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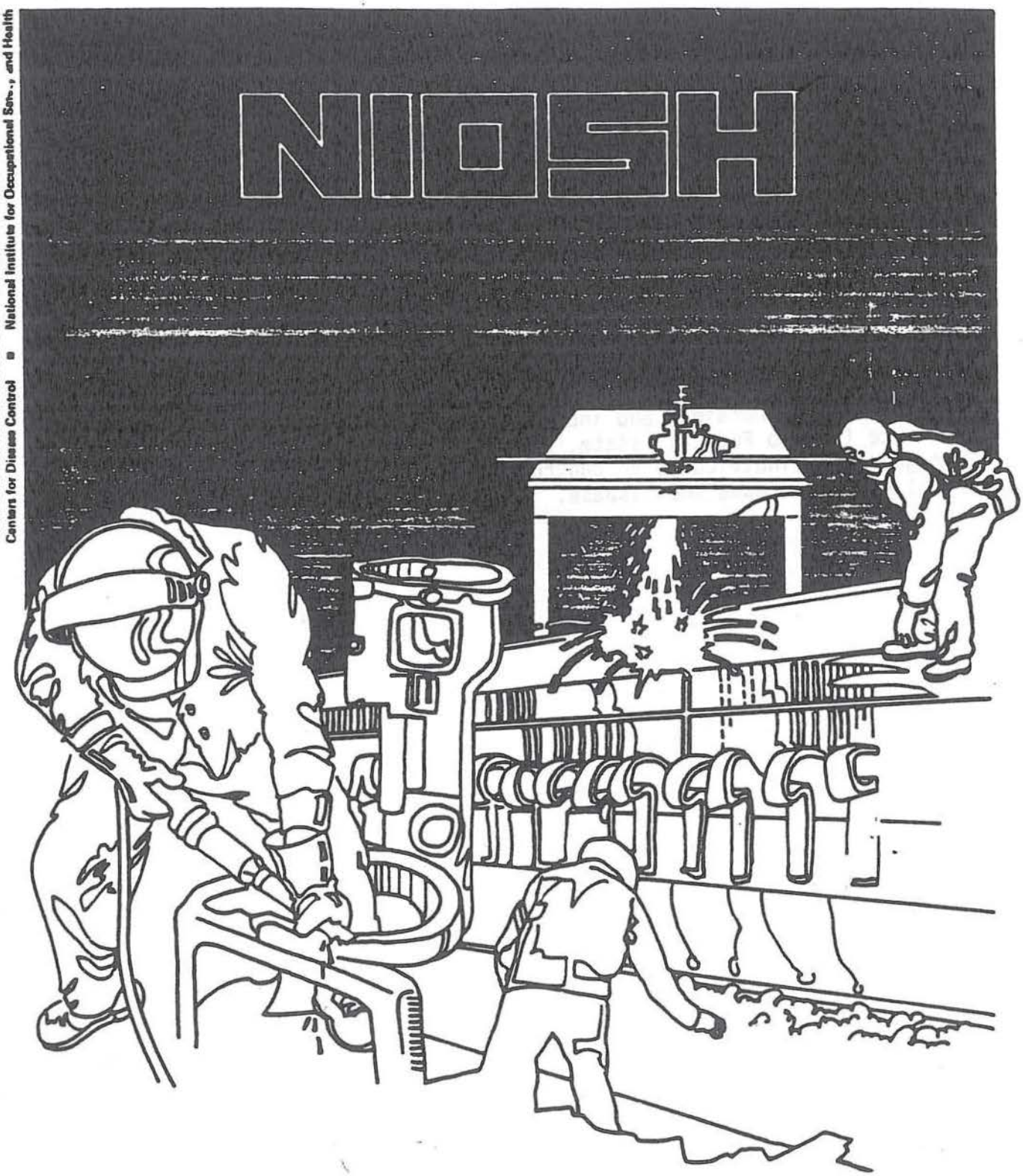

Health Hazard Evaluation Report

HETA 81-319-1114
INMOS CORPORATION
COLORADO SPRINGS, COLORADO

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May 1982

NIOSH INVESTIGATOR:
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I. SUMMARY

In May 1981 the National Institute for Occupational Safety and Health (NIOSH) received a request from the INMOS Corporation, Colorado Springs, Colorado, to evaluate the chemical and physical hazards throughout this semiconductor plant.

On July 15, 1981, a NIOSH Industrial Hygienist collected breathing zone and general room air samples for normal butyl acetate, cellosolve acetate, xylene, and isopropanol, and general room samples for hydrogen fluoride. All samples were either below laboratory detection limits or well within the evaluation criteria established for this report. The values of these samples were: n-butyl acetate samples ranged from less than 0.01 milligrams per sample to 23.3 mg/M^3; cellosolve acetate samples from 0.16 to 75.0 mg/M^3; xylene samples from less than 0.01 mg/sample to 18.3 mg/M^3; isopropanol samples from less than 0.01 mg/sample to 1.80 mg/M^3; and hydrogen fluoride samples were all below detection limits of 0.005 mg/sample. On September 17, 1981, general room air samples were collected for n-butyl acetate, cellosolve acetate, xylene, and hydrochloric acid (HCL). All samples taken for n-butyl acetate, xylene, and hydrochloric acid were below detection limits of 0.01 mg/sample. Cellosolve acetate sample values were 2.5, 4.2, and 1.7 mg/M^3--well below the evaluation criteria of 270 mg/M^3. On September 30 and October 1, 1981, general room air samples were collected for hydrogen peroxide; values were 0.33, 0.13, and 0.04 mg/M^3, below the evaluation criteria of 1.4 mg/M^3. Breathing zone and general room air samples were also collected on September 30 and October 1, 1981, for arsenic, sulfuric acid, crystalline silica and total particulate. Arsenic and crystalline silica samples were below laboratory detection limits. Sulfuric acid samples ranged from less than 0.005 mg/sample to 0.11 mg/M^3, well within the evaluation criteria of 1.0 mg/M^3. Total particulate samples were all less than 0.01 mg/M^3; the evaluation criteria is 5.0 mg/M^3. On October 28, 1981, general room air concentrations of nitric acid and phosphoric acid were determined. Values for nitric acid samples ranged from less than 0.004 mg/sample to 2.5 mg/M^3; the evaluation criteria is 5.0 mg/M^3. Phosphoric acid samples values ranged from less than 0.03 mg/sample to 0.06 mg/M^3; the evaluation criteria is 1.0 mg/M^3.

Radiofrequency (RF) measurements were performed on September 29, 1981. All RF operators were monitored for RF exposure at the face, chest, hands, groin, thigh, knee, and ankle. None of the workers were receiving any exposure. The only deflection of the needle on the RF analyzer was at the point where the power line enters the etching chambers. There was also a slight deflection at the etching chamber window. The highest value at these points produced less than 0.25 A^2/m^2 magnetic field and less than 40,000 V^2/m^2 in the electric field. These deflections were not noted two inches from the window or two inches from where the power line entered the etch chamber. Radiofrequency exposures were not a health hazard at the time of this survey.

Noise measurements were taken on twelve workers in the Clean Room. Their exposures averaged less than 80 dBA. At no time during the work cycle was the evaluation criteria of 85 dBA exceeded.

Most employees were informally interviewed regarding health-related problems associated with their work place. None of the workers had work associated health complaints.

Based on the environmental data and employees interviews, NIOSH concluded that a health hazard at INMOS Corporation, Colorado Springs, Colorado, did not exist at the time of this survey. Due to the variety of chemical and physical agents in this plant, close monitoring and education of employees must be maintained in order to prevent hazards. Recommendations for accomplishing this are included in this report.

KEYWORDS: SIC 3674 (Electronic Components and Accessories/Semiconductors and Related Devices), arsenic, cellosolve acetate, crystalline silica (quartz, cristobalite, total particulate), hydrochloric acid, hydrogen fluoride, hydrogen peroxide, isopropanol, nitric acid, phosphoric acid, sulfuric acid, xylene, semiconductor plants, radiofrequency, noise.

Free crystalline silica (quartz, cristobalite, total respirable particulate) air samples were collected on 37 mm filters using vacuum pumps operated at 1.7 liters per minute and analyzed according to NIOSH P&CAM Method No. 259. One breathing zone and two general room samples were collected.

Two general room air samples for hydrochloric acid were collected on silica gel tubes using vacuum pumps operated at 50 cubic centimeters per minute and analyzed according to NIOSH P&CAM Method No. 310.

Three general room air samples for hydrogen peroxide were collected in impingers using OSHA Method No. VI-6 and analyzed by spectrophotometer.

Four general room air samples for phosphoric acid were collected on 37 mm filters using vacuum pumps operated at 1.5 liters per minute and analyzed according to NIOSH P&CAM Method No. 216.

Five general room air samples for sulfuric acid were collected on 37 mm filters using vacuum pumps operated at 1.5 liters per minute and analyzed according to NIOSH P&CAM Method No. 268.

Noise measurements were taken with Metrosonic noise dosimeters and analyzed with the Metrosonic computer readout machine.

Radiofrequency measurements were made using a Holaday H-3002 Broad Spectrum Radiofrequency Analyzer.

Workers were interviewed at random. None of the workers had symptoms of solvent or acid exposure. RF measurements were explained to each operator.

V. EVALUATION CRITERIA

A. Environmental

Three sources of criteria used to assess the workroom concentrations of the chemicals were (1) recommended Threshold Limit Values (TLVs) and their supporting documentation as set forth by the American Conference of Governmental Industrial Hygienists (ACGIH), 1981, (2) the NIOSH criteria for a recommended standards, and (3) the Occupational Safety and Health Administration (OSHA) standards (29 CFR 1910.1000), July 1980.

	Permissible Exposure Limits 8-Hour Time-Weighted Exposure Basis
Arsenic	0.002 mg/M^3 (C) (NIOSH) 0.2 mg/M^3 (ACGIH) 0.5 mg/M^3 (OSHA)
n-Butyl acetate	710 mg/M^3 (ACGIH, OSHA)
Cellosolve acetate	270 mg/M^3 (ACGIH) 540 mg/M^3 (OSHA)
Crystalline silica (respirable)	0.05 mg/M^3 (NIOSH) $\frac{10\ mg/M^3}{\%\ SiO_2 + 2}$ (OSHA)
Total particulate (respirable)	5.0 mg/M^3 (ACGIH, OSHA)
Hydrogen chloride	7 mg/M^3 (C) (ACGIH, OSHA)
Hydrogen fluoride	2.5 mg/M^3 (NIOSH, ACGIH) 2.0 mg/M^3 (OSHA)

Cellosolve Acetate (2-ethoxyethyl acetate)[1] -- High concentrations of cellosolve acetate may cause irritation of eyes and nose. The material is not very toxic when ingested. Under ordinary working conditions inhalation is not a problem; however, inhaling greater amounts may cause vomiting, kidney damage, paralysis, and death. Cellosolve acetate is easily absorbed through the skin. This is not usually a problem unless greater amounts are absorbed. The OSHA standard is 540 mg/M^3 and the ACGIH TLV is 270 mg/M^3 with a skin notation.

Hydrogen Chloride (HCL)[1] -- Hydrogen chloride is toxic by inhalation, ingestion or skin contact. Short term exposures may cause irritation of eyes and respiratory tract. Burning of throat, coughing, and choking may occur. The exposed area of the body should be washed thoroughly to prevent skin burns and eye damage. Long term exposures may cause dental (teeth) erosion and dermatitis.

Pre-employment physicals should limit the placement of workers with respiratory conditions around HCL exposures. If workers are receiving chronic exposures to HCL, emphasis should be placed on the respiratory system, skin, and eyes. The current OSHA standard of 7 mg/M^3 is a ceiling concentration which should not be exceeded.

Hydrogen Fluoride[1,2] -- The current OSHA TWA standard for hydrogen fluoride (HF) is 3 ppm or 2.5 mg/M^3. NIOSH recommends 2.5 mg/M^3 and a ceiling level of 5.0 mg/M^3 averaged over a 15 minute period.

Hydrogen fluoride can affect the body if it is inhaled, ingested or absorbed through the skin.

1. Short-term Exposure -- HF liquid or vapor causes severe irritation and deep-seated burns of the eye and eyelids if it comes in contact with the eyes. If HF is not removed from the eye immediately, permanent visual defects or blindness may result. HF is a severe irritant to the nose, throat, and lungs. Breathing difficulties may not occur until some hours after exposures has ceased. Death may occur from breathing this chemical. If swallowed, HF will immediately cause severe damage to the throat and stomach.

   A physician should be contacted if anyone develops signs and symptoms of overexposure.

2. Long-term Exposure -- Chronic low level exposures may cause irritation and congestion of nose, throat, and bronchial tubes. Although unlikely from HF exposure due to its acute effects, long-term exposure to excessive fluoride levels can cause mottling of the teeth, increased bone density, and calcification of tendons and ligaments (particularly of the back).

Recommended medical surveillance should include a complete history and medical examination. The purpose is to detect any pre-existing condition that might place the exposed employee at risk. Examinations should include the eyes, respiratory tract, central nervous system, skeletal system, and kidneys.

exposures to sulfuric acid occurred and a large number of the workers had lost all teeth; others had multiple dental problems. The current OSHA standard and NIOSH recommended standard of 1 mg/M^3 should provide sufficient safety for an 8 hour work day, 40 hour work week.

Crystalline Silica[1,3] -- Crystalline silica, usually referred to as free silica, is defined as silicon dioxide (SiO_2) molecules arranged in a fixed pattern as opposed to a nonperiodic, random molecular arrangement defined as amorphous silica. The three most common crystalline forms of free silica encountered in industry are quartz, tridymite, and cristobalite, with quartz being by far the most common. NIOSH, in its recommendations for a free silica standard, has proposed that exposures to all forms of free silica be controlled so that no worker is exposed to respirable airborne concentrations greater than 0.05 mg/M^3, as averaged over a 10 hour working day, 40 hour work week. This recommendation was designed to protect workers from silicosis, a pneumoconiosis due to the inhalation of silicon dioxide-containing dust. Exposures to free silica greater than one-half the recommended standard or "action level" should initiate adherence to the environmental, medical, labeling, recordkeeping, and worker protection guidelines as contained in Chapter I of the NIOSH criteria document, "Occupational Exposure to Crystalline Silica." The current federal or OSHA standard[4] for respirable free silica exposure is an 8 hour timeweighted average based upon the 1968 ACGIH TLV formulas of 10 mg/M^3 divided by the percent SiO_2 plus 2 (10mg/M^3/ %SiO_2+2) for respirable quartz. One-half this amount was established as the limit for cristobalite and tridymite. As can be seen from the calculation, the OSHA regulation is based on the percentage of free silica contained in the respirable particulate exposure, whereas the NIOSH recommended standard applies directly to the airborne concentrations of respirable free silica.

Total Respirable Particulate -- Overexposures to any particulate may produce irritation and possibly damage to the total respiratory system especially if the particulate contains disease producing substances.

Xylene[4] -- Xylene overexposures may cause headache, nausea, gastrointestinal disturbance, and dizziness. Eye, nose, throat, and skin irritation are also common complaints when workers are exposed to xylene.

Radiofrequency (RF) -- The absorption of excessive RF energy by humans may cause adverse thermal effects due to heating of deep body tissue. The current OSHA standard[5] which limits exposures to below 10 milliwatts per square centimeter (mW/cm^2) averaged over any 0.1-hour period was promulgated to protect against thermal effects. In the far field, a power density of 10 mW/cm^2 is equivalent to an electric field strength of 40,000 volts^2/meter^2 (V^2/m^2) and a magnetic field strength of 0.25 amperes^2/meter^2 (A^2/m^2).

Absorption of RF energy may also result in "nonthermal" effects within the human body, which may occur without a measurable increase in tissue or body temperature. These reported "nonthermal" effects in animals at relatively low energy levels (below 10 mW/cm^2) include microscopic ocular changes,[6,7] alterations in neuroendocrine function,[8,9] alterations in the central nervous system,[10,11] behavorial changes,[12,13] changes in the immunologic system,[14] embryotoxic effects,[10,15] and reproductive effects.[16,17]

On September 30, 1981, three general room air samples were collected for hydrogen peroxide (Table 5); the samples ranged from 0.04 to 0.33 mg/M^3 (evaluation criteria 1.4 mg/M^3). On September 30, 1981, two breathing zone air samples for arsenic and five general room air samples for sulfuric acid were collected. Both arsenic samples were below the detection limit of 0.00005 mg/sample (Table 6). The sulfuric acid samples ranged from below the detection limit of 0.005 mg/sample to 0.11 mg/M^3 (evaluation criteria 1.0 mg/M^3) (Table 7).

One breathing zone and two general room air samples were collected on October 1, 1981, for crystalline silica (quartz, cristobalite, total particulate) (Table 8). The quartz and cristobalite samples were all below the detection limit of 0.03 mg/sample. The samples for total particulate ranged from below detection limit to less than 0.01 mg/M^3 (evaluation criteria 5.0 mg/M^3).

On October 28, 1981, six general room air samples were collected for nitric acid (Table 9); values ranged from less than 0.004 mg/M^3 to 2.5 mg/M^3 (evaluation criteria 5.0 mg/M^3). The INMOS Industrial Hygienist checked levels of phosphoric acid (Table 10). Four general room air samples were collected; the results ranged from below detection limits to 0.06 mg/M^3 (evaluation criteria 1.0 mg/M^3).

Radiofrequency measurements were performed on September 29, 1981. All RF operators were monitored for RF exposure at the face, chest, hands, groin, thigh, knee, and ankle. None of the workers were receiving any exposure. The only deflection of the needle on the RF analyzer was at the point where the power line enters the etching chambers. There was also a slight deflection at the etching chamber window. These deflections were not noted two inches from the window or two inches from where the power line entered the etch chamber. Therefore, RF exposures were not a health hazard at the time of this survey.

Noise measurements were taken on twelve workers in the Clean Room. Their exposures averaged less than 80 dBA. At no time during the work cycle was the evaluation criteria of 85 dBA exceeded. Noise is definitely not a hazard.

Ventilation measurements were made on all hoods in the clean room. These were all Laminar flow hoods. Flow through the hoods averaged 130 linear feet per minute (lfpm) at the top of the hood, 100 lfpm at the center of the hood, and 95-100 lfpm at the bottom of the hood. The entire clean room was very balanced as far as ventilation. It was very rare that a person could smell the odor of either an acid or a solvent.

None of the chemical or physical hazards assessed during this survey posed a health hazard. It should be noted that INMOS has an excellent respiratory protection program and a good program for educating workers on the hazards of the chemical and physical agents they work with. Interviews also indicated a clean, healthy work place.

VII. CONCLUSIONS

Based on the environmental data and physical measurements, a health hazard did not exist during this evaluation.

VIII. RECOMMENDATIONS

1. Maintenance personnel should be familiar with and maintain all gaskets and electrical connections and other potential sources of leakage on all plasma etch units.

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TABLE 1

General Room and Breathing Zone Air Concentrations of
n-Butyl Acetate, Cellosolve Acetate, Xylene, and Isopropanol
in the Photo-Wafer Track Department of the Clean Room

INMOS Corporation
Colorado Springs, Colorado

July 15, 1981

Sample Number	Location	Sampling Time	mg/M³ n-Butyl Acetate	Cellosolve Acetate	Xylene	Isopropanol
1	Wafer Track	9:01 AM - 1:45 PM	*	0.83	*	0.83
2	Wafer Track	9:02 AM - 1:40 PM	*	1.02	0.20	1.02
3	Wafer Track	9:00 AM - 1:45 PM	*	0.89	*	0.74
4	Wafer Track	9:00 AM - 1:40 PM	*	0.83	0.83	*
5	Wafer Track	8:59 AM - 1:40 PM	*	0.92	*	0.74
6	Dry Cleaner	9:10 AM - 1:40 PM	4.3	0.16	*	1.80
7	Dry Cleaner	9:10 AM - 1:40 PM	23.3	75.00	18.3	1.67
EVALUATION CRITERIA			710	270	435	980
LABORATORY LIMIT OF DETECTION mg/sample			0.01	0.01	0.01	0.01

* = below laboratory limit of detection

TABLE 3

General Room Air Concentrations of
n-Butyl Acetate, Cellosolve Acetate, and Xylene
in the Wafer Track Area of the Clean Room

INMOS Corporation
Colorado Springs, Colorado

September 17, 1981

Sample Number	Location	Sampling Time	mg/M^3 n-Butyl Acetate	Cellosolve Acetate	Xylene
2	Wafer Track	8:45 AM - 1:00 PM	*	2.5	*
3	Wafer Track	8:45 AM - 1:00 PM	*	4.2	*
4	Wafer Track	8:50 AM - 1:00 PM	*	1.7	*
EVALUATION CRITERIA			710	270	435
LABORATORY LIMIT OF DETECTION mg/sample			0.01	0.01	0.01

* = below laboratory limit of detection

TABLE 5

General Room Air Concentrations of Hydrogen Peroxide
in the Clean Room

INMOS Corporation
Colorado Springs, Colorado

September 30, 1981

Sample Number	Location	Sampling Time	mg/M^3 Hydrogen Peroxide
05	Etch Area (Parana)	10:15 AM - 1:00 PM	0.33
06	Etch Area (Parana)	10:17 AM - 1:00 PM	0.13
07	Etch Area (Parana)	10:20 AM - 1:00 PM	0.04
EVALUATION CRITERIA			1.4
LABORATORY LIMIT OF DETECTION mg/sample			0.0047

TABLE 7

General Room Air Concentrations of Sulfuric Acid
Areas 3(B) and 2(A) in the Clean Room

INMOS Corporation
Colorado Springs, Colorado

September 30, 1981

Sample Number	Location	Sampling Time	mg/M^3 Sulfuric Acid
AA-1	3(B) Clean Off Photo-Resist	9:08 AM - 3:30 PM	0.02
AA-2	3(B) Clean Off Photo-Resist	9:07 AM - 2:00 PM	*
AA-28	2(A) Parana Area	9:05 AM - 3:30 PM	*
AA-12	3(B) Clean Off Photo-Resist	8:34 AM - 2:00 PM	*
M5-5694	3(B) Clean Off Photo-Resist	8:34 AM - 2:00 PM	0.11
EVALUATION CRITERIA			1.0
LABORATORY LIMIT OF DETECTION mg/sample			0.005

* below laboratory limit of detection

TABLE 9

General Room Air Concentrations of Nitric Acid
in the Nitric Acid Bay Area of the Clean Room

INMOS Corporation
Colorado Springs, Colorado

October 28, 1981

Sample Number	Sampling Time	mg/M^3 Nitric Acid
1	8:30 AM - 1:40 PM	1.1
2	8:30 AM - 1:40 PM	1.2
3	8:30 AM - 1:40 PM	2.5
4	8:30 AM - 1:42 PM	0.8
5	8:33 AM - 1:45 PM	*
6	8:35 AM - 1:50 PM	0.3
EVALUATION CRITERIA		5.0
LABORATORY LIMIT OF DETECTION mg/sample		0.004

* below laboratory limit of detection