IN-DEPTH SURVEY REPORT

PERCHLOROETHYLENE EXPOSURES AND ERGONOMIC RISK FACTORS IN COMMERCIAL DRY CLEANERS

AT

Tuchman Cleaners (Shop #24)
Carmel, Indiana

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PLANT SURVEYED	Tuchman Cleaners #24 2184 East 116 Street Carmel, Indiana 46032
SIC CODE	7216
SURVEY DATE	September 6-9, 1994
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DISCLAIMER

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC)

EXECUTIVE SUMMARY

A study was conducted at the Tuchman Cleaners shop #24 located in Carmel, Indiana, to evaluate control of worker exposure to perchloroethylene (PERC) and provide recommendations to reduce exposure The study also evaluated control of ergonomic risk factors Dry cleaning in this shop was done using a transfer unit The transfer unit consisted of two separate machines a J & T® Model 60, 60-pound, washer and a Hoyt® Model SF-145 Solvo-miser reclaimer Both the washer and reclaimer were connected to a Kleenrite® Vapor Condenser The reclaimer had a water cooled condenser and the separate vapor condenser used refrigerant The Hoyt® reclaimer operated in three different modes dry, cool, and aerate During the dry mode, recirculated air was heated and then cooled in the condenser to recover PERC During the cool mode, the air was diverted to the separate vapor condenser and cooled to recover PERC During the final aeration cycle, fresh air was drawn into the reclaimer and exhausted to the atmosphere (outside of the building) During a normal day, eight to twelve loads of clothing were processed

Three of the ten workers at this shop participated in the personal air sampling the machine operator/manager and two pressers The machine operator was exposed to 19 5 ppm TWA perchloroethylene for the entire survey The operator's two-hour samples ranged from 3 9 to 42 3 ppm More than one-half of the operator's exposure resulted from loading/unloading the machine and garment transfer The two pressers, who worked near the dry-cleaning equipment, were exposed to between 3 3 and 3 8 ppm TWA for the entire survey The highest two-hour, area concentrations measured were above the reclaimer door, behind the washer, and near the exhaust pipe from the reclaimer The two-hour concentrations in all three areas averaged approximately 28 ppm The highest geometric mean, area concentration for all four days of the survey was 15 2 ppm, above the reclaimer door

Real-time monitoring showed that the most significant source of operator exposure to PERC occurred during loading/unloading the machines and garment transfer Exposures during this procedure reached instantaneous concentrations between 1,000 and 1,500 ppm The highest average exposure, 500-600 ppm, occurred during transfer of garments from the washer to reclaimer Following garment transfer, the next highest average exposure occurred during loading the washer, unloading the reclaimer, and hanging clothing respectively Again as was seen during earlier surveys, loading was responsible for a greater average exposure than unloading Surprisingly, average PERC exposure during the transfer operation was not as high as average PERC exposure from loading/unloading some of the dry-to-dry machines studied at other shops This can probably be attributed to the fact that the garments being transferred from the washer to the reclaimer had not been heated, and the reclaimer had greater door ventilation than many dry-to-dry machines Analysis of the garment hanging operations showed that although it took a much longer period of time than most other tasks, the average exposure was relatively low, 14-21 ppm Some of the bulkier garments, which retain solvent and take longer to dry, resulted in instantaneous exposures near 70 ppm

Real-time measurements were also used to study garment off-gassing and maintenance activities The garment off-gassing experiment showed that the

machine was less effective at recovering solvent from the garments than many other machines which were studied The total quantity of PERC off-gassed from the test swatch was 10,690 ppm*sec or 89 0 mg PERC/kg cloth The average exposure to the operator during cleaning the lint and button traps was approximately 25 5 ppm The highest maintenance exposures occurred while changing the solvent filters

In addition to PERC exposure from the dry-cleaning process, some employees could be at risk of incurring musculoskeletal strain due to the highly repetitive nature of the work performed Job analyses were performed on the garment transfer, pressing, and clothes bagging operations Most of the ergonomic risk factors observed at this facility involved repetitive motions and awkward postures These problems primarily occurred at the pressing stations Several measures could be taken to reduce these hazards Frequent breaks and worker rotation are often used to control the hazards of repetitive tasks This appears to be a feasible option at this facility Redesign of the workstation could be used to eliminate many of the awkward postures and excessive reaching performed

Controls at Tuchman Cleaners (Shop 24) maintained full-shift TWA exposures to PERC below the OSHA permissible exposure limit (PEL) However, operator, full-shift, TWA PERC exposures exceeded 25 ppm on one of four days Twenty-five ppm is the exposure limit that OSHA encourages dry cleaners to meet NIOSH recommends controlling PERC to the lowest feasible concentration Several measures could be taken to reduce exposures further, such as replacement of the transfer equipment with dry-to-dry equipment Local exhaust ventilation could also significantly reduce exposures The current location of exhaust ducts from the reclaimer appeared to permit contaminated air to reenter the work area through the open door behind the washer A steam pipe connected to the reclaimer permitted contaminated air to be released inside of the shop Improvements to general ventilation could also reduce exposures This building had no openable windows to permit fresh air to enter the building A large propeller fan exhausting air behind the washer and reclaimer would help to reduce exposures Local ventilation should be used during waterproofing operations, or waterproofing should be done completely in the machine using an external tank Personal protective equipment such as a respirator, chemical splash goggles, and proper gloves should be used during waterproofing operations and machine maintenance A respiratory protection program should also be established

INTRODUCTION

The Engineering Control and Technology Branch (ECTB), Division of Physical Sciences and Engineering (DPSE), National Institute for Occupational Safety and Health (NIOSH), has undertaken a study of the dry cleaning industry to update a 1980 NIOSH engineering control study of the industry[1] and provide dry cleaners with recommendations for practical control measures based on current technology (See Appendix A) The focus of this study is to evaluate controls for exposure to perchloroethylene (PERC), however, controls for ergonomic hazards and exposures to chemicals used in the spotting process will be evaluated on a more limited basis

During the initial phase of the study, literature was reviewed to determine areas in need of research Walk-through surveys were conducted to gain familiarity with the industry and determine sites for future in-depth studies In-depth studies lasting several days are now being performed during which quantitative data is collected Personal and area samples are obtained, and real-time monitoring is conducted Detailed reports are being written to document all findings These in-depth reports will be used to prepare technical reports and journal articles that summarize the findings concerning effective controls for occupational health hazards in the dry cleaning industry

This report describes an in-depth study conducted at Tuchman Cleaners (Shop 24), located in Carmel, Indiana The primary purpose of this survey was to evaluate control of worker exposure to PERC from a dry-cleaning transfer unit and evaluate ergonomic risk factors Recommendations for reducing exposure to PERC and ergonomic risk factors are provided

PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

Tuchman Cleaners, a large commercial dry cleaner located in greater Indianapolis, Indiana, has been in business since the 1940s In 1986, it was purchased by Dry Clean U S A but was allowed to keep its name Dry Clean U S A , one of the largest owners of dry cleaning shops in the United States, owns between 300 and 400 shops in 14 different states

There are approximately 31 Tuchman shops located throughout greater Indianapolis Three of the shops are "dry stores" where no dry cleaning occurs The three dry stores receive soiled garments from the customers and transport the garments to another store for cleaning The cleaned garments are delivered to the dry store and returned to the customer Tuchman Cleaners had many more dry stores prior to 1982 However, to improve accountability and service to the customers, dry cleaning equipment was installed in many of the dry stores between 1982 and 1986 In some areas of Indianapolis, it is very important to provide same day service to the customers in order to remain competitive The focus of this in-depth survey was Tuchman Cleaner's (Shop 24) located in Carmel, Indiana, north of Indianapolis

Dry cleaning has been done at the Carmel shop since approximately 1982 The shop was located in a stand alone building near a large shopping mall The building was originally built as a gas station The general shop layout is shown in Figure 1, and a more detailed layout is shown in Figure 2 The shop had one door for customer entrance, and three other doors which were used by employees and delivery personnel The ceiling of the shop was approximately 18 feet high Finished clothing was stored on two different overhead conveyors near the front of the shop Pressing was performed in two different areas Pressing of shirts, which were primarily laundered, was done near the front of the shop, and pressing of dry-cleaned clothing was done adjacent to the dry-cleaning area This shop did all of its own dry cleaning and did not receive clothing from any other stores There was one transfer dry cleaning unit in this shop, located near the southwest corner of the building

The transfer unit consisted of a J & T® Model 60, 60-pound, washer and a Hoyt® Model SF-145 Solvo-miser reclaimer Both the washer and reclaimer were connected to a separate Kleenrite® Vapor Condenser The washer and reclaimer doors were positioned so that their doors were perpendicular to each other When standing in front, facing the machines, the washer was to the left and the reclaimer was to the right A refrigerated condenser was located between the two machines A waterproofing drum was located near the right-side of the reclaimer, and solvent filters were located behind the condenser A Forenta® spotting board was located near the front corner of the washer The restroom and boiler room were along the rear wall of the building between the dry-cleaning and shirt pressing areas There were several ceiling fans located throughout the shop Two large propeller fans exhausted air from the building above the restroom and from the boiler room Hazardous waste storage barrels were located behind the reclaimer and washer An eyewash station was located in the restroom

The shop cleaned between 2,000 and 2,500 pounds of clothing per week On most days eight to twelve, 50-pound loads of clothing were cleaned Hourly workers at this shop belonged to the AFL-CIO Laundry and Dry Cleaning International Union There were five full-time and five part-time employees at this shop, including the shop manager The shop was open for business six days per week

PROCESS DESCRIPTION

Garments were brought to the shop by customers needing their clothing cleaned Garments arrived at the customer counter and were examined and tagged for identification Prior to being loaded into the dry cleaning machine, garments were inspected and sorted according to weight, color, and finish

Garments with visible, localized stains were treated at the spotting station The store manager operated the machine and performed any spotting that was necessary The store manager made an effort to minimize the amount of spotting which was performed Various chemicals were used depending on the type of stain Spotting may be done before or after the clothes are cleaned in the machine Post-spotting is used more frequently today because it reduces the amount of spotting required, which is very labor intensive

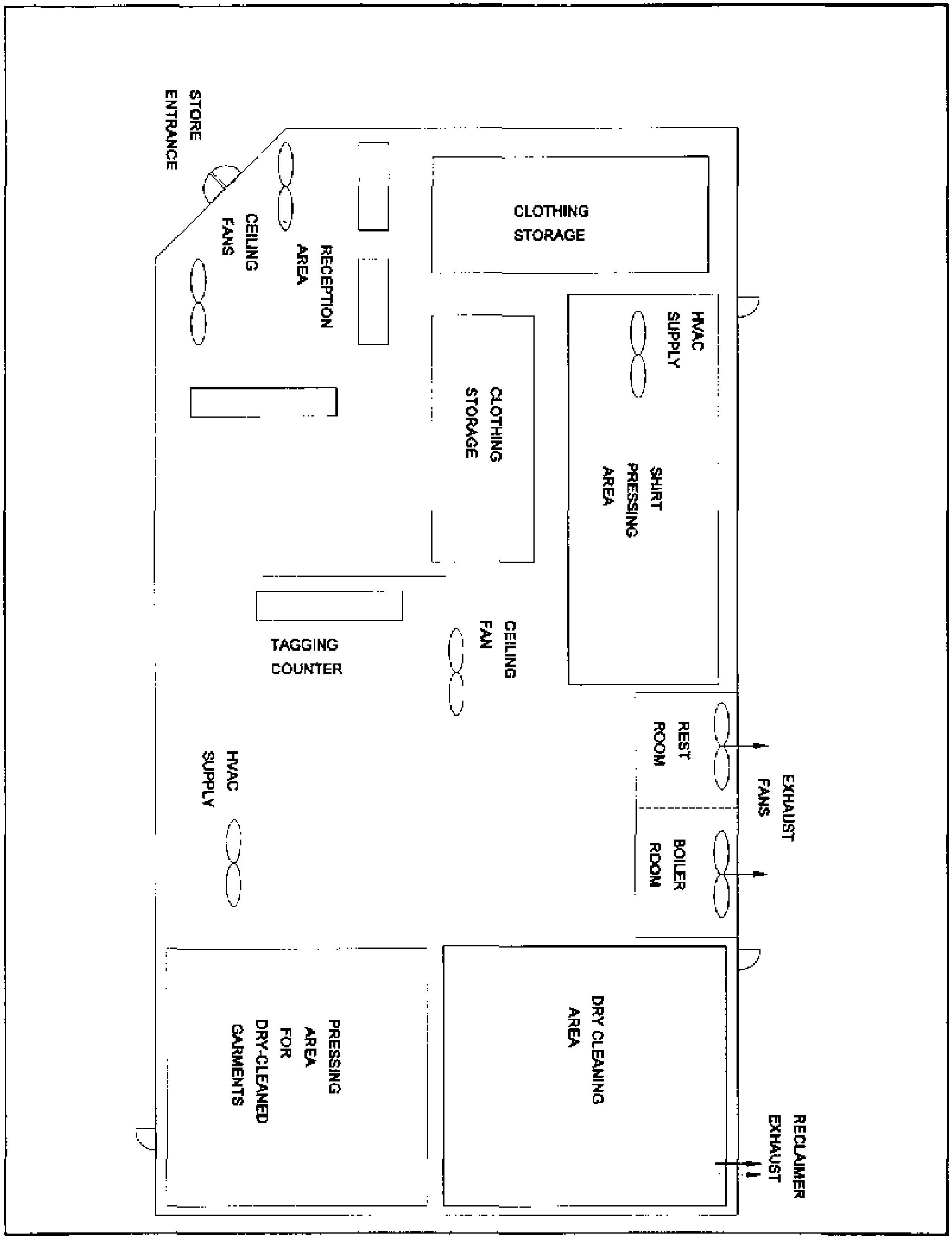

Figure 1 General Shop Layout

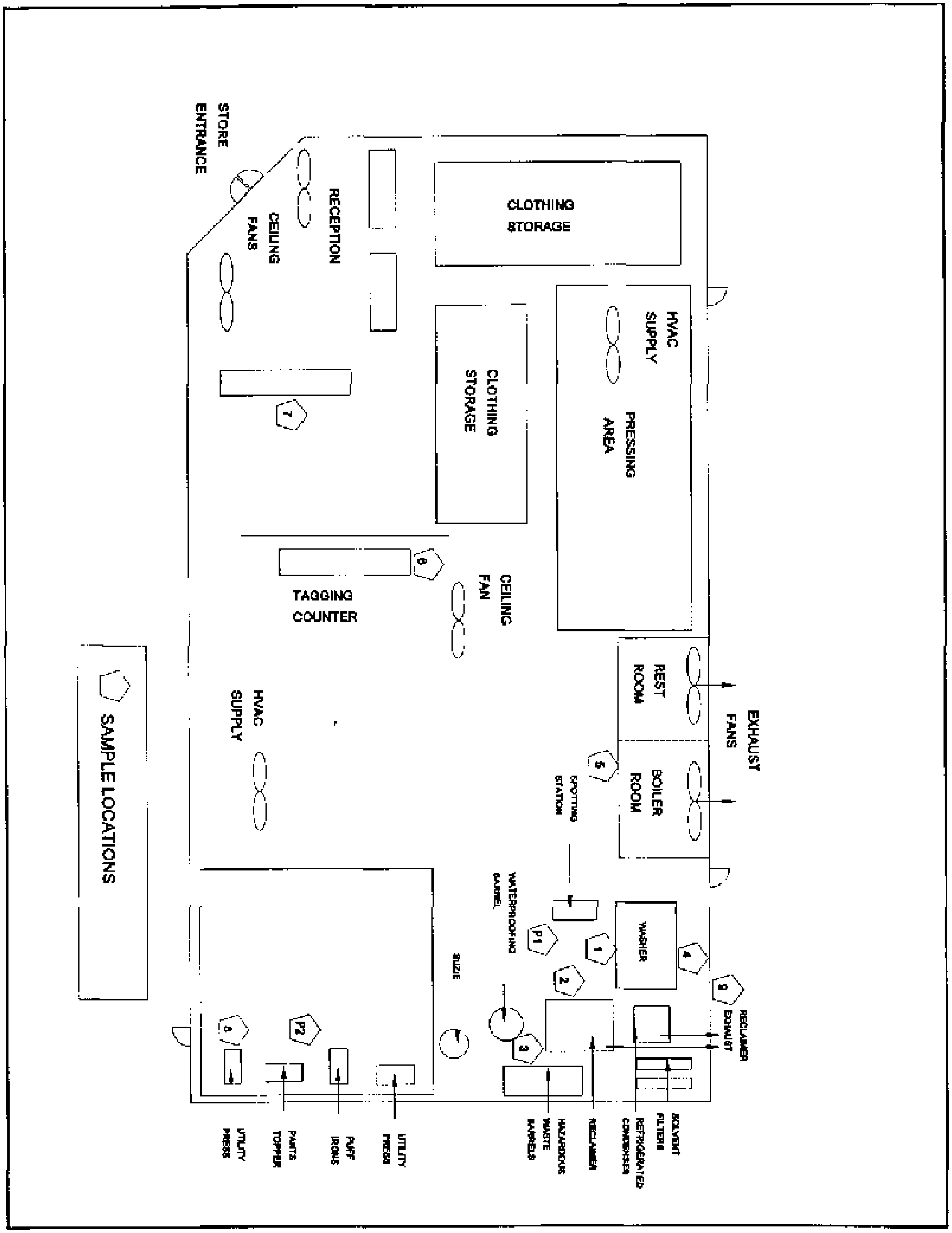

Figure 2 Air Sampling Locations

Stains rarely consist of one single substance The three general categories of stains are water soluble, solvent soluble, and insoluble Each type of stain requires appropriate spotting agents Some of the chemicals and chemical families that are frequently used for stain removal, in addition to PERC, are the following other chlorinated solvents, amyl acetate, petroleum naphtha, oxalic acid, acetic acid, esters, ethers, ketones, dilute hydrofluoric acid, hydrogen peroxide, and aqueous ammonia Each of these chemicals are used in small quantities

Most spotting chemicals used today are purchased from a company that supplies proprietary products to the industry At Tuchman Cleaners, the majority of spotting agents were products from the Laidlaw Corporation and R R Streets Corporation Some of the products used most frequently at this shop were Picrin®, Wetspo®, Ban-Tan®, and amyl acetate Picrin® is primarily trichloroethylene Wetspo® is a mixture of butyl cellusolve, aromatic 100, perchloroethylene, and potassium hydroxide Ban-Tan® is a mixture of hexylene glycol and diacetone alcohol

Spotting chemicals and chemical mixtures are either solvent-based liquids or water-based detergents They were held in small plastic squeeze bottles and applied to the stain when needed Spotting was performed on a spotting board equipped with pressurized air, steam, and water guns designed to flush the chemicals and stain from the garment Air, steam, a small brush, a spatula, and fingers were all used to help breakup the stain and wash it away A pedal actuated vacuum was used to capture the spotting chemicals, and they were held in a storage reservoir until being discarded

The clothing was weighed in a basket prior to loading into the machine The maximum capacity for the machine was 60 pounds of clothing, however, according to log sheets, loads placed into the machine ranged from 40 to 60 pounds The weight of every load was logged onto a daily record Dry cleaning is a three-step process, involving the following washing, extracting, and drying A diagram of this process can be seen in Figure 3 (See Appendix B for dry cleaning technology) To begin washing, clothes were manually loaded into the cylinder of the washer through the front door After the door was closed, PERC was pumped from the solvent tank into the cylinder Detergent was added to each load, based on the weight of the load

The contents of the machine cylinder were then agitated which allowed the solution to remove soils Following this step, the clothes were spun at a high speed to extract the solvent When most of the solvent had been removed, the garments were manually transferred to the reclaimer where the fabric was tumbled dry

The dry-cleaning transfer unit consisted of a J & T® Model 60, 60-pound, washer and a Hoyt® Model SF-145 Solvo-miser reclaimer Both machines were over ten years old Both the washer and reclaimer were connected to a Kleenrite® Vapor Condenser The reclaimer had a water cooled condenser, and the separate vapor condenser used refrigerant The reclaimer operated in three different modes dry, cool, and aerate During the 11 to 14-minute dry mode, the recirculated air was heated by steam and then cooled in the

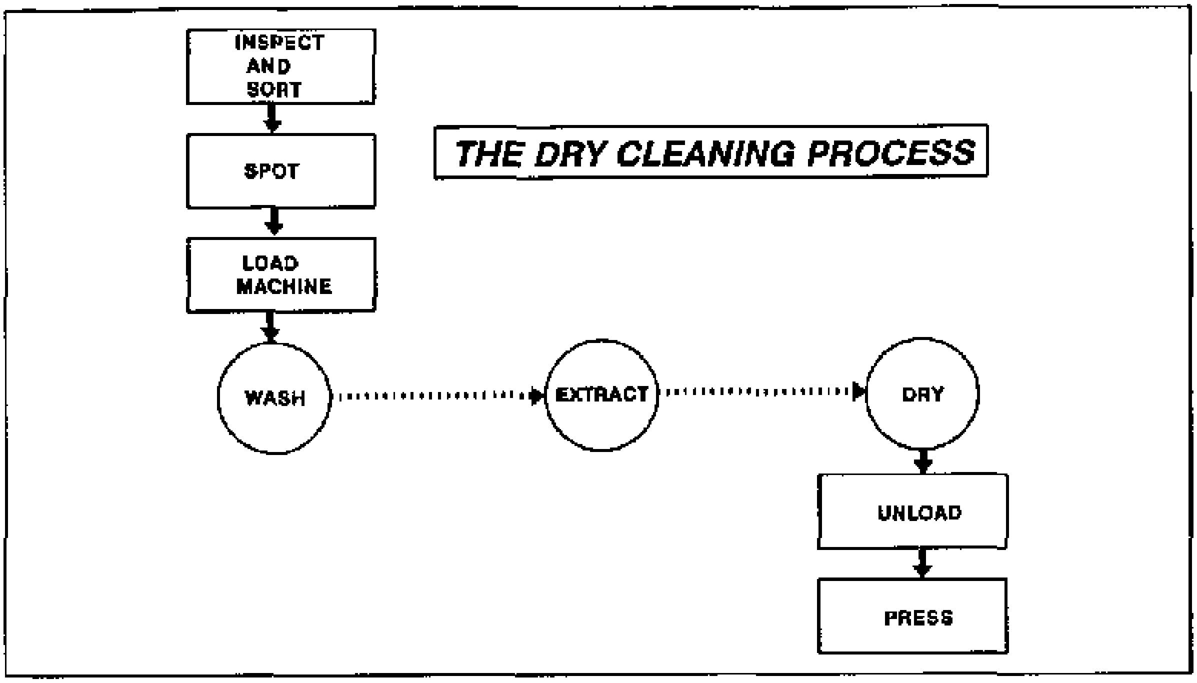

Figure 3 (Process flow diagram)

condenser to recover PERC The air was heated to approximately 140 °F During the drying mode, no fresh air entered the system and no air was exhausted Air was passed through the garments, a lint filter, cooling coils, and finally through a heating coil and back to the drum While passing through the cooling coil, PERC vapors condensed to liquid form and were directed to the separator where the water was removed Liquid PERC flowed back into the tank while the water was piped to an external container

During the cool mode, which takes 6 to 8 minutes, ambient air entered the machine and was diverted to the separate vapor condenser where it was cooled to recover PERC This step reduced excessive wrinkling During the final aeration cycle, fresh air was drawn into the reclaimer and exhausted outside of the building In a normal day, eight to twelve loads of clothing were processed

Garments removed from the machine were placed into a basket and then hung on a rack to await pressing Garments were pressed to remove wrinkles and to restore their original shape The garments were placed on specialized pressing equipment, coming in a variety of shapes and sizes, and using steam heated to temperatures around 300 °F These utility presses and shirt presses were manufactured by Forenta® When the garments were properly situated, they were pressed between two surfaces, at least one of which was hot, to remove the wrinkles Some of the equipment used included general utility presses, puff irons, pants toppers, finishers, electric irons, bosom, body and yoke presses, collar, cuff and yoke presses, and sleevers Once the garments were completely pressed, they were wrapped in plastic and stored on the overhead rack to await customer pick-up

PERC used in the wash cycle was cleaned continuously by passing through a Kleen-rite® filtration system Kleen-rite® clay and carbon filters model KR131 were used to remove soluble and insoluble soils Normally, filtration is used to remove most of the insoluble soils, and distillation is used to remove most of the soluble soils There were five filters in two separate tubes Filters in each tube were changed after cleaning 8,000 pounds of clothing Distillation was eliminated along with the need to clean the still or dispose of hazardous waste produced during distillation

A local contractor supplied and delivered PERC when needed The solvent was delivered by a truck through the rear door of the building and pumped directly into the washer's button trap which eliminated employee handling General dilution ventilation consisted of one large, propeller fan located in the wall above the restroom There was also an exhaust fan from the boiler room and an HVAC supply unit near the rear of the shop and near the shirt pressing area Air was exhausted outside of the building Several ceiling fans were located throughout the shop to circulate air

HAZARDS AND EVALUATION CRITERIA

POTENTIAL HAZARDS

Exposure to PERC is the primary health hazard for workers in dry cleaning facilities today For a complete description of the potential hazards, please refer to Appendix C

EVALUATION CRITERIA

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for PERC is 100 ppm, 8-hour time-weighted average (TWA) The acceptable ceiling concentration is 200 ppm, not to exceed a maximum peak of 300 ppm for 5 minutes in any 3-hour period [2] OSHA had lowered the PEL to 25 ppm in 1989 under the Air Contaminants Standard [3] In July 1992, the 11th Circuit Court of Appeals vacated this standard OSHA is currently enforcing the 100 ppm standard, however, some states operating their own OSHA-approved job safety and health programs will continue to enforce the lower limits of 25 ppm OSHA continues to encourage employers to follow the 25 ppm limit [4] NIOSH considers PERC to be a potential occupational carcinogen and recommends that exposure be reduced to the lowest feasible concentration [5]

METHODOLOGY

INDUSTRIAL HYGIENE SAMPLING

One objective of this site visit was to evaluate the effectiveness of the transfer dry cleaning machine for controlling worker exposure to PERC Personal, area, and background air sampling was conducted using NIOSH Method 1003 for halogenated hydrocarbons This method calls for the use of 100 mg/50 mg coconut shell charcoal tubes and carbon disulfide desorption Analysis was done using a gas chromatograph with flame ionization detector Samples were collected over a 120-minute time period with a flow rate of 0 1 liters/minute and a volume of 12 liters The limit of detection for this process was 0 01 mg/sample [6] Five-minute samples were gathered at a flow rate of 0 2 liters/minute during the transfer operation and changing machine filters

Area samples were taken at various locations throughout the shop Air samples were collected in front of and behind the washer and reclaimer, in the pressing area, near the customer counter, and outside the building (Figure 1)

Full-shift TWA personal sampling was gathered for the machine operator, as well as, both pressers TWA personal sampling results were compared to 25 ppm No air sampling was done for the spotting chemicals

VIDEO EXPOSURE MONITORING

Real-time monitoring was used to study in greater detail how specific manual tasks and maintenance operations affect worker exposure to PERC Some of these procedures occurred frequently throughout the day, such as loading/unloading and transfer while others were less often, such as cleaning the button/lint traps or changing filters Most of these tasks took between 5 and 30 minutes Real-time monitoring of PERC exposures were performed using a MicroTIP® IS3000® (PHOTOVAC Inc, Thornhill, Ontario) with a 10 6 EV ultraviolet lamp This instrument uses a photoionization detector to provide an analog output response proportional to the concentration of ionizable pollutants present in the air The MicroTIP® was spanned using 100 ppm isobutylene span gas and calibrated using five standard concentrations of PERC gas Instrument readings and actual PERC concentrations were used to construct a calibration curve and find a predictive equation The following formula was used to convert the output of the PID (volts) to concentration of contaminant (ppm) $C(t) = IR(t) * CF * MR$

where
$C(t)$ = concentration of vapor at time t (ppm)
$IR(t)$ = instrument response at time t (volts)
CF = conversion factor from calibration equation
MR = MicroTIP® range

Information gathered using the MicroTIP® was electronically recorded on a Rustrak® datalogger (Rustrak® Ranger, Gulton, Inc , East Greenwich, RI) and downloaded to a portable computer using Pronto® software During the gathering of real-time data, a video camera was used to record worker activities This videotape was later used to analyze tasks, code data, and determine which work activities and movements resulted in the highest exposures

Real-time monitoring was also used to study off-gassing of garments and compare vapor recovery efficiency between machines This was accomplished using a standard test swatch approximately 5 inches by 6 inches made of 51 percent rayon and 49 percent polyester When the dry cycle had ended, the test swatch was placed in a small glass test chamber As the PERC residuals vaporized, the concentrations of emitted PERC were monitored and recorded using the MicroTIP® and Rustrak® datalogger The apparatus for measuring off-gassing can be seen in Figure 2

VENTILATION

General ventilation measurements were taken with a Kurz® model 1440 velometer with a measuring range from 0 to 6,000 feet per minute Airflow near the dry cleaning machine was qualitatively evaluated using smoke tubes Air velocity measurements were made at the open face of the washer and reclaimer door The capacity and dimensions of general dilution ventilation systems were also recorded

ERGONOMICS

Hazards and risk factors present during the pressing operation were evaluated by examining workstation design, anthropometry, and conducting time studies of the tasks performed Based upon walk-through surveys, preliminary information indicated that high repetition/insufficient recovery time and awkward postures may be risk factors present during pressing operations Interaction of these and other risk factors have been shown to result in cumulative trauma disorders [7]

Repetitiveness and recovery time was evaluated by examining cycle time This was accomplished by videotaping and analyzing tasks in their elemental forms Low repetition jobs can be classified as such if the cycle time exceeds 30 seconds or less than half the cycle time involved performing the same kind of task High repetition jobs are those with cycle times less than 30 seconds or over half the cycle devoted to similar tasks [8] Awkward and sustained postures performed during the pressing operation were examined to determine whether they were a problem in light of the guidelines which can be found in the current literature Each of the tasks were videotaped and measurements were made to determine height, reach, anthropometric envelope, and physical layout of the workstation

RESULTS AND DISCUSSION

INDUSTRIAL HYGIENE SAMPLING

Results of the individual air samples can be seen in Appendix E Sample locations are shown in Figure 2 A summary of personal air samples for each day can be seen in Figures 4 and 5 All but one of the daily, full-shift TWA personal samples taken at this shop were below 25 ppm Time-weighted average exposures would have been lower if sampling had occurred for a full 8-hour shift, however, the dry cleaning machines were not operated for a complete eight hours during this survey They typically operated six or seven hours

Statistical analysis was performed on log transformed air sampling data for PERC Analysis of variance (ANOVA) showed that sampling location and job title had a significant effect upon concentration (probability > F < 0 0001) A multiple comparison test with 5 percent significance level, least significant difference (LSD), was used to examine concentration differences

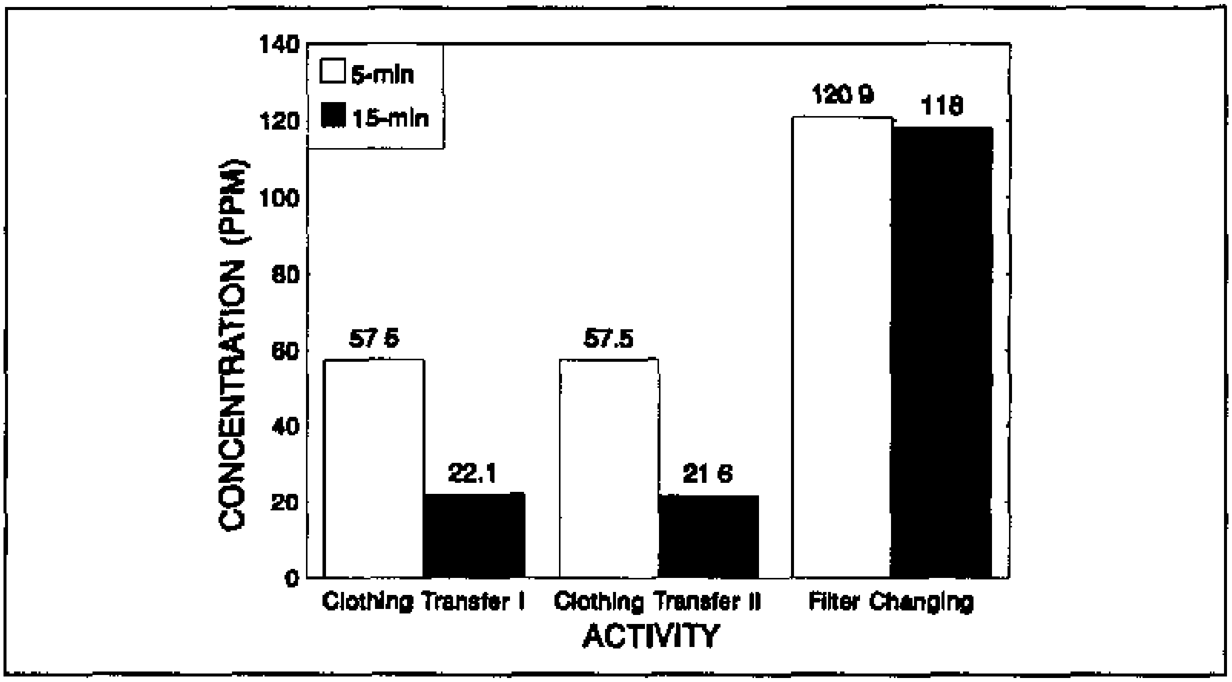

Figure 4 Five-minute and Fifteen-minute Personal Exposures

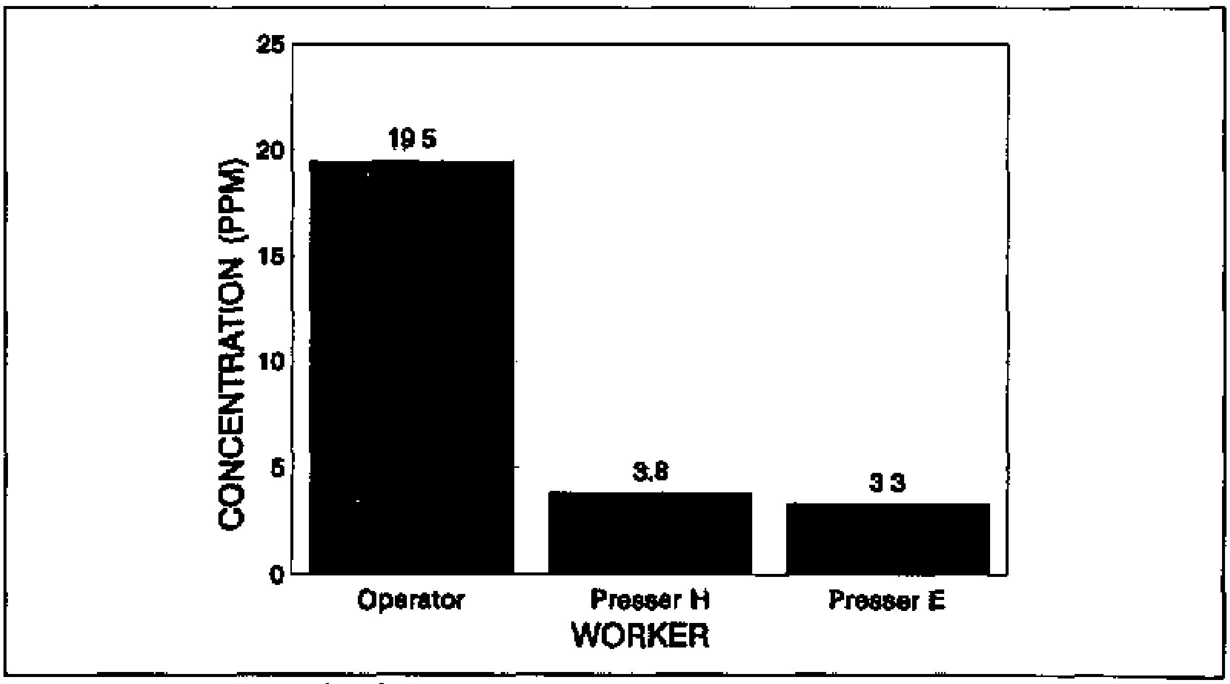

Figure 5 Time-weighted Average Personal Exposures (All four days)

As expected, the machine operator, who was also the shop manager, had the highest full-shift exposure to PERC which ranged from 7 8 to 26 8 ppm TWA on various days The operator's TWA exposure for the entire survey was 19 5 ppm The bulk of this exposure resulted from loading/unloading the machine, garment transfer, and maintenance The highest average exposure during a two hour sampling occurred to the operator on the second morning of sampling That two-hour sample was 42 3 ppm

On each day of sampling, the operator's highest exposures occurred in the morning In addition, in almost all cases the operator's lowest exposures occurred near the end of the day Two factors apparently contributed to this result 1) The two doors near the dry-cleaning area were not opened early in the morning This prevented much of the PERC vapors from dissipating resulting in higher exposures 2) The loads in the morning were usually larger than the loads later in the day

This phenomena was just the opposite for the two pressers The pressers were exposed to the greatest concentrations of PERC in the afternoon and the lowest concentrations in the morning When the shop doors were opened, the air currents carried PERC from the dry-cleaning area to the pressing area The two pressers of dry-cleaned clothing, who did not work in as close proximity to the machine as the operator (see Figure 1), but did work closely with dry cleaned clothing were exposed to between 3 3 and 3 8 ppm TWA during the entire survey Statistical analysis showed a statistically significant difference between the operator's TWA exposure and that of the pressers There was not a statistically significant difference between the two presser's exposures

Five and fifteen-minute personal samples were taken during transfer operations and filter changing Neither of these activities exceeded the OSHA ceiling of 200 ppm or OSHA peak of 300 ppm Exposure during transfer operations was 57 5 ppm for a 5-minute period and 21-22 ppm during a fifteen-minute period Exposure during filter changing was approximately 121 ppm for 5 minutes and 118 ppm for 15 minutes The length of time for the tasks probably contributed to the observed concentration differences

Results of area air sampling can be seen in Figure 6 The highest area concentrations were detected on samples located above the reclaimer door The geometric mean concentration above the reclaimer door for the entire survey was 15 2 ppm which was significantly different from samples in all other areas of the shop This result suggests that the reclaimer is an important source of PERC emissions Real-time monitoring results presented in the following section clearly indicate which operations cause PERC emissions

Although no vapor leaks were detected when using the MicroTIP®, certain areas around the machines had higher concentrations of PERC At some times during the day, concentrations near 200 ppm were measured behind the washer The lowest concentrations measured were found in the reception area Bulk samples were taken of the water separator run-off to see if any PERC exposure could be

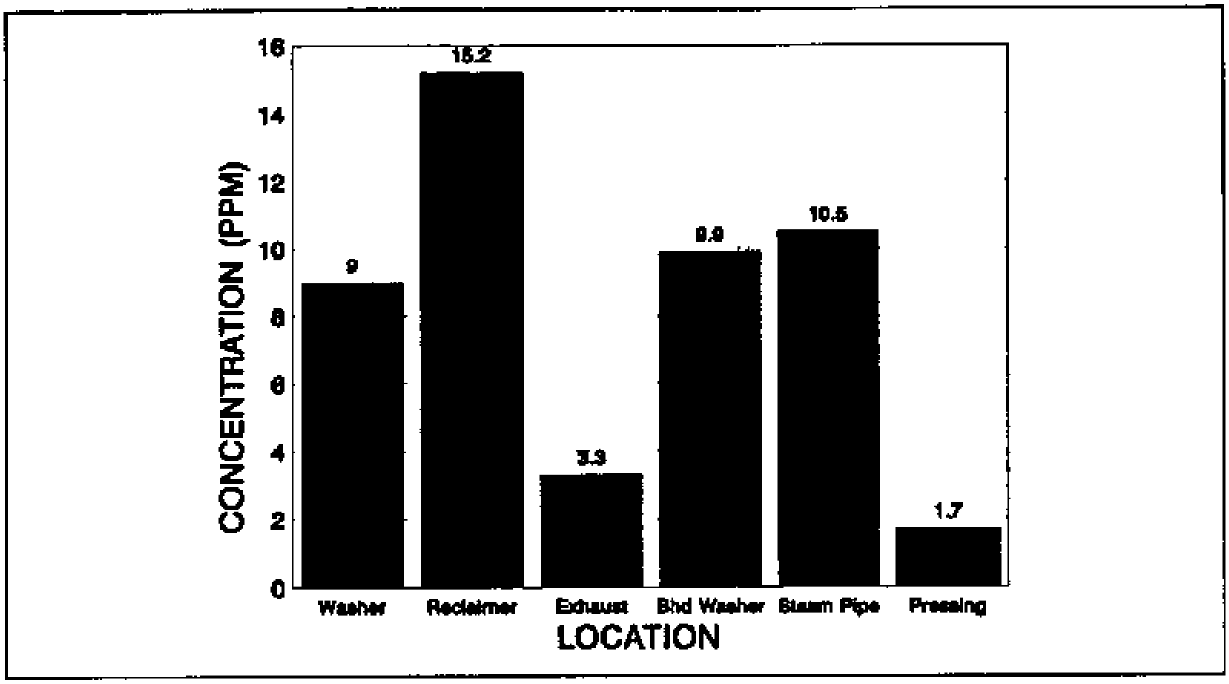

Figure 6 Geometric Mean Area Samples (All four days)

originating from this source Laboratory analysis found only 2 96 micrograms of PERC per gram of sample The limit of detection was 0 5 micrograms per gram of sample

REAL-TIME MONITORING

Video recording and real-time monitoring was performed during loading and unloading the machine, transfer operations, and cleaning the button traps, lint filter, and solvent filters Real-time monitoring was also used to evaluate garment residual off-gassing The MicroTIP® was set for a measuring range between 0 to 200 ppm and 0 to 2,000 ppm depending on the operation being monitored

Clearly, the most significant source of exposure to the operator occurred during loading/unloading the machines and garment transfer Exposures during this procedure reached instantaneous concentrations between 1,000 and 1,500 ppm More importantly, loading/unloading and transfer occurred frequently throughout the day, approximately eight to twelve times a day depending on business Machine maintenance normally occurred once a day, and some maintenance tasks, such as changing solvent filters, occurred less frequently

Figures 7 and 8 show real-time data during transfer of garments from the washer to reclaimer, loading the washer, and hanging the garments Transfer describes the process of unloading clothing from the washer and immediately loading them into the reclaimer There were a number of similarities between

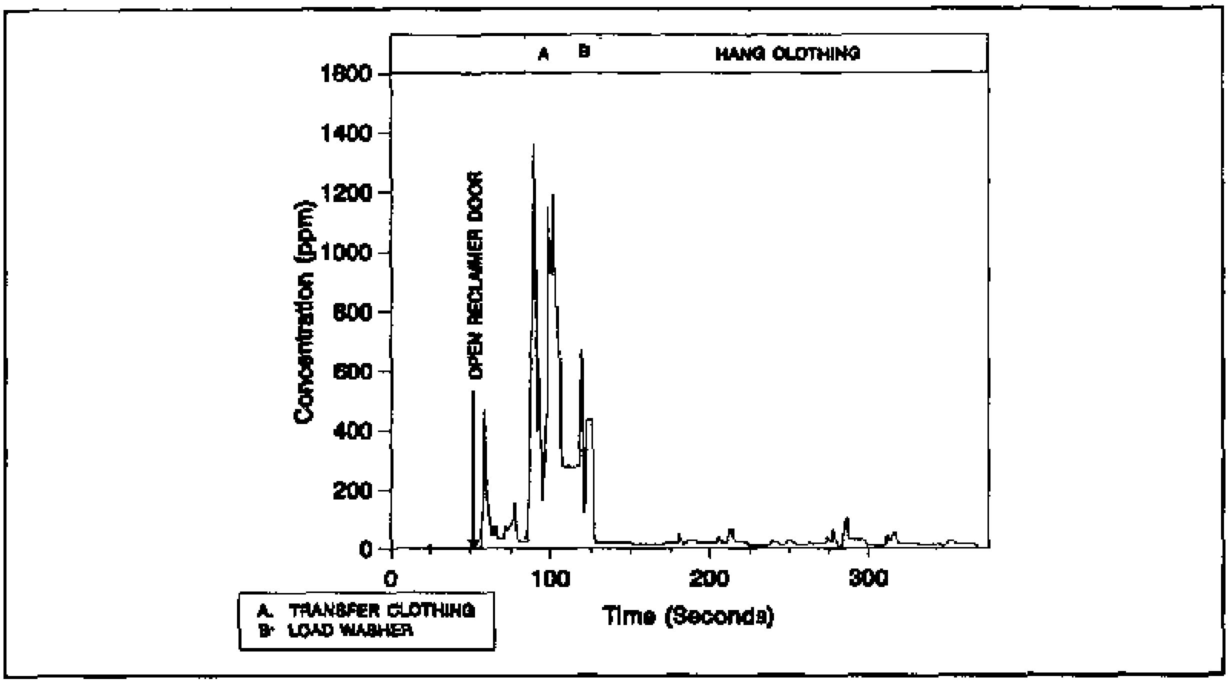

Figure 7 Operator exposure during transfer, loading washer and hanging clothing

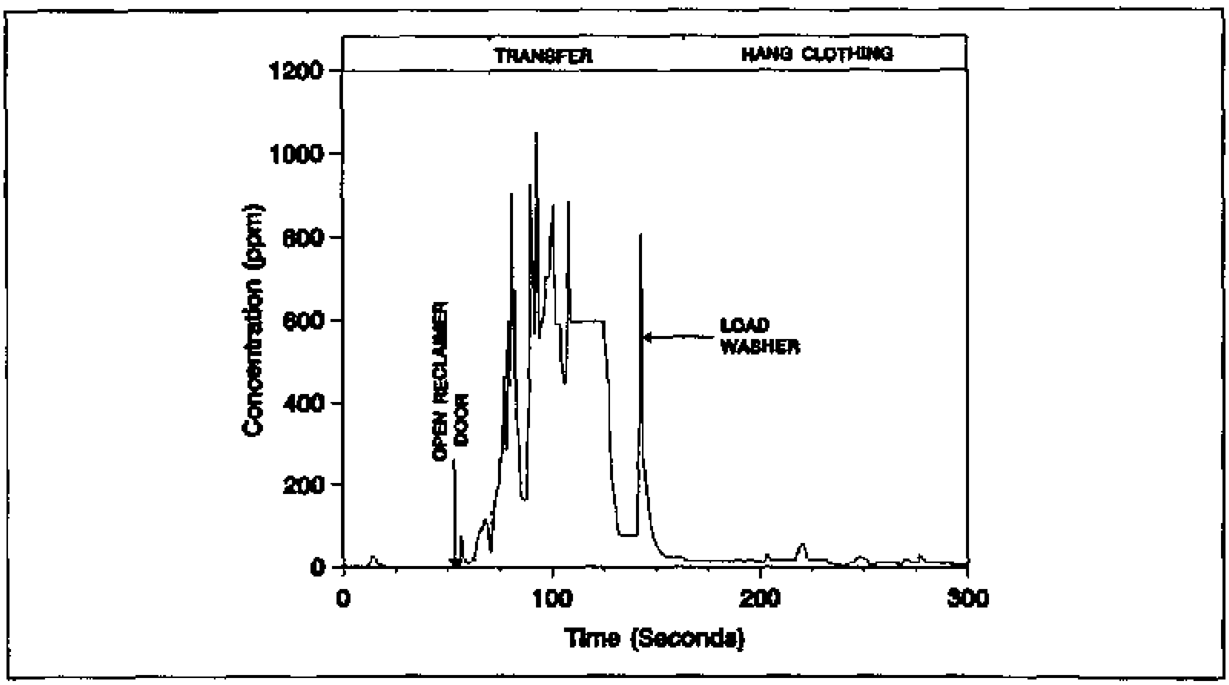

Figure 8 Operator exposure during transfer, loading washer, and hanging clothing

these two figures Statistical analysis of the data indicated that the highest average exposures, 500-600 ppm, occurred during the transfer Following transfer, the next highest exposures occurred during loading the washer, unloading the reclaimer, and hanging clothing For both figures, hanging the clothing took the longest time In fact real-time monitoring was stopped before hanging an entire load of clothing A comparison between unloading the reclaimer, transfer, and loading the washer indicated that transfer generally took more time

Again as was seen in earlier surveys, loading was responsible for a greater average exposure than unloading During earlier surveys, which were primarily done on dry-to-dry machines, loading and unloading occurred on the same machine At this shop the loading was performed on the washer and the unloading was performed on the reclaimer Surprisingly, average PERC exposures during the transfer operation were not as high as average PERC exposures from some of the dry-to-dry machines studied at other shops The concentration-time product (area under the curve) was also higher during transfer than during any other task in these two figures

Real-time analysis of the garment hanging operations found that although it took a much longer period of time than other tasks, the average exposure was relatively low, 14-21 ppm Some of the bulkier garments which retain solvent and take longer to dry resulted in instantaneous exposures near 70 ppm, however, these peaks still resulted in a relatively low average exposure Operator exposure could be reduced by more than half by eliminating exposure during loading, unloading, and transfer This can be seen by determining the operator's TWA total concentration-time product in ppm*seconds during the workday from air sampling (25,200 seconds * 19 5 ppm = 491,400 ppm*sec) and comparing this to the operator total concentration-time product during loading/unloading and transfer from real-time measurements (25,370 ppm*sec * 10 times/day = 253,700 ppm*sec/day)

Figures 9 and 10 show exposure during machine maintenance activities Figure 9 shows exposures during cleaning the lint and button traps and disposing of the hazardous waste Normally this occurred approximately once each day The average exposure during these activities were 25 5 ppm Figure 10 shows exposures during changing the solvent filters There was no still to be cleaned on this machine; rather, the clay and carbon filters were used to remove both soluble and insoluble soils There were several tubes which held five filters each Each tube was changed approximately once for every 10,000 pounds of clothing cleaned or once a month The filters were approximately 1 foot in diameter and 18 inches long Each filter had a hole which ran through the middle of it Real-time monitoring revealed that the greatest exposures occurred when the filter was placed into the hazardous waste container and when the new filters were placed into the tubes Apparently, contaminated air is displaced when the filter was placed into the tube or canister

Although waterproofing dip-tank operations were not evaluated during this in-depth study, exposures during this procedure at other shops were extremely high because the operator worked over an open tank of PERC and other chemicals

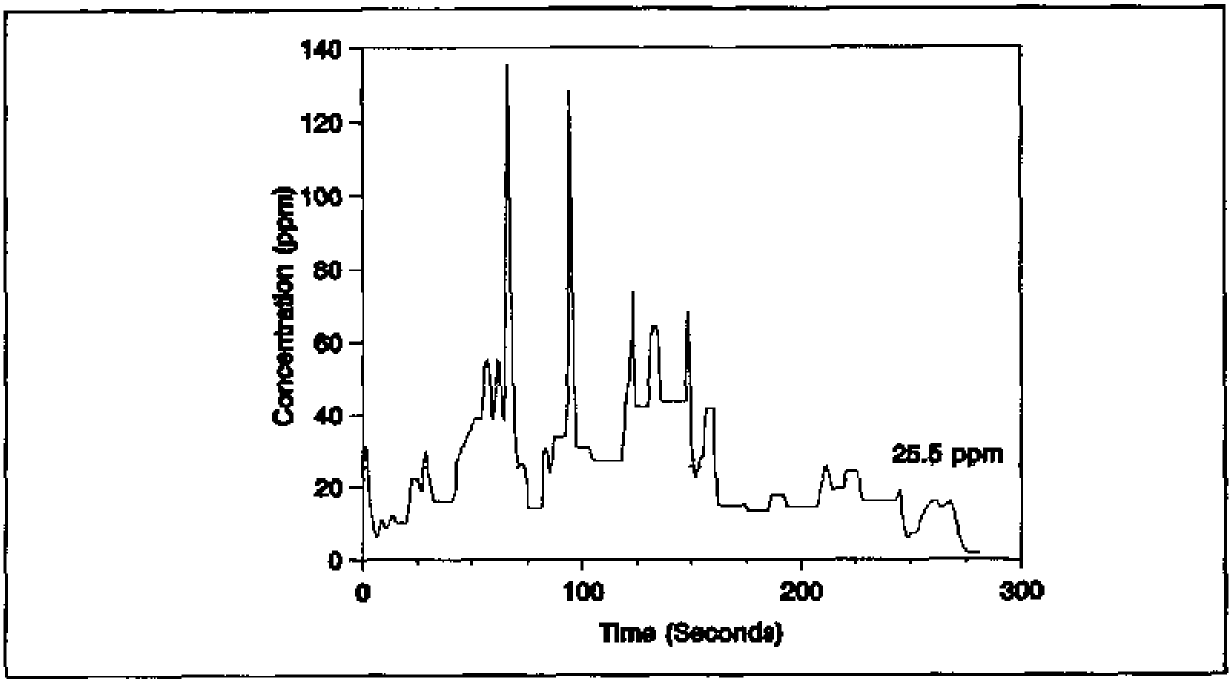

Figure 9 Operator exposure during cleaning lint traps

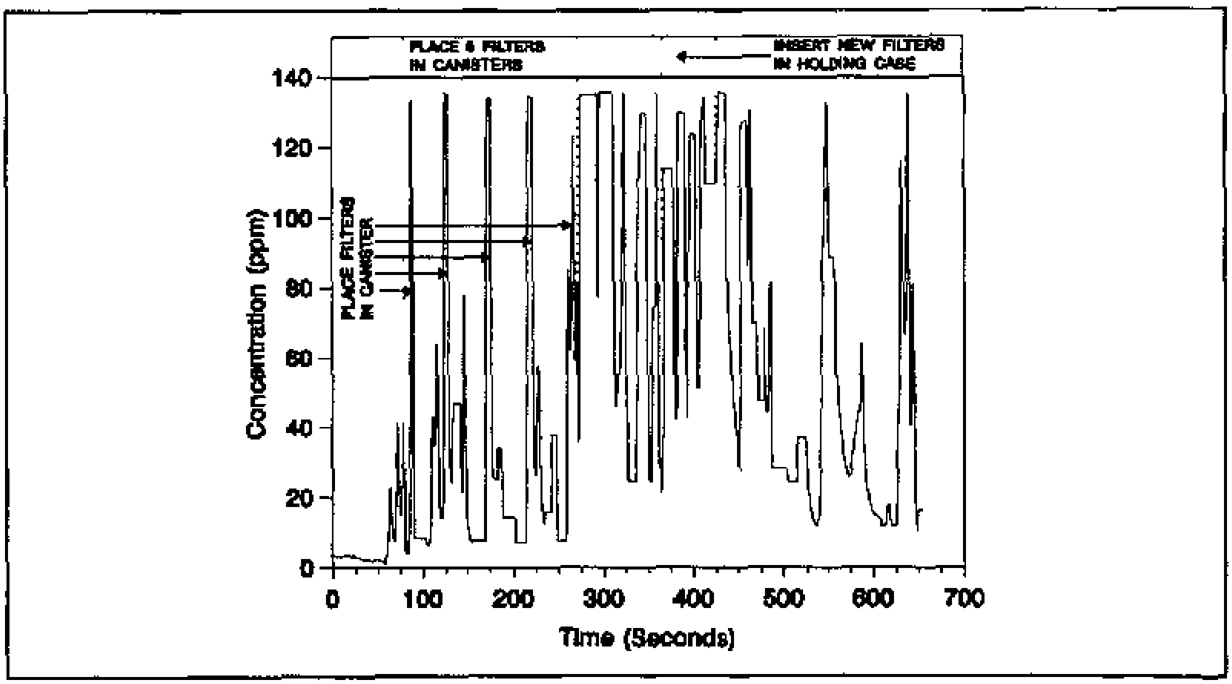

Figure 10 Worker exposure during changing filters

when waterproofing clothing The clothing was dipped in the PERC and then raised and allowed to drain It was then hand carried to the dry cleaning machine Like the other shop studied, there was no ventilation during this procedure It is highly likely that both peak and ceiling exposure limits will be exceeded during waterproofing

Finally, the garment off-gassing experiment is shown in Figure 11 During an average cycle, the machine was less effective than many other machines studied at recovering solvent from the garments The total PERC off-gassing from the test swatch was 10,690 ppm*sec or 89 0 mg PERC/kg cloth

VENTILATION MEASUREMENTS

Ventilation measurements were taken at the face of the open washer and reclaimer doors Measurements taken with a Kurz® hot-wire velometer showed that the face velocity at the reclaimer door was approximately 78 feet per minute (fpm), and the air flow was approximately 221 cubic feet per minute (cfm) The face velocity at the washer door was approximately 39 fpm, and the air flow was approximately 69 cfm Smoke tubes indicated that the reclaimer was able to capture air approximately 2 feet in front of the open door, and the washer could capture air approximately 1 foot in front of the open door Several ventilation measurements were taken in front of the two exterior building doors nearest to the dry-cleaning area Smoke tubes showed that air was rushing into the building through both of these doors Air velocity

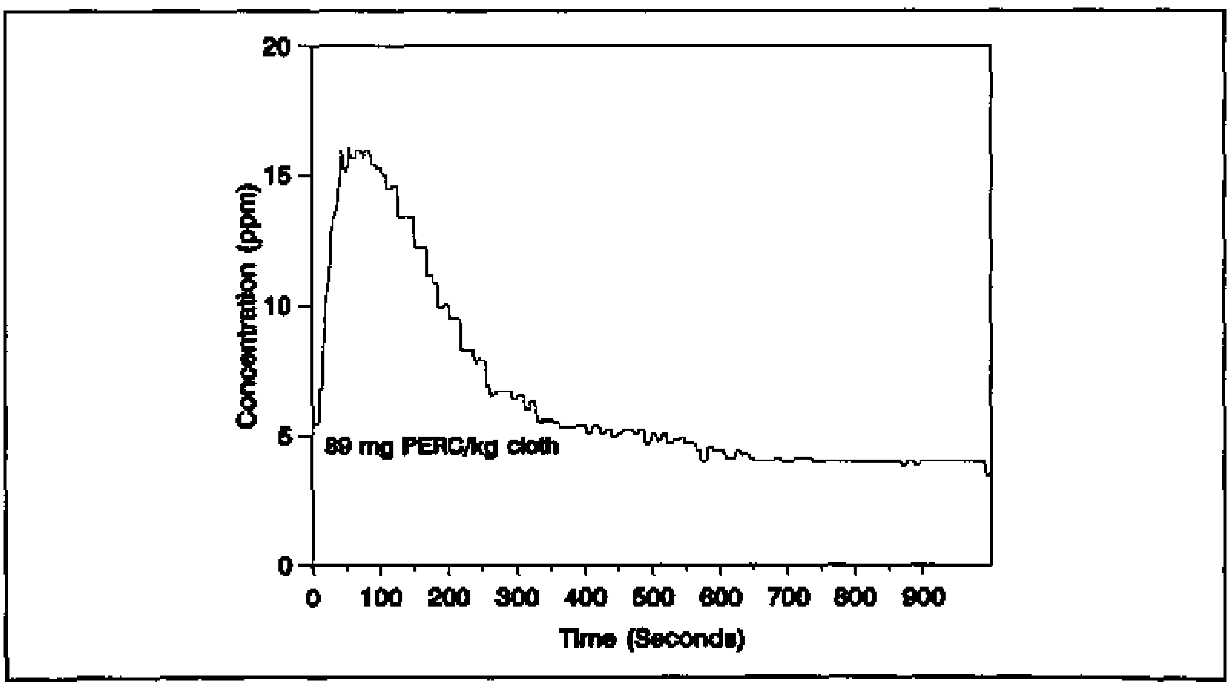

Figure 11 Typical off-gassing of test swatch

measurements and air flow calculations showed that approximately 6,800 cfm was entering the building through the door behind the washer Approximately 4,600 cfm entered the building through the door near the pressing area The air entering the building from behind the washer was able to carry some of the PERC vapors from the dry-cleaning area into the pressing area The air currents entering from both doors collided in the pressing area This resulted in the swirling effect which can be seen in Figure 12 Unfortunately, the reclaimer exhaust ducts were in a poor location During smoke tube testing it appeared that much of the PERC laden air that was exhausted outside of the building reentered the building through the door behind the washer

Other exhaust fans in this building did an adequate job for cooling, however, they had very little effect at diluting air contaminants Contaminant dilution could have been improved by optimizing general ventilation and installing windows which can be opened to permit fresh air to enter

OBSERVATIONS

There were approximately five maintenance personnel responsible for maintaining the 31 Tuchman shops in the Indianapolis area No liquid solvent leaks were detected in this shop during the visit, however, high concentrations were measured behind the dry-cleaning machines A leak

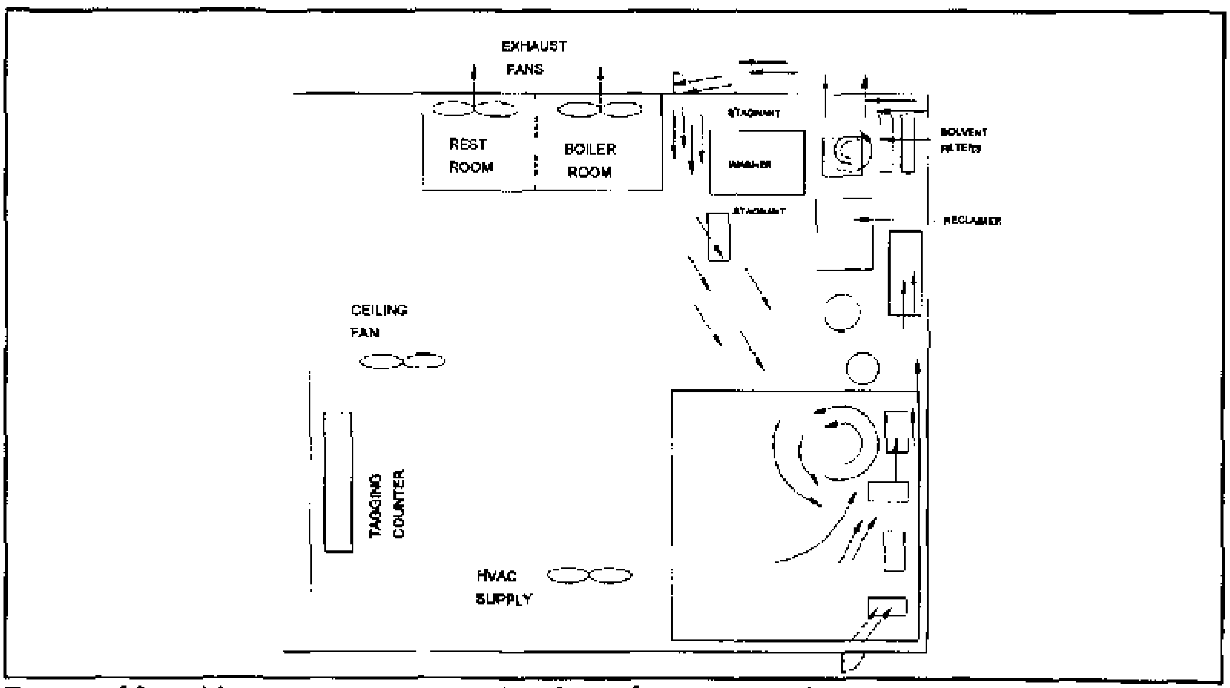

Figure 12 Air currents near the dry-cleaning machines

detector was not present at this shop, however, maintenance personnel from the main shop had a TIF® model 5050 halogen leak detector that was used periodically, and visual checks for leaks were performed and logged every week

This shop had an extremely high ceiling, approximately 18 feet This permitted the PERC coming from the dry-cleaning equipment to diffuse into a larger volume of air There was also significant airflow through the dry-cleaning area when both doors were opened A comparison of International Fabricare Institute (IFI) operator exposure data for similar equipment indicates that exposures at this shop were extremely low for the type of equipment being used This can probably be attributed to two factors the large open area with very high ceiling and the significant air flow when the doors were opened

There were no open containers with solvent or solvent contaminated items observed Blue hazardous waste storage barrels were located behind the dry-cleaning machines Passive monitoring for PERC was conducted at this shop on an annual basis A review of the spotting agents which were used revealed that some of the chemicals were held in unlabeled containers

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment at this shop consisted of respirators and gloves Personal protective equipment was stored on a first-aid shelf between the boiler room and dry-cleaning area The respirator was a North® Model 7700-30M, half-face, respirator with organic vapor/acid gas cartridges The gloves were latex surgical gloves The respirator was only used by the operator in case of a PERC spill and was not used during transfer The manager stated that surgical gloves were sometimes used at the spotting station if a garment was contaminated with body fluids Maintenance personnel did wear a half-face respirator with organic vapor/acid gas cartridges when changing filters, however, neither gloves nor a chemical protective apron were worn There was no personal protective equipment training and no respirator fit testing Management required all new employees to sign a standard HAZCOM form, which explains the hazards present, when they are hired

ERGONOMICS

Along with exposure to PERC during the dry-cleaning process, some employees may also be at risk of incurring musculoskeletal strain due to the repetitive work performed Job analyses were performed on the garment transfer, pressing, and bagging operations The following is a brief description of the jobs investigated, the sub-tasks associated with each, and related findings and observations

Garment Transfer

Garment transfer consisted of transferring clothing from the washer to the reclaimer The amount of clothes handled and the frequency of handling during the transfer process was dependent on what an employee could functionally "grab," which can vary per load The tasks associated with this process were identified as follows

-Moving a cart filled with dirty garments to be placed inside the washer Three different types of carts were used, and the dimensions are shown in Table 1

Table 1
Cart Dimensions

Cart	Height (in)	Width (in)	Length (in)
I	33 5	27	37 5
II	29 5	21	29
III	28 5	18 5	31 5

Note Cart III is equipped with a scale to measure the weight of the load being placed in the cart

-Unloading the reclaimer, hanging clothes such as shirts and blouses, and placing pants on a cart or table to be transferred to the pressing area (Time required for this task may vary During this study unloading time was approximately 15 to 20 seconds),

-Unloading the washer and loading the reclaimer (transfer time was approximately 15 to 30 seconds),

-Loading the washer with the next load of clothing (the loading time was approximately 10 to 15 seconds),

-Setting the controls and turning on each machine,

-Sorting, if necessary, through dried clothes for specific presser designation,

-Transporting dried clothing to the pressing area

At this particular shop the washer and reclaimer were next to one another, requiring the garments to be carried approximately 72 inches during transfer

Pressing Operations
Pressing operations consisted of four separate workstations two multi-press stations for pants, suits, dresses, skirts, coats, and some shirts and blouses, a shirt pressing station, and another station for less typical items such as draperies (NIOSH researchers did not evaluate the drapery presses during the evaluation) A railing was suspended from the ceiling to approximately 74 inches above the floor (the rail height varied due to floor unevenness) The railing was located at each pressing station and used to hold garments and aid in their transport

Multi-press Station

The multi-press station consisted of general utility presses, puff irons, pants toppers, a steam-fed partial mannequin "suzie", and a hand iron The process at this station began by grasping garments from the overhead railing or cart and either placing them on the "suzie", or the pressing machine The decision to use the mannequin depended on the type and material of the garment The mannequin was typically used for jackets, coats, and dresses The presser placed a garment on the mannequin and activated a foot lever which would gradually release steam The presser then began to press other garments on the utility press

The utility press was positioned horizontally The base of the machine was stationary and the top of the press, which was mobile, was activated by the press operator Clothing was positioned on the pad and the operator simultaneously activated the pressing lid and steam via two hand controls and a foot pedal Once the lid had closed the operator pressed down on a lever located on top of the lid to increase the pressure and steam on the garment This procedure was repeated until the article of clothing was fully pressed The operator frequently utilized a hand-held iron to remove smaller wrinkles that were difficult to remove with the utility press The iron, weighed approximately 8 lbs, and was connected to a steam line, and equipped with small buttons and levers for steam generation and regulation

The shirt collar and cuff press was similar to the top loading press The press loading process consists of placing the shirt's collar and cuffs on designated pads and activating the top load press with a front lever bar Additional steam and pressing action was available from levers located on the top load press As with the larger presses, this machine had an automatic timer which stopped the pressing

One potential concern revolved around the dynamic nature of this job Although pressing did not appear to include heavy lifting, it was highly repetitive and involved some awkward postures due to excessive reaching Because the pressing stations could not be adjusted, an average sized person may be required to reach beyond their normal limit This was evident with the use of the material rack The rack was over 6 feet high requiring an average sized employee (male 70 inches, female 64 inches) to frequently reach well overhead when hanging pants or shirts While the dynamic nature of this task was primarily limited to the upper extremity, the static posture of the lower extremity could also present potential problems Aside from scheduled work breaks the employees stood for most of their workday There did not appear to be any quality rubberized floor mats at the pressing stations which could reduce leg fatigue

Shirt Pressing Station

The shirt pressing station included four separate workstations that were used primarily for pressing men's shirts Each station contained three pieces of equipment, which were operated by one worker who stood in the middle of the three machines A description of the machines follows

One machine, the cabinet bag sleever, was devoted to pressing shirt sleeves Sleeves were fit over two vertical posts and placed onto the sleever, one shirt at a time One machine, the collar and cuff press, was used for pressing shirt collars and cuffs This machine was similar to the collar and cuffs press described earlier

One machine, the buck cabinet bosom, body, and yoke press, was designed to press the front and back of the shirt Each shirt was fitted over a vertical plate which moved in and out of the presser Two separate alternating plates were used

These machines were located adjacent to one another with the cabinet bag sleever machine in the center, and the other two machines located on either side perpendicular to the sleever Within this area, a shirt was often fit over the top of a stand with the collar buttoned to allow passive stretching of the collar This helped to prevent shrinkage due to cleaning

At this particular station the employee was able to work at all three machines simultaneously The automatic nature of the shirt pressing operations allowed the employee to go from machine to machine spending 10 to 15 seconds on each machine The concerns of physical stress to the employee at this station were similar to the concerns in the multi-press station

Garment Bagging Area

This was the area where cleaned and pressed garments were wrapped in plastic bags just prior to being placed on the overhead conveyor system behind the customer service desk The clothing were on a hanger and hung on an adjustable "bagging pole " Initially, the pole height was approximately 38 inches, but it could be extended to a height of approximately 68 inches The clothing and the pole were placed under a plastic bag dispenser, where a bag was manually pulled over the garment and hanger while avoiding the pole

CONCLUSIONS AND RECOMMENDATIONS

Controls at Tuchman Cleaners (Shop 24) maintained full-shift TWA exposures to PERC below the OSHA permissible exposure limit (PEL) However, operator, full-shift, TWA PERC exposures exceeded 25 ppm on one of four days Twenty-five ppm is the exposure limit that OSHA encourages dry cleaners to remain beneath NIOSH recommends controlling PERC to the lowest feasible concentration The highest TWA personal exposures were for the dry cleaning machine operator/manager who was exposed to approximately 19 5 ppm TWA during the entire survey The two pressers who were sampled were exposed to between approximately 3 3 and 3.8 ppm TWA for the entire survey

The primary source of exposure to the workers in this shop was the dry cleaning machine Real-time evaluation showed that loading and unloading of the machines and garment transfer had the greatest impact upon exposures Over half of the operator's total exposure was due to loading, unloading, and transfer The operator's exposure could be dramatically reduced by improving controls during these activities

There are a number of different measures which could reduce exposures during loading, unloading, and transfer The most important step which could be taken is to purchase dry-to-dry equipment which completely eliminates the transfer operation Data from the International Fabricare Institute indicates that since 1989, TWA worker exposure using dry-to-dry machines was less than half of the exposure using transfer equipment [9] When purchasing new dry-to-dry equipment, it is important to ensure that the equipment has certain key features which aid in exposure reduction First, the dry-to-dry machine should have two vapor recovery devices a refrigerated condenser and carbon absorber The carbon absorber should have enough carbon to capture PERC for at least a weeks worth of clothing and ideally should desorb automatically Another important feature is adequate ventilation around the door of the machine Air velocity near the face of the machine door should be approximately 100 fpm to minimize escape of contaminated vapors into the worker's breathing zone

If Tuchman Cleaners is unable to replace their transfer equipment immediately, other measures could be taken to further reduce exposures Local exhaust ventilation could be used to significantly reduce exposures This could occur by modifying the current system with a larger fan or by adding simple, inexpensive, external local exhaust ventilation consisting of an exhaust fan, duct work, and hood The fan must provide sufficient airflow to prevent escape of vapor through the loading door into the workers breathing zone A generally accepted air velocity is 100 fpm [10,11] A larger fan could be added to the current system which would increase the airflow and reduce residuals escaping from the cylinder and reaching the operator's breathing zone during loading/unloading A simple, inexpensive, external local ventilation system with a separate exhaust fan, duct work, and hood is another option The captured air could then be ducted outside the building or to a vapor recovery unit Exposures during unloading have been shown to be reduced from 1,000 ppm to 28 ppm using a fan which operated at 990 cfm with a slotted hood design [12]

Controls should be implemented to reduce exposures during waterproofing operations This could occur in a number of different ways Waterproofing dip-tank operations could continue as they are currently being done if local exhaust ventilation were used along with proper respiratory protection and gloves A better option would be to consider purchasing equipment such as a dosing unit or separate tank so that waterproofing could be performed in the machine itself Although waterproofing is done on an infrequent, as needed basis, it is a very significant source of exposure when it does occur

Process isolation can be examined from two perspectives between shops and within the shop Of all 31 Tuchman Cleaners in Indianapolis, only two were "dry stores" where no dry cleaning occurred Workers at these two "dry stores" were isolated from significant exposures to PERC By converting some of the stores which do dry cleaning on the premises to "dry stores," exposures to some of the workers would be reduced

Process isolation was not used within this shop, however, it could be used because this facility was relatively large Some facilities have used a wall or barrier within the shop to separate the dry cleaning machine area from other areas of the shop The Environmental Protection Agency currently requires dry cleaning facilities with a transfer machine that uses over 1,800 gallons of PERC per year to install a room enclosure and vent the enclosure to a carbon absorber [13] The majority of PERC emissions originate from the machine Isolating employees from the dry-cleaning machines by either time or space will reduce exposures to the employee

There were no visible liquid leaks As machines age, leaks may develop and should be repaired promptly Proper maintenance is instrumental in reducing leakage Liquid leaks are more easily seen if proper maintenance and housekeeping is performed Lint build-up is a real problem in most dry cleaning shops If lint is allowed to accumulate on the floor and in and around equipment, leaks are much harder to locate Gaskets prone to deterioration must be inspected and replaced on a regular basis Solvent usage records can be a valuable indicator of solvent leaks or machine malfunctions Several devices can aid in leak detection These include the halide torches, photoionization detectors, and pocket dosimeters The passive exposure monitoring devices used annually in this shop will not aid in leak detection but will alert management when an exposure problem exists [14]

Use of personal protective equipment (PPE) at this shop, like almost every other dry cleaning shop in this study, was not in accordance with Federal Regulation 29 CFR 1910 134 because there was no established program In addition to the measures mentioned earlier, occupational exposure could be further reduced through the proper use of PPE PPE does nothing to reduce or eliminate the source of the hazard and must be used properly to be effective

Though not recommended by NIOSH, because PERC is a potential occupational carcinogen, the current respirators (half-mask facepiece with organic vapor cartridges), used for short-term exposures to low concentrations of PERC, must have the cartridges changed prior to breakthrough (approximately 130 minutes based on room concentrations) [15] Regular cartridge changes are important because the odor threshold of PERC is 27 ppm, and a worker may not smell PERC until significant breakthrough and exposure has occurred [16]

Where employees must wear respirators, an appropriate respiratory protection program in accordance with 29 CFR 1910 134 must be instituted This regulation, shown in Appendix D, contains provisions for

- a written standard operating procedure
- respirator selection based upon hazards
- instruction and training of the user concerning the proper use and limitations of respirators
- regular cleaning, disinfection, and proper storage
- medical review of the health and condition of the respirator user
- use of certified respirators which have been designed according to standards established by competent authorities [17]

It is recommended that at a minimum, proper respirators and gloves be used during machine maintenance and waterproofing operations by the operator

Gloves and goggles should be used to reduce exposure to hazardous chemicals such as PERC Gloves provide limited dermal protection and should be made of solvent resistant materials, such as Viton® fluoroelastomer, polyvinyl alcohol, or unsupported nitrile When a specific glove is chosen, factors such as permeation, durability, dexterity, and cost should be considered

Viton® and polyvinyl alcohol have a PERC breakthrough time in excess of eight hours [18] A 1987 study showed that unsupported nitrile was impervious to PERC after a 2-hour challenge period [19] Some of the drawbacks associated with these materials are that Viton® is expensive, polyvinyl alcohol significantly reduces dexterity, and unsupported nitrile has a high permeation rate Whenever swelling or softening of the gloves or seepage of PERC into the glove is observed, the gloves should be replaced Gloves should also be regularly checked for perforations and cuts

Chemical splash goggles should be worn to prevent eye injury when workers are using hazardous chemicals Accidental contamination of the eye could result in minor irritation or complete loss of vision Use of chemical splash goggles is particularly important during maintenance operations, waterproofing, and spotting Additionally, location of the eye wash station in the restroom is unacceptable An unobstructed eye wash station should be installed in the vicinity of the dry cleaning machine and spotting station to provide prompt eye irrigation in the event it is needed If chemical contamination of the eye does occur, prompt irrigation for at least 15 minutes can play a deciding role in limiting the extent of damage

Many of the ergonomic hazards at this facility involved repetitive motions and awkward postures Most of these problems occurred at the pressing stations A number of measures could be taken in order to control these hazards Redesign of the workstation could be used to eliminate many of the awkward postures and excessive reaching performed Frequent breaks and worker rotation are often used to control the hazards of repetitive tasks The following measures appear to be feasible options at this facility and should help to reduce ergonomic risk factors at the workstations studied

Garment Transfer Recommendations

-Educate and train employees to modify their work technique to grab no more than 15-20 lbs of clothing during the transfer operation,

-Raise the bottom of the clothing cart to 16 inches off the ground or provide a cart with spring loaded bottom no less than 16 inches off the ground that raises the clothes as the cart is unloaded This should reduce the amount of bending and reaching the operator must perform

Multi-press Station Recommendations

-Provide a utility press that permits vertical and horizontal adjustment at the point(s) of operation,

-Reposition the hand iron platform in greater proximity to the worker to reduce excessive reaching Also, provide a suspension device to reduce the amount of weight that the presser must lift

-Replace the two-hand controls with proximity sensors to reduce stress on the fingers,

-Provide a 3/8 inch thick rubberized floor mat with a beveled edge to reduce leg fatigue

Shirt Pressing Station Recommendations

-Raise the height of the cabinet bag sleever hand controls closer to the point of operation to reduce excessive reaching,

-Replace the two-hand presser activation buttons with proximity sensors to reduce stress on the worker's fingers,

-Develop a "button pulling" device/tool to aid the worker in pulling the collar button through the button hole This could reduce the repetitive pinch posture used by the worker

Garment Bagging Area Recommendations

-Provide bagging poles that are vertically adjustable utilizing hydraulic foot pedal controls In the interim, bagging poles should be kept in good working condition by ensuring they are straight and lightly lubricated with a non-staining oil

General Observations

The tasks required in the transfer operation and both pressing stations appeared to be highly repetitive and required reaching and precision gripping Such actions in combination with high work rate and frequency may cause physical discomfort and musculoskeletal problems for individuals working in these areas The dry-cleaning industry should work closely with manufacturers to develop adjustable height workstations

APPENDICES

APPENDIX A BACKGROUND

The National Institute for Occupational Safety and Health (NIOSH), located in the Centers for Disease Control and Prevention (CDC), under the Department of Health and Human Services (DHHS) (formerly the Department of Health, Education, and Welfare), was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct research and education programs separate from the standard setting and enforcement functions conducted by the Occupational Safety and Health Administration (OSHA) in the Department of Labor An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards

The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering has been given the lead within NIOSH to study and develop engineering controls and assess their impact on reducing occupational illness Since 1976, ECTB has conducted a large number of studies to evaluate engineering control technology based upon industry, process, or control technique The objective of each of these studies has been to document and evaluate control techniques and to determine their effectiveness in reducing potential health hazards in an industry or at specific processes

In the late 1970s and early 1980s, a NIOSH sponsored engineering control technology study was conducted in the dry cleaning industry [20] Since that study, significant changes involving equipment, processes, and work practices have occurred within the industry Many of these changes were initiated by new epidemiologic, toxicologic, and environmental data for the primary solvent, perchloroethylene (PERC) This industry currently has in excess of 30,000 commercial shops and approximately 244,000 employees in the United States [21]

Some studies have shown that in addition to the numerous adverse health effects already known for PERC exposure, there is evidence of carcinogenicity [22] PERC is a known animal carcinogen,[23] but there is inadequate evidence of human carcinogenicity [24] In December 1991, the Environmental Protection Agency began regulating PERC as a hazardous air pollutant under Section 112 of the Clean Air Act This regulation was based on environmental research that PERC was a toxic air pollutant [25]

The industry has responded with increased research into alternative solvents and cleaning methods, a shift from transfer machines to closed loop, dry-to-dry machines, and innovations in vapor recovery equipment and other devices to reduce occupational exposures and environmental emissions Many of the exposure problems identified during studies in the late 1970s and early 1980s still exist because transfer equipment is still being used, many controls developed by industry are cost prohibitive, and some work practices are inadequate

Data from the OSHA Integrated Management Information System (IMIS), from 1984-1988, indicates that approximately 20 percent of samples taken at dry cleaning shops exceeded 100 ppm [26] More recent and comprehensive data gathered by the

International Fabricare Institute's (IFI) vapor monitoring service using passive monitoring badges is shown in Table 2

Table 2[27]
IFI'S Passive Monitoring Results

	Before 1/1/87	1/1/87 - 9/30/89	After 10/1/89
TRANSFER (AVG TWA PPM)	55 3 ppm	46 4 ppm	42 ppm
%>25 ppm	76 2%	59 9%	56 8%
%>100 ppm	7 7%	5 6%	7 0%
DRY-TO-DRY*** (AVG TWA PPM)	20 5 ppm	16 1 ppm	17 2 ppm 16 9 ppm* 16 7 ppm**
%>25 ppm	24 3%	18 5%	18 6%* 17 2%**
%>100 ppm	1 0%	8%	1 3%* 8%**

* Denotes dry-to-dry refrigerated with small vent to purge cylinder at end of dry cycle
** Denotes dry-to-dry refrigerated with no vent whatsoever
*** Denotes standard dry-to-dry with water-cooled condenser and vent at end of dry cycle

In 1988, the OSHA Director of Federal-State Operations conducted a nationwide query of the OSHA State Consultation Programs asking for high risk small businesses in need of occupational safety and health research The dry cleaning industry was the second most mentioned small business, falling behind autobody repair shops [28] Preliminary information gathered by the NIOSH, Division of Surveillance, Hazard Evaluations, and Field Studies has shown a high incidence of back pain among laundry and dry cleaning workers [29] This information has not been gathered exclusively for dry cleaning, and, additional research and analysis are needed

Based upon the preceding information, a preliminary hazard analysis (PHA) was performed for the dry cleaning industry For this PHA, a hazard was defined as an activity or condition that poses a threat of loss During this analysis, the hazards listed below were identified

- inhalation of PERC vapors
- ergonomic hazards
- exposure to hazardous chemicals used in the spotting process
- fire/explosion hazards
- direct (dermal) exposure to PERC
- thermal burns
- heat stress
- mechanical hazards
- electrical hazards
- slips/trips/falls

These hazards are listed from top to bottom in decreasing order of risk The degree of risk was based upon two factors

1) likelihood of occurrence
2) severity of consequence

Each risk ranking is of a qualitative nature

APPENDIX B DRY CLEANING TECHNOLOGY

Two types of machines are generally used in dry cleaning transfer and dry-to-dry Transfer machines are older, less expensive, and require manual transfer of solvent laden clothing between the washer and dryer This is the point of highest worker exposure Transfer machines process twice as much clothing as comparably sized dry-to-dry machines because the process time is half that of a dry-to-dry machine Some owners of dry-to-dry machines reduce the cycle time or exceed the load capacity to increase productivity Unfortunately, this practice increases exposure due to residuals left in the clothing [30]

Because of the high exposures that occur during transfer, transfer machines are no longer manufactured in the United States, however, used or reconditioned ones can still be purchased Seventy percent of machines today are dry-to-dry machines using a one step process that eliminates clothing transfer [31] Clothes enter and exit the machine dry PERC exposure from dry-to-dry machines is considerably less than exposure from transfer machines Most federal and state regulations do not require the use of dry-to-dry machines, however, a few states, such as California and New York, have introduced legislation to eliminate the use of transfer machines Worker exposures below 25 ppm are much more difficult to achieve using a transfer machine Most shops are moving or have moved to replace transfer machines with dry-to-dry machines because of the trend toward stricter regulations from both state and federal OSHA and the EPA

Among dry-to-dry machines, there are two general types in use today vented and ventless dry-to-dry machines Vented dry-to-dry machines vent residual solvent vapors directly to the atmosphere or through some form of vapor recovery system during the aeration process Ventless dry-to-dry machines are essentially closed systems which are only open to the atmosphere when the machine door is opened or closed They recirculate heated drying air through a vapor recovery system and back to the drying drum There is no aeration step

Two primary technologies are used to recover PERC vapors the carbon absorber and the refrigerated condenser Carbon absorbers remove PERC molecules from the air by passing solvent laden vapors over activated carbon, which has a high adsorption capacity The PERC is then recovered in a condenser, separated from the water, and returned to the storage tank Desorption typically occurs daily, if not done regularly, the carbon bed will become ineffective for carbon recovery Refrigerated condensers use a refrigerant to cool the solvent laden air below the dew point of the vapor to recover the PERC

Tests have shown that several new technologies are more effective than a carbon absorber or refrigerated condenser alone They are the Boewe® Consorba® and Dow TVS® technology Both of these are a subset of ventless dry-to-dry machines, which reduce occupational exposure by lowering solvent residuals in the cylinder The Boewe® Consorba® has a refrigerated condenser and carbon absorber in series Air passes through the refrigerated condenser where solvent is extracted A drying sensor in the machine switches to a cool-down cycle During this phase, the cooled air leaves the refrigerated condenser and passes through the carbon absorber

Dow's TVS® technology has eliminated the need for condensation equipment and returns the vapors directly to the machine cylinder A polymeric adsorbent has been developed by Dow which has a high capacity for PERC, even at high vapor concentrations The polymer is desorbed by hot air, thereby eliminating any waste water stream which would result if steam were used This system can be used as a primary control and retrofitted to existing, vented, dry-to-dry machines, converting the machine to a closed-loop, no vent system This system can also be used as a secondary control on closed-loop, refrigerated, dry-to-dry machines to lower residuals in the cylinder

Dry cleaners use filtration and distillation to recover and purify the solvent Filtration is used to remove insoluble soils, nonvolatile residues, and loose dyes from the solvent Filtration is usually a continuous process in which the solvent passes through either an adsorbent powder or filter cartridge, both of which must be replaced periodically Additionally, powderless, spin-disc filters[32] and a no filtration process[33] have been developed that significantly reduce the generation of hazardous waste

Distillation, which is used by 90 percent of the industry, separates soluble oils, fatty acids, and greases not removed by filtration [34] Distillation occurs by heating PERC to its boiling point so that it vaporizes and later is condensed back to liquid form During this process, nonvolatile impurities, which cannot be boiled off, remain at the bottom of the still and are discarded as hazardous waste Both filtration and distillation produce solid wastes containing PERC residue

APPENDIX C POTENTIAL HAZARDS

Exposure to PERC is the primary health hazard for workers in dry cleaning facilities today PERC can enter the human body through both respiratory and dermal exposure Symptoms associated with respiratory exposure include the following depression of the central nervous system, damage to the liver and kidneys, impaired memory, confusion, dizziness, headache, drowsiness, and eye, nose, and throat irritation Repeated dermal exposure may result in dry, scaly, and fissured dermatitis [35]

Over the past 15 years, studies conducted by the National Cancer Institute (1977) and the National Toxicology Program (1986) have established a link between PERC exposure and cancer in animals Other studies have shown an elevated risk of urinary tract,[36 37,38] esophageal,[35 39] and pancreatic cancer[40 41] among individuals who work in dry cleaning establishments Most of these studies involved exposure to a variety of solvents and have not been linked to PERC exposure Cancer mortality research is continuing at NIOSH and other research organizations

Spotting involves the selective application of a wide variety of chemicals and steam to remove specific stains Some of the chemicals and chemical families that are used on a fairly regular basis for spotting in addition to PERC are as follows other chlorinated solvents, amyl acetate, petroleum naphtha, oxalic acid, acetic acid, esters, ethers, ketones, dilute hydrofluoric acid, hydrogen peroxide, and aqueous ammonia Individuals who perform the spotting process could be exposed to toxic chemicals through skin or eye contact or inhalation of vapors Use of dilute hydrofluoric acid, which is found in rust removal spotting agents, poses the greatest risk from acute dermal exposure, however, many of the chemicals used can cause occupational dermatoses from chronic exposure to the skin

Previous studies have shown that inhalation exposures are minimized due to the limited quantities of chemicals and the intermittent nature and short duration of the task [20] During personal sampling by the Arthur D Little Company at the International Fabricare Institute's Analysis Laboratory,[42] PERC exposures during spotting were many times lower than OSHA standards and some chemicals being used were below detection limits [43] The primary hazard posed by the majority of chemicals used in the spotting process is skin damage resulting from chronic or acute exposure or injury to the eyes, however, chemicals that readily vaporize and have a high toxicity could pose a risk from inhalation Vapor pressure, toxicity, ventilation, manner and frequency of use, and air concentration should all be considered when assessing the risk from inhalation

Ergonomic hazards in the dry cleaning industry have been given little attention in the past These hazards are primarily seen among workers performing pressing operations where dynamic and repetitive tasks requiring reaching, precision gripping, and awkward postures are used They could also be present during material handling where heavy lifting may occur

The term ergonomic hazard relative to work-related musculoskeletal disorders refers to conditions that pose a risk of injury or illness to the musculoskeletal system of the worker Ergonomic hazards can include excessive manual force, repeated and sustained exertions, temperature extremes, vibration, and awkward postures resulting from inappropriately designed workstations, equipment, and work methods Other factors which play a role are excessive work rates and duration, external pacing of work, shiftwork, imbalanced work to rest ratios, and restriction of worker body movement Work related musculoskeletal disorders can result in damage to tendons, tendon sheaths, muscles, nerves, and ligaments of the area affected [44,45]

Highly repetitive tasks may consist of rapid and frequent muscle contractions with high velocity This causes the muscles to develop less tension than contracting slowly, thereby, requiring more muscle effort and recovery than less repetitive tasks [7] Insufficient recovery time can contribute to the incident rate of cumulative trauma disorders and is often related to repetitive tasks The prevalence of tenosynovitis and humeral tendinitis is significantly higher for workers engaged in machine-paced repetitive assembly work than for workers with variable tasks Repetitive motions of the hands for some workers reach 25,000 cycles per workday [46] Other studies have shown that muscles subjected to static work require more than 12 times longer than the original muscle-contraction duration for complete recovery from fatigue [47] This could be a potential risk factor for pressers' lower limbs because they spend much of the day standing

Awkward or sustained postures can pose a risk of biomechanical stress to the joints of the upper extremity and surrounding soft tissue [7] Several shoulder ailments, such as thoracic outlet syndrome, have been associated with workers repeatedly reaching above shoulder level [48] In addition, work postures involving elevated arms could accelerate tendon degeneration by increasing the friction of tendons [49] This could be related to a decreased amount of synovial fluid acting as a lubricant

APPENDIX D
RESPIRATORY PROTECTION
(Code of Federal Regulations, 29 CFR 1910 134)

(a) Permissible practice (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials) When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements

(2) Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee The employer shall provide the respirators which are applicable and suitable for the purpose intended The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received

(b) Requirements for a minimal acceptable program (1) Written standard operating procedures governing the selection and use of respirators shall be established

1910 134(b)(2)

(2) Respirators shall be selected on the basis of hazards to which the worker is exposed

(3) The user shall be instructed and trained in the proper use of respirators and their limitations

(4) [Reserved]

(5) Respirators shall be regularly cleaned and disinfected Those used by more than one worker shall be thoroughly cleaned and disinfected after each use

(6) Respirators shall be stored in a convenient, clean, and sanitary location

(7) Respirators used routinely shall be inspected during cleaning Worn or deteriorated parts shall be replaced Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use

(8) Appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained

(9) There shall be regular inspection and evaluation to determine the continued effectiveness of the program

(10) Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment The local physician shall determine what health and physical conditions are pertinent The respirator user's medical status should be reviewed periodically (for instance, annually)

1910 134(b)(11)

(11) Approved or accepted respirators shall be used when they are available The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with standards

established by competent authorities The U S Department of Interior, Bureau of Mines, and the U S Department of Agriculture are recognized as such authorities Although respirators listed by the U S Department of Agriculture continue to be acceptable for protection against specified pesticides, the U S Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators

• Selection of respirators Proper selection of respirators shall be made according to the guidance of American National Standard Practices for Respiratory Protection Z88 2-1969

(d) Air quality (1) Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G-7 1-1966 Compressed oxygen shall not be used in supplied-air respirators or in open circuit self-contained breathing apparatus that have previously used compressed air Oxygen must never be used with air line respirators

1910 134(d)(2)

(2) Breathing air may be supplied to respirators from cylinders or air compressors

(I) Cylinders shall be tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR Part 178)

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices A breathing air-type compressor shall be used Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air purifying sorbent beds and filters installed to further assure breathing air quality A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in paragraph (d)(1) of this section

(3) Air line couplings shall be incompatible with outlets for other gas systems to prevent inadvertent servicing of air line respirators with nonrespirable gases or oxygen

1910 134(d)(4)

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48 1-1954, Federal Specification BB-A-1034a, June 21, 1968, Air, Compressed for Breathing Purposes, or Interim Federal Specification GG-B-00675b, April 27, 1965, Breathing Apparatus, Self-Contained

(e) Use of respirators

(1) Standard procedures shall be developed for respirator use These should include all information and guidance necessary for their proper selection, use, and care Possible emergency and routine uses of respirators should be anticipated and planned for

(2) The correct respirator shall be specified for each job The respirator type is usually specified

in the work procedures by a qualified individual supervising the respiratory protective program The individual issuing them shall be adequately instructed to insure that the correct respirator is issued

(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies Personnel shall be familiar with these procedures and the available respirators

1910 134(e)(3)(I)

(I) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present Communications (visual, voice, or signal line) shall be maintained between both or all individuals present Planning shall be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency

(ii) When self-contained breathing apparatus or hose masks with blowers are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment

(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other and equivalent provisions for the rescue of persons from hazardous atmospheres shall be used A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue

(4) Respiratory protection is no better than the respirator in use, even though it is worn conscientiously Frequent random inspections shall be conducted by a qualified individual to assure that respirators are properly selected, used, cleaned, and maintained

1910 134(e)(5)

(5) For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance Both supervisors and workers shall be so instructed by competent persons Training shall provide the men an opportunity to handle the respirator, have it fitted properly, test its facepiece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere

(I) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly Respirators shall not be worn when conditions prevent a good face seal Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses Also, the absence of one or both dentures can seriously affect the fit of a facepiece The worker's diligence in observing these factors shall be evaluated by periodic check To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator This may be done by following the manufacturer's facepiece fitting instructions

(ii) Providing respiratory protection for individuals wearing corrective glasses is a serious problem A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece As a temporary measure, glasses with short temple bars or without temple bars may be taped to the wearer's head Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed Systems have been developed for mounting corrective lenses inside full facepieces When a workman must wear corrective lenses as part of the facepiece, the facepiece and lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal

1910 134(e)(5)(iii)

(iii) If corrective spectacles or goggles are required, they shall be worn so as not to affect the fit of the facepiece Proper selection of equipment will minimize or avoid this problem

(f) Maintenance and care of respirators (1) A program for maintenance and care of respirators shall be adjusted to the type of plant, working conditions, and hazards involved, and shall include the following basic services

(I) Inspection for defects (including a leak check),

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness

(2) (I) All respirators shall be inspected routinely before and after each use A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition

(ii) Self-contained breathing apparatus shall be inspected monthly Air and oxygen cylinders shall be fully charged according to the manufacturer's instructions It shall be determined that the regulator and warning devices function properly

1910 134(f)(2)(iii)

(iii) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters Rubber or elastomer parts shall be inspected for pliability and signs of deterioration Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage

(iv) A record shall be kept of inspection dates and findings for respirators maintained for emergency use

(3) Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer Respirators maintained for emergency use shall be cleaned and disinfected after each use

(4) Replacement or repairs shall be done only by experienced persons with parts designed for the respirator No attempt shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair

1910 134(f)(5)

(5) (I) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals Respirators placed at stations and work areas for emergency use should be quickly accessible at all times and should be stored in compartments built for the purpose The compartments should be clearly marked Routinely used respirators, such as dust respirators, may be

placed in plastic bags Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons

(ii) Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position

(iii) Instructions for proper storage of emergency respirators, such as gas masks and self-contained breathing apparatus, are found in "use and care" instructions usually mounted inside the carrying case lid

(g) Identification of gas mask canisters (1) The primary means of identifying a gas mask canister shall be by means of properly worded labels The secondary means of identifying a gas mask canister shall be by a color code

1910 134(g)(2)

(2) All who issue or use gas masks falling within the scope of this section shall see that all gas mask canisters purchased or used by them are properly labeled and colored in accordance with these requirements before they are placed in service and that the labels and colors are properly maintained at all times thereafter until the canisters have completely served their purpose

(3) On each canister shall appear in bold letters the following

(i) - Canister for____________________________

(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

(ii) In addition, essentially the following wording shall appear beneath the appropriate phrase on the canister label "For respiratory protection in atmospheres containing not more than _______ percent by volume of ________________________ "

Name of atmospheric contaminant)

1910 134(g)(4)

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic particulates shall be labeled with a statement of the type and degree of protection afforded by the filter The label shall be affixed to the neck end of, or to the gray stripe which is around and near the top of, the canister The degree of protection shall be marked as the percent of penetration of the canister by a 0 3-micron-diameter dioctyl phthalate (DOP) smoke at a flow rate of 85 liters per minute

(5) Each canister shall have a label warning that gas masks should be used only in atmospheres containing sufficient oxygen to support life (at least 16 percent by volume), since gas mask canisters are only designed to neutralize or remove contaminants from the air

(6) Each gas mask canister shall be painted a distinctive color or combination of colors indicated in Table I-1 All colors used shall be such that they are clearly identifiable by the user and clearly distinguishable from one another The color coating used shall offer a high degree of resistance to chipping, scaling, peeling, blistering, fading, and the effects of the ordinary atmospheres to which they may be exposed under normal conditions of storage and use Appropriately colored pressure sensitive tape may be used for the stripes

TABLE I-1

Atmospheric contaminants to be protected against	Colors assigned(1)
Acid gases	White
Hydrocyanic acid gas	White with ½-inch green stripe completely around the canister near the bottom
Chlorine gas	White with ½-inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gases	Green with ½-inch white stripe completely around the canister near the bottom
Carbon Monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with ½-inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, excepting tritium and noble gases	Purple (Magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with ½-inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with ½-inch gray stripe completely around the canister near the top

Footnote(1) Gray shall not be assigned as a main color for a canister designed to remove acids or vapors

NOTE Orange shall be used as a complete body, or stripe color to represent gases not included in this table The user will need to refer to the canister label to determine the degree of protection the canister will afford

(Approved by the Office of Management and Budget under control number 1218-0099) [39 FR 23502, June 27, 1974, as amended at 43 FR 49748, Oct 24, 1978, 49 FR 5322, Feb 10, 1984, 49 FR 18295, Apr 30, 1984]

APPENDIX E   RAW AIR SAMPLING AND REAL-TIME DATA

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–6–94	Operator	t212	0 1	120	12	1	2 4	200 00	29 49	3 38
9–6–94	abovewash	t215	0 1	116	11 6	1	0 67	57 76	8 52	2 14
9–6–94	abovedry	t218	0 1	117	11 7	1	1 6	136 75	20 17	3 00
9–6–94	Presser H	t214	0 1	63	6 3	1	0 032	5 08	0 75	–0 29
9–6–94	spotting	t220	0 1	114	11 4	1	0 42	36 84	5 43	1 69
9–6–94	dryright	t204	0 1	113	11 3	1	0 26	23 01	3 39	1 22
9–6–94	washbhind	t217	0 1	113	11 3	1	1 1	97 35	14 36	2 66
9–6–94	tagging	t219	0 1	113	11 3	1	0 24	21 24	3 13	1 14
9–6–94	reception	t209	0 1	113	11 3	1	0 24	21 24	3 13	1 14
9–6–94	leftshop	t211	0 1	110	11	1	0 23	20 91	3 08	1 13
9–6–94	pressing	t210	0 1	65	6 5	1	0 028	4 31	0 64	–0 45
9–6–94	Operator	t208	0 1	122	12 2	2	2 3	188 52	27 80	3 33
9–6–94	abovewash	t216	0 1	120	12	2	0 66	55 00	8 11	2 09
9–6–94	abovedry	t202	0 1	119	11 9	2	1 3	109 24	16 11	2 78
9–6–94	Presser H	t229	0 1	111	11 1	2	0 24	21 62	3 19	1 16
9–6–94	spotting	t206	0 1	120	12	2	0 42	35 00	5 16	1 64
9–6–94	dryright	t203	0 1	122	12 2	2	0 68	55 74	8 22	2 11
9–6–94	washbhind	t213	0 1	120	12	2	0 45	37 50	5 53	1 71
9–6–94	tagging	t207	0 1	120	12	2	0 25	20 83	3 07	1 12
9–6–94	reception	t205	0 1	121	12 1	2	0 23	19 01	2 80	1 03
9–6–94	leftshop	t201	0 1	122	12 2	2	0 22	18 03	2 66	0 98
9–6–94	pressing	t223	0 1	111	11 1	2	0 24	21 62	3 19	1 16
9–6–94	Operator	t224	0 1	113	11 3	3	1 9	168 14	24 80	3 21
9–6–94	abovewash	t235	0 1	120	12	3	0 71	59 17	8 73	2 17
9–6–94	abovedry	t225	0 1	120	12	3	1 1	91 67	13 52	2 60
9–6–94	Presser H	t221	0.1	135	13 5	3	0 39	28 89	4 26	1 45
9–6–94	spotting	t237	0 1	122	12 2	3	0 5	40 98	6 04	1 80
9–6–94	dryright	t222	0 1	119	11 9	3	0 84	70 59	10 41	2 34
9–6–94	washbhind	t226	0 1	122	12 2	3	0 61	50 00	7 37	2 00
9–6–94	tagging	t227	0 1	121	12 1	3	0 31	25 62	3 78	1 33
9–6–94	reception	t233	0 1	121	12 1	3	0 3	24 79	3 66	1 30
9–6–94	leftshop	t240	0 1	121	12 1	3	0 26	21 49	3 17	1 15
9–6–94	pressing	t228	0 1	128	12 8	3	0 38	29 69	4 38	1 48
9–6–94	unknownbk	t230	0 1	136	13 6	3	0 01	0 74	0 11	–2 22
9–6–94	unknownbk	t234	0 1	136	13 6	3	0 01	0 74	0 11	–2 22

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–6–94	insideoutlet	t236b	0.1	104	10 4	3	0 46	44 23	6 52	1 88
9–6–94	Operator	t250	0 1	57	5 7	4	0 9	157 89	23 28	3 15
9–6–94	abovewash	t248	0 1	47	4 7	4	0 26	55 32	8 16	2 10
9–6–94	abovedry	t242	0 1	47	4 7	4	0 51	108 51	16 00	2 77
9–6–94	spotting	t247	0 1	45	4 5	4	0 16	35 56	5 24	1 66
9–6–94	dryright	t232	0 1	42	4 2	4	0 29	69 05	10 18	2 32
9–6–94	washbhind	t245	0 1	47	4 7	4	0 24	51 06	7 53	2 02
9–6–94	tagging	t236a	0 1	43	4 3	4	0 13	30 23	4 46	1 49
9–6–94	reception	t243	0 1	42	4 2	4	0 14	33 33	4 92	1 59
9–6–94	leftshop	t244	0 1	41	4 1	4	0 12	29 27	4 32	1 46
9–6–94	pressing	t231	0 1	37	3 7	4	0 12	32 43	4 78	1 57
9–6–94	outsidewash	t239	0 1	59	5 9	4	0 046	7 80	1 15	0 14
9–6–94	unknownblk	t241	0 1	136	13 6	4	0 01	0 74	0 11	–2 22
9–7–94	Operator	t104	0 1	122	12 2	5	3 5	286 89	42 31	3 74
9–7–94	abovewash	t101	0 1	121	12 1	5	1 4	115 70	17 06	2 84
9–7–94	abovedry	t110	0 1	122	12 2	5	2 3	188 52	27 80	3 33
9–7–94	Presser H	t69	0 1	120	12	5	0 1	8 33	1 23	0 21
9–7–94	spotting	t108	0 1	119	11 9	5	0 9	75 63	11 15	2 41
9–7–94	dryright	t106	0 1	121	12 1	5	1 5	123 97	18 28	2 91
9–7–94	washbhind	t102	0 1	123	12 3	5	2 4	195 12	28 77	3 36
9–7–94	tagging	t107	0 1	122	12 2	5	0 51	41 80	6 16	1 82
9–7–94	reception	t109	0 1	122	12 2	5	0 39	31 97	4 71	1 55
9–7–94	leftshop	t105	0 1	121	12 1	5	0 61	50 41	7 43	2 01
9–7–94	pressing	t52	0 1	117	11 7	5	0 46	39 32	5 80	1 76
9–7–94	outsidewash	t103	0 1	121	12 1	5	1.5	123 97	18 28	2 91
9–7–94	insideoutlet	t60	0 1	120	12	5	2 3	191 67	28 26	3 34
9–7–94	offgassing	t61	0 1	10	1	1	0 01	10 00	1 47	0 39
9–7–94	unknownblk	t129	0 1	136	13 6	5	0 01	0 74	0 11	–2 22
9–7–94	unknownblk	t118	0 1	136	13 6	5	0 01	0 74	0 11	–2 22
9–7–94	Operator	t70	0 1	122	12 2	6	1 4	114 75	16 92	2 83
9–7–94	abovewash	t58	0 1	122	12 2	6	0 56	45 90	6 77	1 91
9–7–94	abovedry	t57	0 1	121	12 1	6	0 89	73 55	10 85	2 38
9–7–94	spotting	t63	0 1	127	12 7	6	0 3	23 62	3 48	1 25
9–7–94	dryright	t68	0 1	124	12 4	6	0 38	30 65	4 52	1 51
9–7–94	washbhind	t67	0 1	122	12 2	6	1 8	147 54	21 76	3 08

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–7–94	tagging	t65	0.1	120	12	6	0.091	7.58	1.12	0.11
9–7–94	reception	t64	0.1	119	11.9	6	0.028	2.35	0.35	−1.06
9–7–94	leftshop	t56	0.1	120	12	6	0.054	4.50	0.66	−0.41
9–7–94	pressing	t59	0.1	124	12.4	6	0.092	7.42	1.09	0.09
9–7–94	outsidewash	t62	0.1	122	12.2	6	0.12	9.84	1.45	0.37
9–7–94	insideoutlet	t66	0.1	118	11.8	6	0.96	81.36	12.00	2.48
9–7–94	offgassing	t51	0.1	3	0.3	2	0.01	33.33	4.92	1.59
9–7–94	Operator	t114	0.1	89	8.9	7	0.57	64.04	9.44	2.25
9–7–94	abovewash	t119	0.1	83	8.3	7	0.45	54.22	8.00	2.08
9–7–94	abovedry	t115	0.1	90	9	7	0.46	51.11	7.54	2.02
9–7–94	Presser H	t71	0.1	24	2.4	7	0.024	10.00	1.47	0.39
9–7–94	spotting	t53	0.1	73	7.3	7	0.39	53.42	7.88	2.06
9–7–94	dryright	t113	0.1	87	8.7	7	0.32	36.78	5.42	1.69
9–7–94	washbhind	t55	0.1	80	8	7	0.4	50.00	7.37	2.00
9–7–94	tagging	t111	0.1	80	8	7	0.13	16.25	2.40	0.87
9–7–94	reception	t112	0.1	81	8.1	7	0.092	11.36	1.67	0.52
9–7–94	leftshop	t116	0.1	81	8.1	7	0.1	12.35	1.82	0.60
9–7–94	pressing	t126	0.1	87	8.7	7	0.13	14.94	2.20	0.79
9–7–94	outsidewash	t128	0.1	77	7.7	7	0.082	10.65	1.57	0.45
9–7–94	insideoutlet	t130	0.1	91	9.1	7	0.55	60.44	8.91	2.19
9–7–94	offgassing	t122	0.1	20	2	3	0.02	10.00	1.47	0.39
9–8–94	unknownblk	t78	0.1	136	13.6	8	0.01	0.74	0.11	−2.22
9–8–94	unknownblk	t77	0.1	136	13.6	8	0.01	0.74	0.11	−2.22
9–8–94	unknownblk	t125	0.1	136	13.6	8	0.01	0.74	0.11	−2.22
9–8–94	unknownblk	t73	0.1	136	13.6	8	0.01	0.74	0.11	−2.22
9–8–94	Operator	t72	0.1	118	11.8	8	1.9	161.02	23.74	3.17
9–8–94	abovewash	t82	0.1	119	11.9	8	1.1	92.44	13.63	2.61
9–8–94	abovedry	t86	0.1	116	11.6	8	1.4	120.69	17.80	2.88
9–8–94	Presser H	t96	0.1	90	9	8	0.066	7.33	1.08	0.08
9–8–94	spotting	t83	0.1	123	12.3	8	0.11	8.94	1.32	0.28
9–8–94	dryright	t88	0.1	123	12.3	8	0.38	30.89	4.56	1.52
9–8–94	washbhind	t79	0.1	120	12	8	0.37	30.83	4.55	1.51
9–8–94	tagging	t81	0.1	120	12	8	0.048	4.00	0.59	−0.53
9–8–94	reception	t87	0.1	120	12	8	0.049	4.08	0.60	−0.51
9–8–94	leftshop	t89	0.1	122	12.2	8	0.065	5.33	0.79	−0.24

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–8–94	pressing	t90	0 1	120	12	8	0 047	3 92	0 58	–0 55
9–8–94	outsidewash	t85	0 1	122	12 2	8	0 78	63 93	9 43	2 24
9–8–94	insideoutlet	t84	0 1	122	12 2	8	0 42	34 43	5 08	1 62
9–8–94	Operator	t9	0 1	122	12 2	9	1 3	106 56	15 71	2 75
9–8–94	abovewash	t93	0 1	125	12 5	9	0 93	74 40	10 97	2 40
9–8–94	abovedry	t7	0 1	125	12 5	9	1 3	104 00	15 34	2 73
9–8–94	Presser H	t1	0 1	120	12	9	0 32	26 67	3 93	1 37
9–8–94	spotting	t94	0 1	122	12 2	9	0 16	13 11	1 93	0 66
9–8–94	dryright	t91	0 1	120	12	9	0 82	68 33	10 08	2 31
9–8–94	washbhind	t98	0 1	120	12	9	0 74	61 67	9 09	2 21
9–8–94	tagging	t95	0 1	115	11 5	9	0 12	10 43	1 54	0 43
9–8–94	reception	t99	0 1	120	12	9	0 058	4 83	0 71	–0 34
9–8–94	leftshop	t100	0 1	120	12	9	0 12	10 00	1 47	0 39
9–8–94	pressing	t97	0 1	120	12	9	0 52	43 33	6 39	1 85
9–8–94	outsidewash	t92	0 1	120	12	9	0 4	33 33	4 92	1 59
9–8–94	insideoutlet	t6	0 1	123	12 3	9	0 8	65 04	9 59	2 26
9–8–94	Operator	t11	0 1	137	13 7	10	1 3	94 89	13 99	2 64
9–8–94	abovewash	t10	0 1	124	12 4	10	0 98	79 03	11 65	2 46
9–8–94	abovedry	t15	0 1	124	12 4	10	1 7	137 10	20 22	3 01
9–8–94	Presser H	t20	0 1	125	12 5	10	0 55	44 00	6 49	1 87
9–8–94	spotting	t19	0 1	120	12	10	0 42	35 00	5 16	1 64
9–8–94	dryright	t2	0 1	120	12	10	1 1	91 67	13 52	2 60
9–8–94	washbhind	t12	0 1	125	12 5	10	1	80 00	11 80	2 47
9–8–94	reception	t4	0 1	118	11 8	10	0 17	14 41	2 12	0 75
9–8–94	leftshop	t5	0 1	118	11 8	10	0 29	24 58	3 62	1 29
9–8–94	pressing	t13	0 1	126	12 6	10	0 01	0 79	0 12	–2 15
9–8–94	outsidewash	t17	0 1	127	12 7	10	0 17	13 39	1 97	0 68
9–8–94	insideoutlet	t18	0 1	126	12 6	10	0 87	69 05	10 18	2 32
9–8–94	unknownblk	t8	0 1	136	13 6	10	0 01	0 74	0 11	–2 22
9–8–94	unknownblk	t16	0 1	136	13 6	10	0 01	0 74	0 11	–2 22
9–8–94	unknownblk	t14	0 1	136	13 6	10	0 01	0 74	0 11	–2 22
9–9–94	Operator	t26	0 1	120	12	11	1 1	91 67	13 52	2 60
9–9–94	abovewash	t24	0 1	122	12 2	11	0 35	28 69	4 23	1 44
9–9–94	abovedry	t29	0 1	120	12	11	1 2	100 00	14 75	2 69
9–9–94	Presser H	t21	0 1	120	12	11	0 028	2 33	0 34	–1 07

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–9–94	spotting	t34	0 1	119	11 9	11	0 088	7 39	1 09	0 09
9–9–94	dryright	t38	0 1	118	11 8	11	0 14	11 86	1 75	0 56
9–9–94	washbhind	t25	0 1	122	12 2	11	0 61	50 00	7 37	2 00
9–9–94	tagging	t40	0 1	114	11 4	11	0 029	2 54	0 38	–0 98
9–9–94	reception	t31	0.1	120	12	11	0.01	0 83	0 12	–2 10
9–9–94	leftshop	t37	0 1	118	11 8	11	0 044	3 73	0 55	–0 60
9–9–94	pressing	t35	0 1	122	12 2	11	0 026	2 13	0 31	–1 16
9–9–94	outsidewash	t23	0 1	120	12	11	0 41	34 17	5 04	1 62
9–9–94	insideoutlet	t22	0 1	120	12	11	0 84	70 00	10 32	2 33
9–9–94	Operate2	t41	0 2	5	1	1	0 39	390 00	57 51	4 05
9–9–94	Operate3	t50	0 2	15	3	1	0 45	150 00	22 12	3 10
9–9–94	knownblk	t131	0 2	120	24	1	0 01	0 42	0 06	–2 79
9–9–94	knownblk	t140	0 2	120	24	1	0 01	0 42	0 06	–2 79
9–9–94	knownblk	t138	0.2	120	24	1	0 01	0 42	0 06	–2 79
9–9–94	Operate2	t36	0 2	5	1	2	0 39	390 00	57 51	4 05
9–9–94	Operate3	t28	0.2	15	3	2	0 44	146 67	21 63	3 07
9–9–94	Operator	t44	0 1	121	12 1	12	0 32	26 45	3 90	1 36
9–9–94	abovewash	t139	0 1	121	12 1	12	0 65	53 72	7 92	2 07
9–9–94	abovedry	t32	0 1	121	12 1	12	1 2	99 17	14 62	2 68
9–9–94	Presser H	t135	0 1	115	11 5	12	0 79	68 70	10 13	2 32
9–9–94	spotting	t48	0 1	120	12	12	0 47	39 17	5 78	1 75
9–9–94	dryright	t137	0 1	121	12 1	12	0 51	42 15	6 22	1 83
9–9–94	washbhind	t47	0 1	120	12	12	0 41	34 17	5 04	1 62
9–9–94	tagging	t49	0 1	121	12 1	12	0 22	18.18	2 68	0 99
9–9–94	reception	t39	0 1	122	12 2	12	0 06	4 92	0 73	–0 32
9–9–94	leftshop	t42	0 1	124	12 4	12	0 18	14 52	2 14	0 76
9–9–94	pressing	t33	0 1	123	12 3	12	0 28	22 76	3 36	1 21
9–9–94	outsidewash	t46	0 1	126	12 6	12	0 41	32 54	4 80	1 57
9–9–94	insideoutlet	t134	0 1	119	11 9	12	1 4	117 65	17 35	2 85
9–9–94	Presser E	t133	0 2	60	12	12	0 14	11 67	1 72	0 54
9–9–94	Maintperson	t136	0 2	5	1	12	0 82	820 00	120 92	4 80
9–9–94	Maintperson	t132	0 2	15	3	12	2 4	800 00	117 97	4 77
9–9–94	Presser E	t160	0 2	58	11 6	13	0 18	15 52	2 29	0 83
9–9–94	Operator	t144	0 1	89	8 9	13	0 33	37 08	5 47	1 70
9–9–94	abovewash	t45	0 1	87	8 7	13	0 55	63 22	9 32	2 23

Tuchman's Cleaners – Carmel, IN September 6–9, 1994

Date	Sample	Tube	Flow (l/min)	Time (min)	Vol (l)	Run	Mass (mg)	Conc (mg/m3)	Conc (ppm)	lnConc
9–9–94	abovedry	t143	0.1	87	8 7	13	0 69	79 31	11 70	2 46
9–9–94	Presser H	t145	0 1	88	8 8	13	0 31	35 23	5 19	1 65
9–9–94	spotting	t148	0.1	86	8 6	13	0 3	34 88	5 14	1.64
9–9–94	dryright	t142	0 1	85	8 5	13	0 33	38 82	5 73	1.74
9–9–94	washbhind	t149	0 1	86	8 6	13	1 3	151 16	22 29	3.10
9–9–94	tagging	t150	0 1	86	8 6	13	0 18	20 93	3 09	1.13
9–9–94	reception	t147	0 1	83	8 3	13	0 05	6 02	0 89	–0.12
9–9–94	leftshop	t151	0 1	83	8 3	13	0 14	16 87	2 49	0 91
9–9–94	pressing	t155	0 1	82	8 2	13	0 17	20 73	3 06	1 12
9–9–94	outsidewash	t152	0 1	82	8 2	13	0 087	10 61	1 56	0 45
9–9–94	insideoutlet	t141	0 1	85	8 5	13	0 52	61 18	9 02	2 20
9–9–94	Presser E	t43	0 2	60	12	13	0 47	39 17	5 78	1 75
9–9–94	unknownblk	t156	0 1	136	13 6	13	0 01	0 74	0 11	–2 22

Multiple range analysis for CARSTAT ppm by CARSTAT sample

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups
knownblk	3	0 06144	X
unknownb	2	0 10843	X
unknownb	11	0 10843	XX
receptio	13	2 03222	XXX
offgassi	3	2 62163	XXXX
leftshop	13	2 63141	XXXXX
tagging	12	2 69928	XXXXX
pressing	13	2 76101	XXXXX
Eli	3	3 26150	XXXXXX
Herman	11	3 46117	XXXXXXX
spotting	13	4 98621	X XXXXXX
outsidew	10	5 01710	X XXXXXX
dryright	13	7 86687	X X XX
abovewas	13	9 46692	XX
insideou	10	11 72407	XX
washbhin	13	11 75652	X
abovedry	13	15 87688	X
Pixie	13	19 26032	X
Pixie3	2	21 87425	X
Pixie2	2	57 51206	X
Jim	2	119 44813	X

contrast		difference	+/- limits	
Pixie	- abovewash	9 79340	3 69495	*
Pixie	- abovedry	3 38344	3 69495	
Pixie	- Herman	15 7991	3 85925	*
Pixie	- spotting	14 2741	3 69495	*
Pixie	- dryright	11 3935	3 69495	*
Pixie	- washbhind	7 50380	3 69495	*
Pixie	- tagging	16 5610	3 77115	*
Pixie	- reception	17 2281	3 69495	*
Pixie	- leftshop	16 6289	3 69495	*
Pixie	- pressing	16 4993	3 69495	*
Pixie	- unknownbk	19 1519	7 15525	*
Pixie	- insideoutlet	7 53625	3 96240	*
Pixie	- outsidewash	14 2432	3 96240	*
Pixie	- unknownblk	19 1519	3 85925	*
Pixie	- offgassing	16 6387	6 03383	*
Pixie	- Pixie2	-38 2517	7 15525	*
Pixie	- Pixie3	-2 61393	7 15525	
Pixie	- knownblk	19 1989	6 03383	*
Pixie	- Eli	15 9988	6 03383	*
Pixie	- Jim	-100 188	7 15525	*
abovewash	- abovedry	-6 40996	3 69495	*
abovewash	- Herman	6 00575	3 85925	*
abovewash	- spotting	4 48071	3 69495	*
abovewash	- dryright	1 60005	3 69495	
abovewash	- washbhind	-2 28960	3 69495	
abovewash	- tagging	6 76764	3 77115	*
abovewash	- reception	7 43471	3 69495	*
abovewash	- leftshop	6 83551	3 69495	*
abovewash	- pressing	6 70591	3 69495	*

* denotes a statistically significant difference

Multiple range analysis for CARSTAT ppm by CARSTAT sample

Method 95 Percent LSD

Level Count Average Homogeneous Groups

abovewash	- unknownbk	9 35849	7.15525	*
abovewash	- insideoutlet	-2 25715	3 96240	
abovewash	- outsidewash	4 44983	3 96240	*
abovewash	- unknownblk	9 35849	3 85925	*
abovewash	- offgassing	6 84529	6 03383	*
abovewash	- Pixie2	-48 0451	7.15525	*
abovewash	- Pixie3	-12 4073	7 15525	*
abovewash	- knownblk	9 40548	6 03383	*
abovewash	- Eli	6 20542	6 03383	*
abovewash	- Jim	-109 981	7 15525	*
abovedry	- Herman	12 4157	3 85925	*
abovedry	- spotting	10 8907	3 69495	*
abovedry	- dryright	8 01001	3 69495	*
abovedry	- washbhind	4 12035	3 69495	*
abovedry	- tagging	13.1776	3 77115	*
abovedry	- reception	13 8447	3 69495	*
abovedry	- leftshop	13 2455	3 69495	*
abovedry	- pressing	13 1159	3 69495	*
abovedry	- unknownbk	15 7684	7 15525	*
abovedry	- insideoutlet	4 15281	3 96240	*
abovedry	- outsidewash	10 8598	3 96240	*
abovedry	- unknownblk	15 7684	3 85925	*
abovedry	- offgassing	13 2552	6 03383	*
abovedry	- Pixie2	-41 6352	7 15525	*
abovedry	- Pixie3	-5 99737	7 15525	
abovedry	- knownblk	15 8154	6 03383	*
abovedry	- Eli	12 6154	6 03383	*
abovedry	- Jim	-103 571	7 15525	*
Herman	- spotting	-1 52504	3 85925	
Herman	- dryright	-4 40570	3 85925	*
Herman	- washbhind	-8 29535	3 85925	*
Herman	- tagging	0 76189	3 93226	
Herman	- reception	1 42896	3 85925	
Herman	- leftshop	0 82976	3 85925	
Herman	- pressing	0 70016	3 85925	
Herman	- unknownbk	3 35274	7 24146	
Herman	- insideoutlet	-8 26290	4 11603	*
Herman	- outsidewash	-1 55592	4 11603	
Herman	- unknownblk	3 35274	4 01684	
Herman	- offgassing	0 83954	6 13582	
Herman	- Pixie2	-54 0509	7 24146	*
Herman	- Pixie3	-18.4131	7.24146	*
Herman	- knownblk	3 39973	6 13582	
Herman	- Eli	0 19967	6 13582	
Herman	- Jim	-115 987	7 24146	*
spotting	- dryright	-2 88066	3 69495	
spotting	- washbhind	-6 77031	3 69495	*
spotting	- tagging	2 28693	3 77115	
spotting	- reception	2 95399	3 69495	
spotting	- leftshop	2 35480	3 69495	
spotting	- pressing	2 22520	3 69495	
spotting	- unknownbk	4 87778	7 15525	

* denotes a statistically significant difference

Multiple range analysis for CARSTAT ppm by CARSTAT sample

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups
spotting	- insideoutlet	-6 73786	3 96240 *
spotting	- outsidewash	-0 03089	3 96240
spotting	- unknownblk	4 87778	3 85925 *
spotting	- offgassing	2 36458	6 03383
spotting	- Pixie2	-52 5259	7 15525 *
spotting	- Pixie3	-16 8880	7 15525 *
spotting	- knownblk	4 92477	6 03383
spotting	- Eli	1 72471	6 03383
spotting	- Jim	-114 462	7 15525 *
dryright	- washbhind	-3 88966	3 69495 *
dryright	- tagging	5 16759	3 77115 *
dryright	- reception	5 83465	3 69495 *
dryright	- leftshop	5 23546	3 69495 *
dryright	- pressing	5 10586	3 69495 *
dryright	- unknownbk	7 75844	7 15525 *
dryright	- insideoutlet	-3 85720	3 96240
dryright	- outsidewash	2 84977	3 96240
dryright	- unknownblk	7 75844	3 85925 *
dryright	- offgassing	5 24524	6 03383
dryright	- Pixie2	-49 6452	7 15525 *
dryright	- Pixie3	-14 0074	7 15525 *
dryright	- knownblk	7 80542	6 03383 *
dryright	- Eli	4 60537	6 03383
dryright	- Jim	-111 581	7 15525 *
washbhind	- tagging	9 05724	3 77115 *
washbhind	- reception	9 72431	3.69495 *
washbhind	- leftshop	9 12511	3 69495 *
washbhind	- pressing	8 99551	3 69495 *
washbhind	- unknownbk	11 6481	7 15525 *
washbhind	- insideoutlet	0 03246	3 96240
washbhind	- outsidewash	6 73943	3 96240 *
washbhind	- unknownblk	11 6481	3 85925 *
washbhind	- offgassing	9 13489	6 03383 *
washbhind	- Pixie2	-45 7555	7 15525 *
washbhind	- Pixie3	-10 1177	7 15525 *
washbhind	- knownblk	11 6951	6 03383 *
washbhind	- Eli	8 49502	6 03383 *
washbhind	- Jim	-107 692	7 15525 *
tagging	- reception	0 66706	3 77115
tagging	- leftshop	0 06787	3 77115
tagging	- pressing	-0 06173	3.77115
tagging	- unknownbk	2 59085	7 19489
tagging	- insideoutlet	-9 02479	4 03354 *
tagging	- outsidewash	-2 31782	4 03354
tagging	- unknownblk	2 59085	3 93226
tagging	- offgassing	0 07765	6 08079
tagging	- Pixie2	-54 8128	7 19489 *
tagging	- Pixie3	-19 1750	7 19489 *
tagging	- knownblk	2 63784	6 08079
tagging	- Eli	-0 56222	6 08079
tagging	- Jim	-116 749	7 19489 *
reception	- leftshop	-0 59919	3 69495

* denotes a statistically significant difference

Multiple range analysis for CARSTAT ppm by CARSTAT sample

Method 95 Percent LSD

Level Count Average Homogeneous Groups

reception - pressing	-0 72879	3 69495	
reception - unknownbk	1 92379	7 15525	
reception - insideoutlet	-9.69185	3 96240	*
reception - outsidewash	-2 98488	3 96240	
reception - unknownblk	1 92379	3 85925	
reception - offgassing	-0 58941	6 03383	
reception - Pixie2	-55 4798	7 15525	*
reception - Pixie3	-19 8420	7 15525	*
reception - knownblk	1 97077	6 03383	
reception - Eli	-1 22929	6 03383	
reception - Jim	-117 416	7 15525	*
leftshop - pressing	-0 12960	3 69495	
leftshop - unknownbk	2 52298	7 15525	
leftshop - insideoutlet	-9 09266	3 96240	*
leftshop - outsidewash	-2 38568	3 96240	
leftshop - unknownblk	2 52298	3 85925	
leftshop - offgassing	0 00978	6 03383	
leftshop - Pixie2	-54 8807	7 15525	*
leftshop - Pixie3	-19 2428	7 15525	*
leftshop - knownblk	2 56997	6 03383	
leftshop - Eli	-0 63009	6 03383	
leftshop - Jim	-116 817	7 15525	*
pressing - unknownbk	2 65258	7 15525	
pressing - insideoutlet	-8 96306	3 96240	*
pressing - outsidewash	-2 25609	3 96240	
pressing - unknownblk	2 65258	3 85925	
pressing - offgassing	0 13938	6 03383	
pressing - Pixie2	-54 7511	7 15525	*
pressing - Pixie3	-19 1132	7 15525	*
pressing - knownblk	2 69957	6 03383	
pressing - Eli	-0 50049	6 03383	
pressing - Jim	-116 687	7 15525	*
unknownbk - insideoutlet	-11 6156	7 29695	*
unknownbk - outsidewash	-4 90867	7 29695	
unknownbk - unknownblk	0 00000	7 24146	
unknownbk - offgassing	-2 51320	8 59953	
unknownbk - Pixie2	-57 4036	9 42032	*
unknownbk - Pixie3	-21 7658	9 42032	*
unknownbk - knownblk	0 04699	8 59953	
unknownbk - Eli	-3 15307	8 59953	
unknownbk - Jim	-119 340	9 42032	*
insideoutlet - outsidewash	6 70697	4 21289	*
insideoutlet - unknownblk	11 6156	4 11603	*
insideoutlet - offgassing	9 10244	6 20121	*
insideoutlet - Pixie2	-45 7880	7 29695	*
insideoutlet - Pixie3	-10 1502	7 29695	*
insideoutlet - knownblk	11 6626	6 20121	*
insideoutlet - Eli	8 46257	6 20121	*
insideoutlet - Jim	-107 724	7 29695	*
outsidewash - unknownblk	4 90867	4 11603	*
outsidewash - offgassing	2 39546	6 20121	
outsidewash - Pixie2	-52 4950	7 29695	*

* denotes a statistically significant difference

Multiple range analysis for CARSTAT ppm by CARSTAT sample

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups

Contrast	Difference	+/- Limits
outsidewash - Pixie3	-16 8571	7 29695 *
outsidewash - knownblk	4 95565	6 20121
outsidewash - Eli	1 75559	6 20121
outsidewash - Jim	-114 431	7 29695 *
unknownblk - offgassing	-2 51320	6 13582
unknownblk - Pixie2	-57 4036	7 24146 *
unknownblk - Pixie3	-21 7658	7 24146 *
unknownblk - knownblk	0 04699	6 13582
unknownblk - Eli	-3 15307	6 13582
unknownblk - Jim	-119 340	7 24146 *
offgassing - Pixie2	-54 8904	8 59953 *
offgassing - Pixie3	-19 2526	8 59953 *
offgassing - knownblk	2 56019	7 69166
offgassing - Eli	-0 63987	7 69166
offgassing - Jim	-116 826	8 59953 *
Pixie2 - Pixie3	35 6378	9 42032 *
Pixie2 - knownblk	57 4506	8 59953 *
Pixie2 - Eli	54 2506	8 59953 *
Pixie2 - Jim	-61 9361	9 42032 *
Pixie3 - knownblk	21 8128	8 59953 *
Pixie3 - Eli	18 6127	8 59953 *
Pixie3 - Jim	-97 5739	9 42032 *
knownblk - Eli	-3 20006	7 69166
knownblk - Jim	-119 387	8 59953 *
Eli - Jim	-116 187	8 59953 *

* denotes a statistically significant difference

Tuchram 2

Level	Sample size	Average	Median	Mode	Geometric mean
unload	22	101 517	74 6380	32 4280	75 7485
transfer	23	590 614	575 798	23 8520	353 089
load	18	302 818	278 318	278 318	230 338
hang	222	20 8352	17 1520	17 1520	18 7183
other	29	83 3434	19 9660	19 9660	28 3528

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
unload	10288 9	101 434	21 6258	32 4280	473 020
transfer	163411	404 241	84 2901	23 8520	1360 37
load	27102 0	164 627	38 8029	19 9660	669 062
hang	158 154	12 5759	0 84404	5 49400	102 778
other	20153 8	141 964	26 3621	1 60800	608 226

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
unload	440 592	44 3540	112 560	68 2060	2 78302
transfer	1336 52	253 662	923 662	670 000	0 11315
load	649 096	257 280	435 098	177 818	0 18898
hang	97 2840	13 8020	22 5120	8 71000	3 55864
other	606 618	19 9660	23 8520	3 88600	2 34754

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
unload	5 32909	8 70140	8 33096	99 9181	2233 38
transfer	0 22154	-0 98710	-0 96632	68 4442	13584 1
load	0 32733	0 38325	0 33190	54 3650	5450 72
hang	21 6464	16 7305	50 8839	60 3590	4625 41
other	5 16103	5 75626	6 32752	170 336	2416 96

Level	Sample size	Average	Median	Mode	Geometric mean
unload	14	43 0087	22 1770	17 1520	23 9826
transfer	50	525 186	594 357	597 372	453 049
load	17	153 115	77 4520	77 4520	102 098
hang	153	13 8832	14 7400	14 8740	11 1885
other	31	184.167	77.4520	597 372	67 2793

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
unload	1477 06	38 4325	10 2715	0 59555	114 972
transfer	53634 0	231 590	32 7518	36 3140	1052 03
load	35297 2	187 876	45 5665	32 9640	807 082
hang	69 8796	8 35940	0 67582	0 67000	57 3520
other	49969 5	223 539	40 1487	0 59555	597 372

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
unload	114 376	12 0600	76 2460	64 1860	0 66284
transfer	1015 72	336 608	600 052	263 444	-0 15506
load	774 118	68 6080	156 244	87 6360	2 96762
hang	56 6820	9 11200	17 5540	8 44200	2 07561
other	596 776	22 6460	342 102	319 456	1 13103

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
unload	1 01250	-1 16334	-0 88851	89 3599	602 122
transfer	-0 44761	-0 27391	-0 39536	44 0968	26259 3
load	4 99525	9 84880	8 28900	122 703	2602 95
hang	10 4813	9 04484	22 8371	60 2125	2124 12
other	2 57086	-0 44557	-0 50639	121 378	5709 19

Variable	LINTCAR ppm
Sample size	282
Average	25 463041
Median	19 4166
Mode	15 879
Geometric mean	20 471356
Variance	326 75038
Standard deviation	18 076238
Standard error	1 076424
Minimum	1 9832
Maximum	135 474
Range	133 4908
Lower quartile	14 3514
Upper quartile	31 6374
Interquartile range	17 286
Skewness	2 384541
Standardized skewness	16 347589
Kurtosis	9 372211
Standardized kurtosis	32 126319
Coeff of variation	70 990099
Sum	7180 5776

FILTER CA

Level	Sample size	Average	Median	Mode	Geometric mean
remove fil	47	36 3399	14 1772	7 66480	20 4344
put in can	28	112 612	134 268	134 965	101.295
insert new	50	103 646	113 753	113 753	97 4712
other	478	49 7732	34 1030	135 581	33 0882

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
remove fil	1427 43	37 7813	5 51097	4 11380	134 523
put in can	1458 33	38 1881	7 21688	14 1638	135 608
insert new	953 798	30 8836	4 36760	38 5116	134 134
other	1769 65	42 0672	1 92411	1 31320	135 581

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
remove fil	130 409	7 66480	62 0956	54 4308	1 27456
put in can	121 444	102 222	134 965	32 7429	-1 52591
insert new	95 6224	90 1552	126 925	36 7696	-1 10142
other	134 268	15 6914	74 4638	58 7724	0 93186

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
remove fil	3 56724	0 74072	1 03657	103 966	1707 98
put in can	-3 29634	0 87271	0 94263	33 9112	3153 14
insert new	-3 17952	-0 32890	-0 47472	29 7974	5182 28
other	8 31746	-0 49178	-2 19471	84 5179	23791 6

Variable	OG1CARME ppm
Sample size	505
Average	3 889799
Median	1 1792
Mode	0 002792
Geometric mean	0 632903
Variance	50 91157
Standard deviation	7 135234
Standard error	0 317514
Minimum	0 002792
Maximum	53 4526
Range	53 449808
Lower quartile	0 201
Upper quartile	4 7168
Interquartile range	4 5158
Skewness	3 335186
Standardized skewness	30 597794
Kurtosis	12 161097
Standardized kurtosis	55 784407
Coeff of variation	183 434531
Sum	1964 348454

Variable	OG4CAR ppm
Sample size	2227
Average	4 799992
Median	4 02
Mode	4 02
Geometric mean	4 294718
Variance	8 476906
Standard deviation	2 911513
Standard error	0 061696
Minimum	2 68
Maximum	16 08
Range	13 4
Lower quartile	3 35
Upper quartile	4 69
Interquartile range	1 34
Skewness	2 56231
Standardized skewness	49 364667
Kurtosis	5 888512
Standardized kurtosis	56 723117
Coeff of variation	60 656616
Sum	10689 582

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