IN-DEPTH SURVEY REPORT: CONTROL OF PERCHLOROETHYLENE (PCE) IN VAPOR DEGREASING OPERATIONS, SITE #4

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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 airless vacuum vapor degreaser Personal breathing-zone air samples for PCE were collected over three days Samples collected in the PBZ of the workers ranged from 0 052 to 0 18 ppm A review of the sampling results showed that the degreaser operators were not exposed to perchloroethylene concentrations in excess of the OSHA PEL nor the ACGIH TLV

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)

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 1), 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 , ≤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 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

Site #4 was founded in 1950 and has been at its present location for 43 years The company is a parts cleaning job shop having cold and vacuum degreasing capabilities In addition to parts cleaning, Site #4 offers impregnation capabilities to solve material porosity problems Clean surfaces are a requirement for the impregnation process, so the degreaser and impregnation operations are complementary Parts handling and primary processing activities took place on the ground floor of the 3-story facility (Figure 2) Office activities were located on the second floor, while auxiliary components of the impregnation system extended into the basement The vacuum and cold degreasers were located entirely on the ground floor The ground floor dimensions were about 70' x 65' x 12' (L x W x H) A 10' x 10' garage door provided access to the street outside Two full-time employees operated the degreasers and impregnation systems Research on the degreasing and impregnation processes was conducted by a laboratory technician in a room on the ground floor

VAPOR DEGREASING (Cleaning) PROCESS

Site #4 utilized two vapor degreasers in its operations A vacuum degreaser was utilized for most parts cleaning jobs and a cold vapor degreaser was utilized for some cleaning jobs PCE was the solvent used in each of the degreasers PCE typically cleans better than all other chlorinated solvents [8] This is due to increased vapor flushing and the higher boiling point (250° F) Oil and greasy soils are more fluid and more soluble at higher temperatures Many buffing compounds contain a waxy binder that is only solvent soluble at higher temperatures when it is molten PCE and other chlorinated vapor degreasing solvents combine with water to form an azeotrope, a mixture that boils at temperatures lower than the boiling point of the individual components PCE is the best drying solvent because its high boiling point (250° F) drives water off the workload rapidly [8]

BASICS - Vacuum Degreasing

The system of primary interest at Site #4 was the airless vacuum degreaser Parts to be cleaned were loaded into a degreasing chamber (Figure 1) The basic process is described in Section III (Airless Vacuum Vapor Degreaser) The chamber was closed, sealed and evacuated The vacuum achieved in degreasing chamber was less than 5 torr Heated PCE solvent vapor was released from the vapor supply tank into the degreasing chamber The warm solvent vapors condensed on all surfaces of the cooler parts, dissolving soluble contaminants, and carrying them off into the bottom of the degreasing tank As the vapor condensed on the hot parts they heat up until condensation ceases If further cleaning was necessary, the parts were sprayed with liquid PCE 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 were completed, the solvent recovery process began Liquid solvent was drained from the bottom of the degreasing chamber to the vapor supply tank Using a vacuum pump, the solvent vapor was removed from the degreasing tank through a heat exchanger, where it was condensed, and then returned to the solvent holding tank Because of the low pressure achievable with the vacuum pump, virtually all of the remaining solvent was vaporized and removed from the degreasing tank The degreasing tank was 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 was again filled with ambient air to atmospheric pressure and opened for parts removal Typical cycle times, from parts loading to removal from the degreaser are 20 to 30 minutes Between the time that the parts are loaded and the degreasing tank is closed, until the time the tank is opened again for parts removal, the cleaning process is controlled automatically by a programmable controller, normally requiring no operator attention

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]

BASICS - Cold Degreasing

A special cold degreasing operation was conducted on some radiators prior to cleaning them in the vacuum degreaser The purpose was to flush out particles remaining inside the cores after their manufacture Since PCE was used for cold degreasing as well as vacuum degreasing, any liquid solvent remaining after cold degreasing would be removed by the vacuum degreasing operation, leaving a clean and dry part The use of the cold degrease is necessitated by the fact that the vacuum degreaser could not reliably remove particles in the interior of the cores because the interior surfaces could not be reached by the spray system in the vacuum degreaser

The cold degreaser, built by Site #4, consisted of a manifold to which the inlet and outlet of each radiator was attached (Figure 3) The PCE liquid solvent was pumped from a 55-gallon drum into one end of the manifold, and could be made to flow either serially or individually through each radiator to the other end of the manifold, where it exited via a hose back into the same 55-gallon drum The flow was maintained in each radiator for several minutes

Since the PCE was not heated and its vapor pressure was relatively low, the cold degreasing process contributed little above the background concentration However, making connections between the radiators and the plenum involved manual contact with the PCE, with the potential for skin exposures, unless appropriate gloves were worn

MAINTENANCE

As previously mentioned, the liquid solvent that condenses on the parts being cleaned in the vacuum degreaser falls to the bottom of the degreasing chamber, and flows back to the vapor supply/distillation tank (VS/DT), carrying dissolved and particulate contamination with it The PCE in the VS/DT must be periodically distilled to remove the soluble dirt This is accomplished by heating the VS/DT and pumping the PCE vapors into the chilled solvent holding tank, where they condense as clean solvent (some apparatus not shown in Figure 1) After the PCE evaporates, the remaining higher boiling point liquid is drained from the VS/DT, along with the particulate sediment, and disposed of as hazardous waste Since most of the PCE has been evaporated from this waste material and recovered in the solvent holding tank, little PCE is lost in this process However, some fresh PCE must occasionally be added to the solvent holding tank to maintain an operational level Rust inhibitors, acid controlling, or other chemicals may also be added to this supply tank periodically The required frequency of these maintenance operations depends greatly upon the condition, nature and number of parts being cleaned

The carbon filter located in the exhaust line to remove trace levels of PCE during the final pump down of the degreasing chamber must also be maintained The saturated carbon media must be replaced with a fresh carbon filter and the used media must be disposed of as hazardous waste The carbon filter was exhausted to the room environment This is not a recommended practice and should be corrected

BUILDING VENTILATION

During our visit, the 10' x 10' garage door at the front of the building was open during business hours, providing for considerable exchange of outside and ground floor air An adjacent wood product manufacturing establishment exhausted fumes from gluing and painting operations into an alleyway separating the two buildings, resulting in an apparent infiltration of these fumes into the facility under some weather conditions In turn, Site #4 had a three foot diameter exhaust fan located in a window opening on this same alley It had a ½ HP motor, with a rated volumetric flow of 10,910 CFM at 0" static pressure A floor fan was in operation near the back of the ground floor, directing air toward a processing tank There was a space heater on the ground floor, but no provision for air conditioning The laboratory also had a small exhaust fan, normally off, servicing a hood used to exhaust emissions from chemistry experiments For the second floor, air conditioning was provided by a unit mounted on the roof The roof unit had an outside air inlet next to the above-mentioned alley

SOLVENT

A stabilized solvent is used to prevent chemical breakdown of solvent and subsequent acid formation Over time, 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 clean out and repair

EMPLOYEE RESPONSIBILITIES

The cleaning of parts is necessary to remove contaminants from part surfaces This facility runs one 8-hour shift during which the airless vacuum degreaser may be operated The degreaser operator and assistant operator place the parts to be cleaned directly into cleaning baskets The cleaning basket is placed on a wheeled cart for transport to the vacuum degreaser The cart is placed next to a wheeled conveyor and the operator or assistant moves the parts basket into the cleaning chamber Using the computer control panel, the operator closes and seals the chamber and then starts the cleaning cycle Cycle times are dependent on the parts to be cleaned During the cleaning cycle the worker(s) leave the immediate vicinity of the vacuum degreaser to prepare loads for cleaning or to unload the previously cleaned parts Theoretically, the cleaned parts should be dry when removed from the degreaser unit The degreaser operator and assistant operator typically spent about one and one-half to two hours per shift at the vacuum degreaser, the remainder of their day was spent unpacking parts to be cleaned, placing parts to be clean into cleaning baskets, removing cleaned parts from the cleaning baskets, and repackaging cleaned parts to be sent back to the customer The degreaser solvent is tested for acidity every week to determine the pH of the solution The degreaser foreman is responsible for adding PCE to the degreaser unit and typically adds about 10 to 20 gallons a year to the unit

VII. RESULTS AND DISCUSSION

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

PCE SAMPLE RESULTS

Personal breathing-zone air (PBZ) samples and passive dosimetry samples were collected on the two employees utilizing the vapor degreaser, and on the Laboratory Technician working in a room adjacent to the degreaser area Additionally, video-exposure monitoring of some cleaning cycles was conducted At the time of the survey, no maintenance operations were conducted

Table 1 presents the results of PBZ air samples collected for PCE during the sampling survey Charcoal tube sample results indicate that employee exposures were well below the OSHA PEL of 100 part per million (ppm) for PCE Samples collected in the PBZ of the workers ranged from 0 052 ppm to 0 18 ppm for the three days of sampling

On August 1 and 2, only the Serec airless vacuum vapor degreaser was utilized for parts cleaning The Degreaser Assistant did most of the loading and unloading of parts and consequently he had the highest exposure concentrations on both days, followed by the Laboratory Technician, and the Degreaser Foreman PCE concentrations during these two days ranged from 0 052 ppm up to 0 12 ppm The Laboratory Technicians exposure was the second highest for these two days The laboratory was located in an enclosed room adjacent to the vapor degreaser (Figure 2) The operation of the laboratory exhaust fans may have pulled air from the vapor degreaser area into the laboratory

Table 1

Perchloroethylene Degreaser Study - Site #4
Vacuum Degreaser Sample Results
August 2001

Date	Job/Location	Sample Time (minutes)	Concentration (ppm)	
			Charcoal Tube	**Passive Dosimeter**
8/1	Degreaser Foreman	480	0.072	0.071
8/1	Degreaser Assistant	479	0.12	0.095
8/1	Lab Tech	469	0.098	0.097
8/2	Degreaser Foreman	385	0.052	Non-detectable
8/2	Degreaser Assistant	385	0.090	0.088
8/2	General Area @ Charcoal Filter	87	0.079	NA
8/2	Lab Tech	312	0.054	Non-detectable
8/3	Degreaser Foreman **(Fullshift)**	287	0.075	Non-detectable
8/3	Degreaser " **(cold)**	199	0.082	NA
8/3	Degreaser " **(vapor)**	86	0.039	NA
8/3	Degreaser Assistant **(Fullshift)**	288	0.13	0.12
8/3	Degreaser " **(cold)**	203	0.18	NA
8/3	Degreaser " **(vapor)**	83	0.057	NA
OSHA 8-hour TWA PEL Criteria **ACGIH 8-hour TWA TLV Criteria**			**100** **25**	**100** **25**

NA - not applicable, matching sample was not collected

On the morning of August 3, a cold degreasing operation was conducted to clean the interior of radiators (described earlier in this report) prior to exterior cleaning using the Serec airless vacuum vapor degreaser later in the day. To distinguish between exposures resulting from the cold degreasing operation and those resulting from the vapor degreasing operation, three separate samples were collected on both the degreaser foreman and the degreaser assistant. One sample was collected over the entire shift to determine the workers full-shift exposures. A second sample was collected during the cold degreasing operation to determine the workers exposures during that operation. When the cold degreasing operation was complete the second samples were replaced with a third sample to determine the exposure resulting from the vapor degreasing operation The sample results indicate that worker exposures during both cold degreasing and vapor degreasing were less than 1 0 ppm compared to the OSHA PEL of 100 ppm and the ACGIH TLV of 25 ppm Sample results did indicate that exposures during cold degreasing were about 2 to 3 times higher than exposures during vapor degreasing

GENERAL AREA RESULTS

A survey of environmental PCE concentrations was conducted during business hours A MiniRae 2000 photoionization detector was carried throughout the building over a period of about one hour on August, 1, 2001, while the instrument readings were recorded in various areas The MiniRae is used to determine when and where higher concentrations may be present in an area and the concentrations recorded are relative concentrations The readings reported below are higher than the personal breathing-zone reported in Table 1, and may be due instrument response to the presence of additional volatile organic chemicals in the areas where readings were collected On the first floor, the concentration ranged from 2 5 to 3 0 ppm, assuming PCE was the sole cause of instrument response On the ground floor, including the laboratory, the concentration ranged from 4 6 to 14 ppm In the basement, the concentration varied from 14 to 23 ppm In the adjacent driveway, the concentration varied from 0 to 2 8 ppm, measured as PCE, but probably caused by some other unknown compound, apparently originating from the woodworking operations next door Periodic measurements of the concentration were made just upwind of the open garage door throughout the day The readings were always zero, or very close to zero at this location, which was the primary source of outside air for the ground floor It seems likely then that the MiniRae readings taken inside were caused by an internal source This interpretation would be consistent with the pervasive odor of PCE throughout the ground floor and basement, although odor is not a reliable indication of exposure, because of considerable individual variation in odor threshold for this chemical

During these general area measurements, one significant localized source was found This was the outlet to the carbon filter, which was intended to remove trace concentrations of PCE from the air released to the environment during the final evacuation of the vacuum degreasing chamber The PCE concentration at this point was greater than 1425 ppm, a full-scale reading for the MiniRae The filter consisted of a 55 gallon drum filled with charcoal The air to be filtered entered at the bottom of the drum and exited at the top The volumetric air flow rate at the exit was about 12 cfm during the exhaust cycle of the vacuum degreaser The charcoal through which the air was flowing was apparently saturated with PCE, possibly as a result of channeling of the flow, or because the filter media was overdue for replacement At this point, the PCE concentration would normally be expected to be nearly undetectable using the MiniRae

VENTILATION DISCUSSION

The primary means for supplying air to the work area was the use of natural ventilation, that is opening the garage doors and the use of a window exhaust fan A pedestal floor fan on the ground floor was located near the wall opposite to the garage door, and was directed into a back corner of the room However, it mainly re-circulated the room air and did not improve the incursion and mixing of outside air with the mildly contaminated room air

VIII. CONCLUSIONS

Sample results indicate that workers operating the airless vacuum vapor degreaser and the cold degreaser were not exposed to PCE in excess of the OSHA PEL of 100 ppm, nor the ACIGH TLV of 25 ppm Airborne PCE concentrations during the NIOSH survey were less than one ppm The airless vacuum vapor degreaser provided excellent control of PCE vapor emissions from the process However, general and local exhaust ventilation of the work area should be thoroughly evaluated

IX. RECOMMENDATIONS

The following recommendations are offered to improve ventilation of the work area An engineering firm with expertise in industrial ventilation should be consulted to determine which options for improving general ventilation of the building would be most feasible from a technical and economical standpoint

1 The Serec airless vacuum vapor degreaser exhaust was connected to a carbon filter outlet which dumped the exhaust directly into the work area after filtration The carbon filter outlet should be ducted directly to the outdoors instead of allowing potentially contaminated air to be reintroduced into the work room Exhausting potentially contaminated air to the outdoors may require an EPA permit and should be investigated Additionally, regular maintenance and replacement of the charcoal filter bed should be conducted

2 The degreaser unit should also be located away from or isolated from heat sources The presence of heat sources near the unit 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 Employees responsible for adding PCE to the vapor degreaser should be sampled to determine their PCE exposure concentrations when adding solvent to the vapor degreaser The degreaser operators should be trained about the potential hazards of exposure to PCE and the employees conducting this work should be provided with appropriate personal protective clothing, such as safety glasses, face shield, neoprene apron, and neoprene gloves, to prevent dermal exposure and to protect the eyes Until it can be shown that the workers conducting this operation are not at risk of exposure to concentrations higher than the OSHA PEL, the employees should be provided with an organic vapor respirator The OSHA regulations require that a formal respiratory protection program be established when providing employees respiratory protection

4 Degreaser operators should receive annual training to ensure that they are thoroughly familiar with its operation and to ensure that it operates at maximum efficiency Preventive maintenance, routine maintenance, and comprehensive employee education are key to proper operation and maintenance of the vapor degreaser The employees should be trained in the operation of the vapor degreaser and how to recognize when maintenance is indicated Employees will then be able to alert the department foreman of operational problems when they occur

5 The PCE concentrations measured were well below the OSHA PEL for PCE, however, improving general ventilation of the work areas should be explored in-depth with a ventilation consultant experienced in industrial ventilation applications The proper option should be implemented after considering the trade-offs and practicalities

6 If an improved general ventilation for the work area is considered, the following features should be included a) the ventilation system for the laboratory should be integrated with the make-up and exhaust air systems for the production areas to prevent the exchange of air between the two areas, under any ventilation conditions, and b) the office space should be maintained, at all times, at a positive pressure with respect to the production areas and laboratory areas

7 A floor pedestal fan located on the ground floor near the wall opposite to the garage door was directed toward a back corner of the room The fan served mainly to re-circulate room air and did not improve the incursion and mixing of outdoor air with the mildly contaminated room air If the fan had been located at the garage door opening and directed towards the back wall, it could be used to improve the exchange of outdoor air with the contaminated air, thereby reducing the contaminant concentrations throughout the ground floor However, the use of fans in this manner is not a recommended means for controlling PCE concentrations in the building and this option would not be available during cold weather months

8 During warm weather months when all of the overhead and side doors to the building are open to provide natural ventilation, there is adequate makeup air available for ventilation

of the building However, during the cold winter months the amount of make-up air provided to the building will be limited, to conserve energy, by keeping the building doors and windows closed There are several options for providing make-up air to the building during the cold winter months First, outside air entering the building can be preheated with exhaust air exiting the building using an air-to-air heat exchanger Maintenance of the heat exchanger would be required Second, ducted make-up air could be provided to the building with no air-to-air heat exchanger Because of street traffic emissions and emissions from neighboring businesses, the make-up air should preferably come from a roof level inlet This option would have a lower initial cost, lower maintenance costs, but higher operating costs

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APPENDIX

1. FIGURE 1 - Airless Vacuum Degreasing System Diagram
2. FIGURE 2 - Plant Diagram, Ground Floor
3. FIGURE 3 - Cold Degreaser Diagram

Figure 1
PCE Site #4
Airless Vacuum Degreaser

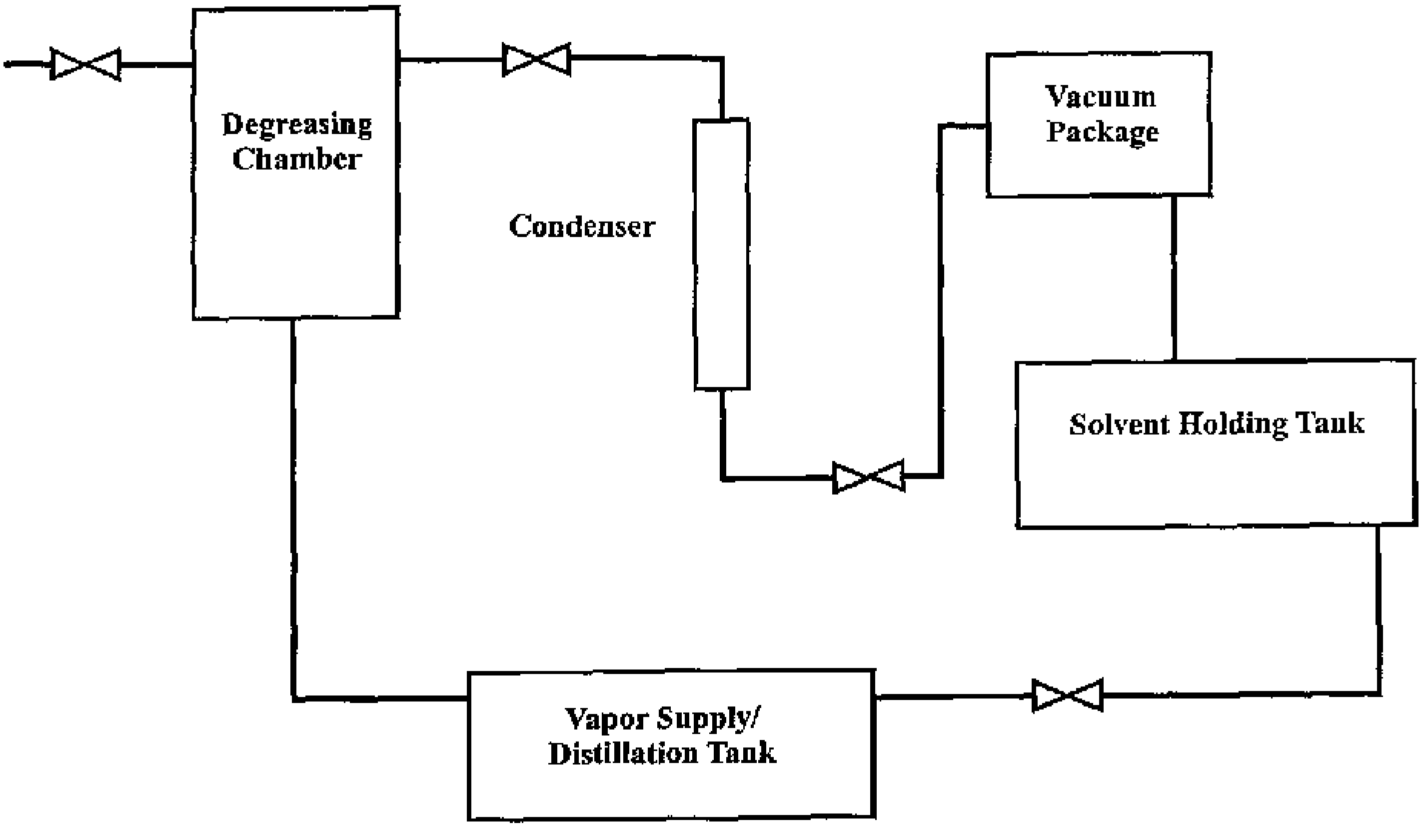

Figure 2
PCE Site #4
Plant Diagram, Ground Floor

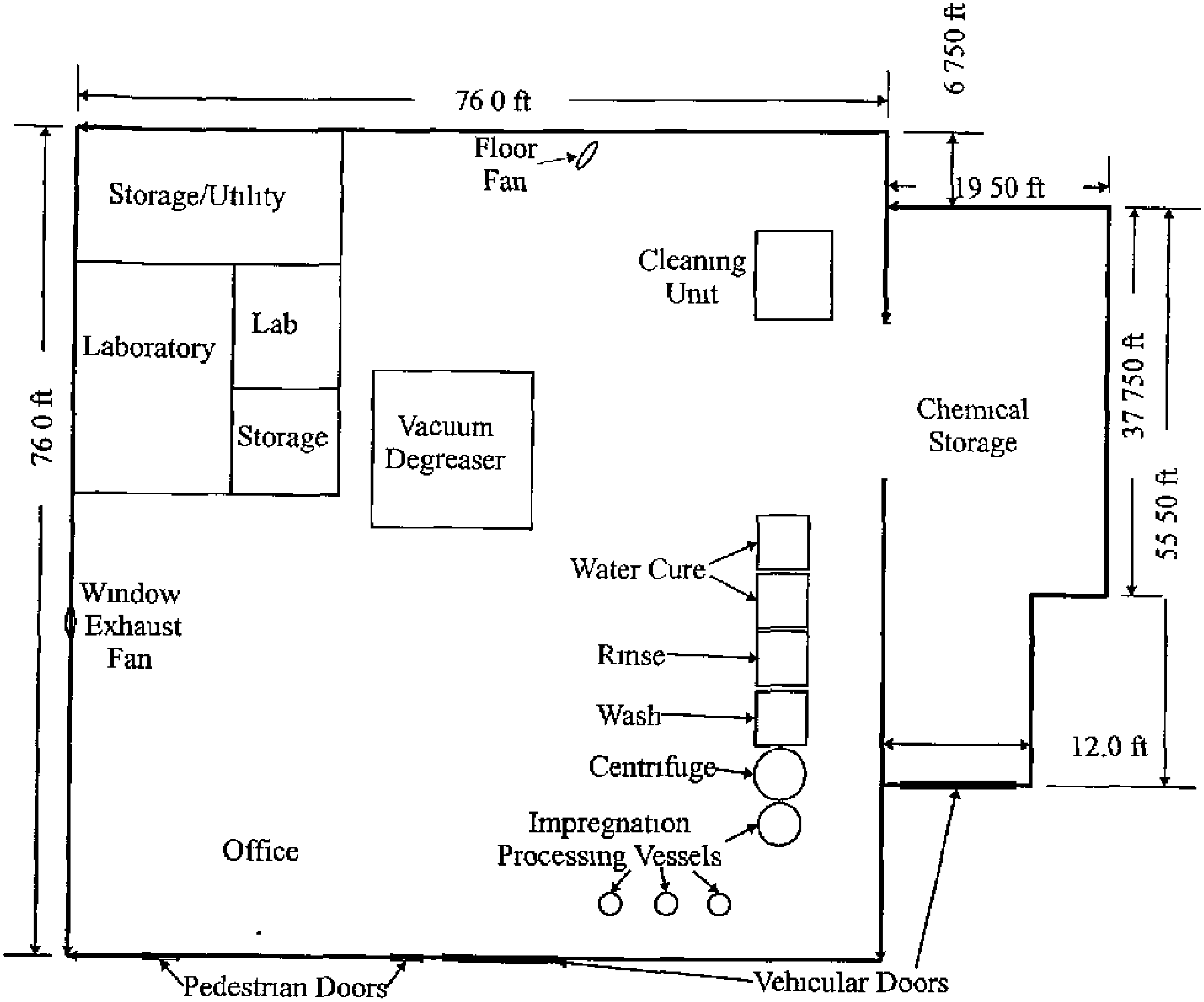

Figure 3
PCE Site #4
Diagram Cold
Degreaser System