IN-DEPTH SURVEY REPORT: CONTROL OF PERCHLOROETHYLENE (PCE) IN VAPOR DEGREASING OPERATIONS, SITE #1

PRINCIPAL AUTHORS
Daniel Almaguer
Stan Shulman
Amir Khan

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U S DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology
Engineering and Physical Hazards Branch
4676 Columbia Parkway, R5
Cincinnati, Ohio 45226

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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 two open-top vapor degreasers and one airless vacuum vapor degreaser at the loading/unloading stations Air samples for PCE were collected on two separate occasions covering five days of degreasing operations Personal breathing-zone concentrations for the airless vacuum vapor degreaser operator ranged from 0 08 parts per million (ppm) to 0 4 ppm These workers typically spent 80% to 90% of their work shift at the vapor degreaser One maintenance worker adding PCE to the airless vacuum degreaser had a short-term exposure of 2 5 ppm Personal breathing-zone concentrations measured at the two open-top vapor degreasers ranged from 0 09 ppm up to 2 8 ppm A review of the sampling data and results showed that the degreaser operators 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/degreasing [1] 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), (Figure 1)

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 then 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 (Figure 2), 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 collects the contaminants which are then pumped 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 need 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 vaporized 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

$$\mathrm{TWA} = \frac{C_1T_1 + C_2T_2 + \quad C_nT_n}{\text{sample time}} \qquad (1)$$

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 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 milliters 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 company is a manufacturer of aircraft located in the pacific northwest since 1974, employing approximately 1300 people The facility visited produces fabricated metal parts and assemblies for various aircraft The facility has three vapor degreasers located on in two separate buildings The three degreasers are utilized in two separate metal finishing processes and one assembly line Metal finishing processes are conducted for corrosion protection and surface preparation at two plating processes and one assembly operation

VI. VAPOR DEGREASING (Cleaning) PROCESSES

The cleaning of parts is necessary for the removal of dirt and oils from metal parts prior to electroplating and assembly processes This facility had two open-top vapor degreasers and one airless vacuum vapor degreaser The three degreasers were located in three different areas and were used for three different processes Table 1 presents information about the three vapor degreasers used at Facility #1 A Serec Airless Vacuum Vapor Degreaser was used in the Vapor Degreasing and Plating Department A Durr Ecoclean Vapor Degreaser was used in another Vapor Degreaser and Plating Department Finally, a Greco Brothers, Incorporated, Immersion/Vapor-Spray Degreaser, Model IDG1510IREH was used in the Gearline Assembly Department Each of the three units are described in more detail below

TABLE 1
VAPOR DEGREASER COMPARISONS

Manufacturer	Degreaser Type	Amenities
Serec	Airless Vacuum	Solvent still, carbon filter
Durr	Open-top	Automated, hoist, solvent still
Greco	Open-top	Manual, hoist

SEREC - Airless Vacuum Vapor Degreaser

A Serec Airless Vacuum Vapor Degreaser was purchased and installed for use in Vapor Degreasing and Plating Department The unit was located in the middle of the building in a high bay area Parts were loaded into a degreasing chamber (Figure 2) and the chamber was evacuated after closing and sealing the chamber The vacuum achieved in the degreaser chamber was less than 5 torr Theoretically, because air does not contact the solvent (PCE) in a vacuum degreaser, the problems caused by condensation of water vapor into the system, such as corrosion and increased solvent loss, are considerably reduced, compared to open-top degreasers [9]

The still is drained and cleaned about once per month, and maintenance personnel add about 1 liter of stabilizer and about 50 gallons of PCE per month to the Serec airless vapor degreaser

DURR - Open-Top Vapor Degreaser (OTVD)

A Durr Ecoclean Vapor Degreaser equipped with a still for cleaning and recycling PCE was purchased and installed in 1994 The Durr was located in the center of the building, off a main aisle, in a high bay area, near a wall separating the vapor degreaser unit from the electroplating area One, 4' by 6' general exhaust ventilation wall fan was located on the north wall approximately 35' from the degreaser machine and 16' up the wall

The Durr is an open-top vapor degreaser used for cleaning carriages, engine mounts, landing gear and other assembly parts in the Vapor Degreaser and Plating Department The unit holds a total of 420 gallons of PCE in four tanks, the main still tank, the spray tank, boiling tank, and the overflow tank This unit is approximately 22 feet long, by 8 feet wide, by 10 feet high, and the top door opening is approximately 14 feet length by 5 5 feet wide The parts cleaning basket is approximately 10 feet long, by 3 feet wide, by one foot deep to accommodate the large parts cleaned in this unit The degreaser operator utilized a two-ton overhead crane for lifting and placing parts into the parts cleaning basket and for raising and lowering the parts cleaning basket into and out of the vapor degreaser The cleaning basket is raised and positioned over the degreaser and lower into the unit for cleaning Once inside the unit, the parts basket is detached from the overhead crane and the unit door is closed The cleaning cycle is normally about 45 to 60 minutes in duration After closing the unit door the degreaser operator leaves the area to conduct other operations in the adjacent electroplating area The degreaser operator is responsible for adding PCE and stabilizer to the unit Approximately two 55 gallon drums of PCE and 3 5 liters of stabilizer are added to the unit one time per month

A contractor is retained do conduct a total clean-out of the Durr OTVD approximately every 18 months During the clean-out operation, PCE is drained from the unit, the tanks and interior of the unit are cleaned, and the bearings, belts and seals are replaced as needed New PCE is then added to the degreaser and the degreaser still

GRECO - Open-Top Vapor Degreaser (OTVD)

The vapor degreaser utilized in gearline assembly department was purchased and installed in 1998 The unit was manufactured by Greco Brothers, Incorporated, and is an Immersion/Vapor-Spray Degreaser, Model IDG15101REH The exterior dimensions of the unit are approximately ' 6 5' long by 2 5' wide by 6' high The unit had two tanks (sumps) with a total solvent capacity of 50 gallons, a 20 gallon boiling tank and a 30 gallon rinse tank The unit was also equipped with hoist for material handling, spray lance, water separator, a primary cooling system, a secondary coiling system, and a drop-seal cover The primary cooling system maintains the primary coiling coils at approximately 55° F The secondary cooling system is located in the freeboard area of the unit and maintains the cooling coils at temperatures between -5° F and -20° F [10]

This OTVD was used for cleaning small parts used at the gearline assembly and was loaded and unloaded through the top A five step stairway leads to the loading platform and the top of the vapor degreaser was about 40 inches above the loading platform The top of the unit was equipped with a drop-seal cover which includes and inner and outer cover The outer cover rolls into place during operation and the inner cover is used to seal the unit from the exterior atmosphere The degreaser has a work clearance area (opening) of 39" x 27" inches The vapor level is 4 feet below the top of the degreaser An electric hoist was used to raise and lower the parts basket into and out of the unit The hoist speed was approximately 8 feet per minute

The GRECO OTVD was utilized for parts cleaning by 15 to 20 assemblers from the gearline assembly The cleaning process takes place in two locations within the degreaser, the vapor zone and the immersion (rinse) tank The workers using the vapor degreaser manually loaded small parts into mesh metal baskets The cleaning basket was attached to the hoist chain and positioned over the OTVD opening The worker opened the sliding cover doors, lowered the basket until the parts were within the vapor zone, the part(s) may also have been immersed in the rinse compartment depending on the part(s) being cleaned After the specified time period the worker used a hand held spray lance to rinse the parts with liquid PCE The total time period of the cleaning cycle and dwell time in the freeboard area was dependent on the parts to be cleaned The gearline assemblers would typically clean one to two load per day and spend less than ten minutes at the degreaser After cleaning, the basket was removed from the vapor degreaser and the assembler would leave the area to return to the gearline assembly department One employee was responsible for adding PCE and stabilizer to the unit The unit uses approximately three 55-gallon drums of PCE per year and approximately 0 5 liters of stabilizer per month The sump and water separator are cleaned out every 4-6 weeks

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 Greco vapor degreaser was equipped with the following safety controls low liquid cutout, high temperature cutout, high vapor cutout, and chiller overload These controls were designed to shut down the degreaser should conditions occur that would interfere with the proper operation of degreaser [10]

SOLVENT

A double stabilized solvent was used in all three vapor degreasers to prevent chemical breakdown of solvent and subsequent acid formation Over time, solvent stabilizers are depleted and must be added to prevent acid formation The pH of the degreaser PCE must be tested weekly to determine when and how much chemical stabilizers are needed Acid formation in the degreaser will cause many potential problems necessitating shut down of the unit for cleanout and repair

EMPLOYEE RESPONSIBILITIES

Employees involved in vapor degreasing operations receive training on the operation of the unit they use, the health effects of PCE, and the NESHAP regulations before using the unit for the first time Workers utilizing the vapor degreasers placed parts to be cleaned directly into cleaning baskets, or attached larger parts to the hoist chain Cleaning baskets were placed on wheeled carts and moved to the aisle adjacent to the vapor degreaser where the basket or part was attached to the hoist chain The parts basket was moved into position above the degreaser unit and lowered The 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 to rinse the part with solvent At the Durr and Greco OTVDs, one employee were responsible for checking the pH of the PCE solvent twice a week An alternate worker was responsible for adding PCE to the degreaser unit when the primary individual was not available These employees were also responsible for adding PCE and stabilizer to their unit Maintenance personnel were responsible for adding PCE and stabilizer to Serec airless vacuum vapor degreaser The employees wear Nitrile gloves when drawing solvent samples from the unit and when adding PCE and/or stabilizer to the units

Table 2 presents information about the amount of time workers spent working at the three vapor degreasers used in this facility One to two operators typically worked at the Serec airless vacuum vapor degreaser, staying in the area during the entire shift, with the exception of breaks One degreaser operator worked at the Durr OTVD per shift This operator typically loaded and unloaded parts for cleaning two to five times per day or about 60-80 minutes total time in the degreaser area, the remainder of their day was spent working in the adjacent plating shop Workers from the gearline typically spent about one-half of one hour per shift utilizing the Greco vapor degreaser The remainder of their day was spent in other areas of the gearline

TABLE 2
TIME SPENT at VAPOR DEGREASER

Degreaser Manufacturer and degreaser type	Amount of Time Spent In Degreaser Area	Relative Size of Degreaser
Serec airless vacuum vapor degreaser	Remained in degreasing area during the entire shift (>90%)	Large
Durr OTVD	Operator loaded degreaser unit and left degreaser area (~20%)	Large
Greco OTVD	Remained in degreasing area only during cleaning cycle (<10%)	Small

VII. RESULTS AND DISCUSSION

During the two site visits conducted at this facility, 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 Charcoal tube sample results are provide below in Tables 3 thru 5 Passive dosimeter samplers provided concentration measurements similar to the charcoal tube sample results A separate publication on the comparison of these two methods will be prepared and will be provided when published

PCE SAMPLE RESULTS - Serec Airless Vacuum Vapor Degreaser

Table 3 presents the results of personal sampling for PCE at the Serec Airless Vacuum Vapor Degreaser During the September 2000 site visit, one PBZ sample was collected on the employee operating the Serec degreaser The PCE concentration detected on that sample was 0 14 ppm A subsequent visit to the facility in October 2000 revealed similar PBZ concentrations for the Serec Operator and Assistant Operator Four days of sampling indicated that PBZ for these two employees ranged from 0 08 ppm to 0 4 ppm, averaged over the work shift General area samples collected in the center (exterior) of the degreaser ranged form 0 15 ppm to 1 5 ppm

During the October 2000 visit, two routine maintenance operations were conducted at the Serec degreaser Short-term PBZ air samples collected on the maintenance worker adding PCE to the Serec degreaser indicated that no detectable concentrations While short-term PBZ air samples collected on the maintenance worker changing the Serec Carbon filtration units was 0 25 ppm during that operation

Table 3
Perchloroethylene Degreaser Study - Site #1
SEREC Airless Vacuum Degreaser Sample Results
September/October 2000

Date	Job/Location	Sample Time (minutes)	Concentration (ppm)	
			Charcoal Tube	Passive Dosimeter
	FIRST SHIFT 7 - 3pm			
9/19	Serec Operator	284	0 14	NA
	SECOND SHIFT 3 - 11pm			
10/23	Serec Operator	279	0 08	NA
10/23	Serec General Area - center of unit	264	0 15	NA
10/23	Serec General Area - load/unload area	258	1 5	NA
10/23	Maintenance worker, changing Serec carbon filters	27	ND	NA
10/23	Maintenance worker - add PCE to the Serec degreaser	9	2 5	NA
	SECOND SHIFT 3 - 11pm			
10/24	Serec Operator	349	0 4	0 55
10/24	Serec General Area	392	0 34	NA
	FIRST SHIFT 7 - 3pm			
10/25	Serec Operator	397	0 19	(0 23)
10/25	Serec-Area	388	0 19	NA
10/25	Serec Operator Assistant	137	0 15	Non-detectable
	FIRST SHIFT 7 - 3pm			
10/26	Serec Operator	405	0 27	(0 28)
10/26	Serec Operator	406	0 18	NA
OSHA 8-hour TWA PEL Criteria			**100**	**100**
ACGIH 8-hour TWA TLV Criteria			**25**	**25**

Values in parentheses were between the analytical limit of detection and limit of quantitation
NA - not applicable, matching sample not collected

Table 4
Perchloroethylene Degreaser Study - Site #1
DURR Open Top Vapor Degreaser Sample Results
September/October 2000

Date	Job/Location	Sample Time (minutes)	Concentration (ppm)	
			Charcoal Tube	Passive Dosimeter
	FIRST SHIFT 7 - 3pm			
9/19	Durr Operator	109	2.8	2.9
	SECOND SHIFT 3 - 11pm			
10/23	Durr Operator	250	1.6	NA
10/23	Durr General Area - inspection booth adjacent to Durr	253	0.99	NA
	SECOND SHIFT 3 - 11pm			
10/24	Durr Operator	433	0.55	0.6
10/24	Durr General Area - inspection booth	475	0.51	NA
	FIRST SHIFT 7 - 3pm			
10/25	Durr Operator	371	0.89	0.95
10/25	Durr-area	250	0.86	NA
	FIRST SHIFT 7 - 3pm			
10/26	Durr Operator	416	1.1	1.3
10/26	Durr-area	488	0.74	NA
OSHA 8-hour TWA PEL Criteria			**100**	**100**
ACGIH 8-hour TWA TLV Criteria			**25**	**25**

Values in parentheses were between the analytical limit of detection and limit of quantitation
NA - not applicable, matching sample not collected

PCE SAMPLE RESULTS - Durr Open-top Vapor Degreaser

Table 4 presents the results of personal sampling for PCE at the Durr Open-top Vapor Degreaser One PBZ air sample collected on the degreaser operator during the September 2000 site visit indicated that the operators exposure was 2 8 ppm during a 109 minute sample Samples collected during the four day October visit showed that PBZ samples collected on the degreaser operator ranged from 0 55 ppm to 1 6 ppm, sample times ranged from 250 to 433 minutes Generally, the Durr degreaser operator would load the degreaser unit, leave the area to work in the electroplating area and return to unload and reload the unit General area samples collected about 10 feet from the front of the unit were less that 1 ppm

PCE SAMPLE RESULTS - Greco Open-top Vapor Degreaser

Table 5 presents the results of personal sampling for PCE at the Greco Open-top Vapor Degreaser One day of sampling was conducted in September 2000 and three days of sampling were conducted in October 2000 Sample results indicated that PBZ air concentrations for the gearline assembly workers utilizing the Greco degreaser ranged from 0 09 ppm up to 0 76 ppm, with sample times of 116 minutes up to 438 minutes Two general area samples collected near at the degreaser opening showed concentrations of 14 ppm and 8 ppm, averaged over 120 minutes and 425 minutes, respectively The workers utilizing the Greco degreaser generally cleaned two to four loads, spending less than 10 minutes per load at the unit The remainder of their time was spent at the assembly line

Table 5
Perchloroethylene Degreaser Study - Site #1
GRECO Open Top Vapor Degreaser Sample Results
September/October 2000

Date	Job/Location	Sample Time (minutes)	Concentration (ppm)	
			Charcoal Tube	Passive Dosimeter
	FIRST SHIFT 7 - 3pm			
9/19	Greco Operator	116	0 76	(0 82)
9/19	General area sample @ Greco	120	14	15 8
	SECOND SHIFT 3 - 11pm			
10/24	Greco Operator	359	0 21	(0 28)
	FIRST SHIFT 7 - 3pm			
10/25	Greco Operator	328	0 58	(0 35)
10/25	Greco Operator	370	0 20	(0 15)
10/25	Greco Operator	318	0 09	Non-detectable
	FIRST SHIFT 7 - 3pm			
10/26	Greco Operator	318	0 39	0 39
10/26	Greco Operator	404	0 18	(0 2)
10/26	Greco Operator	438	0 32	0 34
10/26	Greco-area	425	8 0	NA
OSHA 8-hour TWA PEL Criteria			**100**	**100**
ACGIH 8-hour TWA TLV Criteria			**25**	**25**

Values in parentheses were between the analytical limit of detection and limit of quantitation
NA - not applicable, matching sample not collected

VIII. CONCLUSIONS

Charcoal tube sampling results indicate that the employees utilizing the three vapor degreasers 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 Personal breathing-zone concentrations for the airless vacuum vapor degreaser operator ranged from 0 08 parts per million (ppm) to 0 4 ppm These workers typically spent 80% to 90% of their work shift at the vapor degreaser One maintenance worker adding PCE to the airless vacuum degreaser had a short-term exposure of 2 5 ppm Personal breathing-zone concentrations measured at the two open-top vapor degreasers ranged from 0 09 ppm up to 2 8 ppm However, these employees spent less than 20% of their work shift at the vapor degreasers as opposed to greater than 80% for the employees working at the airless vacuum degreaser

While not discussed in detail, the passive dosimeter samplers provided results 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

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 degreasers the units 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 "[10]

2 The presence of heat sources near vapor degreaser units can react with PCE emissions forming other hazardous substances The Material Safety Data Sheet provided by the PCE distributer 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 Personal breathing-zone air sampling should be conducted on employees adding PCE to the vapor degreaser units to determine short-term exposure concentrations during these operations 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 and maintenance of vapor degreasers The degreaser operators should receive annual training to ensure that

the vapor degreasers operate 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 Preventive maintenance and routine maintenance are key ingredients to proper operation of vapor degreasers

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 degreased, the interior cleaned, and that the vapor degreaser be refilled 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 Room air currents 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] Efforts should be made to ensure that air speeds around the vapor degreaser opening do not exceed the manufacturer's recommendations

7 To ensure that PCE vapors do not escape from the degreaser units through preventable leaks the vapor degreaser should be checked monthly using a direct reading instrument to detect PCE vapor leaks around the vapor degreasers

X. REFERENCES

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APPENDIX

1. Figure 1 - Open-top vapor degreaser (OTVD) showing major components of OTVDs

2. Figure 2 - Schematic drawing of Airless Vacuum Vapor Degreaser showing major components

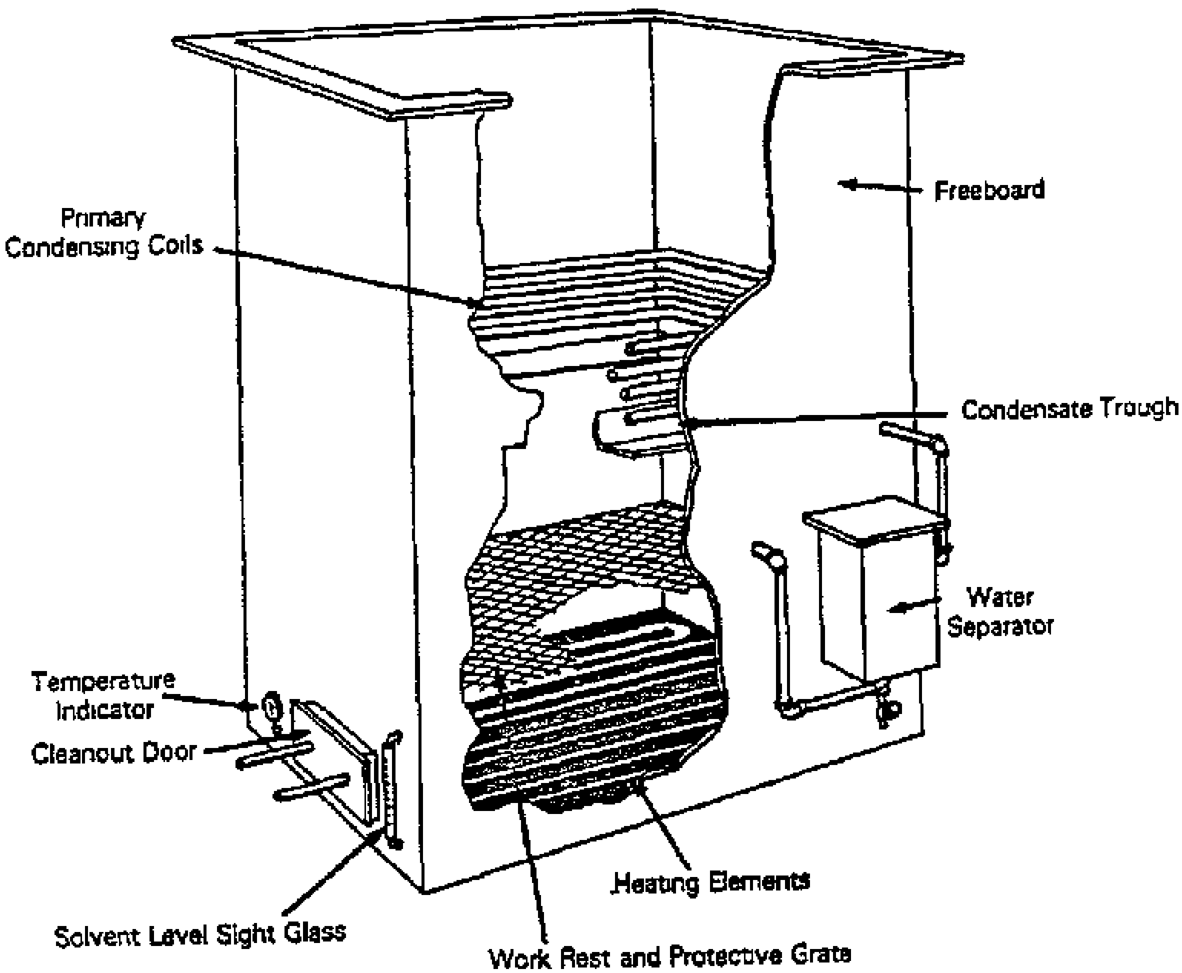

Figure 1
PCE Site #1
Open-top Vapor Degreaser

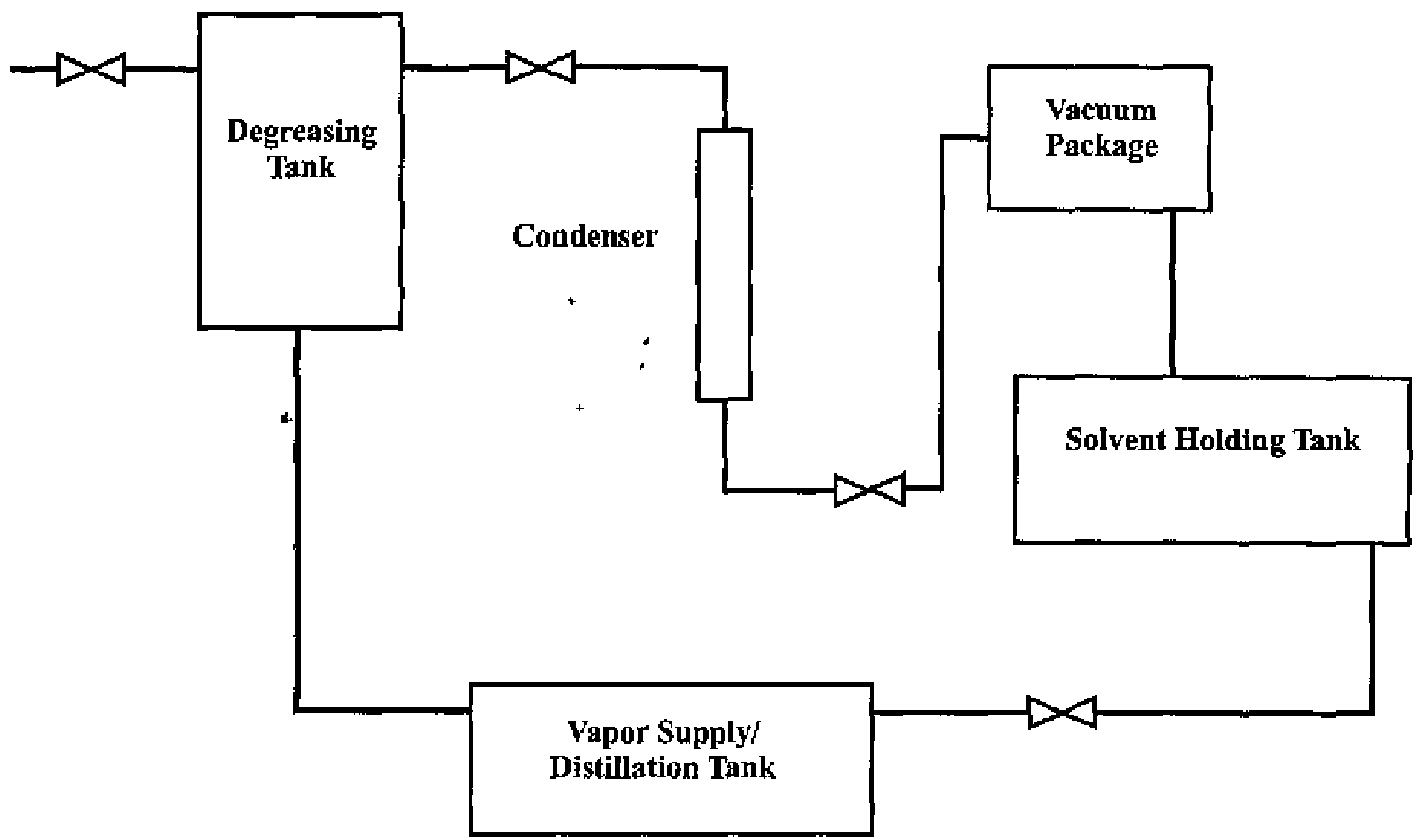

Figure 2
PCE Site #1
Airless Vacuum Vapor Degreaser