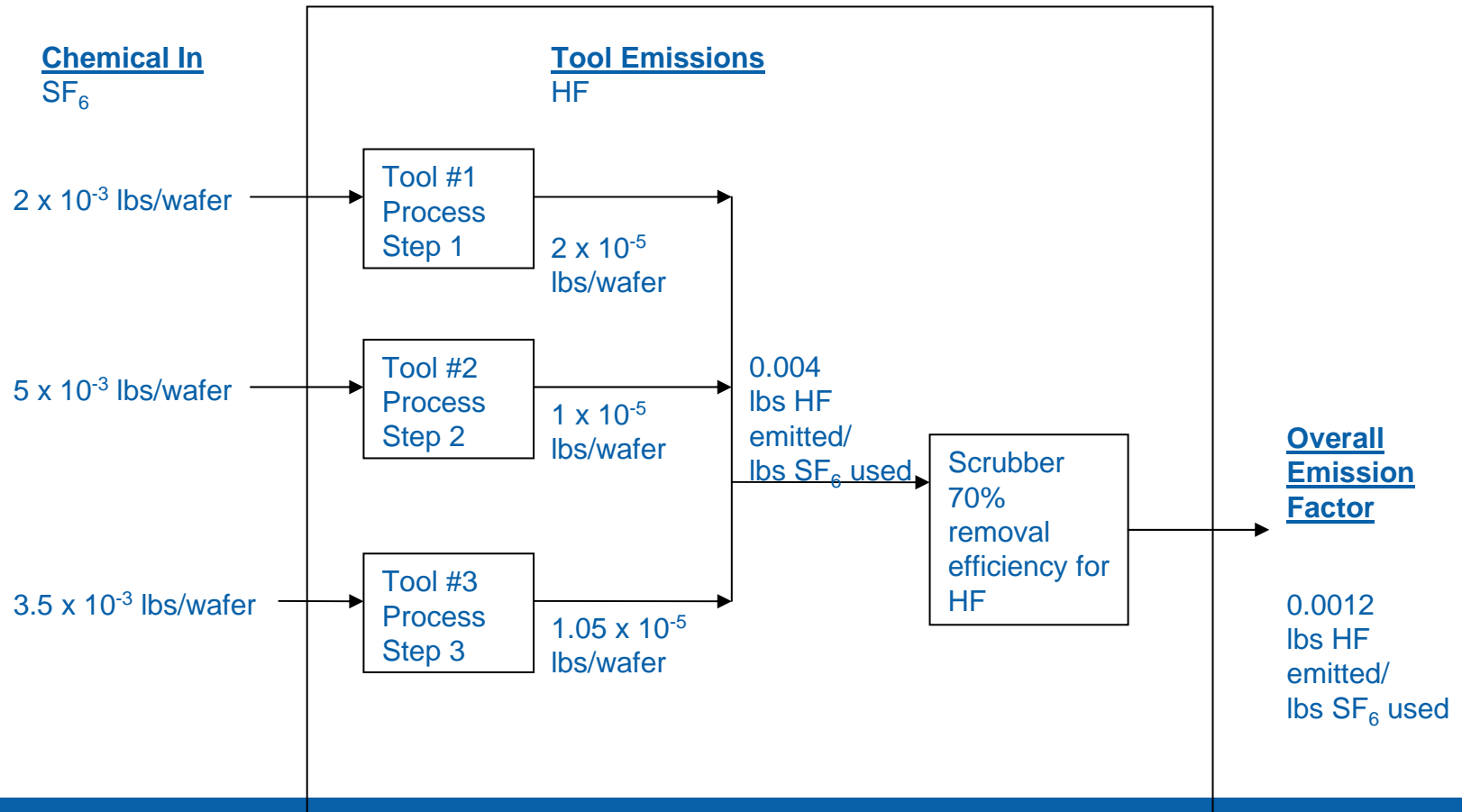
Emission factors based on 2 years operating and testing data:

- Average firing rate
- Maximum stack testing data

NO<sub>x</sub>/CO stack testing data collected during quarterly compliance testing

# HAP & VOC Emission Factors

## Example Calculation



# HAP & VOC Emission Factors

## What information is used?

### Chemical Use

- Each process has a specific recipe that is used for each step of the process
- Recipe specifies the amount of chemical used per wafer run

### Tool Testing

- Emissions measured directly from the individual tool
- Airflow in the tool exhaust measured

### How do we get a single emission factor for each chemical?

- For each chemical, the above information is gathered for every step and summed for all steps in the process to develop an overall emission factor
- This is done for every process run at Intel



# HAP & VOC Emission Factors

## Chemical Use

Product lines developed in development factories

Defined process parameters for each step in manufacturing process

- Type(s) of chemical/gas, amount of chemical/gas, temperature, flow rate, etc.- set during development

Approval required for changes and modifications to manufacturing process

- All changes are documented and tracked



# HAP & VOC Emission Factors Tool Testing

Tools tested at development site as part of product development

Tools tested using an FTIR

- Documented protocol is used for testing -  
<http://www.sematech.org/docubase/document/4197axfr.pdf>

Emissions verified at 1<sup>st</sup> high volume manufacturing site product is taken to

- Representative 12" process tools currently running in Fab 11X were tested Q2'04 (Robert S. from NMED observed testing)



# Emission Factor Verification

## External verification of all Intel emission factors

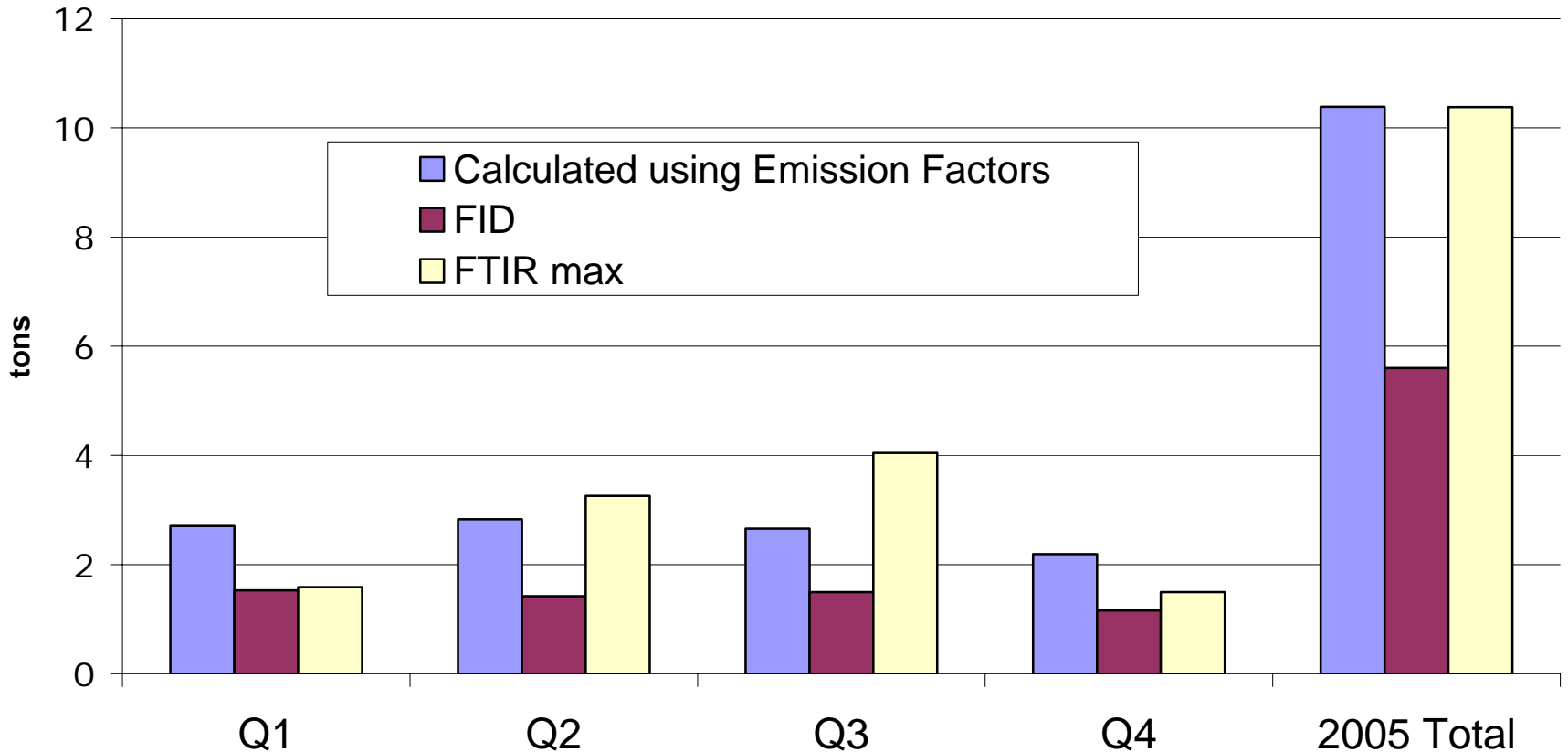
- Permit requires recordkeeping of all information used to calculate emissions
  - NMED reviews records during inspections
- Compliance Testing
  - Requirements set in permit
  - NMED typically observes

## Internal verification for HAPs & VOC emission factors

- Peer environmental engineers from all Intel sites review all changes made to emission factors
- Verification testing done at 1<sup>st</sup> high volume manufacturing site product taken to
- Quarterly review of data from each site running process



# NM Site Emissions Comparison Stack Emissions only 2005



FTIR Max - used detection limits to calculate emissions, detection limits vary each quarter, all VOCs non-detect except for methanol for Fab 11X Fab RTO stack

FID Data - reported as lbs propane and converted to lbs VOCs by assuming average mix of largest VOC constituents



# Summary

Emission factors used by Intel each quarter to calculate emissions

- Report submitted to NMED along with spreadsheets for their verification

Emission factors based on EPA data or Intel operating and testing data

Emissions verified

- Externally – data submitted to NMED, stack testing
- Internally – verification tool testing at manufacturing site, quarterly review of data



# Additional Information



# HAP & VOC Emission Factors Example Calculation

One process step uses 0.0025 lbs of Cl<sub>2</sub> per wafer

Results in emissions of both Cl<sub>2</sub> and HCl (formed as a byproduct)

Emissions testing on this step measured both of these pollutants and produced an average result of:

- $8.3 \times 10^{-5}$  lbs of HCl per wafer
- 0.0018 lbs of Cl<sub>2</sub> per wafer

The emission factor results would be:

- Cl<sub>2</sub> to HCl EF =  $(8.3 \times 10^{-5}) / (0.0025) = 0.03$
- Cl<sub>2</sub> to Cl<sub>2</sub> EF =  $(0.0018) / (0.0025) = 0.72$

In other words, every 100 lbs of Cl<sub>2</sub> used will generate 3 lbs of HCl emissions and 72 lbs of Cl<sub>2</sub> emissions

This type of information is then developed for every step which creates these emissions and an overall emission factor is developed

