REVIEW REPORT

Hynix Semiconductor Manufacturing America, Inc. **Permit No. 203531**

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1. General Background / Description

Hynix Semiconductor Manufacturing America, Inc. (Hynix) operates a facility at the above location where it manufactures integrated circuits (ICs) on prefabricated substrate wafers (specifically, dynamic-random access memory devices). Hynix was issued its original Air Contaminant Discharge Permit (ACDP) in May of 1996, which was initially issued under the Hyundai name. The facility normally operates continuously (8,760 hours per year).

As mentioned, Hynix produces ICs on prefabricated wafers. Processes used to form an IC on a substrate wafer include oxidation, photoresist, etching, doping, and layering. Additional processes include chemical mechanical polishing (CMP), solvent stations, wet chemical stations and wipe cleaning. The chemicals and solvents used in these processes generate emissions of volatile organic compounds (VOC) and hazardous air pollutants (HAP). The associated emissions control equipment includes wet and dry scrubbers, thermal oxidation and carbon adsorption.

Additional equipment supporting Hynix operations includes natural gas-fired boilers, oil-fired emergency generators and storage tanks. The following Table 1.1 summarizes Hynix operations as they relate to air quality.

Table 1.1 Process and Emissions Overview

Emission Unit	Regulated Pollutants Emitted	Control Devices
Fabrication Building (Five (5) Acid Fume Scrubbers)	Fluorides (as hydrofluoric acid), sulfuric acid mist, and HAPs*	5 CPSV-3060-4 Acid Fume Scrubbers; 4 Point-of-Use Controls (scrubbers, thermal oxidizers)
	VOCs	1 Durr Rotary Concentrator/Thermal Oxidizer System; 1 Barneby & Sutcliff Model P4 Carbon Adsorber (Backup)
5 Central Utility Bldg (CUB) gas-fired boilers with low-NO_X burners, 26.8 MMBtu/hr input each	PM_{10}, SO_2, NO_X, CO, VOC	None
2 Admin. Bldg. (gas-fired) boilers, 2.98 MMBtu/hr input each	PM_{10}, SO_2, NO_X, CO, VOC	None

Emission Unit	Regulated Pollutants Emitted	Control Devices
4 Emergency Generators (No. 2 oil fired), 2,876 bhp each	PM_{10}, SO_2, NO_X, CO, VOC	None

Note: Hazardous Air Pollutants under Title III of the 1990 Amendments to the Clean Air Act

2. Reasons for Permit Issuance

Hynix's permit is due for renewal. In addition to its permit renewal, Hynix has requested a permit modification for an increased permit limit for hydrogen fluoride (HF) from 1.8 tons per year to 5.0 tons per year. This request is based on a steady incline in production and shifts in raw chemicals coupled with the methods for calculating HF emissions. The Hynix modification request is only for an increased emissions limit for HF. No construction and/or changes in other permit limits are being requested.

3. New Source Review

In the course of re-examining the related issues, LRAPA found that the initial determination of New Source Review (NSR) under LRAPA Title 38 is not applicable. ***NSR does not apply*** based on the following: Hazardous Air Pollutants (HAPs) under Title III of the U.S. Clean Air Act (CAA), which include HF, are regulated on a *technology basis*, which contrasts regulation of criteria pollutants on an *impact basis* pursuant to the CAA. The same technology basis for regulating HAPs comprises the bulk of LRAPA Title 37, also reflecting federal rules stemming from the CAA. As given in the Federal Register, December 31, 2002, p. 80240, EPA explicitly excludes HF from the "fluorides" category of the Significant Emission Rate (SER) list, which matches the SER list of LRAPA Title 38 and ODEQ rules. The exclusion of HF from the SER for fluorides is consistent with both the LRAPA's and ODEQ's use of the same SER list, and the absence of any differing language in the local or state rules. EPA excludes Hazardous Air Pollutants (HAPs) from regulation under NSR at Title 40 CFR §51.166(b)(49)(iv).

4. Offsite Impacts of HF

4.1 ***Background***

Hydrogen fluoride (HF) is a colorless gas that, at Hynix, is emitted when gas-phase processes such as dry etching liberate fluorine to bond with other constituents. A portion of this fluorine bonds with hydrogen to form HF. HF is on the EPA list of Hazardous Air Pollutants (HAPs) under Title III of the Clean Air Act. HF is highly corrosive and reacts with moisture and in the presence of light. Owing to its instability, HF often dissociates to form salts such as calcium fluoride and sodium fluoride, as well as other compounds. HF is one part fluorine, which is an element found abundantly in nature. Like HF, fluorine is highly reactive and will bond with the vast majority of chemical elements.

4.2 ***Screen Dispersion Modeling (SCREEN3)***

The air quality impact of HF at the requested emission level was initially examined by running a SCREEN3 model using the proposed emissions limit for HF to estimate offsite concentrations. SCREEN3 is a first-step means for projecting offsite concentrations from air pollution sources and, therefore, is recognized as a conservative estimation tool. The collective input data for the subject model run represent a worst-case scheme. Actual offsite concentrations resulting from Hynix operations are likely to be lower than SCREEN3 modeling.

For the SCREEN3 model run, stack parameters were acquired from the permit application, and additional geographic data (plant property boundaries proximal to stack location) were gathered from available maps. Total emissions at the proposed limit of 5.0 tons per year were combined into one (1) of five (5) identical stacks using screening guidance from EPA-454/R92-019. The resultant maximum offsite concentration is given in the following Table 4.1.

Table 4.1 SCREEN3 Modeling Results

Maximum Offsite HF Concentration		
1-hour Avg ($\mu g/m^3$)	30-day Avg ($\mu g/m^3$)	Annual Avg ($\mu g/m^3$)
4.1	1.23 *	0.33 *

* Values adjusted from the 1-hour modeled result using EPA scaling guidance.

4.3 *Refined Dispersion Modeling (AERMOD)*

The public review period resulted in numerous comments expressing concern about non-human impacts of HF, particularly impacts on vegetation. On this basis, further modeling was deemed appropriate. Trinity Consultants, on behalf of Hynix, conducted a more refined model using **AERMOD**. AERMOD is an EPA-recommended dispersion model (see Title 40 CFR Part 51, Appendix A-W) that allows for a more detailed set of considerations, including complex terrain, if applicable, and specific, local meteorological data. Input data for AERMOD are collectively much more specific than SCREEN3. The following Table 4.2 summarizes the refined air dispersion modeling results. A modeling protocol was submitted by Trinity before AERMOD was run. The protocol was reviewed by LRAPA and found to adhere to EPA guidance for AERMOD. Modeling results were also reviewed and approved by LRAPA.

Table 4.2 AERMOD Modeling Results

Maximum Offsite HF Concentrations (Sensitive Areas Grid)		
24-hour Avg ($\mu g/m^3$)	Monthly Avg ($\mu g/m^3$)	Annual Avg ($\mu g/m^3$)
1.18	0.26	0.13

4.4 *Human Impacts*

Acute (short-term) effects of HF inhalation at significant levels include irritation to the eyes, skin and respiratory system. Inhalation of high levels of HF and/or chronic (long-term) inhalation at sufficient levels may result in heart damage and/or skeletal fluorosis.

LRAPA *Rules and Regulations* do not include ambient standards for toxic pollutants such as HF. The California Office of Environmental Health Hazard Assessment (OEHHA) lists an acute and a chronic inhalation reference exposure level (REL, non-cancer) for several pollutants, including HF and fluorides. A chronic REL is an airborne level that would pose no significant risk to individuals indefinitely exposed to that level (reference OEHHA literature and/or website at

www.oehha.ca.gov/air/chronic_rel/hyfluocrel.html).

An acute REL carries the same meaning, but applies to short-term exposure (1-hour average for the HF standard). The Oregon Department of Environmental Quality (ODEQ) has adopted the OEHHA chronic REL as an ambient benchmark for HF at OAR-340-246-0090. These standards are summarized in the following Table 4.3.

Table 4.3 HF Impact Thresholds – Human Inhalation

Regulatory Jurisdiction	Threshold Concentration ($\mu g/m^3$)	
	1-hr Avg Exposure	Annual Avg
California	240	14
Oregon	---	14

<u>*Summary and Conclusions -- Human Impacts*</u>

A comparison of the health standards of the above Table 4.3 with the modeling results given in Tables 4.1 and 4.2 indicates the modeled concentrations to be well below the health impact thresholds, indicating no adverse health impact.

4.5 ***Vegetative Impacts***

Gaseous HF can directly attack plant foliage, especially if present in high concentrations. In low concentrations, plant leaves can absorb HF. The most apparent effect of fluoride, including HF, is necrosis or tip burn, but exposure to fluoride in sufficient quantities also may result in growth abnormalities or a decrease in reproductivity in both plants and animals that consume plants effected by HF. Livestock that drink fluoride-contaminated water or eat contaminated foliage may have dental lesions, bone overgrowth, lameness, loss of appetite, a decrease in milk production, and reduced reproductivity.

No ambient air standards for vegetative impacts from HF or fluorides have been established in Oregon. A small number of regulatory jurisdictions have such standards. The following Table 4.4 summarizes those standards, and provides a basis for comparison against the modeling results. ***Based on the modeling results shown in Table 4.2 and the HF vegetative standards in the following Table 4.4, the permitted HF levels are within an acceptable range for the protection of vegetation.***

Table 4.4 HF Standards for Impacts on Vegetation

Regulatory Jurisdiction	Standard (µg/m^3)		
	24-hr average exposure	30-day average	Annual average
Ontario [1]	0.86	0.34	---
Quebec	---	---	0.4
Canada [2]	1.1	0.4	---
Wyoming	1.8	0.4	---
New York	2.85	0.8	---
Washington[3]	2.9	0.84	---

1 Ontario Ministry of the Environment (MOE); ½ hr Avg = 4.3 µg/m^3; standards listed are for the growing season (non-growing season standards are double those given here).

2 Canadian Council of Ministries of the Environment (CCME)

3 Washington Administrative Code (WAC) lists a growing season (6 mos) exposure standard of 0.5 µg/m^3.

Summary and Conclusions (Vegetative Impacts)

The ODEQ has adopted an ambient air "benchmark" for HF pertaining to human impacts (see Table 4.3), but no such guideline exists for vegetative impacts. In the absence of an Oregon standard for vegetative impacts, Table 4.4 summarizes standards from other regulatory jurisdictions that provide the basis for comparison with modeled offsite HF concentrations. The concentrations given in Table 4.4 are intended for protection against adverse effects on ***sensitive plant species*** and, in some cases, foraging animals. Many plant species have been shown tolerant to higher levels of airborne HF and/or fluoride exposure.

LRAPA regulations do not require determination of vegetative impacts for HF. Such a determination is only required under New Source Review (NSR), as discussed in the above Section 3. In its response to public comments, LRAPA compared the dispersion modeling results given in Table 4.2 to the vegetative standards for HF shown in Table 4.4. The results indicate that the 24-hour, monthly and annual average HF concentrations are within acceptable concentrations for those vegetative standards.

5. Facility Emissions

As mentioned, Hynix employs a range of processes and materials in the course of IC manufacture. However, three (3) general process categories originate air emissions. These are: fuel combustion of natural gas (boilers and a thermal oxidizer) and diesel fuel (emergency generators); liquid processes (VOC and acid gas emissions); and specialty gas processes (VOC and acid gas emissions). The following Table 5.1 summarizes estimated actual emissions at Hynix.

Table 5.1 Current Actual Emissions (tons/yr)

Source	PM_{10}	SO_2	NO_X	CO	VOC	HF	HCl	H_2SO_4
Fabrication Process Acid Scrubber Stacks	NA	NA	NA	NA	3.1	1.8	0.3	0.1
Fabrication Process VOC Abatement System Stack	NA	NA	0.8	0.6	3.5	NA	NA	NA
Gas-fired Boilers	2.0	0.2	6.9	21.7	3.3	NA	NA	NA
Totals	**2.0**	**0.2**	**7.7**	**22.3**	**10.2**	**1.8**	**0.3**	**0.1**

NA refers to emissions less than one (1) ton per year

5.1 *Volatile Organic Compounds (VOCs)*

Emissions of VOCs are generated from both fuel combustion and manufacturing processes. Fuel combustion emissions, including VOCs, are summarized in the following section (*Fuel Combustion Emissions*) and Table 5.1.

The balance of VOC emissions originate from ***liquid process materials*** such as photoresist materials (including more than a dozen chemicals) and isopropyl alcohol (IPA), and ***VOC-containing process gases*** such as tetraethyl orthosilicate (TEOS), trimethyl borate (TMB), and trimethyl phosphate (TMP). VOC emissions originating from liquid process materials are all routed to, and controlled at, the rotary concentrator/thermal oxidizer. VOCs originating from process gases are controlled with point-of-use control equipment, the exhausts of which are then routed to the plant acid scrubber.

5.2 *Fuel Combustion Emissions*

Each of the five (5) CUB boilers is rated at 26.8 x 10^6 Btu/hr input capacity and each of the two (2) administrative building boilers is rated at 2.98 x 10^6 Btu/hr, for a total input capacity of 140 x 10^6 Btu/hr. Actual operating input is a small fraction of total capacity (normally about 20 x 10^6 Btu/hr). All seven (7) boilers are fired on natural gas, and air emissions are typical of natural gas-fired boilers. Boiler emissions are summarized in the following tables. Emission calculation methods are further described in Attachment B of the permit and are based on factors from the boiler manufacturers.

The facility's thermal oxidizer burns natural gas and emissions are calculated based on AP-42 and hours of operation, also described in Attachment B of the permit. Four (4) emergency generators are driven by internal combustion engines, which operate on No. 2 fuel oil. Each of these engines is rated at 2,876 brake horsepower. Normally these units are operated monthly for a brief period, solely to ensure their operational integrity and to reveal any maintenance concerns. Emissions are typical of diesel engines, but are not included in the following tables due to their exemption from PSELs in accordance with LRAPA 34-060-3.

5.3 Emissions from Process Gases

Five (5) ***organic gases*** are used in the diffusion and thin film processes. Three (3) of these generate volatile organic compound (VOC) emissions and are treated with point-of-use control devices comprising wet scrubbers and a scrubber/thermal oxidizer (CD-4.1 & CD-4.2). A fourth gas, dichloroethane (DCE), is converted in process to hydrogen chloride (HCl) and CO_2. These gases are vented through the facility wet acid scrubber system, which was demonstrated to have a control efficiency of 85% (for HCl) at the time of compliance testing. The fifth gas, trimethyl aluminum, is highly reactive in air and therefore contributes negligible emissions.

Fifteen (15) ***inorganic gases*** contain fluorine or chlorine (the aforementioned DCE is the single gas containing chlorine). In the course of production, emissions of fluorides (chiefly HF) and chloride are generated. The gas quantities converted to HCl are determined based on available chlorine in the reactant gases. All available chlorine is assumed to be converted to HCl, in the absence of a reasonable method for determining the fraction going to Cl_2. Hynix personnel hope to access such a method in the future. At present, HCl emissions estimates are understood to be conservative. The quantities of fluorine-bearing gases that convert to HF are determined using methodology given in **permit Attachment C** (Chapter 3, Section 3.6.1 from *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, a document from the Intergovernmental Panel for Climate Change). Essentially, a fraction of the reduced fluorine is allocated (stoichiometrically) as fluorinated greenhouse gases, the balance is understood to produce HF. Emissions from process gases are summarized in the following tables.

5.4 *Wet Station Emissions*

Hynix uses aqueous acid and caustic stations for select processes. Vapors from these processes are routed through either of two (2) control systems, the acid exhaust system (5 wet scrubbers) or the ammonia/caustic exhaust system (2 wet scrubbers). Recently it was realized that the only appreciable emissions here occur at those stations that are heated, comprising those that generate sulfuric acid (H_2SO_4) emissions. Estimations of these emissions are based on 1999 test results, which are further described in Attachment B to the permit. Acid emissions from wet stations are summarized in the above Table 5.1.

5.5 *Hazardous Air Pollutants (HAPs)*

A summary of the current estimated plant-wide emissions of Title III HAPs is given in the following Table 5.2. These are based on the compliance submittal of March 2006, which covered calendar year 2005. Emission limits are provided in the permit for hydrochloric and hydrofluoric acids, but not as PSELs in accordance with LRAPA 34-060-6A&B.

Table 5.2 2005 Estimated Emissions of HAPs

Pollutant	Estimated Actual Emissions (tons/yr)
HF	1.78
HCl	0.31
Chlorine	1.96
Catechol	0.05

Pollutant	Estimated Actual Emissions (tons/yr)
Phosphine	0.0004
Arsine	0.0006
Total HAPs (tons/yr)	**4.1**

6. Plant Site Emission Limits (PSELs)

In accordance with LRAPA 34-060-5.G., PSELs are based on projected operating conditions, as reflected in the permit application. The following Table 6.1 summarizes the PSELs as they appear in the proposed permit, while Table 6.2 gives a comparison of PSELs to significant emission rates (SERs). It should be noted that, because this facility was not in operation until well after 1978, baseline emission rates (BERs) for all pollutants are zero (0).

Table 6.1 Annual PSELs (tons/yr)

Source	PM_{10}	SO_2	NO_X	CO	VOC	H_2SO_4
Fabrication Process Acid Scrubber Stacks	NA	NA	NA	NA	5	1
Fabrication Process VOC Control System Exhaust	NA	NA	1	1	16	NA
5 CUB Gas-fired Boiler Stacks	2	1	7	22	4	NA
Totals	**2**	**1**	**8**	**23**	**25**	**1**

NA refers to emissions less than one (1) ton per year

Table 6.2 Comparison of PSELs with SERs *

Pollutant	Limit (tons/yr)	SER (tons/yr)
PM_{10}	2	15
SO_2	1	40
NO_X	8	40

Pollutant	Limit (tons/yr)	SER (tons/yr)
CO	23	100
VOC	25	40
Sulfuric Acid Mist	1	7

* Baseline emission rates are all zero (0). HF is not included under fluorides because it is a HAP, and HAPs are excluded from the fluorides SER as discussed in the above Section 3.

7. Additional Performance Standards and Emission Limits

HF and HCl are given permit limits (5.0 tons per year and 0.5 tons per year, respectively) separate from the PSEL section of the permit in accordance with LRAPA 34-060-6, which addresses PSELs and HAPs.

The permit limits natural gas usage in the five (5) CUB gas-fired boilers to 394,000,000 cubic feet per year. Hynix agreed to this limit, prior to this renewal, as an emissions reduction measure. The PM limit of 0.1 grains per dry standard cubic foot is the emission limit for new combustion sources in LRAPA Title 32. The permit limits the total operating time for each emergency generator to 500 hours per year. This is consistent with EPA guidance on estimating the potential to emit for emergency generators and is based on the maximum expected usage for such generators.

LRAPA's process weight rule specifies limits on the emissions of PM for specific processes as a function of process throughput (LRAPA 32-045-A.). Because PM emissions, other than combustion emissions, are not expected from semiconductor manufacturing, LRAPA 32-045-A does not apply to the source.

8. New Source Performance Standards (NSPS)

Hynix's five (5) CUB boilers, which were installed in 1997 and are each rated at 26.8 x 10^6 Btu/hr, are subject to the New Source Performance Standard (NSPS) at Title 40 CFR Subpart Dc (§§60.40c - 60.48c) – Small Industrial-Commercial-Institutional Steam Generating Units. Because these boilers are fired on natural gas, the only applicable requirements are §60.48c (fuel usage record keeping).

9. New Emission Standards for Hazardous Air Pollutants (NESHAP)

Hynix's potential to emit (PTE) hazardous air pollutants (HAPs), given its physical and operational limits, is estimated to be 7 tons per year (combined HAPs). This is below the Title V Major Source thresholds of 10 tons per year of any single HAP and 25 tons per year of combined HAPs. Therefore, Hynix is not subject to the NESHAP for Semiconductor Manufacturing (Title 40 CFR Part 63 Subpart BBBBB).

10. Operation and Maintenance Requirements

The facility is required to maintain an operation and maintenance (O&M) plan covering the acid fume scrubbers, rotary concentrator/thermal oxidizer, and carbon adsorber. The O&M Plan must identify control device operating parameters for each device and the associated values necessary to assure compliance with the conditions of the permit.

As a result of public comment, the permit conditions require the O&M plan to be based on compliant levels of operation established by an initial performance test and subsequent semiannual testing.

11. HF Emissions Control System Performance

Hynix uses packed-bed wet scrubber systems for controlling acid emissions, including HF. Based on reviews conducted by both LRAPA and Hynix, wet scrubber systems are an industry standard for this application. Additionally, the aforementioned NESHAP for semiconductor manufacturers gives an inorganic HAP emission control system standard (for performance test compliance demonstration) of 95% control efficiency ***or*** 0.42 ppmv (see Title 40 CFR 63.7184(c)). The referenced testing of Hynix's scrubber system in 1999 gave results of <0.24 ppmv total inorganic HAP. Although the NESHAP does not apply to the subject Hynix facility, the 1999 test demonstrated compliance with this performance standard.

The permit requires initial performance testing of the wet scrubber systems that control HF emissions followed by semi-annual testing to verify continued control of HF and assess mass emission rates (see performance testing).

12. Typically Achievable Control Technology (TACT)

LRAPA Title 32 requires an existing source to meet TACT if the source is required to have a permit and has emissions of greater than 5 tons per year of PM_{10} or 10 tons per year of VOC, NO_X, SO_2, or CO (LRAPA 32-008-1.C.). With regards to the projected emissions from the facility, these criteria are satisfied only for VOC emissions from the semiconductor manufacturing process. Therefore, the source (fabrication building) should be required to meet TACT for VOC emissions. The VOC abatement system, which consists of a rotary concentrator/thermal oxidizer and a carbon adsorption system as backup, meets TACT.

13. Pollution Prevention

Hynix is a hazardous waste generator and, therefore, is subject to the requirements of the Toxic Use and Hazardous Waste Reduction Act (TUHWRA). Although this regulation does not pertain directly to air quality, it encompasses sources of toxic pollution in all media. It is included in the text of the permit to ensure public access to related information under this statute. Insofar as Hynix's effort to prevent pollution, the rule requires subject sources to maintain a plan or program to demonstrate this pursuit. Compliance with this statute is demonstrated to the Hazardous Waste Section of the Oregon DEQ.

14. Compliance History

Hynix had incurred no enforcement action prior to the December 31, 2006 expiration date of the current permit. A review of the Hynix Monitoring files revealed 12 complaints over the history of the facility. The most recent of these, Complaint No. 12892 (6/1/2005), alleged visible emissions from the wet acid scrubber stacks for about five (5) minutes. In the course of the investigation, two (2) of the five (5) stacks were observed on recorded video to show detectable opacity. Continued investigation, which included observations of recorded parametric data at Hynix, revealed inadequate support for enforcement action.

On May 8, 2007, LRAPA issued Notice of Non-Compliance (NON) 2925 to Hynix for the exceedance of its 1.8 ton per year plant site emission limit for HF. Based on the current permit HF emission factors, Hynix emitted 2.06 tons per year HF in calendar year 2006, exceeding the limit by

0.26 tons per year HF. Based on the most recent emission factors (see Permit Attachment B), Hynix exceeded the HF permit limit by 0.39 tons in calendar year 2006. LRAPA issued a Notice of Civil Penalty Assessment Number 07-2926 to Hynix on July 25, 2007, for $800. Hynix paid the civil penalty, closing the case.

Permit limits have been placed on Hynix that require HF emissions be assessed on at least a semiannual basis. In addition, within six-months of permit issuance, the permit conditions require Hynix to have quarterly production recordkeeping in place to track and forecast its compliance status with the annual HF limits.

15. Performance Testing

Hynix was originally required to conduct stack testing at the exhausts of the acid fume scrubbers, and VOC abatement system (rotary concentrator/thermal oxidizer). The performance test results of 1999 demonstrated compliance with permit limits. In addition, these results provided the basis for establishing control system efficiencies based on pollutant quantities at the inlet and outlet of the thermal oxidizer and wet scrubbers.

The aforementioned testing was conducted to demonstrate compliance and as a baseline for establishing emissions rates reflecting representative operations at Hynix. Comparable testing is required to be performed once during the permit term. This requirement ensures the effective operation of the acid fume scrubbers and the rotary concentrator/thermal oxidizer. The test requirement for the plant scrubbers cites HF, HCl and H_2SO_4. The test requirement for the rotary concentrator/thermal oxidizer cites VOCs. These test requirements are equivalent to those for the testing performed in 1999.

In addition to testing all pollutants once during the permit, the permit limits require Hynix to test for HF emissions on at least two (2) scrubbers on a semiannual basis. The scrubbers will be tested on a rotating basis. The semiannual testing plan and units selected for testing are subject to LRAPA approval.

16. Control Equipment Destruction and Removal Efficiencies (DREs)

The permit requires that the source estimate annual emissions of hydrofluoric acid, sulfuric acid, hydrochloric acid, and VOCs based on source tested emission rates at the acid fume scrubbers and rotary concentrator/thermal oxidizer.

17. Monitoring and Continuous Compliance

Continuous compliance is ensured by a combination of applying emission factors to materials and fuel usage, periodic reporting, and adherence to the permittee's O&M plan.

18. Accidental Release

Hynix uses hydrofluoric acid, which is received in aqueous solution at a concentration of 49% in 55-gallon drums. Hydrofluoric acid is a Regulated Toxic Chemical listed in Table 1 of Title 40 CFR Subpart A, §60.130. The Table 1 threshold concentration is 50%. Because hydrofluoric acid is used at a concentration of 49%, the rule is not applicable.

19. Public Notice

This permit was open for public comment from November 17, 2006 through March 31, 2007. The permit was placed on public notice from November 17, 2006 to December 19, 2006 by advertisement in the Eugene Register-Guard. A public hearing was requested on December 7, 2006. The public hearing notice appeared in the Eugene Register Guard on January 9, 2007, for the hearing to be held on February 12, 2007, with the public comment period to end on February 13, 2007. Twenty-five (25) citizens attended the hearing, and five (5) provided oral testimony. At the time of the hearing, the public requested an extension on the public comment period, which was granted, and the comment period was extended to March 15, 2007. Additional request(s) for continuance were granted and the comment period was extended to March 31, 2007. A total of 275 people submitted comments. Issues expressed during public review, and the LRAPA's responses, are described in the following Section 20. Actions taken by the LRAPA following consideration of public review are described in the subsequent Section 21.

20. Public Comments and Responses

The following is a list of the substantial issues raised during the public comment period, with responses, in accordance with Title 14-120-4 of LRAPA's *Rules and Regulations*.

20.1 Request for Public Hearing and Extensions to the Public Comment Period: The Oregon Toxics Alliance requested a public hearing in a letter dated 12/7/06. Several requests were made to extend the public comment period. Greg Slowik requested another public hearing in an e-mail on 3/29/07.

Response: The public comment period began on November 17, 2006. Based on the request for a public hearing, the hearing was arranged and held on February 12, 2007. Based on multiple requests for continuance following the public hearing, the public comment period was extended to March 13, 2007. No additional extensions or hearings were granted in accordance with Title 34-130-5 of LRAPA's *Rules and Regulations*.

20.2 Additional Offsite Impact Considerations: A total of eight (8) comments expressed concerns about air quality impacts of hydrogen fluoride (HF), most notably on vegetation, but also concerning multiple pathway risks (risks resulting from pollutants deposited in soil or water and/or risks resulting from interaction with other pollutants). More than one of the commenters cited quantitative concentrations at which adverse impacts on certain plant species and/or foraging animals could be expected.

Response: LRAPA requested that Hynix re-examine the offsite impacts including the next level of air dispersion modeling. Hynix performed the modeling and the offsite impact analysis. The results are summarized in Table 4.2 of this report. The modeling results described in Section 4 of this report indicate no significant offsite impact.

HF is not a suitable candidate for multiple pathway risk analyses based on its physical/chemical properties, according to Bruce Hope, Toxicologist for the Oregon Department of Environmental Quality (ODEQ). This assertion is supported by the ODEQ's work in establishing the ambient benchmarks for toxic pollutants. HF breaks down readily and forms bonds with most other elements. Its defining element, fluorine, is pervasive in nature in many forms. Therefore, establishing the origin of fluoride compounds is difficult.

20.3 Adequacy of Emissions Controls: A total of ten (10) comments expressed concern relating to emissions control technology at Hynix and questioned what emissions control measures are used at comparable plants. Additionally, more than one commenter suggested that the frequency of stack testing is inadequate.

Response:

Control Systems -- Hynix uses five (5) packed-bed wet scrubbers to control acid emissions, including HF. This type of system has been used to meet Best Available Control Technology (BACT) requirements. Additionally, the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Semiconductor Manufacturing requires scrubbers as maximum available control technology. Although ***Hynix is not subject*** to this federal rule because its HF emissions are not great enough, the scrubber systems at Hynix are consistent with the requirements of the NESHAP.

Test Frequency – The purpose of testing is to demonstrate compliance with emission limits and to ensure the effective operation of the control equipment. The permit requires testing every five (5) years. This is more frequent testing than that required by the semiconductor NESHAP rule (the NESHAP requires testing to be performed only at start-up or within six (6) months of the effective date of the rule). The following *comparable facilities/permits* section provides further information on the adequacy of the testing requirements.

Additionally, in response to public comment, LRAPA added permit requirements for semiannual testing and the establishment of optimal scrubber parameters that must be included, and followed by operators, in the facility's maintenance and operation (M & O) plan.

Comparable Facilities/Permits -- As a comparison to similar operations, the LRAPA gathered the following information:

- LRAPA contacted the Oregon Department of Environmental Quality (ODEQ) concerning the air quality permit for the Intel integrated circuit plant in Hillsboro, Oregon. Based on the Intel permit and conversations with ODEQ, systems for controlling HF and other acids at Hynix are similar to the packed-bed wet scrubbers at Intel. Hynix systems and requirements appear to be at least as effective/stringent as the ODEQ permit requirements for Intel.

- LRAPA contacted the Bay Area Air Quality Management District (BAAQMD), which regulates several semiconductor manufacturers. In an e-mail follow-up on 3/19/07, a permit engineer said that HF is not heavily regulated; scrubbers are used as control devices, but not required by permit. HF emissions are not quantified by the BAAQMD because they are controlled by scrubbers and believed to be negligible. The HF emissions at Hynix are controlled at least as well as comparable facilities regulated by the BAAQMD.

- LRAPA contacted the Puget Sound Clean Air Agency (PSCAA) in Washington State. This jurisdiction has a single, but inactive, semiconductor manufacturing facility (Microchip Technology Incorporated). The construction permit for this facility cites requirements similar to those in the Hynix permit. The PSCAA construction permit conditions limit emissions of HF to no more than 4.86 tons per year. Wet scrubbers are required for controlling HF. Hynix systems and requirements appear to be comparable to those of the PSCAA permit for Microchip Technology Incorporated.

- LRAPA contacted the Virginia Department of Environmental Quality (VDEQ) concerning a semiconductor manufacturer in Manassas, VA (Micron Technology, Inc.). The permit includes emission limits for HF, and requirements to control these emissions with wet packed bed scrubbers. The permit does not require testing of the scrubbers. No offsite impact analysis was performed for this facility. Hynix systems and requirements appear to be at least as effective/stringent as the VDEQ permit requirements for Micron Technology, Inc.

- LRAPA contacted the Idaho Department of Environmental Quality (IDEQ) concerning a semiconductor manufacturer in Nampa, ID, near Boise (Micron Technology, Inc.). IDEQ stated that this facility is subject to the federal NESHAP for semiconductor manufacturers. Micron Technologies uses wet scrubbers to control HF. Hynix systems and requirements appear to be at least as effective/stringent as the IDEQ permit requirements for Micron Technology, Inc.

20.4 Concerns Based on Toxic Effects: A total of 254 comments expressed varying degrees of concern and/or opposition relating to the proposed increase in emissions, several on the basis of toxic effects, particularly health effects. A few commenters suggested a link between cancer and HF exposure.

Response: In Section 4 of the review report, LRAPA examined the potential human health impact of offsite HF concentrations given the proposed emissions level. This analysis showed no significant adverse impact. Additional dispersion modeling was performed by Hynix to further examine offsite impacts, most notably impacts on vegetation. The modeling results indicate no adverse impacts on human health or vegetation.

LRAPA considered the specific HF concentrations provided by Dr. Paul Engelking and others. Hynix performed additional air dispersion modeling to further examine the concern regarding offsite impacts cited in these comments (See results of Tables 4.1 and 4.2).

The Hynix permit review, specifically the dispersion modeling and risk analysis, pertains to non-cancer risk. The scientific evidence has not established a link between HF exposure and cancer.

20.5 HF Emissions and Greenhouse Gases: One (1) comment expressed concern that emissions of both HF and PFC (perfluorocarbons, greenhouse gases) be minimized, rather than lowering PFC at the cost of raising HF.

Response: Hynix has expressed its intention to lower its use of fluorinated compounds in general. The company described its intention to continuously look for ways to better control HF emissions, such as point-of-use control devices, when feasible, and to maintain all of its emissions control systems. Hynix also acknowledges increased production over the years. The company explained that market forces constantly necessitate changes in the types of products made. Additionally, the IPCC made a recent change in the method for calculating PFC's, which also effects HF emissions determinations. Such a change in methodology changes the emissions determinations based on better scientific understanding.

20.6 Testing and Minimizing Emissions: One (1) comment expressed concern that Hynix be held to the "absolute minimum output of all potentially harmful emissions," and that LRAPA not "rely on Hynix to do the only stack tests."

Response: The impact of HF emissions at the level proposed by Hynix has been reviewed by LRAPA (see Section 4 of this review report). This review includes air dispersion modeling and the results indicate no significant offsite health risk at the maximum proposed HF emission rate at Hynix.

As part of the permit renewal requirements, Hynix will be required to perform a stack test to demonstrate compliance with the permitted HF emission rate limit. LRAPA requires Hynix to submit a source test plan and receive approval in advance of any testing. An independent, professional, testing firm that adheres to the required test procedures must perform the testing. The test plan must demonstrate that the procedures, sampling and laboratory analysis will follow the methods in the Oregon DEQ (ODEQ) *Air Quality Source Sampling Manual*. LRAPA representatives observe source tests to ensure adherence to testing requirements and operating requirements during testing.

Before accepting reported test results, LRAPA evaluates the raw data, operating parameters, calculations and laboratory analyses to ensure testing meets the terms prescribed by the ODEQ *Air Quality Source Sampling Manual*. The LRAPA monitoring staff that reviews the test plans and results has expertise in performing and evaluating source tests. Hence, the compliance determination relies not on Hynix, but on LRAPA observation and review of the test data.

Testing oversight and LRAPA approval of test plans are also requisite to the semiannual testing that Hynix must perform on the scrubbers.

20.7 Emissions, Emissions Control and Safety: One (1) comment expressed concern about emissions of perfluorocarbons (PFCs), the overall emissions quantities, and the potential adverse impact on the area surrounding Hynix.

Response: Although LRAPA does not regulate PFCs, this class of compounds contributes to global warming and Hynix uses a method of calculating PFCs in the course of determining emissions of HF. The determination of both HF and PFC emissions relate to the "fate" of available gaseous fluorine. This determination is made using a segment of a document published by the Intergovernmental Panel on Climate Change (IPCC) -- *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.* This document provides a means of determining greenhouse gas formation from available fluorine. The methodology attributes a fraction of the available fluorine to greenhouse gases and the balance is assumed to form HF. Because Hynix uses a method of calculating HF that includes PFC quantities, these quantities are included in the annual reports. For reporting year 2005, Hynix estimated emissions of 19.7 tons of PFCs.

20.8 Alternatives to HF for Electrochemical Etching: One (1) comment provided literature citing alternative materials suitable for etching in the course of semiconductor production.

Response: The referenced research, which cites etching alternatives in the liquid phase, was passed to Hynix personnel for their consideration. HF emissions at Hynix result from gas-phase processes, however. Additionally, HF gas is not a raw material at Hynix, but is formed when gases such as NF_3 and CH_4 dissociate and provide available fluorine for the formation of HF. These emissions are routed through the scrubber control system.

20.9 Monitoring Near the Hynix Plant: One (1) comment suggested monitoring should be performed near Hynix.

Response: Hynix performed further dispersion modeling to better address offsite impacts of HF emissions. Dispersion modeling is the standard of analysis for review of permitting situations of this kind. It is approved by and discussed extensively by the U.S. EPA for the review of permitted sources of air emissions. (See preferred/recommended models at http://www.epa.gov/scram001/guidance_permit.htm.)

20.10 Support for Hynix: One (1) comment expressed support for Hynix and its economic contribution to the community. One commenter also suggested that actual emissions measurements should be taken and possibly further measures taken to control emissions.

Response: The permit includes periodic stack testing to measure emissions from Hynix. LRAPA has added monitoring requirements pertaining to scrubber operation to ensure the effective control of acid emissions, including HF.

20.11 Hynix Comments: Hynix submitted written comments on February 28, 2007. In the comments, Hynix described the reasons for the request for increased HF emissions. In summary, production has increased, accounting in part for the request. Secondly, the determination of the fate of fluorine, specifically how much of it becomes HF versus greenhouse gases, has changed recently, thereby elevating the amount attributed to HF.

Hynix also commented that additional testing, beyond what is specified in the permit, must have justification. The comments outlined the scrubber control systems and the measures taken to ensure continued scrubber effectiveness.

Hynix disagrees with the alleged vegetative damage, specifically damage to lichens, as attributable specifically to the HF emissions from its operations. Hynix argued that lichen damage is associated with general urban pollution, but not with a specific stressor. The condition of lichen, they stated, is an unreliable basis for analysis.

LRAPA Response: LRAPA has considered the concerns expressed relating to the effective operation of control systems. The agency intends for any permit, including that of Hynix, to include requirements that ensure control system effectiveness. Hynix has conducted additional dispersion modeling as discussed in Section 4 of this review report.

20.12 Biological Monitoring: One (1) comment called for monitoring to examine biological impacts. Several similar comments were made suggesting soil and/or water sampling and monitoring. In its written comments, the Oregon Toxic Alliance (OTA) suggested such monitoring. The OTA stated, “LRAPA should require Hynix to perform in situ biological monitoring. This is necessary to determine whether the HF emitted by Hynix thus far has damaged the vegetation and animals of the wetlands west and southwest and to the forested areas to the south of the facility. The updated information would establish a new baseline to evaluate any future detrimental effects of HF emissions.” The OTA continued, “Furthermore, Dr. Paul Engelking, an LRAPA advisory board member, gave testimony on HF’s damage to vegetation. LRAPA should give his testimony foremost consideration.”

Response: The topic of adverse impacts of HF and fluorides on plant species was considered and discussed within LRAPA, and with Hynix. Dr. Engelking’s comments were given considerable attention by LRAPA for the additional review of the offsite emissions impact on vegetation. Hynix performed additional dispersion modeling to better clarify the offsite impacts (see Section 4 of this review report).

20.13 Transport, Handling and Storage of HF: One (1) comment expressed concerns relating to how HF is delivered to the Hynix site, how it is stored, what effect the proposed HF emissions increase will have on these aspects, and the possibility of an industrial accident.

Response: LRAPA has no direct authority in the areas of materials transport, handling and storage. However, LRAPA would expect to be notified in the event of an incident resulting in excess emissions. As explained in Section 18 of this review report, Hynix is not subject to the federal requirements pertaining to accidental release under Title 40 CFR 60.130.

20.14 Reduction of PFC Emissions: One comment from Mr. Fred Hamlin asked about methods of realizing a 10% decrease in PFCs as directed by the World Semiconductor Council. Mr. Hamlin stated, “How are other plants making this reduction to comply with the 2010 deadline?”

Response: As mentioned, LRAPA does not have authority to regulate PFCs. However, the Semiconductor Industry Association, with which Hynix is affiliated, has agreed to a 10% reduction in PFCs by 2010. More information on this and other semiconductor industry issues can be found at: http://www.sia-online.org .

21. Summary of LRAPA Actions Based on Public Comments

Below are the key LRAPA actions taken based on public comments. For a more complete description of the LRAPA's responses to comments, considerations of comments, as well as related details, see Sections 4 and 20 of this review report.

21.1 Toxic Impacts: To address the concerns regarding offsite impacts of HF, LRAPA asked Hynix to examine vegetative impacts, including performance of more refined dispersion modeling. LRAPA reviewed the available literature, particularly that provided by Dr. Paul Engelking. Studies were identified in which HF impacts on plant species were examined, and threshold concentrations established. This further work allowed for comparison of modeling results to more stringent ambient air standards to protect plant species. No such standard for HF exists in the state of Oregon. However, standards for HF that cover vegetative impacts were identified from other air quality jurisdictions in North America. The full description of considerations and actions taken on this comment, including modeling results and discussion of these results, is given in Section 4 of this review report.

21.2 Adequacy of Emissions Controls: This issue encompasses control systems, test frequency and the operation of comparable semiconductor manufacturing facilities, all of which are discussed in Section 20.3 of this review report.

Conclusion: LRAPA expanded the permit conditions to further monitor continued effective operation of the scrubber control systems in response to public comments (see permit Conditions 25, 26 and 27). Based on the Federal NESHAP for semiconductor facilities and the review of comparable permitting of semiconductor facilities in other jurisdictions, the requirements of the Hynix permit provide comparable stringency to ensure effective control of emissions. In addition to testing all pollutants once during the permit, the permit limits require Hynix to test for HF emissions on at least two (2) scrubbers on a semiannual basis. The scrubbers will be tested on a rotating basis. The semiannual testing plan and units selected for testing are subject to LRAPA approval.

In addition, permit conditions have been added that require HF emissions be assessed on at least a semiannual basis. Further, within six (6) months of permit issuance, the permit conditions require Hynix to have quarterly production recordkeeping in place to track and forecast its compliance status with the annual HF limits.

21.3 New Source Review (NSR): As explained in the above Section 3, LRAPA found upon re-examination of the regulatory issues that NSR does not apply. Therefore the review report and permit were changed to reflect this determination.

21.4 Additional Limitations and Requirements: In the course of considering public comments, LRAPA found merit in adding semi-annual testing requirements and emission tracking for hydrogen fluoride (HF). These requirements are found in Conditions 27 and 31.

21.5 Biological Testing: As described in the 3rd paragraph of the above comment, Section 20.12, LRAPA is continuing its pursuit of the details surrounding possible studies of lichens as an indicator of HF emissions near Hynix. A botanist who has worked with the U.S. Forest Service has proposed an initial area assessment of lichens near Hynix as Phase 1 of such a study. The field work was completed in August of 2007, with a report describing the findings to follow. The report is expected to include recommendations addressing the merits of further study and analysis.

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