

**IN-DEPTH SURVEY REPORT:
CONTROL OF PERCHLOROETHYLENE (PCE)
IN VAPOR DEGREASING OPERATIONS, SITE #3**

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ABSTRACT

Worker exposures to perchloroethylene (PCE) occur in a large number of industries where PCE is used for organic solvent vapor cleaning (degreasing). Solvent degreasing does not constitute a distinct industrial category, but is an integral part of many major industries. This report examines worker exposures to PCE during the loading and unloading of parts, and the performance of an open-top vapor degreaser. Air samples for PCE were collected over three days of degreasing operations. The PCE concentrations measured in the building ranged from 0.12 to 17.1 ppm. A review of the sampling results showed that the electroplaters utilizing the open-top vapor degreaser were not exposed to perchloroethylene concentrations in excess of the OSHA PEL.

I. BACKGROUND AND PURPOSE

The National Institute for Occupational Safety and Health (NIOSH), working under an inter-agency agreement with the Office of Regulatory Analysis of the Occupational Safety and Health Administration (OSHA), is conducting a study to survey occupational exposures to tetrachloroethylene, commonly known as perchloroethylene (PCE) in vapor degreasing (parts cleaning) operations, and to document engineering controls and work practices affecting those exposures

This study will determine the extent of employee exposures and control technology in industries that utilize vapor degreasing with PCE, thus providing OSHA with data for its analysis of the technological feasibility for a possible revision of the PCE regulations. The study will provide information on PCE degreasing equipment currently available to industry, engineering controls available to industry, and work practices utilized to reduce employee exposures, use of personal protective equipment, affected industries, maintenance procedures, and the extent of employee exposures. The three most commonly used vapor degreasers include open-top vapor degreasers (OTVD), in-line vapor degreasers, and vacuum degreasers. The Halogenated Solvents Industry Alliance (HSIA) estimates that approximately 10% of the 344 million pounds of PCE solvent used in the United States in 1998 was used for metal cleaning/degreasing¹. However, the industries using PCE and percentages of degreaser types utilizing PCE are not well defined or are unknown at this time.

The performance of a thorough industrial hygiene survey for a variety of individual employers will provide valuable and useful information to the public and employers in the industries included in the work. NIOSH has conducted 6 sampling surveys at 4 sites to document engineering controls and the associated worker exposures to PCE. The principal objectives of this survey are

To identify and describe the control technology and work practices in use in degreasing operations associated with potential occupational exposures to PCE, as well as determining additional controls, work practices, substitute materials, or technology that can further reduce occupational PCE exposures

To measure full-shift, personal breathing-zone exposures to PCE. These samples will provide examples of exposures to PCE among workers across the many industries where PCE degreasing is encountered. These exposure data, along with the engineering control data described above, will provide a picture of the conditions in the selected industries

II PERCHLOROETHYLENE (PCE) HEALTH EFFECTS

Perchloroethylene is a non-flammable liquid with a molecular structure containing two carbon atoms and four chlorine atoms, a molecular weight of 165.8 (about 5.5 times as dense as air), a

boiling point of 250° F, specific gravity of 1.62, and a vapor pressure of 14 mmHg at 70° F. Inhalation of perchloroethylene can cause CNS depression (producing symptoms of vertigo, dizziness, nausea, narcosis, in-coordination, headache, if exposures are high enough unconsciousness and death may occur), and direct contact with the liquid may impair the mucous membranes, eyes, and skin.^{2,3} Chronic exposure to perchloroethylene has been reported to cause liver damage and peripheral neuropathy in humans, and liver carcinomas in experimental animals.⁴ The International Agency for Research on Cancer (IARC) position regarding perchloroethylene is that there is insufficient epidemiological evidence to establish the carcinogenic risk to humans.⁵

NIOSH considers perchloroethylene to be an occupational carcinogen, and recommends that exposures be reduced to the lowest feasible level.⁶ The current OSHA permissible exposure limits (PEL) for perchloroethylene are 100 parts per million (ppm) measured as an 8-hour time-weighted average (TWA), 200 ppm ceiling and a maximum peak of 300 ppm for 5 minutes in any three hours. In 1989 OSHA lowered the PEL for perchloroethylene from 100 ppm to 25 ppm, but a 1993 federal court reversed this action. Several states have retained the 1989 limit. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value for PCE is 25 ppm averaged over an 8-hour period, and the 15-minute short-term exposure limit (STEL) is 100 ppm. ACGIH lists perchloroethylene as an animal carcinogen (A3) and, based on the available evidence, considers it unlikely to be a human carcinogen, except under uncommon or unlikely routes and levels of exposure.²

III. METAL DEGREASING INDUSTRY BACKGROUND

Perchloroethylene exposures occur in a large number of industries. Organic solvent cleaning (degreasing) does not constitute a distinct industrial category, but is an integral part of many major industries. The three most commonly used halogenated solvents are methylene chloride, perchloroethylene, and trichloroethylene. In November 1993, the United States Environmental Protection Agency (EPA) published its National Emission Standards for Hazardous Air Pollutants: Halogenated Solvent Cleaning - Background Information Document.⁷ In that document, they report that the five 2-digit Standard Industrial Classification (SIC) codes that use the largest quantities of halogenated solvents for cleaning are SIC 25 (furniture and fixtures), SIC 34 (fabricated metal products), SIC 36 (electric and electronic equipment), and SIC 39 (miscellaneous manufacturing industries). Additional industries that use halogenated solvents for cleaning include SIC 20 (food and kindred products), SIC 33 (primary metals), SIC 35 (non-electric machinery), and SIC 38 (instruments and clocks). Non-manufacturing industries such as railroad, bus, aircraft, and truck maintenance facilities, automotive and electric tool repair shops, automobile dealers, and service stations (SIC 40, 41, 42, 45, 49, 55, and 75, respectively) also use organic solvent cleaners. The above may also include cold degreasing or metal cleaning operations. In particular, the automobile dealers and service stations would more likely use PCE as a cold degreaser than a vapor degreaser. The EPA estimated that in 1991, there were about 2070 degreasers using perchloroethylene in the U.S.⁷

Vapor degreasing is an industrial process used to remove grease, oil, temporary coatings, and dirt or other solids, where clean, dry surfaces are required. The process is commonly used to clean all types of metal and solvent resistant plastics and may be used at any stage of a manufacturing process to clean parts of varying sizes, and parts containing recesses, blind holes, perforations, crevices, or welded seams. Vapor degreasing may occur before painting, enameling, or lacquering, electroplating, inspection, assembly, or packing. It can also be used before and after machining, before further metal work, or treatment or other special applications.²

Due its increased vapor flushing and higher boiling point (250° F) PCE solvent is typically used to remove oil and greasy soils which become more fluid and are more soluble at higher temperatures.⁸ Many buffing compounds contain a waxy binder that is only solvent soluble at higher temperatures when it is molten. PCE is the best drying solvent because its high boiling point (250° F) drives water off the workload rapidly.⁸

THEORY OF PROCESS - Open top vapor degreasers (OTVD)

Metal parts are cleaned in vapor degreasers by boiling cleaning solvent in the degreaser sump(s), producing a heavy vapor. Cold metal part(s) are introduced to the warm vapor zone causing the solvent vapor to condense on the surface of the cold part(s).

Open-top vapor degreasers consist of several sections

- A tank - solvent is heated to a boil in the tank
- The vapor zone - area immediately above the heated tank where vaporized solvent is present. The part(s) to be cleaned are held in the vapor zone until they reach the temperature of the vapor and surface contaminants are flushed off the part(s) by liquid solvent condensation. At this point, condensation or flushing ceases and cleaning is complete. The part is then removed from the unit clean and dry.
- Condensation coils - vapors are condensed on the degreaser condensation coils thereby preventing the vapors from escaping the degreaser. This forms a sharply defined interface between the solvent and air above the coils.
- The freeboard - this is the area between the condensation coils and the top of the degreaser. This area provides additional control in containing the solvent vapor.

The built-in heat balance provides an equilibrium whereby the coil condenses vapors as fast as they are produced by the heaters in the boiling sump. The condensed vapors drip into the collection trough and course through the water separator to the rinse sump and back to the first sump to complete the "Distillate Turnover Cycle".⁸

Vapor degreasers are equipped with water separators to remove water from the process. Water enters a vapor degreaser through condensation of atmospheric moisture. Water in a vapor degreaser increases corrosion and contributes to higher losses because the PCE/water vapor has a lower density than that of dry solvent. The water separator operates on the principle of gravity.

separation, since water is less dense and essentially immiscible in PCE, the water floats to the top. The water is then directed towards disposal while the PCE is returned to the tank sump.⁸

Stills are used to increase recovery of the cleaning solvent. The still can be operated batch-wise or continuously. In continuous operation solvent is fed to the still from the degreaser boiling sump and the distillate returns to the condensate reservoir. A float control is used to keep the level of solvent in the still constant.⁸

Other auxiliary equipment commonly used for OTVDs include refrigerated freeboard devices to reduce solvent losses and carbon adsorption for removal of solvent vapor from the air.⁸

THEORY OF PROCESS - Airless Vacuum Vapor Degreasers

This process is performed in an airless, closed vacuum system where cleaning compounds are used in their vapor or liquid state combined with optional spray, tumbling or soaking cycles to completely remove contaminants such as grease, oil, wax or particulate matter from the part surface. Parts to be cleaned are loaded into a preheated degreasing chamber, the chamber is closed, sealed and evacuated. The vacuum achieved is generally less than 5 torr [1 torr equals 1 millimeter (mm) Hg]. After pump down, solvent is heated under vacuum pressure to operational temperature and the heated solvent vapor is released from the vapor supply tank into the degreasing chamber. The vapors clean the parts similar to the operations of a traditional vapor degreaser. The warm solvent vapors are condensed on the surfaces of the cooler parts, dissolving soluble contaminants, and carrying them off into the bottom of the degreasing chamber. As the vapor condenses on the parts, the parts heat up until the surface reached the chamber temperature and condensation ceases. If further cleaning is necessary, the parts are sprayed with liquid solvent to cool them down, followed by a second release of vapor into the degreasing chamber. The clean/spray cycle could be repeated as many times as desired. After the cleaning cycles are complete, the solvent recovery process begins. Using a vacuum pump, the liquid solvent and contaminants are drained from the bottom of the degreasing chamber to the distillation chamber. By placing the chamber under a vacuum, virtually all of the remaining solvent is vaporized and removed from the degreasing chamber. The degreasing chamber is then back-filled with ambient air, and pumped down once more, this time passing the exhausted air through a carbon filter to remove traces of PCE before releasing it to the environment. Finally, the chamber is again filled with ambient air to atmospheric pressure and opened for parts removal. Typical cycle times, from parts loading to removal from the degreaser chamber are 20 to 30 minutes. The cleaning process is controlled automatically by a programmable controller, normally requiring no operator attention.⁹

Vacuum or airless vapor degreasers consist of several components.⁹

- **Pumps** - the pumps are used to reduce the system pressure from 760 torr (atmospheric pressure) down to the operating pressure of less than 5 torr
- **Solvent storage tanks** - the solvent storage tank is kept at ambient temperature. The vapor supply tank is maintained at operating temperature (~250°F)

- **Distillation** - stills are used to increase recovery of the cleaning solvent. The distillation column is a jacketed pressure vessel. At low system pressure, the solvent boils at low temperature. Vapors are condensed in the distillation column and a sump at the bottom of the column pumps the contaminants to a waste storage vessel. Waste from the system contains approximately 5% solvent, conventional open-top vapor degreaser distillation waste contains approximately 30% solvent.
- **Cooling** - cooling capacity is needed to cool solvent to the liquid form for spraying and to keep solvent storage tank at ambient temperature for efficient pumping.
- **Heating** - electrical or steam heat is needed to vaporize the solvent.
- **Air** - is required to operate door lifts, actuate valves, and pneumatic pumps.
- **Electrical** - electrical requirements are dependent upon whether the unit utilized an electrical boiler, chiller, pumps size, and size of the degreasing vessel.
- **Cleaning chamber** - part(s) to be cleaned are held in the cleaning chamber until they reach the temperature of the vapor and surface contaminants are flushed off the part(s) by liquid solvent condensation.

IV. STUDY METHODS

This field study was conducted in accordance with 42 CFR 85a, the NIOSH regulations governing the investigation of places of employment.

INDUSTRY AND PROCESS SELECTION

A preliminary review of information about degreasing technology was conducted and a plan was then developed to assess worker exposures. The primary criteria for inclusion in this study was the use of PCE as the degreasing solvent, and the use of control technologies to reduce worker exposures. Other criteria used for plant selection were, that the plant be a full-time operation, and that the plant management be willing to participate in the study.

To determine suitability for study, the plant management was contacted by telephone to request participation and to obtain information necessary for scheduling a field visit. Survey participation by facility management and individual employees was entirely voluntary. The selection of the actual survey site was based upon the control technology information received from the facility and any pertinent information received from industry groups, trade associations, or other persons or organizations familiar with the facilities. The intent was to select facilities that appeared to be typical (not necessarily representative) of that specific industry, not the best or the worst. A summary of the study protocol was provided to the plant management in advance of the field survey.

INFORMATION COLLECTION

The first day of the site visit was spent meeting with company personnel (company management and employees), conducting a walk through of the plant to begin the industrial hygiene assessment of exposure and control technology used in the degreasing operations, and to arrange sampling on the subsequent day. The initial walk-through survey was intended to characterize potential exposure levels, and to identify workers for full-shift personal sampling. Employees with the highest potential PCE exposures in the degreasing area were the major focus of the site visits and were selected for personal sampling. Workers selected for sampling were briefed on the sampling procedures to be conducted. Because the goal of this study is to assess the effects of engineering controls and work practices on PCE exposures, sample media were placed outside of any respiratory protective equipment worn by the worker.

Pertinent data on the employer and the industry were also collected including, company name and location, number of employees by job title, products produced, processes used, and work schedules. Information about the facility or building(s) included the type of building construction, descriptions of general ventilation present, and age of the facility. Most of this information, while not mandatory for successful completion of the study, was helpful for understanding the operations and processes being sampled.

At the discretion of the industrial hygienist, additional area and/or background samples were collected using NIOSH Manual of Analytical Methods, Method #1003, photo-ionization detector (PID), or other techniques, if during the course of an investigation it was determined that such measurements would add to the usefulness of the study.

AIR SAMPLING METHODOLOGIES

This section summarizes the sampling, analytical, and engineering evaluation methods used during the course of this study to measure workplace levels of PCE and methods used to assess the effectiveness of the available control technologies. The effectiveness of the OTVD used at this facility was evaluated primarily by collecting personal breathing-zone (PBZ) air samples for PCE during operation of the vapor degreasers. PBZ samples were collected on the vapor degreaser operator, the assistant operator, the core assemblers (clean room), the brazing furnace operator, and the fan assembly operator.

Personal breathing-zone air samples were collected to determine employees' full-shift, time-weighted average, PBZ concentrations of PCE. Worker exposures were measured by placing a battery-operated sampling pump on the workers with the air sampler placed in the workers' breathing-zone. Samples were collected at a flow rate of 0.2 liters per minute (lpm) on solid sorbent, coconut shell, charcoal tubes, in accordance with NIOSH Method #1003. Samples were analyzed for PCE by the NIOSH contract laboratory.

Sample data sheets were filled out by the field survey team to document all samples collected. Information contained on the sample sheets included facility name, facility location, process name, worker identifier (included only to allow the "matching" of samples from the same worker on different days), job title and task performed, pump number, pump flow rate, start times, stop times, and sample number. In addition, any unusual conditions, work practices, and use of personal protective equipment, and the number of workers at the facility in that particular job classification, were also noted. Data transmitted to the laboratory included sample date, sample number, a NIOSH identification code, and a unique sample location code. The identity of the worker corresponding to the sample location codes are known only to NIOSH researchers.

A second set of personal full-shift TWA measurements were collected separately using passive "badge" samplers. This set of measurements consisted of samples collected concurrently with those samples listed above and analyzed via NIOSH Method #1003. The simultaneous sampling allows for a comparison of the two methods.

CALCULATION OF ANALYTICAL RESULTS

For each employee sampled, a full-shift (up to 10-hour) TWA exposure to PCE was calculated. Assuming that no exposure occurred during the unsampled period means that the TWA is calculated using the following equation:

$$TWA = \frac{C_1 T_1 + C_2 T_2 + \dots + C_n T_n}{\text{sample time}} \quad (1)$$

Because most of the samples were single, full-shift samples, when the analysis of a sample results in a value less than the limit of detection (LOD) of the analytical method, the LOD was used to calculate the TWA, and the value(s) are reported as "at or below" the calculated value (e.g., $\leq 0.05 \text{ mg/m}^3$).

VIDEO EXPOSURE MONITORING

Video Exposure Monitoring (VEM) is a technique that employs a video camera and a direct-reading instrument. Synchronization of the internal clocks of both the camera and the instrument is required. For this particular study, the MiniRae 2000 Portable VOC Monitor, Model PGM-7600, (manufactured by Rae Systems Incorporated) served as the direct-reading instrument. The MiniRae 2000 is a compact monitor designed as a broadband volatile organic chemical (VOC) gas monitor and datalogger, capable of storing the data measurements over one-second intervals. It monitors VOCs using a photoionization detector (PID) at an internally integrated flow rate of 450 - 550 milliliters per minute (ml/min). The resulting concentration measurements were downloaded to a notebook personal computer immediately following the sampling session for data storage.

Degreaser operators were monitored during several exposure events using the VEM technique to determine peak exposure events using the MiniRae 2000. Peak exposure events are primarily unloading/loading operations, but could also include repair or maintenance operations which could result in increased PCE exposure (e.g., addition of PCE to the degreaser unit). The MiniRae 2000 was calibrated on-site with a commercially procured 100 ppm isobutylene calibration gas (a surrogate of known proportional response), and operated according to manufacturers instructions. The flow rates for the two MiniRAEs used during these surveys were 533 ml/min and 480 ml/min.

Each exposure event was monitored for the duration of that event, and for a sufficient time prior and subsequent to establish a background concentration such that 5, 10 and 15 minute average exposures can be calculated. As the worker's exposure was being collected, an 8mm video camera mounted on a tripod was recording the worker's movements. The exposures were later combined with the videotape and the data appear as a moving bar graph that is superimposed at the edge of the viewing screen. The VEM technique is an excellent tool for illustrating cause and effect relationships in the working environment.

ENGINEERING AND VENTILATION EVALUATION

A detailed description of the degreasing equipment and auxiliary equipment (e.g. still, carbon filter beds, etc.) were obtained, as well as information about related maintenance operations including the frequency of those operations. Depending on the frequency of the activity and who performs the activity, it may be treated as maintenance activity or as part of the operators' normal activities. Background information about the degreaser including the type of equipment (e.g., OTVD), the equipment manufacturer, the equipment design operation and performance parameters (e.g., automation, enclosure, superheat, distillation unit, carbon absorbers, etc.), ventilation, materials or parts cleaned, maintenance or repair procedures (e.g., still clean-out) and personal protective equipment used (e.g., gloves, respirators) were gathered. Plant and process layout diagrams were obtained from plant management and are included in the attachments.

Like the information on processes, the summary of engineering controls is a mix of narrative description and physical measurements. The measurements include such items as ventilation flow rates and distance measurements. The proximity of the control systems to open doors or windows, general ventilation intakes and exhausts, and other interacting equipment (i.e., pedestal fans) were also noted. The age and history of the control systems, cost of control installation, maintenance practices, and operation and maintenance costs are included if provided by the facility management.

One technique used to evaluate the effectiveness of the local exhaust ventilation system was the use of a smoke generator. The Rosco, Model 1500 smoke generator was used to visualize airflow patterns at the loading and unloading area of the vapor degreaser. Additionally, airflow measurements were taken across the open section of the vapor degreaser associated with loading and unloading of the vapor degreaser using a VelociCalc Plus, Model 8386 airflow meter.

V. COMPANY BACKGROUND

This facility is a multi-faceted plating, abrasive blasting, and non-destructive inspection shop with 36 metal finishing processes involved in the repair and refurbishing of aircraft. Metal finishing processes are conducted for wear replacement, corrosion protection, and surface preparation of aluminum, magnesium, copper, brass, titanium, steel and stainless steel alloys. The vapor degreaser is located in the plating area of the building which was renovated in 1993 at a cost of approximately \$15 million.

VI VAPOR DEGREASING (Cleaning) PROCESS

A Detrex open-top vapor degreaser (OTVD), Model VS-2000-Special, Serial number 73544, was utilized at this facility for the parts cleaning operation. The unit was installed in 1996 and modified for PCE use in 1997. The exterior dimensions of the vapor degreaser are approximately 13' 6" long by 4' 8" wide by 11' 2" high, and has a tank capacity of 255 gallons. The unit was equipped with two sliding panels that meet in the middle when closed. The degreaser is located in the plating department. The top of the degreaser is 42 inches above the floor grating. The degreaser has a work clearance area (opening) of 30 by 114 inches. The degreaser was loaded and unloaded from the top. The sliding panels occupied a total area of about 35 x 125 inches. The vapor level is 6' 6" below the top of the degreaser. The degreaser has a single tank (sump). Two hoists are used to lower and raise the cleaning baskets into and out of the degreaser unit. The hoist speed is not to exceed 11 feet per minute. A review of the monthly inspection records indicated that the two hoists travel at a rate of 8.7 and 8.5 feet per minute. About 26 workers from the plating department, the blasting area and non-destructive inspection, utilize the vapor degreaser at this facility.

The solvent still was a Detrex Model MR-200-SW, Serial No. 73547. The exterior dimensions of the still were approximately 6' 8" long by 4' 8" wide by 8' 9" high. The tank had a capacity of 260 gallons. The vapor degreaser was not equipped with a dedicated chiller system, but rather was connected to the plating department chiller system.

The Detrex vapor degreaser utilized in this operation was an open top vapor degreaser (batch) unit, equipped with hoist for material handling, solvent still, spray lance, water separator and hot oil unit for super heated vapor (see Figure 1). The superheated temperature was set to reach 265° to 270° Fahrenheit (°F). When the unit was originally purchased it was equipped with a chiller unit, but due to recurring maintenance problems the chiller was disconnected and the vapor degreaser was connected to the plating department chiller. The workers (electroplaters) using the vapor degreaser manually loaded parts into mesh metal baskets of varying sizes, on wheeled carts. The cart and basket were then positioned in the aisle next to the degreaser and the hoist chain was attached to the cleaning basket. The basket was then raised, moved via hoist, and positioned over the OTVD opening. The worker opened the sliding panel doors, lowered the basket until the parts were within the vapor zone and closed the panel doors. After the specified

time period the worker used the hand held spray lance to rinse the parts with PCE solvent. The total time period of the cleaning cycle was dependent on the parts to be cleaned. After cleaning, the basket was raised and brought back to the aisle, lowered on to the wheeled cart, and transported to the next operation.

The PCE solvent was boiled in the degreaser sump, thereby generating a vapor several times heavier than air. The vapor was condensed on the circumferential condensing coil and the condensed distillate was collected in a trough below the coil. The collecting trough was pitched to one end of the tank so that the solvent condensate flowed via gravity to the water separator, which in turn flowed to the offset distillation sump.

The vapor degreaser was equipped with a freeboard safety vapor level control and sump safety temperature control. Both are electrically wired to a heat input shut-off switch. Additionally, the degreaser has a low solvent level shut-off and safety temperature control and has a freeboard ratio greater than one. These controls were intended to shut down the heating elements if PCE vapors rise above the condensing coils due to inadequate cooling and are intended to prevent improper operation of the vapor degreaser.¹⁰

SOLVENT

Chemical stabilizers were used to prevent chemical breakdown of solvent and subsequent acid formation. Over time, the solvent stabilizers are depleted. To prevent acid formation the pH of the degreaser PCE must be tested weekly and chemical stabilizers added as needed. Acid formation in the degreaser will cause many potential problems necessitating shut down of the unit for cleanout and repair. It was indicated that about 5 gallons of stabilizer were added to the system every two weeks.

EMPLOYEE RESPONSIBILITIES

The cleaning of parts is necessary to remove dirt and oils from metal parts prior to electroplating or other processes. The vapor degreaser was utilized by employees from many different departments within the inspection and plating shops. The cleaning cycle time was dependent on the parts being cleaned. The workers generally remained at the degreaser during the cleaning cycle, because the cycle times were generally of a short duration and the worker generally used a spray lance at the end of the cycle to rinse the part with PCE solvent. Theoretically, the cleaned parts should be dry when removed from the degreaser unit. The workers typically spent about one-half of one hour per shift utilizing the vapor degreaser. The remainder of the day was spent in other areas of the inspection shop.

One individual was responsible for ensuring that the vapor degreaser tank had adequate PCE solvent. An alternate person was responsible for adding PCE to the degreaser unit when the primary individual was not available. Typically, one 55-gallon drum of PCE was added to the degreaser sump approximately once per month. When the degreaser sump level approached 200

gallons, the worker added one 55-gallon drum of PCE to the degreaser solvent tank. A hand cart was used to transport the 55-gallon drum of PCE to the vapor degreaser. An air pump hose with leak proof couplings was inserted into the 55-gallon PCE drum, the other end was connected to the bottom of the vapor degreaser boil chamber, making sure that the hose was below the heating coil. Solvent was pumped into the degreaser and when the drum was emptied the hose was withdrawn, the drum sealed and removed to be properly disposed of. The worker wore safety goggles, a hardhat with face shield to guard against splashes, a neoprene apron, and neoprene gloves.

BUILDING VENTILATION

The vapor degreaser was located in a ground-floor room, dimensions approximately 180' x 100' x 30', with 171 other tanks in 11 rows. The open-top tanks, many containing heated liquid, were used for cleaning, treating and plating parts. Not all the tanks were in active use. Tanks with potential for release of hazardous airborne material were equipped with local exhaust ventilation (LEV), which was in continuous operation. The vapor degreaser had no LEV, but did have a closeable top. Walk-ways between tank rows were typically steel gratings, open to the floor below. The floor below contained pumps, piping, tanks, and other accessory apparatus associated with the cleaning and plating tanks on the ground floor. Also, the exhaust ducts for the LEV were located on the lower floor. The exhaust fans and stacks for the LEV were located outside the building, four at the east end of the building, and seven at the west end. Conditioned make-up air was supplied by four ceiling-level plenum runs having five diffusers each, uniformly distributed over the area of the room. Unconditioned outside air also entered the room through four 7.5' x 7.5' louvered wall penetrations, which were open during our visit. There were eight floor fans in the room, including two PortaCool[®] units (portable cooling fans).

VII. RESULTS AND DISCUSSION

The passive dosimeter samplers provided concentration measurements similar to the results of the charcoal tube analyses. A separate publication on the comparison of these two methods will be prepared and will be provided when published. The results of charcoal tube sampling is provided below.

PCE SAMPLE RESULTS

Table 1 presents the results of personal sampling for PCE during the sampling survey. Personal breathing-zone air samples and passive dosimetry samples were collected on the employees utilizing or likely to utilize the vapor degreaser. Additionally, video-exposure monitoring of cleaning cycles was conducted. At the time of the survey, no maintenance operations were conducted.

A total of seven different electroplaters participated in the sampling effort, some on multiple days. The electroplaters who used the vapor degreaser wore the following personal protective equipment and clothing: safety glasses, face shields and gloves. Aprons were available, however, none of the workers actually used the aprons.

On May 15th samples were collected on five electroplaters from the beginning of the shift until approximately 1:30 pm. Sampling was ended early due to the fact that the vapor degreaser was not operational because of a malfunctioning chiller. The vapor degreaser used the building chiller system to operate the degreaser cooling coils. Because the chiller was not operational the vapor degreaser was never used on this day. It was indicated at the beginning of the shift that the unit should be operational within a couple of hours. Typically, one to two hours are required to heat the PCE solvent to its boiling temperature. Consequently, the PCE levels measured on the May 15th are not considered typical worker exposures for this operation.

On May 16th samples were collected on three electroplaters. The vapor degreaser was started at 7:45 am and required about 2 hours to get the solvent to operating temperature. The degreaser was used for a total of approximately 55 minutes throughout the day. Each of the three electroplaters cleaned a single load and each spent about five to eight minutes in the degreaser area. Electroplater #1 placed a load in the degreaser and left the area for his lunch break. When he returned he used the hand held lance to spray the basket of parts (while it was still within the degreaser vapor zone), left the parts within the free board area to dry and then removed the parts. The worker spent a total of about 5 minutes within the vapor degreaser area.

On May 17th, samples were collected on four electroplaters. Three of the four utilized the vapor degreaser during the shift. The highest concentration was detected on electroplater #4, who spent approximately one hour at the vapor degreaser cleaning parts. His TWA concentration for the sample period (398 minutes) was 15.6 ppm. The lowest concentration for the sampling period (0.21 ppm) was on electroplater #6, who did not use the vapor degreaser during the sample period (446 minutes). Electroplater #3 cleaned one load of parts and spent approximately 15 minutes at the vapor degreaser. His TWA concentration for the sample period (458 minutes) was 0.87 ppm. Electroplater #7 cleaned two loads and spent about two minutes per load at the vapor degreaser. His TWA concentration was 0.65 ppm over the 427 minute sample period. A fifth sample was collected on the 17th. One 16-minute sample was collected on electroplater #3 to assess short-term exposures during the parts cleaning process. This employee had a short-term exposure (16 minute sample) of 17.1 ppm during the cleaning process, while his full-shift exposure was 0.87 ppm averaged over the sample period (458 minutes). The OSHA PEL is 100 ppm as an 8-hour TWA and 200 ppm as a 15-minute STEL.

Table 1

**Perchloroethylene Degreaser Study - Site #3
Open-Top Degreaser Sample Results
May 2001**

Date	Job/Location	Sample Time (minutes)	Concentration (ppm)	
			Charcoal Tube	Passive Dosimeter
5/15	Electroplater #1	317	0.26	0.27
5/15	Electroplater #2	321	0.37	0.39
5/15	Electroplater #3	324	0.16	0.29
5/15	Electroplater #4	316	0.93	1.04
5/15	Electroplater #5	312	5.7	3.6
5/15	General Area - aisleway	274	0.3#	NA
5/16	Electroplater #3	475	0.12	0.12
5/16	Electroplater #1	461	0.77	1.4
5/16	Electroplater #5	457	0.65	1.6
5/16	General Area - aisleway	478	1.9	NA
5/17	Electroplater #3	458	0.87	0.69
5/17	Electroplater #6	446	0.21	0.23
5/17	Electroplater #7	427	0.65	1.3
5/17	Electroplater #4	398	15.6	21
5/17	Electroplater #3	16	17.1	NA
OSHA 8-hour TWA PEL Criteria			100	100
ACGIH 8-hour TWA TLV Criteria			25	25

NA - not applicable, matching sample was not collected

- other analytes present in this sample included acetone, toluene, n-decane, 1,2,4-trimethyl benzene, dichlorobenzene (unknown isomer), and n-undecane

OBSERVATIONS

Employees were required to receive training and pass an examination on the proper operation including startup and shutdown of the degreaser unit. Additionally, employees were required to conduct daily and weekly checks of a variety of operating parameters to ensure that the unit was being operated and maintained according to the manufacturer's recommendations. The operators' daily checks include hoist speed, operation of the liquid solvent level and vapor level automatic sump heat shut off, operation of the primary condenser, ensure degreaser panel doors are in place during idling and downtime, and ensure panel doors completely cover the degreaser opening.

VENTILATION RESULTS

With all of the passage-ways to the plating room closed, a negative pressure of 0.23 inches (w.g.) was measured in the plating room, with respect to both the outdoors and the adjacent room within the building.

The degreaser was loaded and unloaded from the top by sliding apart two panels that met in the middle when closed. The sliding panels occupied a total area of about 35.25 x 125 inches. Air speed and direction were determined at 12 points about 1 inch from the edge of the degreaser, and about 0.5 inch above the opening. It has been recommended that drafts around the opening to an open-top vapor degreaser should be less than 30 ft/min, to minimize loss of vapor during loading and unloading.¹¹ As shown in Figure 2, seven of the 12 measured air speeds exceeded this criterion. The air speeds were measured with a TSI Velocicalc[®], Model 8386, using a 5 second averaging time per data point. The flow direction was determined with a smoke tube, and was variable in several cases.

A MiniRae 2000 Portable VOC Monitor[®], Model PGM-7600, was used for about 30 minutes to survey the perchloroethylene concentration near the degreaser. The degreaser unit was on but not in active use at the time these measurements were collected (i.e., PCE tank was being heated, but there was no active loading or unloading). The data, corrected for calibration with isobutylene, are shown in Figure 3A. Generally, the PID showed PCE concentrations below 10 ppm where an operator's breathing zone would normally be located (1403 of 1808 measurements). However, there were a number of places around the degreaser case where very high concentrations were found, indicating the likelihood of leaks in perchloroethylene plumbing or containment components. The size of the leaks was not determined, so their significance is not clear. Figure 3B shows the number of PCE measurements collected during the this 30 minute period and the number of data points logged in each of the concentration ranges shown.

VIII. CONCLUSIONS

The sampling results indicate that the employees utilizing the Detrex Vapor Degreaser at this facility were not exposed to PCE in excess of the OSHA PEL, nor the ACGIH TLV of 25 ppm during the time of our site visit. The PCE concentrations in the building could be reduced through proper preventive maintenance.

While not discussed in detail the passive dosimeter samplers provided results similar to the results of the charcoal tube analyses.

IX. RECOMMENDATIONS

The following recommendations are offered to reduce PCE concentrations and subsequent employee exposures:

1. To minimize the influence of the immediate environment on the operation of the vapor degreaser the unit should be located in a "draft-free position away from windows, doors, heater blowers, and air intakes. Drafts must not blow into the load/unload area."^{8,10} Drafts around the opening to an open-top vapor degreaser should be less than 30 ft/min, to minimize loss of vapor during loading and unloading.¹¹ Figure 2 shows that seven of the 12 measured air speeds exceeded this criterion. The source of the air disturbance was not determined, but efforts should be made to determine the source to ensure that air speeds around the vapor degreaser opening do not exceed the manufacturer's recommendations.
2. The presence of heat sources near the degreaser unit can react with PCE emissions forming other hazardous substances. The Material Safety Data Sheet provided by the PCE distributor indicates that "This product may decompose when it comes in contact with open flames, heating elements, electrical arcs (such as electrical motors) or combustion engines. Due to vapor density, ignition sources distant from areas of handling material need to be considered." The MSDS indicates that "Decomposition by-products may include chlorine, hydrogen chloride, carbon monoxide, carbon dioxide, and possible traces of phosgene."
3. Employees should be sampled when adding PCE to the degreaser unit to determine short-term exposure concentrations during this operation. Contract employees involved in degreaser clean-outs should be sampled to determine exposure levels associated with degreaser clean-out operations.
4. Comprehensive employee education is a key to proper operation of vapor degreasers. The degreaser operators should receive annual training to ensure that the vapor degreaser operates at maximum efficiency. Degreaser operators should be trained, not only in the

operation of the vapor degreaser, but also on recognizing when routine preventive maintenance is indicated. Routine preventive maintenance is second key ingredient to proper operation of vapor degreasers. Maintenance records indicated that for the 12-month period preceding the NIOSH visit the vapor degreaser had been out of service a total of 11 times. Two of those times the degreaser was shutdown for clean-out of the unit (August 2000 and March 2001).

5. A concentration of 20-30% oil in solvent indicates that the solvent should be replaced and the unit cleaned. This operation is conducted by a contractor and requires that the unit be shutdown, all solvent drained from the vapor degreaser, the interior cleaned, and the vapor degreaser filled with clean solvent. Degreaser operators should be trained to recognize and test the solvent to insure that the concentration of oil in the solvent does not exceed this level.
6. To ensure that PCE vapors do not escape from the degreaser unit through preventable leaks, the vapor degreaser should be checked monthly using a direct reading instrument to detect PCE vapor leaks around the vapor degreaser. The MimiRac 2000 Portable VOC Monitor[®] data showed very high PCE concentrations at a number of locations around the vapor degreaser, indicating the likelihood of leaks in perchloroethylene plumbing or containment components (see Figures 3A and 3B). PCE concentrations detected near the degreaser where an operator's breathing zone would normally be located were below 10 ppm.

X. REFERENCES

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APPENDIX

- 1 Figure 1 - Degreaser unit showing operator location, vapor zone and freeboard
- 2 Figure 2 - Top view of vapor degreaser, showing air movement around the vapor degreaser opening
- 3 Figure 3A - MiniRae data showing ppm fluctuations, reading taken one per second
- 4 Figure 3B - MiniRae data showing concentration spectrum

Figure 1
PCE Site #3

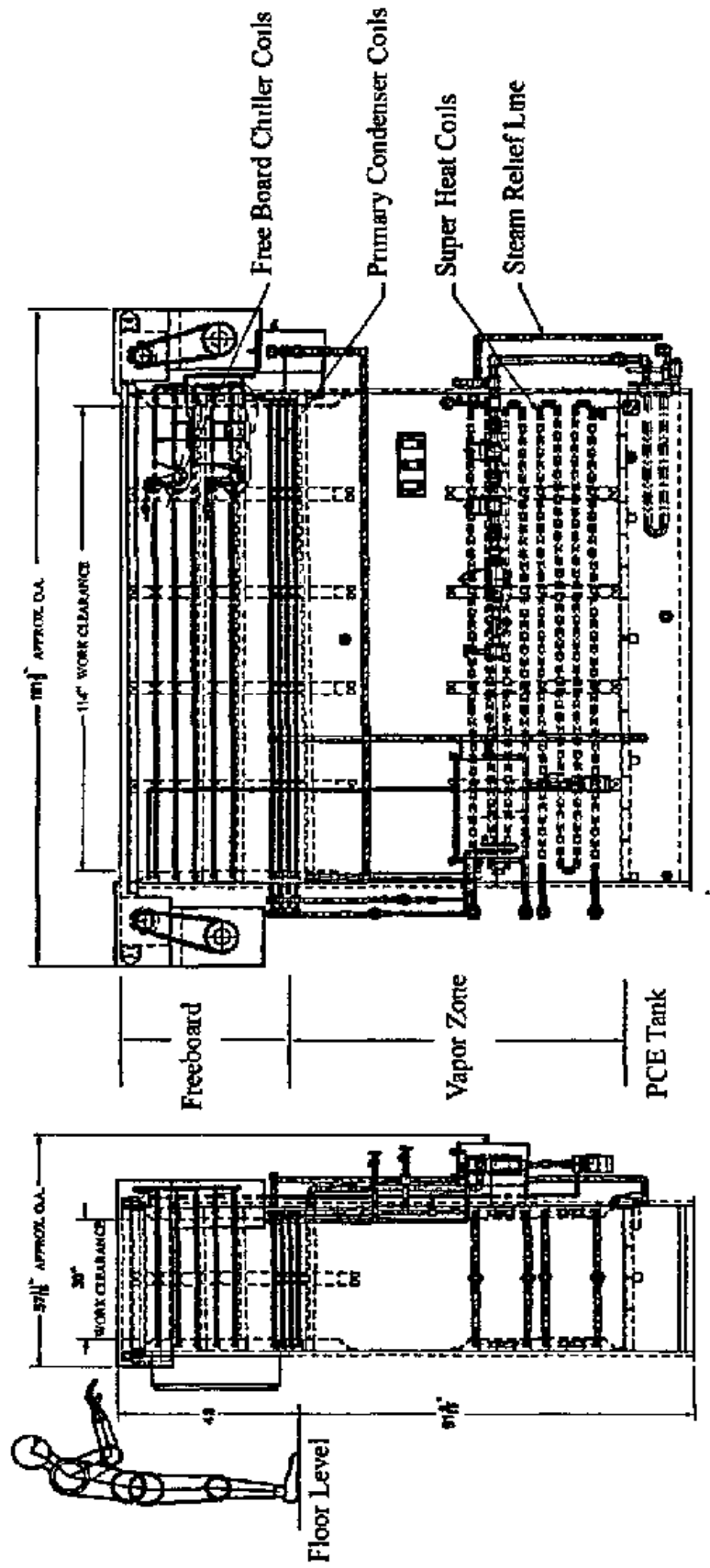


Figure 2
 PCE Site #3
 Top view of vapor degreaser, showing direction and
 magnitude in ft/min of the air velocity around the opening.

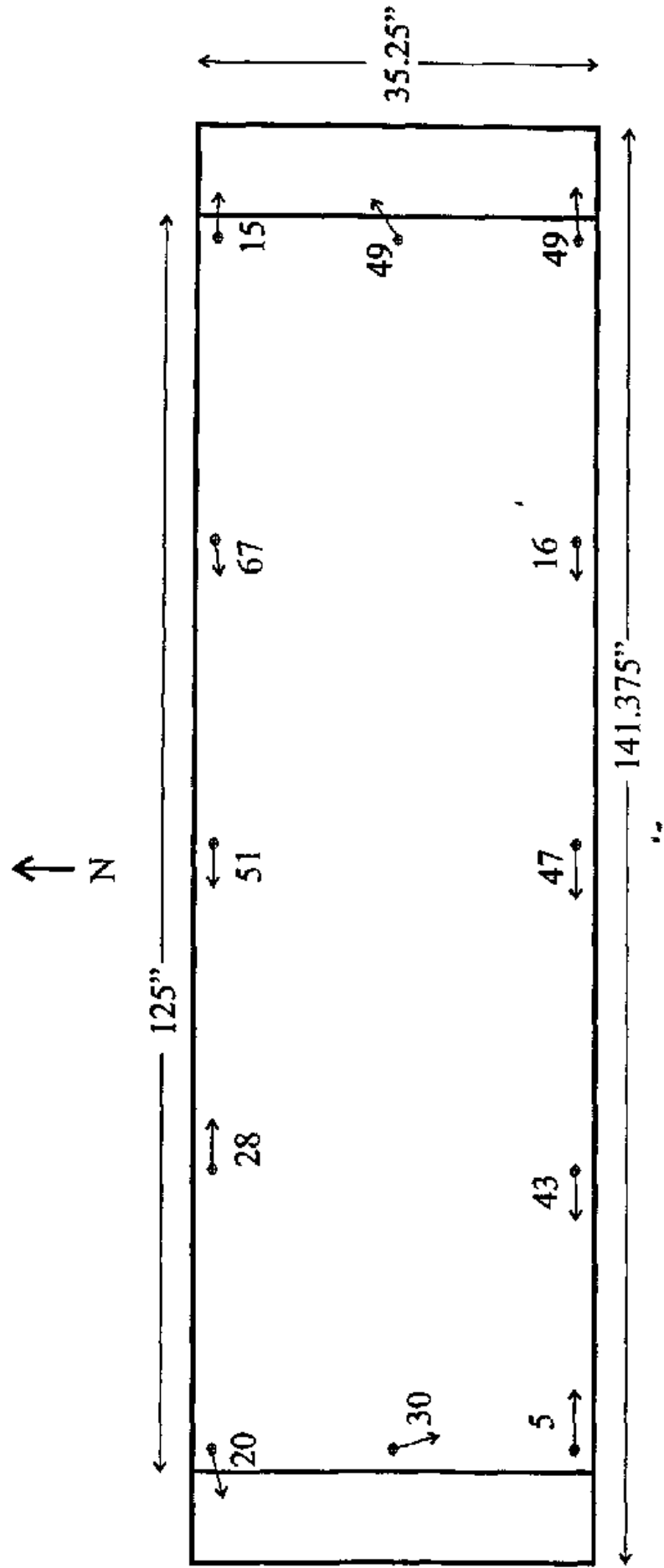


Figure 3A.
PCE Site #3
Concentration vs Time, MiniRae 2000, May 16, 2001

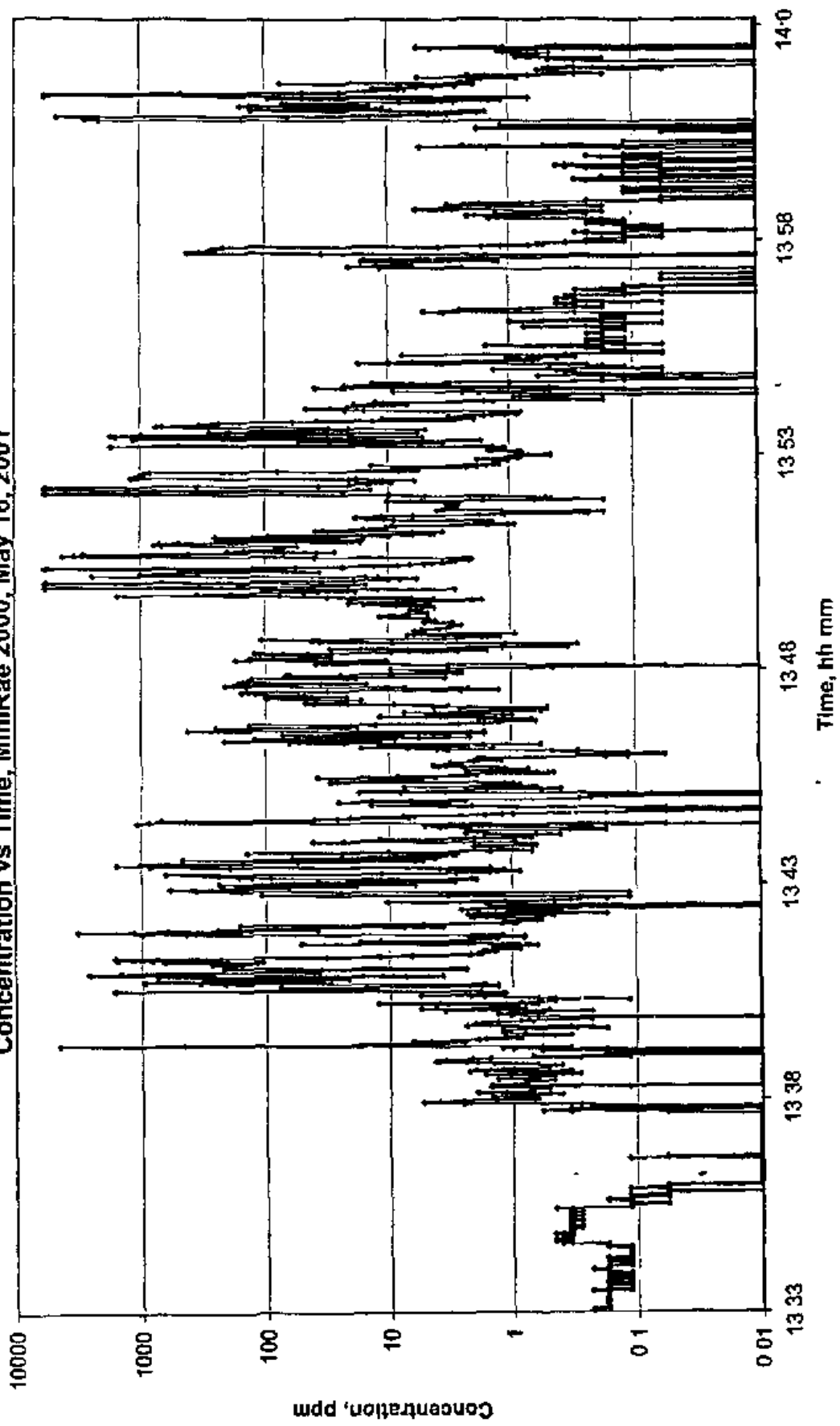


Figure 3B.
PCE Site #3
Concentration Spectrum, MiniRae, Degreaser, May 16, 2001.

