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WILTECH OF FLORIDA, INC.
KENNEDY SPACE CENTER, FLORIDA;
ROTHE DEVELOPMENT, INC.
JOHNSON SPACE CENTER, TEXAS

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I. SUMMARY

In October 1984, the International Association of Machinists and Allied Workers Union (IAMAW) requested that NIOSH evaluate worker exposure to 1,1,2-Trichloro-1,2,2-trifluoroethane at Wiltech of Florida. Wiltech provides cleaning services to Kennedy Space Center, Florida. This compound, known by the trade name Freon® 113, and also as fluorocarbon (FC) 113, is used to clean aerospace components. The primary hazard evaluation objective was to determine whether FC 113 exposure correlated with an increase in the number of cardiac arrhythmias.

An in-depth industrial hygiene/medical evaluation was performed at Wiltech in February 1990. A similar evaluation was also performed at Rothe Development, Inc., Houston, Texas, in March 1990. A total of thiry-one workers--22 workers from Wiltech, 9 from Rothe--working at various cleaning operations participated in the study. Each worker wore a Holter® monitor to determine cardiac functioning; concurrently, short-term exposure measurements were made for FC 113. Sequential short-term exposure measurements were used to calculate eight hour time-weighted averages (8-TWA) and to characterize exposures associated with specific cleaning tasks.

Among clean room workers, 8-TWA exposures at Wiltech ranged from 151 ppm to 439 ppm with a mean of 274 ppm; at Rothe, exposures ranged from 70 to 935 ppm with a mean of 271 ppm. Among pre-clean workers, 8-TWA exposures at Wiltech ranged from 49 ppm to 186 ppm with a mean of 110 ppm. At Rothe, exposures ranged from 2 ppm to 103 ppm with a mean of 25 ppm. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) and the NIOSH Recommended Exposure Limit (REL) for FC 113 is 1000 parts per million (ppm).

For short-term exposures in the clean room at Wiltech, the sampling task had the highest mean exposure--497 ppm. At Rothe, the sampling task also had the highest mean exposure--1144 ppm. The OSHA Short Term Exposure Limit (STEL) for FC 113 (measured over a 15 minute sampling period) is 1250 ppm. The NIOSH REL for this sampling period is also 1250 ppm. Several exposures measured during performance of this task at both facilities exceeded 1250 ppm. In the pre-clean areas at both facilities, the cleaning task, associated with use of the FC 113 vapor degreaser, had the highest mean exposure: 153 ppm at Wiltech, 40 ppm at Rothe.

Cardiac monitoring data and FC 113 exposure data from each facility were combined for the evaluation of cardiotoxic effects of FC 113 exposure. Exposure and ambulatory electrocardiographic (ECG) monitoring were conducted simultaneously on 31 workers, 16 of whom were examined on both exposed and low or non-exposed workdays.

For the 16 workers examined on exposed and low or non-exposed workdays, no within subject differences were found in the rate of ventricular premature beats (VPB's) or supraventricular premature beats (SVPB's), fluctuations in the length of the P-R interval, or heart rate. For the 31 workers monitored on an exposed day, we found no discernable effect of peak short-term exposures on VPB's, SVPB's, heart rate, or the length of the P-R interval.

The study results suggested that the observed levels of FC 113 exposures at these two facilities did not induce cardiac dysrhythmias or subtle changes in cardiac activity. Exposure data indicated all 8-TWA exposures to be below the OSHA PEL and the NIOSH REL of 1000 parts per million (ppm). However, several short-term exposures during the sampling task at both Wiltech and Rothe exceeded the OSHA STEL 1250 ppm. Recommendations regarding exposure monitoring for the sampling task, employee work practices, the use of protective gloves, the use of chemical alternatives to FC 113, and the use of a vapor degreaser at Rothe as an alternative to spray application of FC 113 are made in Section IX of this report.

Key Words: SIC 3471 (Electroplating, Plating, Polishing, Anodizing and Coloring), FC 113, 1,1,2-Trichloro-1,2,2-trifluoroethane (CAS No. 76-13-1), Freon 113, cardiac arrhythmias

II. INTRODUCTION

In October 1984, the International Association of Machinists and Allied Workers Union (IAMAW) requested that NIOSH evaluate the exposure to 1,1,2-Trichloro-1,2,2-trifluoroethane, also known as FC 113, during aerospace component cleaning operations at Wiltech of Florida. Wiltech is located at Kennedy Space Center (KSC), Florida. The IAMAW indicated that FC 113 was used on a daily basis in the clean room. The FC 113 vapors are inhaled by employees; skin contact was also reportedly occurring.

Based on reports of several worker fatalities as result of exposure to FC 113 and subsequent cardiac arrhythmia or asphyxiation[1], the primary study objective was to determine if exposure to FC 113 was correlated with an increase in the number of cardiac arrhythmias. Preliminary exposure measurement surveys were performed at Wiltech in November 1984 and September 1985. The medical evaluation component, involving determination of cardiac arrhythmias, was put in abeyance due to the Shuttle accident in 1986. The project was reactivated in 1989.

Another aerospace component cleaning facility operated by Rothe Development, Inc for the Johnson Space Center, (JSC) Houston, Texas expressed interest in participating in the hazard evaluation and was subsequently included.

In-depth industrial hygiene/medical evaluations were performed at Wiltech in February 1990 and at Rothe in March 1990. Individual tests results and exposure measurement data were mailed to participants in July 1990.

III. BACKGROUND

Facilities

At KSC, cleaning activities have been ongoing at the current location since 1966 under several contractors. Wiltech has had the contract since 1982. At JSC, cleaning activities began at the current location in 1968; Rothe has had the contract since 1978. Clean room and pre-clean operations were conducted over two shifts at Wiltech; field cleaning activities were carried out primarily on the first shift, but may also be conducted at any time depending on KSC needs. Rothe used only one shift. FC 113 has been used as the primary cleaning solvent at both facilities since start-up.
The clean room at Wiltech was substantially larger than that at Rothe. The former occupied approximately 2400 ft^2 of floor space; the latter about 900 ft^2.

The clean rooms at both facilities used a laminar air flow scheme to provide an environment suitable for precision cleaning and packaging of aerospace components of various sizes and configurations. However, Wiltech used a horizontal air flow scheme while Rothe used a vertical (ceiling to floor) air flow scheme. Both clean rooms provided about 10% fresh make-up air and recirculation of 90%.

Job Titles

[NOTE TO READERS: Words in **bold** type denote a job title; words in *italic* denote a specific work task.]

For both facilities, there were four major job titles: **Clean Room Mechanic**; **Clean Room Mechanic: Quality Assurance**; **Pre-Clean Mechanic** and **Pre-Clean Mechanic: Quality Assurance**. Each of these job titles performed a variety of tasks.

- The **Clean Room Mechanics** performed washing (referred to as *sampling*) of parts with FC 113. They also performed *assembly* and *packaging* of cleaned parts.

- **Pre-Clean Mechanics** performed initial *cleaning* of parts using a variety of detergents. Dip cleaning of parts in a Freon 113 vapor degreaser was also performed as required.

- **Clean Room Mechanics: Quality Assurance** performed *inspection* of parts for adequacy of cleaning. They also performed physical *testing* of parts as necessary. The *testing* task included analysis of FC 113 solutions for organic residues.

- **Pre-Clean Mechanics: Quality Assurance** performed *inspection* of parts for adequacy of pre-cleaning.

At Wiltech, workers in a separate classification performed cleaning of parts that were too large for cleaning in the clean room. As part of this process, the **Field Clean Mechanics** performed a *sampling* task using FC 113 in an open outside shed which was physically separated from the clean room. Prior to the *sampling* task, the parts were first *set up* using a crane or other mechanical support. For some parts, a FC 113 cleaning technique referred to as *flow-cleaning* was employed. Parts included large hoses and large component structures. Cleaning activities included internal rinsing (i.e. *sampling*) of large hoses with FC 113. The **Field Clean Mechanics: Quality Assurance** performed *inspection* and *testing* tasks related to field cleaning.

The component cleaning process related to clean room operations was essentially similar at both facilities. Parts were first *cleaned* in a pre-clean room using a FC 113 vapor degreaser, followed by additional cleaning in a series of acid and detergent baths. Following *inspection* in the pre-clean room, the parts were brought to the clean room. The parts underwent an initial cleaning flush (i.e. *sampling*) with FC 113. A small amount of the flushed FC 113 solution was then collected and a particle count performed under a microscope.

If the particle count exceeded specifications, indicating that the pre-cleaning process did not clean the part sufficiently, the part underwent recleaning. This recleaning involved another flush (i.e. *sampling*) of the part with FC 113. If the subsequent particle count indicated sufficient cleaning, the part was then *packaged* in polyethylene bags and heat sealed. If the part was from a larger component, the component was *assembled* and then *packaged*.

While the cleaning process was essentially the same at both facilities, the actual cleaning methods used were different. Wiltech used a dip cleaning process whereby the **Clean Room Mechanic** first grasped the parts to be cleaned with tongs and then dipped the parts into a cylindrical container which was situated in a metal sink. The container was continuously supplied with FC 113 issuing forth from a spigot. The FC 113 overflowed the container, flowed into the sink drain, and was piped to a filtration system for cleaning and recycling.

In contrast, Rothe used a spray-cleaning process whereby the **Clean Room Mechanic** placed the parts to be cleaned into a rectangular metal tub situated on a table surface and then applied FC 113 onto the parts using a spray wand. The tub was connected via hose to a drain. FC 113 was then piped to a filtration system for cleaning and recycling. If the part to be cleaned was a long narrow tube, FC 113 was flushed through the tube and collected in small pan situated on the floor. The pan was then emptied into one of the metal tubs.
At both facilities, several workers used protective gloves made from natural rubber. This type of glove is not considered to provide adequate protection against FC 113 penetration. Gloves made from nitrile rubber or neoprene are recommended for such use.[2]

IV. EVALUATION CRITERIA: 1,1,2-Trichloro-1,2,2-trifluoroethane

Environmental Criteria

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are the following: 1) NIOSH Recommended Exposure Limits (RELs), 2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs), and 3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs). The OSHA PELs may be required to take into account the feasibility of controlling exposures in various industries where the agents are used; the NIOSH RELs, by contrast, are based primarily on concerns relating to the prevention of occupational disease. In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that the lowest exposure criteria was used; however, industry is legally required to meet those levels specified by the OSHA standard.
A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 to 10-hour workday. Some substances have recommended short-term exposure limits (STELs) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from high short-term exposures.

The current Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for FC 113 is 1000 ppm as an 8-hour TWA (8-TWA) with a 15-minute short-term exposure limit (STEL) of 1250 ppm.[3] NIOSH concurs with the current OSHA PEL.[4] However, NIOSH has also determined that 4500 ppm is immediately dangerous to life and health. NIOSH considers this substance to have poor warning properties because it is nearly odorless and its irritant effects are only slight and transient at concentrations near the PEL.[1]

The current American Conference of Governmental Industrial Hygienists threshold limit value (TLV) for FC 113 is identical to the PEL for both 8-TWA and STEL. The TLV is based on "providing a margin of safety for systemic effects and an adequate margin against cardiac sensitization".[5]

Cardiotoxicity

FC 113 is a colorless, non-combustible liquid with a molecular weight of 197.5 and a specific gravity of 1.56 at 25°C. It has a vapor pressure of 284 millimeters of mercury at 20°C.[5] Because of this high vapor pressure at room temperature, FC 113 can produce high ambient concentrations of vapor during normal use.

To our knowledge, no studies have examined the cardiotoxic effects of FC 113 in humans. Animal studies have shown that FC 113 and other fluorocarbons have cardiotoxic effects,[6,7] and lethal arrhythmias have been implicated as the cause of sudden death among occupationally exposed workers[1] and aerosol sniffers.[8]

The occupational sudden death cases involved workers exposed primarily in confined spaces. The twelve fatalities were attributed to cardiac arrhythmias or asphyxiation or both. In two of the 12 cases, estimates of exposure levels were made. In one case, exposure was estimated at 7600 ppm. Death was attributed to cardiac arrhythmia. In the other case, exposure was estimated as high as 300,000 ppm. For this case, death was attributed to asphyxiation and pulmonary edema.[1] Three human chamber studies have examined the cardiotoxic potential of fluorocarbons. Reduced heart rate was associated with 15 to 60 seconds of exposure to FC 11, FC 12, and FC 114 among ten healthy individuals examined by Valic and colleagues.[9] Two of the ten subjects experienced tachycardia and negative T-waves and one subject developed atrioventricular block at levels reported to be as high as 16,150 ppm.

Among 46 healthy volunteers examined by Stewart, an increase in premature ventricular contractions occurred after 1 hour of FC 12 exposure at 1,000 ppm in only one subject. No other effects were noted.[10] In a chamber study conducted by Azar, no ECG disturbances were observed among 2 volunteers exposed to FC 12 at levels of 1,000 and 10,000 ppm for 2.5 hours.[11]

Only a few occupational studies have attempted to examine the relationship between fluorocarbon exposure and arrhythmias at the work site.[12,13] Among six refrigerator repairmen, a workday involving FC exposure was not clearly associated with an excess in ectopic beats when compared to workdays without exposure. Exposures to FC 12 and FC 22 ranged from 170 to 815 ppm for 48 to 150 minutes.

However, in a study of 89 refrigerator repairmen, Edling found that five workers in a high fluorocarbon exposure category (exposure for 10 or more minutes at greater than 750 ppm, with instantaneous peaks exceeding 5,000 ppm), had a slightly greater number of ectopic beats and a greater duration of sinus bradycardia than during periods of no exposure during the same day among the same individuals.[13] Exposed/non-exposed differences for these parameters were statistically significant (using a one-tailed signed rank test) only among 14 individuals in the medium-exposure category (exposure between 5 and 10 minutes at greater than 750 ppm with instantaneous peaks between 3,000 to 5,000 ppm) but not among the 5 individuals in the high exposure category. Although a variety of fluorocarbons were represented in the study, the majority of workers were exposed to FC 12 and FC 22.

The exact mechanisms accounting for the cardiotoxic effects of fluorocarbons are not well defined. Animal studies have shown that these compounds depress cardiac output and contractility, stimulate the release of and cardiac sensitization to epinephrine, and influence the autonomic nervous system. All of these mechanisms could precipitate a variety of dysrhythmias. Little is known, however, about whether chronic exposure to fluorocarbons may result in long-term health effects.[14]

V. EVALUATION DESIGN AND METHODS

A. Medical

The primary study objective was to determine whether low-level occupational exposure to FC 113 is related to the occurrence of cardiac dysrhythmias. The dysrhythmias of interest include sinus bradycardia, first degree AV block, T-wave abnormalities, and ventricular and supraventricular premature beats. The basic study approach was to compare dysrhythmia data obtained from an exposed group to that obtained from a non-exposed group. However, since there is extensive variability in dysrhythmia rates between individuals, and because the workplace may influence dysrhythmia rates independent of exposure, we decided to have each person serve as his own control for this study.

Study participants at each facility were evaluated on one day in the clean room, which constituted an exposed work day and on one day in the pre-clean room, considered to be a non-exposed workday. This strategy was based on data obtained during preliminary survey which indicated that exposure to FC 113 during pre-clean activities was minimal. It should be pointed out, however, that data obtained during this indepth survey indicated that this assumption was not entirely valid for all members of the study cohort. Because some individuals received significant exposures in the pre-clean area, their exposed/non-exposed workday comparisons were removed from the analyses.

<u>Study Selection Criteria</u>

At both Wiltech and Rothe, all clean room mechanics were asked to participate in the study. In addition, mechanics assigned to field cleaning activities with exposure to FC 113 at Wiltech were also asked to participate. A combined total of 31 individuals participated in the study. For 21 of the individuals, Holter measurements and exposure measurements were obtained on both an exposed and unexposed day.

<u>Dysrhythmia Monitoring</u>

Ambulatory electrocardiographic (ECG) monitoring data were collected simultaneously on each participant. We attached an ambulatory ECG Holter monitor (CircaMed Workstation Holter Recorder) to each study participant prior to the beginning of the work shift, and removed the ECG monitor at the end of the work shift. The ECG monitor had a timing track and recorded two channels, using 4 leads and one ground electrode. We tested the conductance of the electrodes, and calibrated the readings by checking a data strip obtained on each participant, using a portable office ECG machine.

The ECG tapes were sent to the ECG laboratory at the University of Minnesota, Division of Epidemiology, where a trained technician reviewed the tapes for ventricular and supraventricular premature beats, A-V block, T-wave inversion, ST segment depression, heart rate, and P-R interval length. The ECG data were provided to us in 15 minute intervals for each person's total period of monitoring. All questionable readings were reviewed by a cardiologist.

B. Exposure Measurement

For each individual wearing an ECG monitor, we concurrently measured airborne FC 113 exposures. The sampling strategy involved collection of a series of sequential short-term personal exposure samples during the entire work shift using charcoal tubes and vacuum pumps. Sampling times in the clean room at both facilities ranged from 14 minutes to 79 minutes, with a median sampling time of 44 minutes at Wiltech and 40 minutes at Rothe. Longer sampling times were used in the pre-clean areas at each facility due to the anticipated lower exposures and the resulting need to ensure the collection of detectable quantities of FC 113 if present.

These exposure measurements were used in calculating 8-TWA's from consecutive short-term samples and in characterizing exposures associated with specific cleaning tasks. Since clean room employees (i.e. **Clean Room Mechanics** and **Clean Room Mechanics: Quality Assurance**) left the clean room during break periods, the air sampler was removed before they went on break and donned prior to their reentry into the clean room. The average duration of simultaneous exposure and Holter monitoring was 7 hours.

For exposure assessment, breathing zone samples were collected by drawing air at a rate of approximately 50 cubic centimeters per minute through a sampling tube containing coconut shell charcoal attached to the lapel. The charcoal tubes were subsequently analyzed by gas chromatography using NIOSH analytical method 1003.[15]

The calculated limit of detection for the FC 113 samples was 0.7 ppm (based on a 2 Liter air sample). For each sample collected, the worker's job title and primary work task performed during the measurement period were noted.

To supplement the personal exposure monitoring at both facilities, general work area levels of FC 113 at selected clean room locations were monitored continuously using a MIRAN® 1B Infrared Analyzer. Calibration was performed at the NIOSH laboratory with FC 113 in the range of 0-2000 ppm; the parameters for this calibration were stored in the microprocessor. The MIRAN® 1B was also used as a personal monitor during the survey at Wiltech. The sampling head was attached near the lapel of one **Clean Room Mechanic** to monitor exposures during performance of *sampling* and *bottle washing* tasks.

Air velocity measurements were also made in the clean rooms using a TSI velometer.

C. Additional Data Collection

In addition to the exposure and ECG monitoring, we queried each worker regarding the timing and amount of smoking, caffeine intake, medication usage, and symptoms of headache, lightheadedness, palpitations and chest pain during the days that they participated in the study. This information was collected prior to the start of the work shift, after each break, and at the end of the work shift.

D. Statistical Analysis

Environmental

For each facility, the short-term exposure measurements were used in calculating 8-TWAs from consecutive samples for each job title. They were also used in characterizing exposures associated with the cleaning tasks. The 8-TWA, calculated over a 480 minute period, assumed a zero exposure for the unsampled unexposed break periods.

Medical

The dependent variables examined included the number of ventricular premature beats (VPB's) and supraventricular premature beats (SVPB's) per 1,000 heart beats, and changes in the P-R interval and heart rate.

Exposed Day versus Non-exposed Day Analyses

To determine whether there were greater rates of VPB's and SVBP's on exposed workdays relative to a comparable low- or non-exposed workdays, a nonparametric (signed rank) test was used to compare the mean difference in the rate of each outcome between the two days. Parametric (paired T-tests) were used to compare the mean P-R interval and heart rate between exposed and non-exposed workdays.

Because some workers had greater exposures than other workers, we examined whether the magnitude of the change in exposure between low- and high-exposed workdays was related to greater changes in the dependent variables. We compared the change in the rate of VPB's and SVPB's relative to the change in the full-shift TWA exposure using Spearman's rank correlation coefficient. We used linear regression analysis to examine the relationship of the change in the full-shift TWA exposure with the change in P-R interval and heart rate.

Peak Short-Term Exposure Analysis

There is no optimal statistical procedure for examining whether fluctuating short-term exposures are related to dysrhythmias. To examine this question for VPB's and SVPB's, Spearman's rank correlation coefficients for each individual who had these events were calculated.

For heart rate and the P-R interval, linear regression analysis was used to examine the association between outcome and exposure during the day. This technique is comparable to that presented by Rosner and colleagues.[16] These models included the worker term, classified as a categorical variable; the exposure term, classified as a continuous variable; and a worker by exposure interaction term.

Since ECG data were recorded in 15-minute intervals, the short-term exposure related to the corresponding 15-minute ECG data was used for the aforementioned analyses. Because of the possibility of a lag-time in an exposure-related effect, we also examined the relationship between the effect and the short-term exposure which occurred in the 15-minute interval prior to the ECG data. However, because the median sampling time for the short-term samples was 44 minutes, the analysis based on a 15 minute lag time in an exposure related effect was similar to that based on concurrent exposure effects. Analyses of exposure related effects for longer lag times was considered. However, the overall occurrence of few ECG events combined with the range of sampling times (most of which were longer than 15 minutes) resulted in a decision to restrict the analyses to just the 15 minute interval prior to the recorded effect.

VI. RESULTS

Environmental

For Wiltech, Table 1 provides the raw data for each sample collected. Tables 2, 2a, 3, and 3a provide the statistical summaries of the data for the first and second shifts for 8-TWA and task exposures respectively. For Rothe, Table 4 provides the raw data; Tables 5 and 6 provide the statistical summaries for 8-TWA and task exposures, respectively. Table 7 compares 8-TWA data by area between Wiltech and Rothe.

It should be reemphasized that descriptive statistical data for each task may not be totally exclusive for that task since other tasks may have been performed during the sampling period. As indicated previously in EVALUATION DESIGN AND METHODS, Exposure Measurement section, the primary task reported by the worker during the sampling period was recorded. Nevertheless, the data reported for each task are considered to be a reasonably good indicator of the exposure experienced for that task.

Wiltech

Over the 5 day study period at Wiltech, 174 personal measurements were obtained: 158 on the first shift, 16 on the second shift. Table 1 data indicate that all individual 8-TWAs were below the OSHA PEL for FC 113 and the NIOSH REL of 1000 ppm. Table 2 and 2a show first and second shift 8-TWA data for the job titles. For the first shift in the clean room, Table 2 shows that of the two job titles assigned, the **Clean Room Mechanic** had the higher 8-TWA mean exposure--290 ppm. Of the two job titles assigned to the pre-clean room, the **Pre-Clean Mechanic** had the higher 8-TWA mean exposure--115 ppm.

Comparing data between Tables 2 and 2a, it is clear that exposures were lower on second shift than on the first shift. This can be attributed to the decreased clean room and pre-clean room activity with a resulting lower number of FC 113 exposure occasions.

Table 3 indicates that in the clean room, the *sampling* task had the highest mean short-term exposure--497 ppm. Table 3a shows that exposures for the *sampling* task in the clean room were lower during the second shift. The highest single measurement of 1080 ppm was measured during an *assembly* task. The worker assembled parts at a table that was in close proximity to the FC 113 sinks where the parts were flushed (*sampling*). The horizontal air flow carries FC 113 vapors away from the sinks and across the table near the breathing zone of the worker.

In the pre-clean area, the *cleaning* task, associated with use of the FC 113 vapor degreaser, had a mean exposure 153 ppm [range: 86 ppm to 472 ppm]. The maximum exposure for this task seemed high considering that the degreaser was the only exposure source and that there was natural ventilation in the pre-clean area. One possibility may be that the vapor degreaser was not effectively containing the vapors. This may have been due to the occurrence of air drafts over the top of the degreaser, or removal of parts from the degreaser too rapidly. Both of these actions may have lead to disturbance of the vapor-air interface thus leading to diffusion of FC 113 from the tank.

The 8-TWA for the **Field Clean Mechanic** was only 129 ppm. However, exposures appear to be highly variable. One of two short-term levels measured for the *sampling* task was 3316 ppm; the other was 212 ppm; a third measurement during a *flow-cleaning* task was 11 ppm. The highest concentration was measured during FC 113 sampling of a large hose and can be attributed to the proximity of the worker's breathing zone to the point at which the FC 113 exited the hose. It seems clear that there is much variation in task exposure for this job classification, leading to variation in 8-TWA exposure.

A plan view of the clean room depicting MIRAN® 1B sampling locations and air velocity measurements is shown in Figure 1. Figures 2-4 show continuous monitoring results. For the area monitoring results, peak concentrations measured were 500 ppm (Figure 2) and 800 ppm (Figure 3).

Concentrations measured during personal monitoring with the MIRAN® 1B are shown in Figure 4. Data were collected directly in front of sink No. 3 (see Figure 1). Of note is the 1600 ppm "spike" measured during *sampling*. As expected, significant concentrations (1600 ppm; 1900 ppm) exist directly above the sink edge. The fluctuation in continuous monitoring data seemed to reflect the occurrence of the FC 113 *sampling* activity. After a short "lag", area concentrations would increase during performance of the task and then recede (following a short "lag") upon completion of the task. Figures 2 through 4 show increasing concentrations as one moves closer to the sink. 8-TWA exposures would also be higher for those individuals who work closer to the sink area.

During the MIRAN® 1B monitoring, we noticed the practice of several **Clean Room Mechanics** standing directly in front of the sink during the *sampling* task. Consequently, the air flow carrying FC 113 vapors was diverted by the torso into the breathing zone, resulting in a peak exposure. Modification of this work practice, whereby the workers would stand to one side of the sink during the task, should reduce peak FC 113 exposures.

Air velocity measurements obtained at various locations in the clean room ranged from 40-140 feet per minute (fpm). The 40 fpm reading at the sink edge was measured with a flow diverter in place at the rear of the sink. The diverter was installed to reduce the air flow directly over the sinks, thus reducing the entrainment of FC 113 vapors from the sink. The diverter seemed to have an effect on the velocity over the sink, since air flow increased to 85 fpm above the horizontal plane of the diverter.

Rothe

Over the 2 day study period at Rothe, 92 personal samples were obtained. Table 4 shows that all individual 8-hour TWAs were below the OSHA PEL of and the NIOSH REL of 1000 parts per million (ppm). However, one 8-TWA, 935 ppm for a **Clean Room Mechanic**, was very near the OSHA PEL. The TWA concentration, 1476 ppm, which assumed no exposure during the unsampled during break periods, exceeded the OSHA PEL and NIOSH REL of 1000 ppm. The individual's height was shorter than average and resulted in the breathing zone being closer to the point of FC 113 application. Exposure potential was further enhanced due to the aerosolization of the FC 113, which has the effect of greatly increasing the liquid surface area available for vaporization.

The relatively high 8-TWA is reflected in the high short-term sample results for this individual. In particular, FC 113 concentrations of 2522 (13 minute sample period), 2732 (29 minute sample period), 3010 (59 minute sample period), and 3380 ppm (38 minute sample period) were measured. The aforementioned exposures relate to the *sampling* task performed on the first day of the study. Based on a 15 minute sampling period, the first of the aforementioned concentrations would exceed the STEL, even assuming a 0 ppm exposure for the final 2 minutes of the 15 minute period. The latter three concentrations are of such magnitude that the STEL was probably exceeded during at least one 15 minute period during the respective sampling periods.

For another individual also performing the *sampling* task, short-term exposures were 1471 and 1451 ppm. The 8-TWA for this individual was 298 ppm. This individual's breathing zone was not as close to the point of application as that of the individual who had the exposures. This finding would suggest that proximity of the breathing zone to the application point is not the only factor influencing the occurrence of high short-term exposure. Variation in amount of FC 113 sprayed onto the parts by the **Clean Room Mechanics** may also be a factor.

Table 5 shows that for the two jobs assigned to the clean room, the **Clean Room Mechanic** job title had the higher mean 8-TWA exposure--289 ppm. Of the two jobs assigned to the pre-clean room, the **Pre-Clean Mechanic** had the higher mean 8-TWA--30 ppm).

Table 6 shows that in the clean room, the *sampling* task had the highest mean short-term exposure--1144 ppm. Besides this task, short term FC 113 exposures greater than 1250 ppm (the current OSHA STEL and NIOSH REL) were also measured during the *inspection* task performed by the **Clean Room Mechanic: Quality Assurance**. Of the two tasks measured in the pre-clean room, the *cleaning* task had the higher mean exposure of 40 ppm [range: 1 ppm to 550 ppm]. As was the case at Wiltech, the maximum exposure for this task seemed high since the degreaser was the only exposure source in the pre-clean area. One possibility may be that the vapor degreaser was not effectively containing the vapors.

A plan view of the vertical laminar flow clean room depicting the MIRAN® 1B measurement location and air velocity measurements is shown in Figure 5. Figure 6 illustrates the continuous monitoring results. MIRAN® 1B personal monitoring was carried out during a *sampling* activity at the beginning of the shift; area measurements at various clean room locations were carried out during the remainder of the shift.

During the *sampling* activity, a peak of 1200 ppm was measured. The breathing zone of the individual monitored during the task was well above the point of FC 113 application. The peak at the end of the day (1000 ppm) resulted when some FC 113 leaked from a connection in a drain pipe thus increasing the concentration. This did not appear to constitute a prevailing condition, since the leak did not occur during the previous day of the study.

Air velocity measurements obtained at various locations in the vertical air flow clean room ranged from 95-130 feet per minute (fpm) in open areas. Of note was the noticeable reduction of air movement at points just above the table surfaces. Velocities of 35 fpm and 50 fpm (with some turbulence) were measured. The lower velocity was measured at one of the tables where FC 113 *sampling* was performed. The lower air velocity can lead to reduction of FC 113 vapor removal from the breathing zone area.

Wiltech/Rothe Comparison of 8-TWA

Table 7 shows that viewing clean room workers as a group, 8-TWA exposures on the first shift at Wiltech ranged from 151 ppm to 439 ppm with a mean of 274 ppm; at Rothe, exposures ranged from 70 to 935 ppm with a mean of 271 ppm. Among pre-clean workers, 8-TWA exposures at Wiltech ranged from 49 ppm to 186 ppm with a mean of 110 ppm. At Rothe, exposures ranged from 2 ppm to 103 ppm with a mean of 25 ppm.

<u>Medical</u>

Thirty-one workers, representing 89% of the eligible (i.e exposed) workers, participated in the study (Table 8). All 31 workers were monitored on an exposed day, and 21 workers were eligible and volunteered to be monitored on a low- exposed or non-exposed workday. The average age of the study group was 40.8 years, and the average length of employment was 8.1 years (Table 9).

Exposed versus Non-exposed Workers Comparison Analysis

Five of the 21 workers monitored on both exposed and low/non-exposed workdays were excluded from the analyses, because exposure monitoring found only small differences (< 100 ppm) in the time-weighted average FC 113 exposure levels between the 2 days. Differences in exposure levels between the two days were minimal for three workers because the clean room was shut down during monitoring for most of their shift, for one worker because job duties in the clean room did not involve significant exposures, and for another worker because work in the precleaning area was associated with FC 113 levels comparable to that of the clean room. The latter may have been due to an operational deficiency of the vapor degreaser located in the precleaning area or to undocumented movement into the clean room.

Among the remaining 16 individuals examined on an exposed and non-exposed day, the mean full-shift time-weighted-average (TWA) exposure (not including break periods) was 442.1 ppm during the exposed day and 64.4 ppm during the low exposed day ($p<.001$). The highest full-shift TWA exposure was 1,476 ppm on the exposed day (Table 10). When the 8-TWAs were calculated, which factored in the non exposed break periods, the mean 8-TWA was 273 ppm, and the highest 8-TWA was 935 ppm. Thus, this population of workers had an 8-hour TWA exposure level within the OSHA PEL and NIOSH REL of 1000 ppm.

Smoking and caffeine intake among the 16 workers were comparable on the exposed and low exposed/non-exposed workdays: mean of the paired difference was -1.5 for the number of cigarettes smoked, and -0.5 for the number of caffeine drinks consumed. The differences between the two groups for both attributes were not statistically significant (p > .05).

The non-parametric analysis in Table 11 shows that the mean of the paired differences between exposed and low exposed/non-exposed days in VPB's per 1000 heart beats was -0.15 (p=.20); for SVPB's the mean of the paired difference was 0.03 (p=.66). The Spearman rank correlation coefficients that were calculated for the rate of VPB's (r=.17, p=.52) and SVPB's (r=.31, p=.23) showed no significant dose-response effect.

For the parametric analysis, Table 12 shows no effect of exposure on heart rate (mean difference=-3.13, p=.14) or the length of the P-R interval (mean difference=-0.0006, p=.75). Linear regression coefficients calculated for heart rate (Beta=-0.002, p=.82) and P-R interval (Beta=-0.000004, p=.51) showed no dose-response effect.

It should be noted that one individual had an episode of sinus rhythm bradycardia on the exposed day only. But, another worker with S-T segment depression had similar ECG patterns on both the exposed and non-exposed workdays. There were no occurrences of A-V block or T-wave inversion on either of the two days among the study participants.

Short-Term Exposure Analysis

Among the 31 individuals examined on an exposed day, the short-term exposures ranged from 154 to 3,380 ppm, with a mean level of 749.9 ppm (standard deviation = 579.0). Overall, we saw no discernable effect of short-term exposures on heart rate, the length of the P-R interval, or the number of VPB's or SVPB's. The analyses suggested, however, that exposures may have been related to variation in heart rate in two individuals, but the effect was inconsistent. One had a positive association (i.e. increasing exposures were related to increasing heart rates); one had a negative association (i.e. increasing exposures were related to a decreasing heart rate).

The Spearman's rank correlation coefficients and their corresponding 95% confidence intervals for VPB's for each of the 11 persons who had events are depicted in Figure 7. Because the short-term exposure level was different for each participant, the Spearman's rank correlation coefficients are plotted by each individual's peak short-term exposure level. The Spearman's rank correlation coefficients ranged from -.12 to .30.

Most confidence intervals were wide and included zero. A correlation of zero means that there is no relationship between fluctuating exposures and the number of ECG events. Also, there was no upward trend in the value of the coefficients with increasing peak short-term exposure (Figure 7).

All participants that had positive correlation coefficients had very few VPB's. Examples of two participants with positive correlation coefficients are depicted in Figures 8 and 9. In contrast, Figure 10 depicts an individual with excessive numbers of VPB's which occurred throughout the day regardless of exposure levels.

VII. DISCUSSION

Environmental

At both facilities, mean 8-TWAs for the exposed job titles in the clean room seem remarkably similar despite the different laminar air flow arrangement and different method of FC 113 application. At Wiltech, which employs a horizontal flow arrangement, the **Clean Room Mechanic** mean 8-TWA exposure was 290 ppm; at Rothe, which uses a vertical flow arrangement, the mean 8-TWA was 254 ppm. For the **Quality Assurance Mechanics**, 8-TWA exposure was 254 ppm for the former, 213 ppm for the latter. This may be the consequence of similar percentages of recirculated air at both facilities. Increase in the percentage of fresh air brought into the clean room should reduce the 8-TWA.

The 8-TWA concentrations in the clean rooms are a function of concentrations generated during the *sampling* task. The continuous monitoring data obtained at Wiltech indicated that FC 113 concentrations increase as one moves closer to the sink where this task is performed. This would suggest that as concentrations are lowered for the *sampling* activity, job title exposures elsewhere in the clean room would be reduced in tandem.

Short-term exposures were higher in the vertical air flow arrangement (Rothe) than for the horizontal air flow arrangement (Wiltech). This would suggest that, in general, the horizontal flow scheme is more effective at removing FC 113 vapors from the breathing zone than is the vertical scheme. This observation must be qualified to the extent that the *sampling* task in the vertical air flow scheme used a FC 113 spray process, which involves a higher degree of aerosolization than the dip process used in the horizontal flow scheme (Wiltech).

Medical

Overall, an exposed workday was not associated with a greater number of dysrhythmic events than a comparable non-exposed workday in this population. Although a few individuals may have had a tendency to have a few VPB's during periods of high exposure, overall we observed no discernable effect of peak short-term exposures on the ECG parameters examined.

One strength of this study is that the same workers were evaluated on comparable exposed and low exposed/non-exposed days. Caffeine intake, tobacco usage, and the physical activity level during work in the exposed and low exposed/non-exposed areas were very similar. Another strength of the study is that we had sufficient power to detect small differences because of the small within subject variance in the ECG data. For example, we had 80% power to detect a 0.34 difference in VPB rates and a 0.10 difference in SVPB rates between the exposed and the low exposed/non-exposed days with 95% confidence.

A number of study constraints, however, limit the ability to generalize from these results to other populations of workers. Because there may be differences in susceptibility to FC113 among individuals, a sample of 31 workers may not have been sufficiently large to detect an exposure effect. Also, because fluorocarbons are thought to sensitize the heart to epinephrine[11], this study's negative findings based on sedentary workers may not be generalizable to workers engaged in more physically demanding work. High exposures in this population of workers occurred while the workers were standing at the sinks, dipping, or spraying the parts with FC 113, which required minimal physical effort.

Another limitation of the study is that a cross-sectional study design was used. Therefore, workers who felt affected by FC 113 while working in the clean room may have selected out of the exposed area and would not have been available for recruitment for our study. Also, healthy individuals were selected for the cleaning and precleaning work through mandatory pre-employment physical examinations at Facility B, and periodic physical examinations at both facilities. While medical records are available on all employees, we have no information on the proportion of job applicants who were ineligible for employment on the basis of preexisting heart conditions.

Another study constraint was that we only observed each participant on one exposed day. Given that many of the ECG events were relatively rare in this group of healthy workers, and that the magnitude of exposures may vary from day to day, additional days of observation would have been advantageous. However, additional days of monitoring would have been logistically difficult. The exposure and ECG monitoring was labor intensive and disruptive to the work environment. Also, because the clean rooms had quotas on the number of individuals allowed in the room, the number of workers monitored was limited by the number of NIOSH industrial hygienists allowed into the room to change the sampling tubes.

VIII. CONCLUSIONS

The study results suggest that the observed levels of FC 113 exposures do not induce cardiac dysrhythmias or subtle changes in cardiac activity in this sample of workers. However, the generalizability of the results to workers with different working conditions, host susceptibilities, or greater FC 113 exposures is limited.

Exposure data indicated that all individual 8-TWA exposures were below the OSHA PEL and NIOSH REL of 1000 parts per million (ppm). It is likely that several short-term exposure measurements obtained at Rothe appeared to exceed the OSHA STEL and NIOSH REL of 1250 ppm; one measurement at Wiltech appeared to exceed the OSHA STEL and NIOSH REL. For these exposure scenarios, this appeared to be due to the close proximity of the breathing zone to the point of FC 113 application.

Of all the work tasks evaluated, the *sampling* task appeared to be the one giving rise to the highest short term exposure. In general, the data seem consistent with FC 113 exposure potential for the task and job title.

Despite the difference in laminar air flow arrangement, 8-TWA exposures in the clean rooms of both facilities were remarkably similar.

IX. RECOMMENDATIONS

On the basis of measurements and observations made during this study, the following recommendations should be considered by the NASA contractors in reducing exposure:

1) Both facilities should perform monitoring of the FC 113 *sampling* task. Exposure remediation measures should be implemented if the OSHA PEL and NIOSH REL is found to be exceeded.

2) Wiltech **Clean Room Mechanics** performing *assembly* tasks should work at the opposite end of the clean room from the FC 113 sinks. This would likely lead to a reduction of short-term exposures since the FC 113-laden air would become more diluted before reaching the worker's breathing zone.

3) Wiltech **Field Clean Mechanics** performing *sampling* tasks should position themselves in such a fashion that wind induced air flow is allowed to flow across the area of application. This will help pull FC 113 vapors away from the breathing zone.

4) Both facilities should evaluate the technical feasibility of the use of gloves made from nitrile rubber or neoprene as hand protection when working with FC 113. The gloves in use at the time of the survey at both facilities were made from natural rubber. This type of glove is not considered to provide adequate protection against FC 113 penetration.

5) Both facilities should evaluate the feasibility of increasing the percentage of fresh air brought into the clean room. An increase in percentage should reduce 8-TWAs for clean room workers.

6) Wiltech **Clean Room Mechanics** performing the *sampling* task should stand to one side of the sink during the task. This allows the horizontal air flow to carry the FC 113 vapors away from the worker's breathing zone thus reducing short-term exposure. (During the survey, several of the mechanics would stand directly in front of sink during the task. This resulted in the air flow carrying FC 113 vapors into the breathing zone).

7) Both facilities should examine the functioning of the vapor degreaser in the pre-clean area to determine if FC 113 vapors are escaping from the tank. In particular, the existence of cross drafts in the area of the degreaser and the practice of removing parts from the degreaser too rapidly should be investigated. The recommended withdrawal speed is 5-10 feet/minute.[17]

8) As an alternative to spraying components with FC 113, Rothe should evaluate the feasibility of the use of a vapor degreaser in the clean room for low-level production cleaning of components. This would result in less FC 113 becoming aerosolized.

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6. OSHA, Region IV, Atlanta, Georgia
7. Florida Department of Health and Rehabilitative Services, Tallahassee, Florida
8. Texas Department of Health, Austin, Texas.

For the purpose of informing affected employees, copies of this report should be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Table 1

Freon 113 Air Sample Results

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
001	2	Pers	2/12	Cln Rm Mech	Test	4	1547	1757	130	94		
001	2	Pers	2/12	Cln Rm Mech	Test	9	1808	1959	111	107		
001	2	Pers	2/12	Cln Rm Mech	Test	10	2000	2317	197	46		
									438		76	69
002	2	Pers	2/12	Pr Cln Mech	Clean	3	1544	1810	146	39		
002	2	Pers	2/12	Pr Cln Mech	Clean	7	1811	2040	149	22		
002	2	Pers	2/12	Pr Cln Mech	Clean	12	2040	2316	156	17		
									451		26	24
003	2	Pers	2/12	Cln Rm Mech	Asmbly	1	1602	1804	122	105		
003	2	Pers	2/12	Cln Rm Mech	Smplng	8	1805	2030	145	163		
003	2	Pers	2/12	Cln Rm Mech	Pckg	11	2031	2311	160	50		
									427		104	93
004	1	Pers	2/13	Cln Rm Mech	Smplng	16	720	806	46	553		
004	1	Pers	2/13	Cln Rm Mech	Pckg	21	808	857	49	635		
004	1	Pers	2/13	Cln Rm Mech	Smplng	27	927	1002	35	519		
004	1	Pers	2/13	Cln Rm Mech	Pckg	32	1003	1044	41	304		
004	1	Pers	2/13	Cln Rm Mech	Pckg	36	1044	1128	44	407		
004	1	Pers	2/13	Cln Rm Mech	Smplng	71	1202	1254	52	394		
004	1	Pers	2/13	Cln Rm Mech	Smplng	46	1255	1339	44	537		
004	1	Pers	2/13	Cln Rm Mech	Smplng	78	1414	1459	45	317		
004	1	Pers	2/13	Cln Rm Mech	Smplng	82	1459	1512	14	222		
									370		450	347
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	19	813	857	44	525		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	25	922	957	35	458		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	31	958	1040	42	409		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	40	1040	1124	44	301		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	73	1204	1322	78	318		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	49	1323	1347	24	422		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	77	1411	1459	48	217		
005	1	Pers	2/13	Cln Rm Mech: QA	Insp	85	1500	1522	22	179		
									337		352	247

*Time-weighted average over all sampled periods.

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February 12-16, 1990

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006	1	Pers	2/13	Cln Rm Mech	Pckg	18	732	817	45	761		
006	1	Pers	2/13	Cln Rm Mech	Pckg	22	818	858	40	685		
006	1	Pers	2/13	Cln Rm Mech	Pckg	28	930	1018	48	523		
006	1	Pers	2/13	Cln Rm Mech	Pckg	34	1019	1102	43	472		
006	1	Pers	2/13	Cln Rm Mech	Pckg	37	1102	1126	24	352		
006	1	Pers	2/13	Cln Rm Mech	Pckg	72	1203	1257	54	368		
006	1	Pers	2/13	Cln Rm Mech	Pckg	47	1258	1351	53	517		
006	1	Pers	2/13	Cln Rm Mech	Pckg	80	1419	1457	38	264		
006	1	Pers	2/13	Cln Rm Mech	Pckg	84	1458	1524	26	219		
									371		481	372
007	1	Pers	2/13	Cln Rm Mech	Smplng	17	728	815	47	680		
007	1	Pers	2/13	Cln Rm Mech	Smplng	23	816	858	42	644		
007	1	Pers	2/13	Cln Rm Mech	Pckg	26	923	1005	42	515		
007	1	Pers	2/13	Cln Rm Mech	Pckg	33	1015	1126	71	346		
007	1	Pers	2/13	Cln Rm Mech	Pckg	74	1206	1259	53	385		
007	1	Pers	2/13	Cln Rm Mech	Pckg	48	1300	1350	50	423		
007	1	Pers	2/13	Cln Rm Mech	Pckg	79	1415	1512	57	242		
									362		444	335
008	1	Pers	2/13	Cln Rm Mech	Asmbly	30	947	1026	39	541		
008	1	Pers	2/13	Cln Rm Mech	Asmbly	35	1027	1110	43	395		
008	1	Pers	2/13	Cln Rm Mech	Asmbly	38	1110	1207	57	334		
008	1	Pers	2/13	Cln Rm Mech	Asmbly	75	1213	1252	39	310		
008	1	Pers	2/13	Cln Rm Mech	Smplng	45	1253	1412	79	424		
008	1	Pers	2/13	Cln Rm Mech	Asmbly	81	1444	1524	40	302		
									297		387	316
009	1	Pers	2/13	Pr Cln Mech	Clean	13	751	1047	176	267		
009	1	Pers	2/13	Pr Cln Mech	Office	50	1048	1304	136	146		
009	1	Pers	2/13	Pr Cln Mech	Office	44	1306	1501	115	163		
									427		200	178
010	1	Pers	2/13	Pr Cln Mech	Clean	14	826	1050	144	472		
010	1	Pers	2/13	Pr Cln Mech	Clean	51	1053	1314	141	86		

*Time-weighted average over all sampled periods.

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010	1	Pers	2/13	Pr Cln Mech	Clean	55	1317	1504	107	87		
									392		228	186
011	1	Pers	2/13	Fld Cln Mech	SetUp	29	959	1121	82	21		
011	1	Pers	2/13	Fld Cln Mech	SetUp	57	1123	1428	185	22		
011	1	Pers	2/13	Fld Cln Mech	Smplng	53	1430	1515	45	3316		
									312		497	323
012	1	Pers	2/13	Pr Cln Mech: QA	Insp	15	802	1058	176	123		
012	1	Pers	2/13	Pr Cln Mech: QA	Insp	52	1100	1210	130	57		
012	1	Pers	2/13	Pr Cln Mech: QA	Insp	41	1312	1503	111	121		
									417		102	88
013	1	Pers	2/14	Cln Rm Mech	Smplng	90	731	807	36	360		
013	1	Pers	2/14	Cln Rm Mech	Non-Work	94	808	835	27	136		
013	1	Pers	2/14	Cln Rm Mech	Clean	97	838	954	79	86		
013	1	Pers	2/14	Cln Rm Mech	Smplng	101	955	1036	39	678		
013	1	Pers	2/14	Cln Rm Mech	Smplng	109	1035	1122	36	782		
013	1	Pers	2/14	Cln Rm Mech	Pckg	122	1245	1320	35	531		
013	1	Pers	2/14	Cln Rm Mech	Pckg	126	1320	1422	62	186		
013	1	Pers	2/14	Cln Rm Mech	Pckg	130	1422	1505	43	196		
									357		326	243
009	1	Pers	2/14	Cln Rm Mech	Smplng	92	736	810	34	463		
009	1	Pers	2/14	Cln Rm Mech	Smplng	95	811	858	47	733		
009	1	Pers	2/14	Cln Rm Mech	Pckg	99	929	1019	50	738		
009	1	Pers	2/14	Cln Rm Mech	Pckg	108	1020	1107	47	680		
009	1	Pers	2/14	Cln Rm Mech	Pckg	111	1108	1127	29	390		
009	1	Pers	2/14	Cln Rm Mech	Pckg	121	1224	1258	34	557		
009	1	Pers	2/14	Cln Rm Mech	Pckg	125	1258	1330	32	484		
009	1	Pers	2/14	Cln Rm Mech	Pckg	129	1330	1443	73	135		
009	1	Pers	2/14	Cln Rm Mech	Pckg	134	1443	1504	21	199		
									367		487	373
005	1	Pers	2/14	Pr Cln Mech	Office	91	724	1024	164	61		
005	1	Pers	2/14	Pr Cln Mech	Clean	105	1010	1219	129	122		

*Time-weighted average over all sampled periods.

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February 12-16, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
005	1	Pers	2/14	Pr Cln Mech	Clean	118	1220	1447	147	107		
005	1	Pers	2/14	Pr Cln Mech	Office	135	1448	1512	24	80		
									464		94	91
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	89	737	813	36	369		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	96	814	910	56	544		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	100	940	1016	36	653		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	107	1017	1123	66	461		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	114	1208	1253	45	430		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	124	1253	1327	34	391		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	128	1327	1422	55	156		
012	1	Pers	2/14	Cln Rm Mech: QA	Insp	132	1423	1508	45	154		
									373		391	304
011	1	Pers	2/14	Fld Cln Mech	SetUp	83	0812	1019	127	12		
011	1	Pers	2/14	Fld Cln Mech	SetUp	104	1020	1240	140	11		
011	1	Pers	2/14	Fld Cln Mech	SetUp	117	1241	1501	140	27		
									407		17	14
014	1	Pers	2/14	Cln Rm Mech	Asmbly	86	0725	0803	38	446		
014	1	Pers	2/14	Cln Rm Mech	Asmbly	93	0804	0854	50	658		
014	1	Pers	2/14	Cln Rm Mech	Smplng	98	0924	1008	44	805		
014	1	Pers	2/14	Cln Rm Mech	Smplng	106	1010	1104	54	796		
014	1	Pers	2/14	Cln Rm Mech	Smplng	110	1105	1120	15	961		
014	1	Pers	2/14	Cln Rm Mech	Asmbly	113	1210	1249	39	648		
014	1	Pers	2/14	Cln Rm Mech	Asmbly	123	1249	1323	34	647		
014	1	Pers	2/14	Cln Rm Mech	Asmbly	127	1323	1424	61	174		
014	1	Pers	2/14	Cln Rm Mech	Asmbly	131	1425	1510	45	230		
									380		555	439
007	1	Pers	2/14	Pr Cln Mech	Office	87	727	1041	194	86		
007	1	Pers	2/14	Pr Cln Mech	Clean	102	1042	1220	106	142		
007	1	Pers	2/14	Pr Cln Mech	Clean	120	1229	1420	111	140		
007	1	Pers	2/14	Pr Cln Mech	Clean	133	1420	1511	51	116		
									462		115	111

*Time-weighted average over all sampled periods.

Table 1

Freon 113 Air Sample Results

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
004	1	Pers	2/14	Pr Cln Mech	Clean	88	715	1124	249	125		
004	1	Pers	2/14	Pr Cln Mech	Office	103	1125	1223	58	153		
004	1	Pers	2/14	Pr Cln Mech	Office	119	1223	1449	146	171		
004	1	Pers	2/14	Pr Cln Mech	Office	136	1449	1508	19	103		
									472		142	140
003	2	Pers	2/14	Cln Rm Mech	Test	137	1553	1649	56	111		
003	2	Pers	2/14	Cln Rm Mech	Test	142	1826	2054	148	438		
									204		348	148
001	2	Pers	2/14	Cln Rm Mech	Test	139	1554	1446	52	100		
001	2	Pers	2/14	Cln Rm Mech	Test	143	1828	2059	151	154		
									203		140	59
002	2	Pers	2/14	Cln Rm Mech	Smplng	138	1543	1645	62	352		
002	2	Pers	2/14	Cln Rm Mech	Smplng	141	1863	2053	150	403		
002	2	Pers	2/14	Cln Rm Mech	Smplng	144	2134	2204	30	184		
									242		363	183
015	1	Pers	2/15	Cln Rm Mech	Test	150	733	819	46	306		
015	1	Pers	2/15	Cln Rm Mech	Test	160	819	858	39	310		
015	1	Pers	2/15	Cln Rm Mech	Test	167	930	1010	40	384		
015	1	Pers	2/15	Cln Rm Mech	Test	171	1012	1126	74	612		
015	1	Pers	2/15	Cln Rm Mech	Test	176	1203	1253	50	191		
									249		387	201
016	1	Pers	2/15	Cln Rm Mech: QA	Test	151	719	816	57	204		
016	1	Pers	2/15	Cln Rm Mech: QA	Insp	163	816	857	41	284		
016	1	Pers	2/15	Cln Rm Mech: QA	Insp	166	927	1007	40	371		
016	1	Pers	2/15	Cln Rm Mech: QA	Insp	172	1009	1125	76	631		
016	1	Pers	2/15	Cln Rm Mech: QA	Test	175	1159	1245	46	104		
016	1	Pers	2/15	Cln Rm Mech: QA	Insp	182	1308	1347	39	316		
016	1	Pers	2/15	Cln Rm Mech: QA	Insp	185	1416	1528	72	276		
									371		332	256
017	1	Pers	2/15	Cln Rm Frmn	Frmn	148	718	805	47	216		
017	1	Pers	2/15	Cln Rm Frmn	Frmn	162	805	855	50	291		

*Time-weighted average over all sampled periods.

Table 1

Freon 113 Air Sample Results

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
017	1	Pers	2/15	Cln Rm Frmn	Frmn	169	945	1043	58	673		
017	1	Pers	2/15	Cln Rm Frmn	Frmn	173	1044	1124	40	215		
									195		371	151
019	1	Pers	2/15	Fld Cln Mech: QA	Insp	153	726	958	152	151		
019	1	Pers	2/15	Fld Cln Mech: QA	Test	177	1220	1349	89	87		
019	1	Pers	2/15	Fld Cln Mech: QA	Test	184	1350	1457	67	111		
									308		124	79
011	1	Pers	2/15	Fld Cln Mech	Smplng	149	802	919	77	212		
011	1	Pers	2/15	Fld Cln Mech	SetUp	157	920	1038	78	50		
011	1	Pers	2/15	Fld Cln Mech	Flw Cln	174	1038	1226	108	11		
011	1	Pers	2/15	Fld Cln Mech	Flw Cln	180	1227	1351	84	13		
011	1	Pers	2/15	Fld Cln Mech	Flw Cln	183	1352	1457	65	18		
									412		57	49
100	1	Area	2/15	Clean Room		156	748	1032	164	663		
100	1	Area	2/15	Clean Room		164	1032	1301	149	475		
100	1	Area	2/15	Clean Room		181	1302	1530	148	256		
									461		472	453
101	1	Area	2/15	Office		158	926	1530	364	58		
									364		58	44
020	1	Pers	2/16	Cln Rm Mech	Office	198	806	937	91	55		
020	1	Pers	2/16	Cln Rm Mech	Clean	207	937	1131	114	97		
020	1	Pers	2/16	Cln Rm Mech	Sp Act	214	1131	1333	122	155		
020	1	Pers	2/16	Cln Rm Mech	Sp Act	217	1334	1433	59	725		
020	1	Pers	2/16	Cln Rm Mech	Sp Act	225	1433	1505	32	464		
									418		222	193
021	1	Pers	2/16	Cln Rm Mech	Asmbly	228	1333	1423	50	314		
021	1	Pers	2/16	Cln Rm Mech	Asmbly	224	1424	1508	44	178		
									94		250	49
008	1	Pers	2/16	Cln Rm Mech	Asmbly	194	727	819	52	309		
008	1	Pers	2/16	Cln Rm Mech	Smplng	201	819	917	58	620		
008	1	Pers	2/16	Cln Rm Mech	Asmbly	206	940	1027	47	394		

*Time-weighted average over all sampled periods.

Table 1

Freon 113 Air Sample Results

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
008	1	Pers	2/16	Cln Rm Mech	Asmbly	209	1028	1120	53	240		
008	1	Pers	2/16	Cln Rm Mech	Non-Work	211	1120	1200	50	70		
008	1	Pers	2/16	Cln Rm Mech	Asmbly	216	1209	1306	57	384		
008	1	Pers	2/16	Cln Rm Mech	Asmbly	219	1306	1406	60	383		
008	1	Pers	2/16	Cln Rm Mech	Asmbly	223	1406	1504	58	4		
									435		303	275
018	1	Pers	2/16	Cln Rm Mech: QA	Test	196	737	820	43	344		
018	1	Pers	2/16	Cln Rm Mech: QA	Test	202	820	901	41	367		
018	1	Pers	2/16	Cln Rm Mech: QA	Test	205	929	1014	45	430		
018	1	Pers	2/16	Cln Rm Mech: QA	Test	210	1124	1202	38	219		
018	1	Pers	2/16	Cln Rm Mech: QA	Test	215	1325	1426	61	379		
018	1	Pers	2/16	Cln Rm Mech: QA	Test	220	1426	1505	39	489		
									267		373	208
022	1	Pers	2/16	Cln Rm Mech	Asmbly	195	739	816	37	306		
022	1	Pers	2/16	Cln Rm Mech	Asmbly	199	817	858	41	534		
022	1	Pers	2/16	Cln Rm Mech	Smplng	203	1023	1128	65	212		
022	1	Pers	2/16	Cln Rm Mech	Asmbly	213	1203	1308	65	454		
022	1	Pers	2/16	Cln Rm Mech	Asmbly	221	1308	1349	41	1080		
022	1	Pers	2/16	Cln Rm Mech	Asmbly	227	1445	1604	19	544		
									268		489	273
023	1	Pers	2/16	Cln Rm Mech	Smplng	197	731	818	47	281		
023	1	Pers	2/16	Cln Rm Mech	Smplng	200	818	900	42	355		
023	1	Pers	2/16	Cln Rm Mech	Smplng	204	928	1024	56	407		
023	1	Pers	2/16	Cln Rm Mech	Smplng	208	1025	1116	51	232		
023	1	Pers	2/16	Cln Rm Mech	Smplng	212	1210	1305	55	317		
023	1	Pers	2/16	Cln Rm Mech	Smplng	218	1305	1348	43	301		
023	1	Pers	2/16	Cln Rm Mech	Smplng	229	1427	1508	41	336		
									335		319	223

*Time-weighted average over all sampled periods.

Table 2

Freon 113 8-Hour Time Weighted Average Exposure
Summary by Job Title: First Shift

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Job Title	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim ppm	95 Upr Conf Lim ppm
Cln Rm Mechanic	13	178	439	290	279	1.3	240	338
Cln Rm Mechanic: QA	4	208	304	254	252	1.2	165	342
Cln Rm Foreman	1	151			151			
Pr Cln Mechanic	5	49	186	115	105	1.7	36	194
Pr Cln Mechanic: QA	1	88			88			
Fld Cln Mechanic	3	14	323	129	61	4.8	27	231
Fld Cln Mechanic: QA	1	79			79			

Upper and lower confidence limits for arithmetic mean.

Table 2a

Freon 113 8-Hour Time Weighted Average Exposure by Job Title: Second Shift

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Job Title	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim ppm	95 Upr Conf Lim ppm
Cln Rm Mechanic	5	59	183	110	101	1.6	44	177
Pr Cln Mechanic	1	24			24			

Table 3

Freon 113 Short-Term Exposure Summary
by Task: First Shift

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Task	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim ppm	95 Upr Conf Lim ppm
Sampling: Cln Rm	26	212	961	497	455	1.5	400	595
Packg: Cln Rm	27	135	761	426	387	1.6	331	522
Assmbly: Cln Rm	24	4	1080	409	320	2.8	307	509
Testing: Cln Rm	13	104	612	334	305	1.6	196	471
Insp: Cln Rm	21	154	653	374	347	1.5	266	483
Sp Act: Cln Rm	3	155	725	448	373	2.2	161	734
Foreman: Cln Rm	4	215	673	349	309	1.7	100	596
Office	9	55	171	113	104	1.5	0	278
Cleaning: Pr Cln	12	86	472	153	133	1.7	11	297
Insp: Pr Cln	3	57	123	100	94	1.6	0	386
Set Up: Fld Cln	6	11	50	24	21	1.7	0	226
Sampling: Fld Cln	2	212	3316	1764	838	7.0	1413	2114
Flow Cln: Fld Cln	3	11	18	14	13	1.3	0	300
Insp: Fld Cln	1	151			151			
Testing: Fld Cln	2	87	111	99	98	1.2	0	450
Non-Work Act	2	70	136	103	98	1.6	0	453

Upper and lower confidence limits for arithmetic mean.

Table 3a

Freon 113 Short-Term Exposure Summary
by Task: Second Shift

Wiltech of Florida
Kennedy Space Center, Florida
HETA 89-344

February 12-16, 1990

Task	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim pm	95 Upr Conf Lim ppm
Sampling: Cln Rm	4	163	403	275	256	1.6	149	403
Packg: Cln Rm	1	50			50			
Assmbly: Cln Rm	1	105			105			
Testing: Cln Rm	7	46	438	150	120	2.0	54	246
Cleaning: Pr Cln	3	17	39	26	24	1.5	0	172

Upper and lower confidence limits for arithmetic mean.

Table 4

Freon 113 Air Sample Results

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
001	1	Pers	3/1	Pr Cln Mech	Clean	6	801	942	101	1		
001	1	Pers	3/1	Cln Rm Mech	Test	15	943	1035	52	496		
001	1	Pers	3/1	Cln Rm Mech	Test	28	1036	1115	39	4		
001	1	Pers	3/1	Cln Rm Mech	Test	30	1225	1407	102	52		
001	1	Pers	3/1	Cln Rm Mech	Test	39	1245	1513	28	88		
									322		105	70
003	1	Pers	3/1	Cln Rm Mech	Smplng	7	718	829	71	409		
003	1	Pers	3/1	Cln Rm Mech	Smplng	10	830	904	34	1470		
003	1	Pers	3/1	Cln Rm Mech	Smplng	19	904	918	14	1451		
003	1	Pers	3/1	Cln Rm Mech	Smplng	22	1001	1032	31	534		
003	1	Pers	3/1	Cln Rm Mech	Smplng	27	1033	1113	40	492		
003	1	Pers	3/1	Cln Rm Mech	Pckg	31	1222	1400	98	51		
003	1	Pers	3/1	Cln Rm Mech	Pckg	40	1435	1512	37	64		
									325		440	298
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	3	740	833	53	635		
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	11	833	909	36	1438		
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	20	909	918	9	1726		
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	24	1001	1030	29	562		
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	26	1031	1109	38	545		
004	1	Pers	3/1	Cln Rm Mech: QA	Insp	32	1223	1256	33	77		
									198		710	293
002	1	Pers	3/1	Cln Rm Mech	Smplng	8	737	836	59	3010		
002	1	Pers	3/1	Cln Rm Mech	Smplng	12	836	905	29	2732		
002	1	Pers	3/1	Cln Rm Mech	Smplng	21	905	918	13	2522		
002	1	Pers	3/1	Cln Rm Mech	Smplng	23	959	1034	35	648		
002	1	Pers	3/1	Cln Rm Mech	Smplng	25	1035	1113	38	3380		
002	1	Pers	3/1	Cln Rm Mech	Pckg	29	1224	1400	96	54		
002	1	Pers	3/1	Cln Rm Mech	Pckg	41	1438	1512	34	80		
									304		1476	935
007	1	Pers	3/1	Pr Cln Mech	Clean	1	714	956	152	86		
007	1	Pers	3/1	Pr Cln Mech	Clean	17	958	1123	86	59		
007	1	Pers	3/1	Pr Cln Mech	Clean	36	1234	1424	110	4		
007	1	Pers	3/1	Pr Cln Mech	Clean	44	1425	1526	61	7		

*Time-weighted average over all sampled periods.

Table 4

Freon 113 Air Sample Results

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
									409		46	40
005	1	Pers	3/1	Pr Cln Mech	Clean	9	1228	1421	113	5		
005	1	Pers	3/1	Pr Cln Mech	Clean	13	1423	1518	55	5		
									168		5	2
009	1	Pers	3/1	Pr Cln Mech	Clean	4	0754	0958	124	48		
009	1	Pers	3/1	Pr Cln Mech	Clean	14	1000	1122	82	22		
009	1	Pers	3/1	Pr Cln Mech	Clean	34	1237	1418	101	8		
009	1	Pers	3/1	Pr Cln Mech	Clean	43	1420	1518	58	5		
									365		24	18
008	1	Pers	3/1	Pr Cln Mech	Clean	2	0714	1002	168	50		
008	1	Pers	3/1	Pr Cln Mech	Clean	16	1003	1120	77	33		
008	1	Pers	3/1	Pr Cln Mech	Clean	35	1235	1415	100	6		
008	1	Pers	3/1	Pr Cln Mech	Clean	42	1418	1515	57	7		
									402		29	25
006	1	Pers	3/1	Pr Cln Mech: QA	Insp	5	0742	1004	142	23		
006	1	Pers	3/1	Pr Cln Mech: QA	Insp	18	1006	1124	78	17		
006	1	Pers	3/1	Pr Cln Mech: QA	Insp	37	1236	1427	111	2		
006	1	Pers	3/1	Pr Cln Mech: QA	Insp	45	1427	1509	42	9		
									373		14	11
001	1	Pers	3/2	Pr Cln Mech	Clean	49	0755	0932	157	12		
001	1	Pers	3/2	Pr Cln Mech	Clean	61	0933	1041	68	10		
001	1	Pers	3/2	Pr Cln Mech	Clean	81	1042	1116	34	14		
001	1	Pers	3/2	Pr Cln Mech	Clean	93	1242	1503	141	13		
									400		12	10
002	1	Pers	3/2	Pr Cln Mech	Clean	52	0715	0936	141	48		
002	1	Pers	3/2	Pr Cln Mech	Clean	59	0937	1049	72	550		
002	1	Pers	3/2	Pr Cln Mech	Clean	84	1050	1240	110	11		
002	1	Pers	3/2	Pr Cln Mech	Clean	92	1241	1504	143	13		
									466		106	103
003	1	Pers	3/2	Pr Cln Mech	Clean	50	0730	0935	135	16		
003	1	Pers	3/2	Pr Cln Mech	Clean	60	0936	1044	68	21		
003	1	Pers	3/2	Pr Cln Mech	Clean	82	1045	1116	31	10		
003	1	Pers	3/2	Pr Cln Mech	Clean	94	1235	1504	149	14		

*Time-weighted average over all sampled periods.

Table 4

Freon 113 Air Sample Results

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
									383		16	13
004	1	Pers	3/2	Pr Cln Mech: QA	Insp	51	0739	0938	119	15		
004	1	Pers	3/2	Pr Cln Mech: QA	Insp	62	0939	1056	77	6		
004	1	Pers	3/2	Pr Cln Mech: QA	Insp	83	1056	1231	95	3		
004	1	Pers	3/2	Pr Cln Mech: QA	Insp	91	1231	1500	149	5		
									440		7	7
005	1	Pers	3/2	Cln Rm Mech	Smplng	57	0750	0834	44	277		
005	1	Pers	3/2	Cln Rm Mech	Smplng	63	0834	0928	54	636		
005	1	Pers	3/2	Cln Rm Mech	Asmbly	70	1005	1115	70	76		
005	1	Pers	3/2	Cln Rm Mech	Asmbly	76	1224	1300	36	174		
005	1	Pers	3/2	Cln Rm Mech	Asmbly	96	1304	1410	66	156		
005	1	Pers	3/2	Cln Rm Mech	Asmbly	102	1450	1513	23	557		
									293		277	169
006	1	Pers	3/2	Cln Rm Mech: QA	Insp	56	0742	0839	57	296		
006	1	Pers	3/2	Cln Rm Mech: QA	Insp	67	0839	0930	51	605		
006	1	Pers	3/2	Cln Rm Mech: QA	Insp	73	1013	1057	44	178		
006	1	Pers	3/2	Cln Rm Mech: QA	Insp	79	1057	1111	14	186		
006	1	Pers	3/2	Cln Rm Mech: QA	Insp	86	1221	1252	32	156		
006	1	Pers	3/2	Pr Cln Mech: QA	Insp	95	1256	1327	31	27		
									229		279	133
007	1	Pers	3/2	Cln Rm Mech	Smplng	53	0724	0838	74	194		
007	1	Pers	3/2	Cln Rm Mech	Pckg	64	0838	0929	51	626		
007	1	Pers	3/2	Cln Rm Mech	Asmbly	72	1002	1057	55	150		
007	1	Pers	3/2	Cln Rm Mech	Asmbly	77	1057	1120	23	197		
007	1	Pers	3/2	Cln Rm Mech	Pckg	87	1216	1307	51	104		
007	1	Pers	3/2	Cln Rm Mech	Pckg	98	1307	1409	62	137		
007	1	Pers	3/2	Cln Rm Mech	Pckg	104	1439	1509	30	417		
									346		247	178
008	1	Pers	3/2	Cln Rm Mech	Smplng	55	0719	0836	77	174		
008	1	Pers	3/2	Cln Rm Mech	Smplng	66	0836	0929	53	621		
008	1	Pers	3/2	Cln Rm Mech	Pckg	71	1007	1055	48	148		
008	1	Pers	3/2	Cln Rm Mech	Pckg	78	1055	1107	12	194		
008	1	Pers	3/2	Cln Rm Mech	Pckg	88	1217	1308	51	169		

*Time-weighted average over all sampled periods.

Table 4

Freon 113 Air Sample Results

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Prsn Code	Shft	Sam Typ	Sam Date	Job Title	Task	Sam No	Time On	Time Off	Time min	FC 113 ppm	TWA* ppm	8HR-TWA ppm
008	1	Pers	3/2	Cln Rm Mech	Pckg	99	1309	1408	59	137		
008	1	Pers	3/2	Cln Rm Mech	Pckg	105	1439	1507	28	389		
									328		254	174
009	1	Pers	3/2	Cln Rm Mech	Smplng	54	0752	0831	39	292		
009	1	Pers	3/2	Cln Rm Mech	Test	65	0831	0928	57	636		
009	1	Pers	3/2	Cln Rm Mech	Pckg	69	1003	1054	51	137		
009	1	Pers	3/2	Cln Rm Mech	Pckg	75	1054	1122	28	203		
009	1	Pers	3/2	Cln Rm Mech	Pckg	89	1219	1305	46	169		
009	1	Pers	3/2	Cln Rm Mech	Pckg	97	1306	1406	60	147		
009	1	Pers	3/2	Cln Rm Mech	Smplng	100	1445	1514	29	607		
									310		305	197
100	1	Area	3/2	Clean Room		58	0810	0843	33	751		
100	1	Area	3/2	Clean Room		68	0843	0930	47	722		
100	1	Area	3/2	Clean Room		74	1017	1105	48	158		
100	1	Area	3/2	Clean Room		80	1105	1310	125	271		
100	1	Area	3/2	Clean Room		90	1312	1411	59	195		
100	1	Area	3/2	Clean Room		101	1412	1515	63	406		
									375		366	286

*Time-weighted average over all sampled periods.

Table 5

Freon 113 8-Hour Time Weighted Average Exposure
Summary by Job Title

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Job Title	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim ppm	95 Upr Conf Lim ppm
Cln Rm Mechanic	7	70	935	289	213	2.2	130	447
Cln Rm Mechanic: QA	2	133	293	213	197	1.7	0	509
Pr Cln Mechanic	7	2	103	30	17	3.6	0	188
Pr Cln Mechanic: QA	2	7	11	9	9	1.4	0	305

Upper and lower confidence limits for arithmetic mean.

Table 6

Freon 113 Short-Term Exposure Summary by Task

Rothe Development, Inc.
Johnson Space Center, Houston, Texas
HETA 89-344

March 1-2, 1990

Task	No Sam	Min ppm	Max ppm	Arith Mean ppm	Geo Mean ppm	Geo St Dev	95 Lwr Conf Lim ppm	95 Upr Conf Lim ppm
Sampling: Cln Rm	17	174	3380	1144	746	2.6	894	1394
Packg: Cln Rm	17	51	626	190	150	2.0	0	440
Insp: Cln Rm	11	77	1726	582	393	2.6	271	893
Assmbly: Cln Rm	6	76	557	218	180	1.9	0	639
Testing: Cln Rm	5	4	636	255	88	8.1	0	716
Cleaning: Pr Cln	27	1	550	40	15	3.5	0	238
Insp: Pr Cln	9	2	27	12	9	2.5	0	355

Upper and lower confidence limits for arithmetic mean.

Table 7

Freon 113 8-Hour Time Weighted Average Exposure
Summary by Location and Area
HETA 89-344

Area	Wiltech No Values	Wiltech Min ppm	Wiltech Max ppm	Wiltech Arith Mean ppm	Wiltech Geo Mean ppm	Wiltech Geo St Dev	Wiltech 95 Lwr Conf Lim ppm	Wiltech 95 Upr Conf Lim ppm	Rothe No Values	Rothe Min ppm	Rothe Max ppm	Rothe Arith Mean ppm	Rothe Geo Mean ppm	Rothe Geo St Dev	Rothe 95 Lwr Conf Lim ppm	Rothe 95 Upr Conf Lim ppm
First Shift																
Clean Room	18	151	439	274	263	1.7	234	314	9	70	935	271	210	2	142	402
Pre-Clean	6	49	186	110	101	1.6	41	181	9	2	103	25	15	3.2	0	155
Field Clean	4	14	323	116	65	3.6	31	202								
2nd Shift																
Clean Room	5	59	186	115	105	1.7	36	194								
Pre-Clean	1		24	24												

Upper and lower confidence limits for arithmetic mean.

Table 8

Summary of worker populations for dysrhythmia and FC 113 analyses

Analyses	Facility A	Facility B	Total
Paired Comparison (exposed vs. nonexposed day)	9	12	21
Exposed Day only	0	10	10
Total Monitored on Exposed Day (% of Eligible Workers)	9 (100)	22 (85)	31 (89)

Table 9

Characteristics of study population

Characteristic	Paired Comparison	Total Monitored
No. of Participants	16	31
Age (years)	41.7 ± 11.5*	40.8 ± 12.9*
Body Mass Index (kg/m^2)	25.5 ± 4.3*	27.1 ± 4.9*
Employment (yrs)	7.8 ± 5.6*	8.1 ± 7.3*
Male (%)	63	81
Smokers (%)	50	36

*standard deviation

Table 10

Full-shift time weighted average (TWA) FC 113 exposures (ppm) on exposed and non-exposed days for the 16 paired comparisons

Exposure	Exposed Day ppm	Nonexposed Day ppm	Paired Difference ppm
Mean	442.1 ± 300[1]	64.4 ± 59.5[1]	377.7 ± 289.[1]*
Minimum	247	0	201
Maximum	1,476	200	1,370

[1] standard deviation
* p < .001, paired t-test for differences in means

Table 11

Non-parametric analysis of mean frequency of premature beats and mean intraindividual differences between exposed and nonexposed workday

Event	Exposed Day Mean (min, max)	Nonexposed Day Mean (min, max)	Mean of Paired Differences Mean (min, max)	Signed Rank p-value
VPB Total	2.19 (0, 23.00)	7.19 (0, 78.0)	-5.00 (-75, 3.0)	.28
VPB Rate	0.21 (0, 0.62)	0.60 (0, 2.19)	-0.15 (-2.1, 0.1)	.20
SVPB Total	1.89 (0, 16.00)	1.45 (0, 12.0)	0.44 (-8.0, 14.0)	.85
SVPB Rate	0.07 (0, 0.63)	0.04 (0, 0.34)	0.03 (-.19, 0.6)	.66

Median score of the paired differences for the total count and rate of VPB's and SVPB's was 0.

Table 12

Parametric analysis of mean heart rate and length of p-r interval and mean intraindividual differences between exposed and nonexposed workday

Event	Exposed Day Mean (min, max)	Nonexposed Day Mean (min, max)	Mean of Paired Differences Mean (Std Dev)	Paired T-test p-value
Heart Rate	88.09 (64.8,116.2)	91.22 (64.2,113.6)	-3.13(8.06)	.14
P-R Interval	0.13 (0.10, 0.17)	0.13 (0.10, 0.18	0.001(0.01)	.75

Figure 1: Plan view of clean room: Wiltech

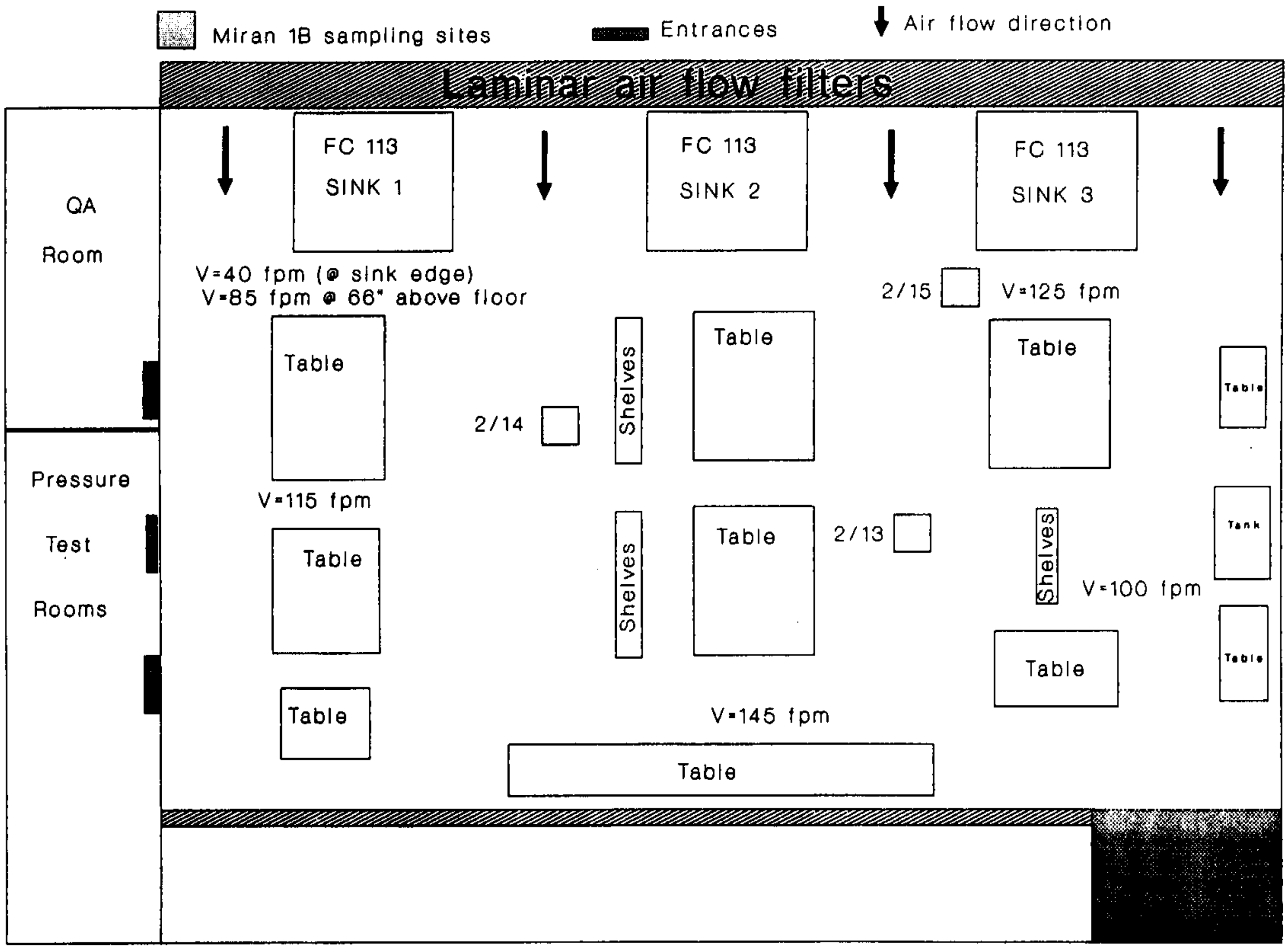


FIGURE 2. FC 113 area concentration vs time at Wiltech on February 13, 1990. Sample location was approximately 15 ft. in front of sink #2. (See Figure 1)

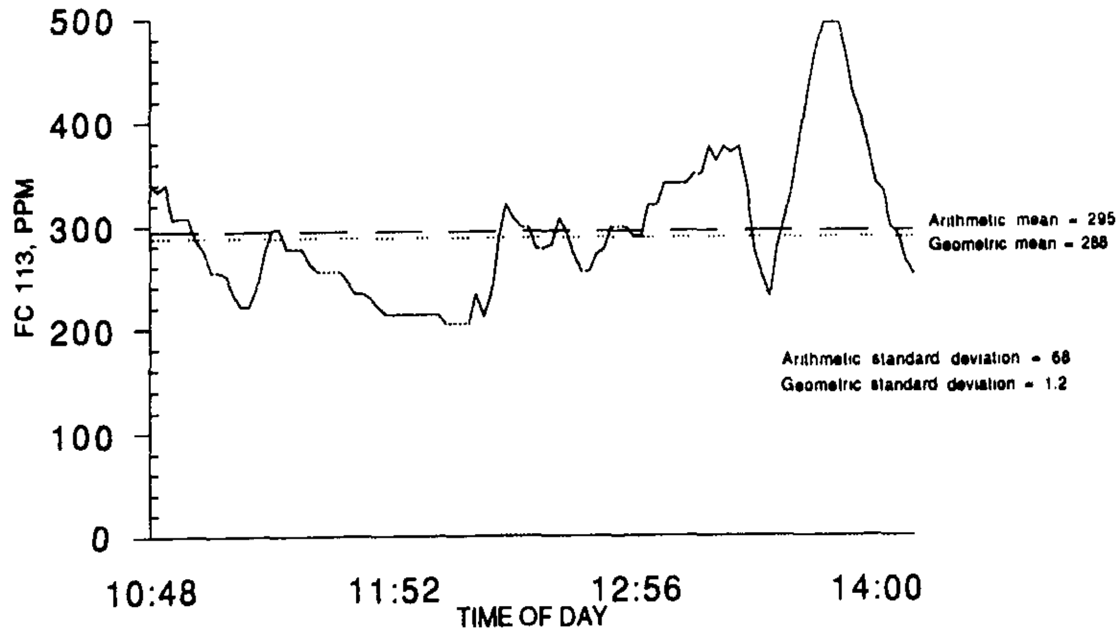


FIGURE 3. FC 113 area concentrations vs time at Wiltech,on February 14, 1990. Sample location was approximately 8 ft. in front of sink #2. (See Figure 1)

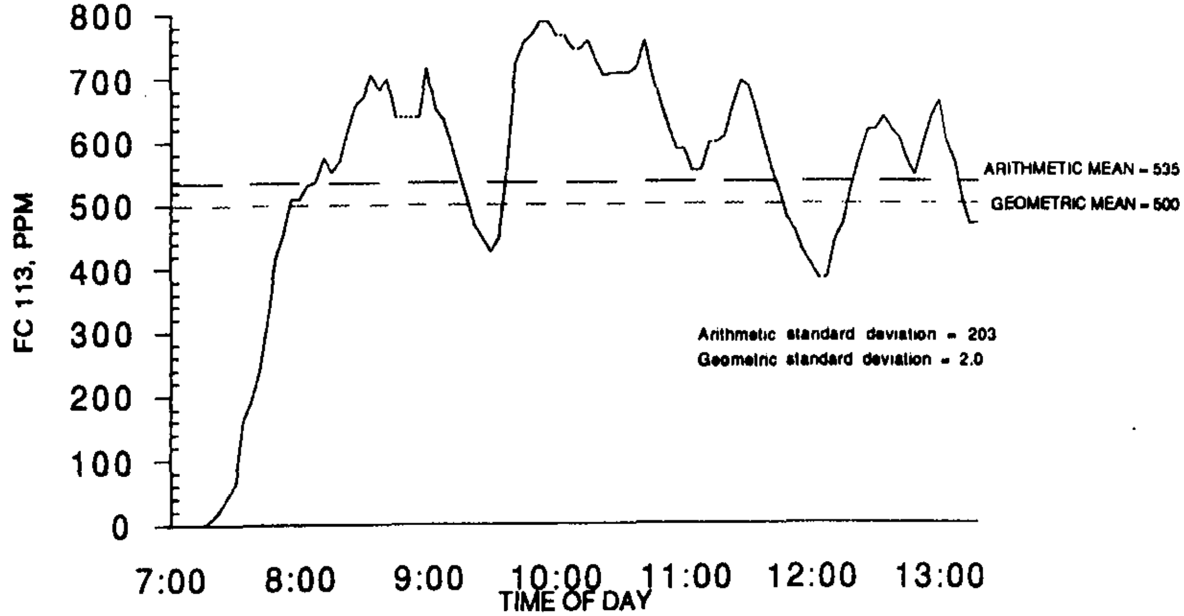


FIGURE 4. FC 113 area and personal concentrations vs time at Wiltech, on February 15, 1990. Sample location was directly in front of sink no. 3. (See Figure 1)

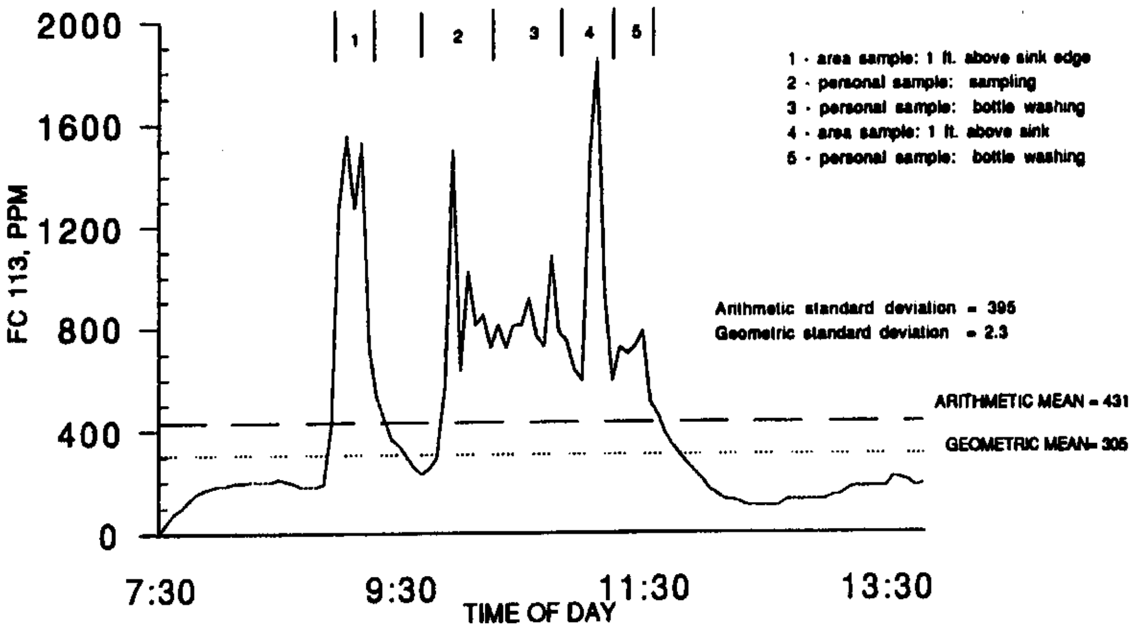


Figure 5. Plan view of clean room: Rothe

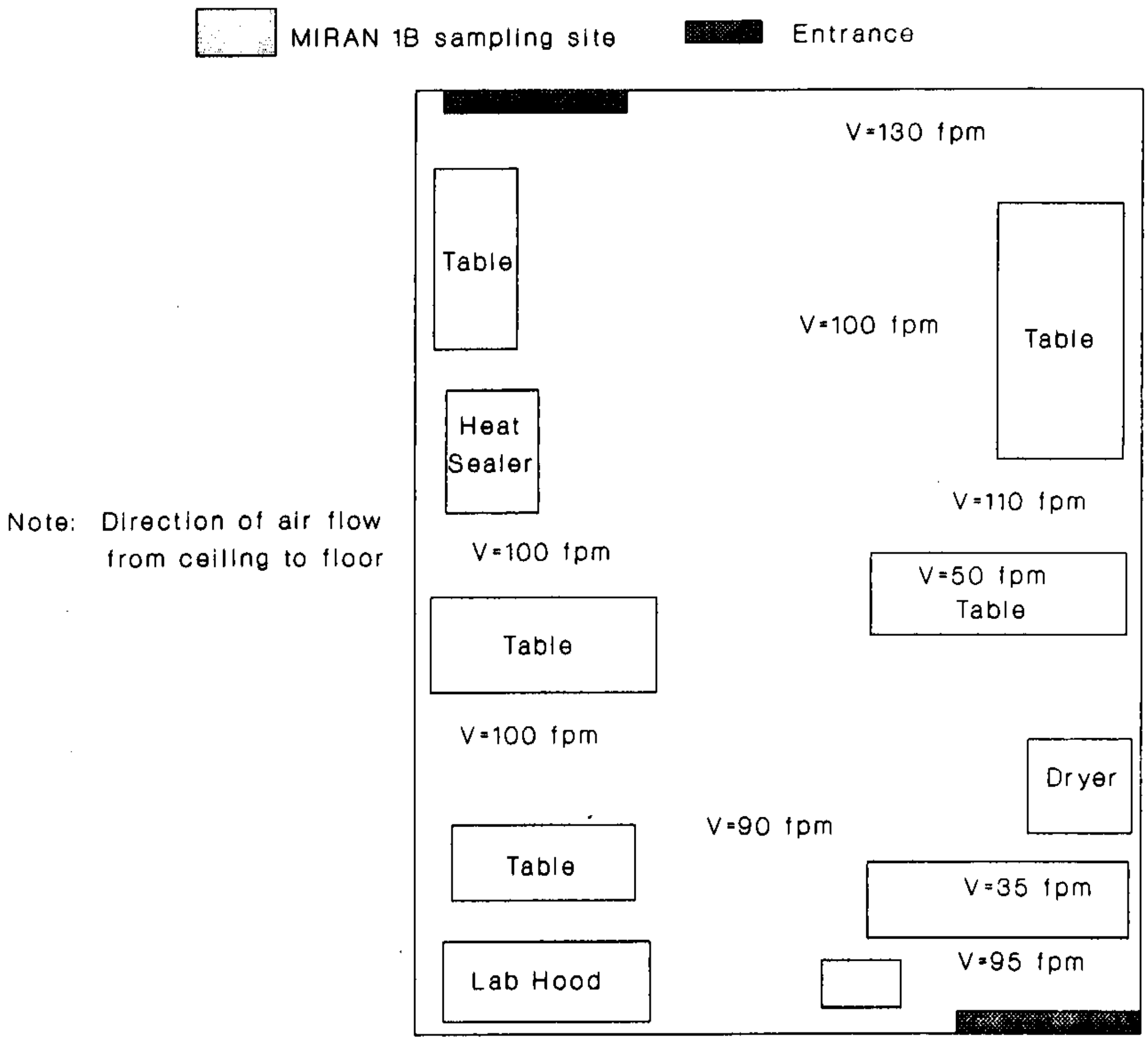


Figure 6. FC 113 personal and area concentrations at Rothe on March 2, 1990. Sample location was near table closest to clean room entrance. (See Figure 5)

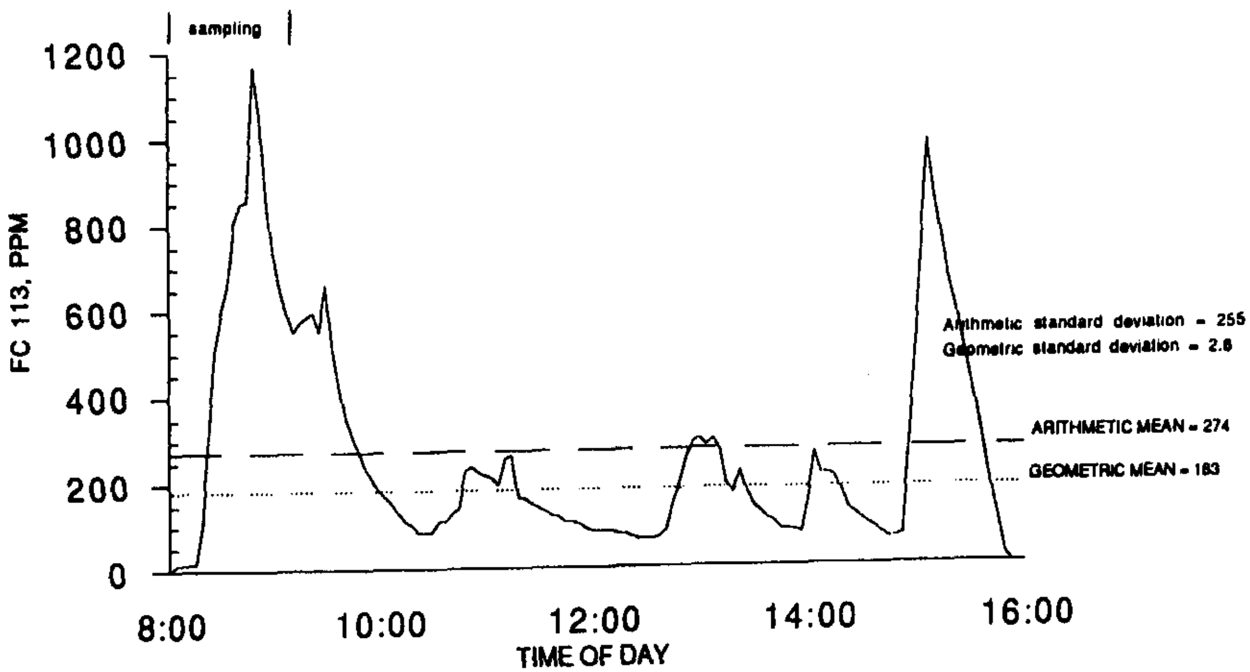
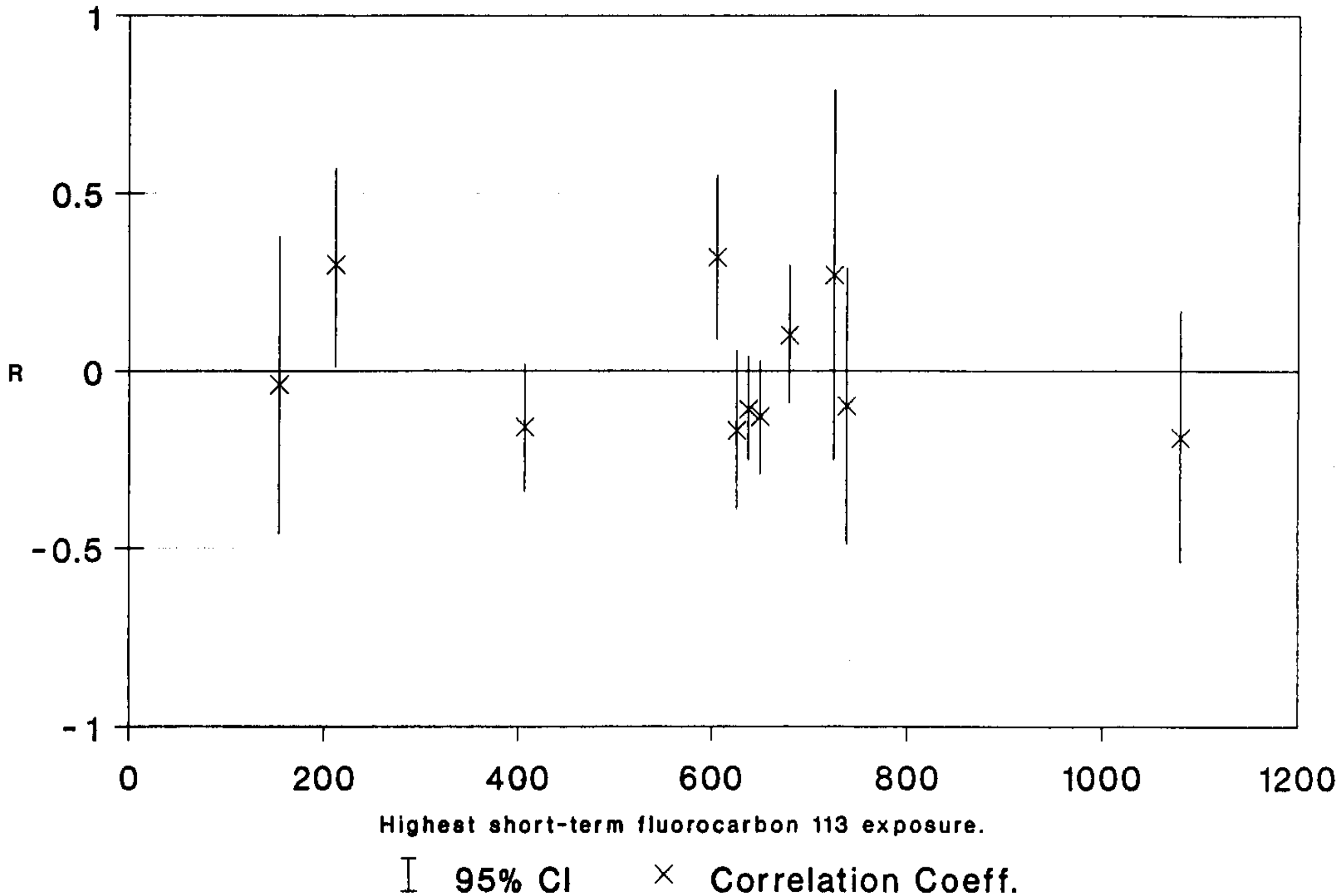


Figure 7. Spearman's rank correlation coefficient* (R) and confidence intervals for 11 participants as a function of highest measured short-term exposure.



*Fluorocarbon 113 exposure and premature ventricular beats

Figure 8. Fluorocarbon (FC) 113 exposure and premature ventricular beats (VPB) as a function of time for participant A.

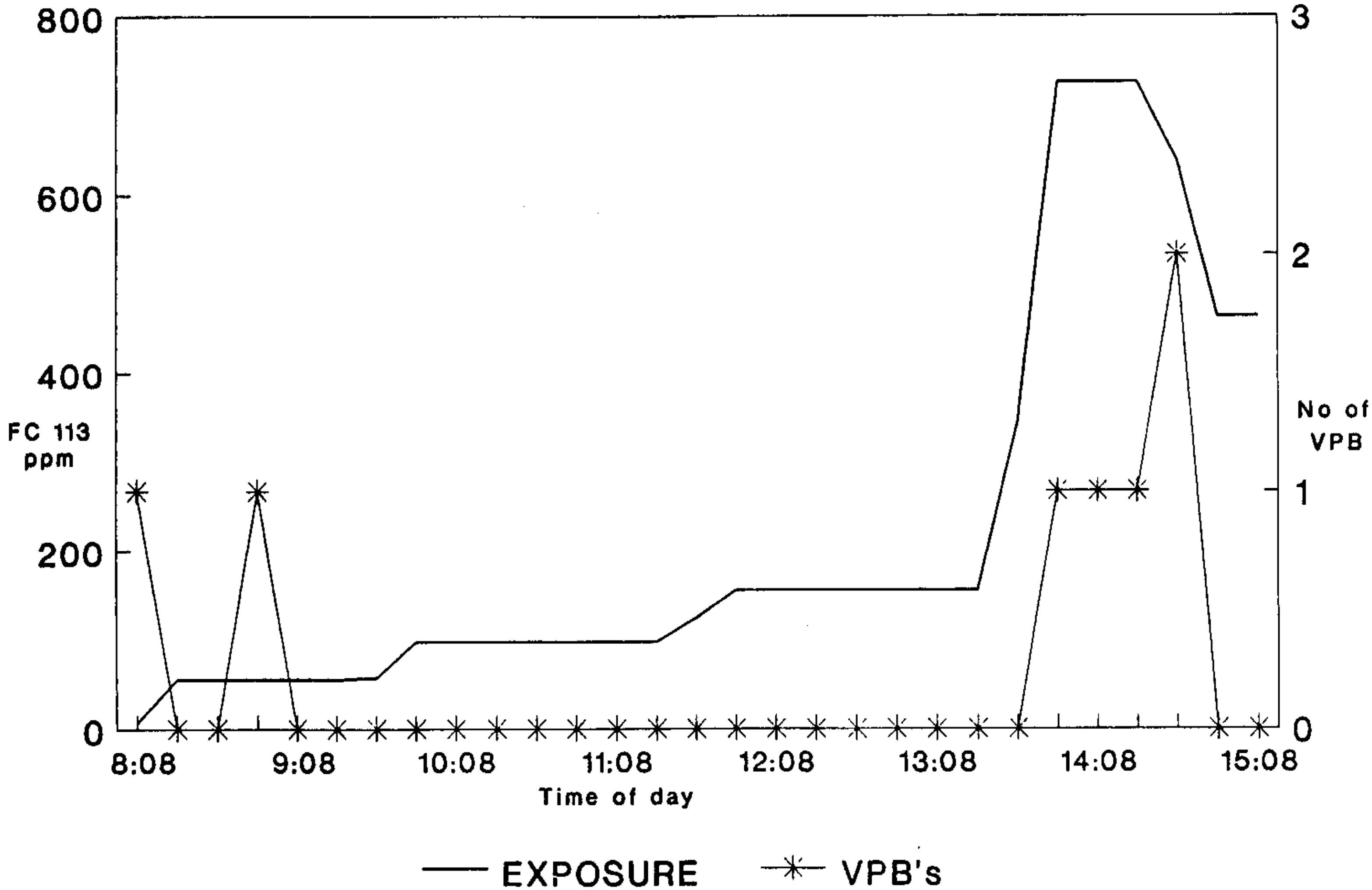


Figure 9. Fluorocarbon (FC) 113 exposure and premature ventricular beats (VPB) as a function of time for participant B.

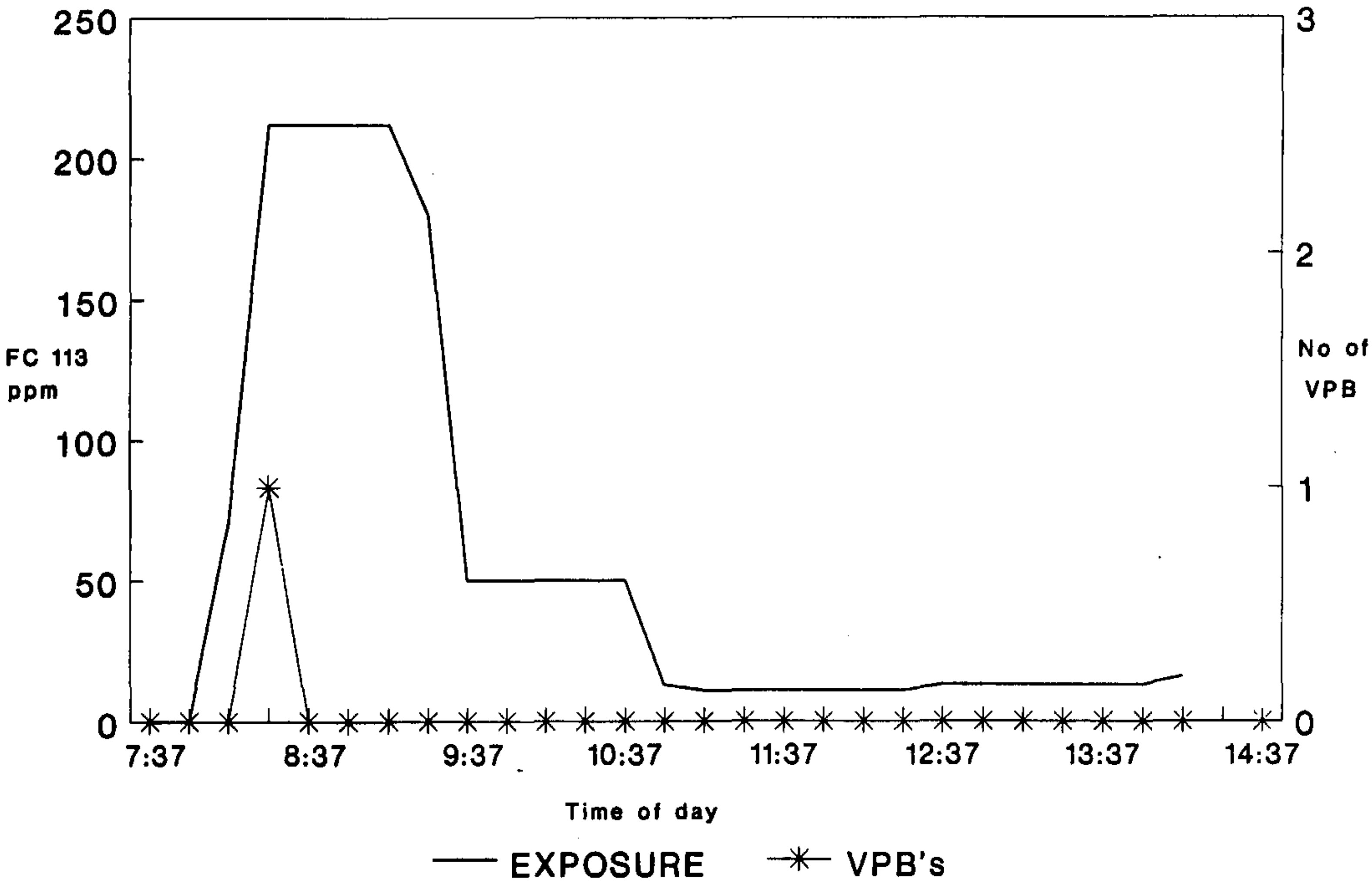


Figure 10. Fluorocarbon (FC) 113 exposure and premature beats (VPB) as a function of time for participant C.