IN-DEPTH SURVEY REPORT

PERCHLOROETHYLENE EXPOSURES IN COMMERCIAL DRY CLEANERS

at

Brown's Cleaners
Santa Monica, California

REPORT WRITTEN BY
Gary S Earnest
Amy Beasley Spencer

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

PLANT SURVEYED	Brown's Cleaners 1223 Montana Avenue Santa Monica, California 90403
SIC CODE	7216
SURVEY DATE	August 15-18, 1994
SURVEY CONDUCTED BY	Gary S Earnest Amy Beasley Spencer Dennis O'Brien
EMPLOYER REPRESENTATIVES	Lois vonMorganroth, Owner Myriam Testa, Store Manager
EMPLOYEE REPRESENTATIVES	None
MANUSCRIPT PREPARED BY	Bernice L Clark

TABLE OF CONTENTS

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 Brown's Cleaners in Santa Monica, California, to evaluate control of worker exposure to perchloroethylene (PERC) and provide recommendations to reduce exposure Dry cleaning in this shop was done using two Boewe Passat® machines One machine was a Model P546, 46-pound dry-to-dry machine The other machine was a Model P536, 36-pound dry-to-dry machine Both machines had an integrated, refrigerated condenser in series, with a carbon absorber to recover PERC vapors during the dry cycle These machines were designed to lower the PERC concentration in the cylinder at the end of the dry cycle to below 290 ppm This was accomplished using a single beam infrared photometer to continuously monitor the PERC concentration in the machine cylinder and a carbon adsorption system using spherical beads of activated carbon to rapidly capture PERC in the airstream An interlock on the machine door prevented opening until the PERC concentration in the cylinder was below 290 ppm Solvent distillation was accomplished by a device that required still raking only once every three weeks During the busiest days, approximately eight loads of clothing were processed in each machine

There were sixteen employees at this shop Two workers were sampled the machine operator and a presser All of the personal samples were well below 25 ppm time-weighted average (TWA) The operator of the machine had the highest exposure to PERC, which ranged from 0 31 to 4 9 ppm TWA on various days The bulk of exposure to PERC resulted from loading and unloading the machine and performing machine maintenance On the final day of sampling, the operator was exposed to approximately 12 ppm during a two-hour period and 4 9 ppm full-shift TWA All presser samples were at or below the limit of detection PERC off-gassing from the clothing was negligible PERC originating from the machine was isolated from other areas of the shop using effective ventilation and barriers

Real-time monitoring showed that the most significant source of daily exposure to the operator occurred during unloading/loading the machines, where concentrations peaked near 160 ppm During most of the cycles, average PERC exposure while unloading the machine was higher than the average PERC exposure while loading Likewise, the total dose was usually higher during unloading the machines than loading, on average for both machines 466 ppm*sec versus 401 ppm*sec Relatively significant exposures occurred while loading the machine during the first cycle of the day The TWA exposure to the operator while cleaning both stills was approximately 68 2 ppm and while cleaning both lint traps was 28 8 ppm The highest daily maintenance exposure occurred while cleaning the Model 546 lint trap and peaked near 160 ppm Both machines were extremely effective at recovering solvent from the garments The total quantity of PERC off-gassed from the test swatch, cleaned in the 46-pound machine, was 161 ppm*sec or 1 34 x 10^3 μg PERC/Kg cloth The total quantity of PERC off-gassed from the test swatch, cleaned in the 36-pound machine, was 346 ppm*sec or 2 89 x 10^3 μg PERC/Kg cloth The average PERC concentration was less than 2 ppm

Controls at Brown's Cleaners were excellent and maintained exposures well below 25 ppm, which is the concentration limit that OSHA encourages dry cleaners to follow NIOSH recommends controlling PERC to the lowest feasible

limit There is nothing that Brown's Cleaners is required to do to further reduce exposures However, exposures while loading the machine could be further reduced by ensuring that the purge cycle runs immediately prior to the machine doors being opened or by making minor design changes Use of personal protective equipment during machine maintenance was very good Chemical splash goggles and proper protective gloves should be used during spotting to reduce dermal exposure to hazardous chemicals

INTRODUCTION

The Engineering Control 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 Brown's Cleaners located in Santa Monica, California The primary purpose of this survey was to evaluate control of worker exposure to PERC from two enclosed, dry-to-dry machines having a fully integrated refrigerated condenser in series with a carbon absorber Recommendations and conclusions are provided

PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

Brown's Cleaners, a large commercial dry cleaner located in Santa Monica, California, has been in business since the 1940s There are no "dry stores" associated with Brown's Cleaners, and all of the dry cleaning occurs on the premises The shop was located in a stand-alone building, between a daycare center and an alley The shop layout is shown in Figure 1 The front of the store faced the street and had one door for customers The customer counter was in the front of the shop There were several doors near the rear of the shop for workers, maintenance, and deliveries There was also one door near the rear of the shop for customers using the parking lot There were two dry cleaning machines in this shop, located near the front of the store, a Boewe® Model 536, 36-pound machine and a Model 546, 46-pound machine

When one stood facing the front of the machines, the 36-pound machine was located near the front wall of the building The 46-pound machine was located next to the 36-pound machine and a spotting station was located next to the 46-pound machine Both machines were situated on top of a safety trough to provide protection against a solvent leak reaching the ground or ground water A vacuum extraction system, consisting of a vacuum and probes which reach deep into the ground, was located near the dry cleaning machines This system was

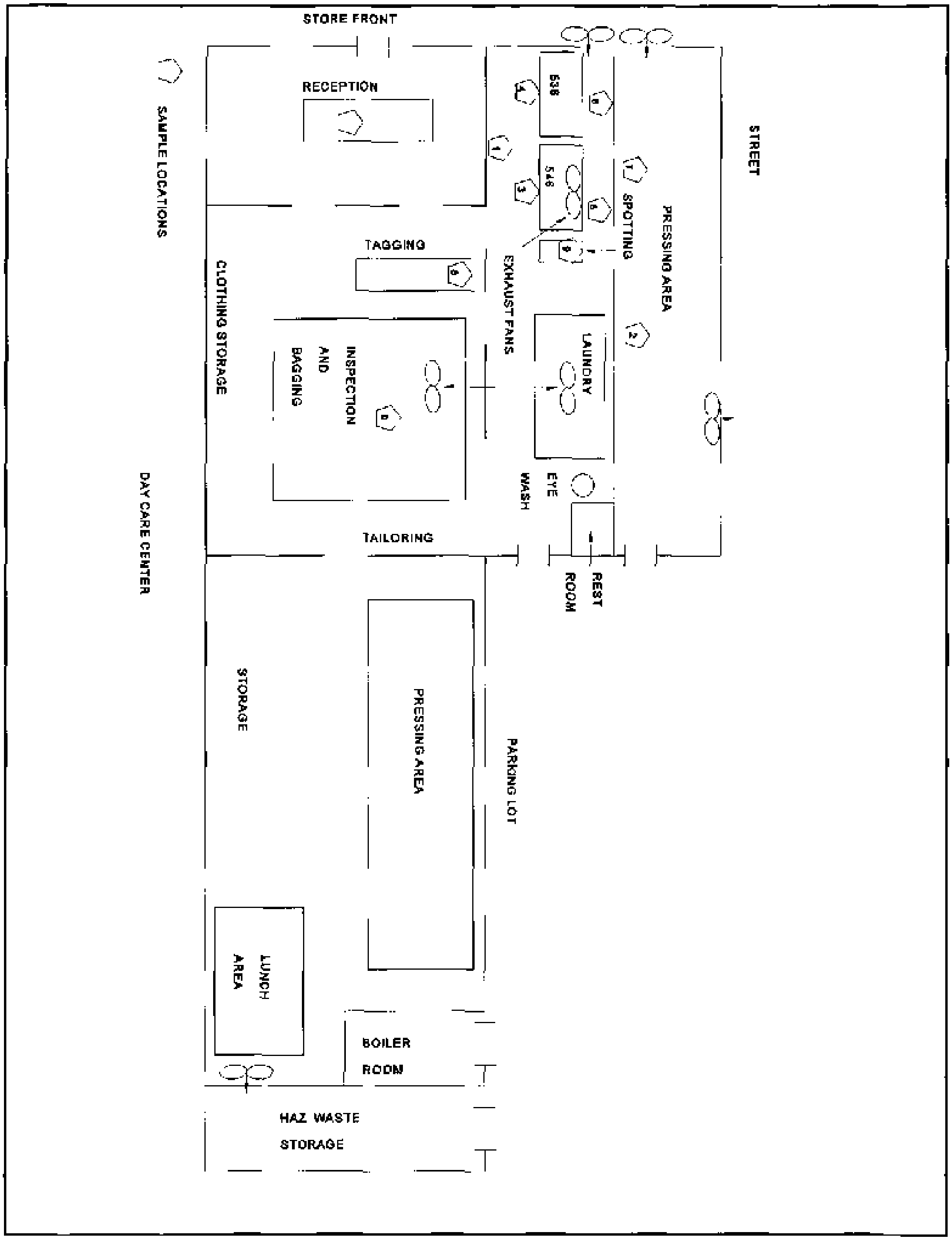

Figure 1 Shop Layout of Brown's Cleaners

used to monitor, detect, and recycle any PERC that could potentially reach and contaminate the soil under the shop

Dry cleaned clothing was pressed in an area adjacent to the dry cleaning machines, and laundered items were pressed near the rear of the building Two gas-fired boilers were located near the rear of the building and provided steam to the presses and dry cleaning machines Several fans provided general ventilation for dilution and cooling

Pressed clothing was hung on a long, motorized clothing rack, which transported clothing to a storage area on the second floor Laundry and wet cleaning were done between the dry cleaning area and the restroom An eyewash was located near the restroom, and hazardous waste storage barrels were located outside the rear of the building A waste water disposal system was also located in this area This waste water disposal system used a phase separator to remove PERC from the machines' separator water and to recycle the PERC to the dry cleaning machines The remaining water was passed through treated carbon to capture any remaining PERC The water was then distilled Filters were disposed of monthly as hazardous waste

The shop cleaned between 2,400 and 3,000 pounds of clothing per week On Monday or Tuesday, the busiest days, eight 40-pound loads of clothing and eight 30-pound loads of clothing were cleaned Later in the week, there was generally less clothing to be cleaned Hourly workers at this shop were not unionized but participated in a profit-sharing program There were sixteen hourly and two salaried employees Most employees worked 40 hours or more a week The shop was open for business from 7 00 a m to 7 00 p m , Monday through Friday and 8 00 a m to 6 00 p m on Saturday

PROCESS DESCRIPTION

Garments were brought to 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 Generally, one person operated the dry cleaning machines and performed any spotting that was necessary Various chemicals were used depending on the type of stain

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 Brown's Cleaners, the spotting agents were products from a variety of companies, such as R R Streets, Caled, Wilson, and Van Waters & Rogers Corporations The products used most frequently at this shop were POG®, Scramblood®, and a mixture of Picrin® and Streetex® called "Two-in-one " POG® is a mixture of diacetone alcohol, perchloroethylene, aromatic 100, orthodichlorobenzene, and pale oil Scramblood® contains isopropyl alcohol and triethanol amine Picrin® is primarily 1,1,1-trichloroethane Streetex® 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, which were then held in a storage reservoir until being discarded as hazardous waste

Dry cleaning in this shop was done using two modern, closed-loop, dry-to-dry, perchloroethylene dry cleaning machines One was a 46-pound machine, and the other was a 36-pound machine Both machines were about two years old Each machine had an integrated, in-line refrigerated condenser and carbon absorber to recover PERC vapors during the dry cycle This system was called the "Consorba® " The refrigerated condenser used R-22 refrigerant to condense PERC vapors during the dry cycle Chilled water was used to condense PERC vapors in the still, cool solvent in the base tank, and to remove heat during cool-down

These machines were designed to recover residual PERC vapors in the cylinder during loading and unloading and to lower the PERC concentration in the cylinder, at the end of the dry cycle, to below 290 ppm as reported by the manufacturer This was accomplished by using several technologies A single beam infrared photometer, called the PMS 2000®, was used to continuously monitor the PERC concentration in the machine cylinder and in the work environment An interlock on the machine door did not allow the door to open unless the PERC concentration in the cylinder was below 290 ppm As long as the concentration in the cylinder was above this limit, the drying/vapor recovery process continued to operate

The carbon adsorption system used spherical beads of activated carbon, with a significantly larger external surface area than normal, to capture PERC in the airstream These spherical carbon beads were automatically desorbed, using hot air, during the next dry cycle Since steam was not used, this process eliminated water vapor from being retained in the carbon, adding to the hazardous waste that is produced Figure 2 depicts how the PERC concentration in the cylinder was reduced during the vapor recovery process

The drying process occurred in the same machine During the main drying cycle, the solvent laden air recirculated through the refrigerated condenser, which vaporized and recovered most of the residual solvent While passing through the cooling coil, PERC vapors condensed and were directed to the separator where the water was removed Liquid PERC flowed back into the machine tank while the water was piped to an external container A drying sensor between the refrigerated condenser and water separator automatically

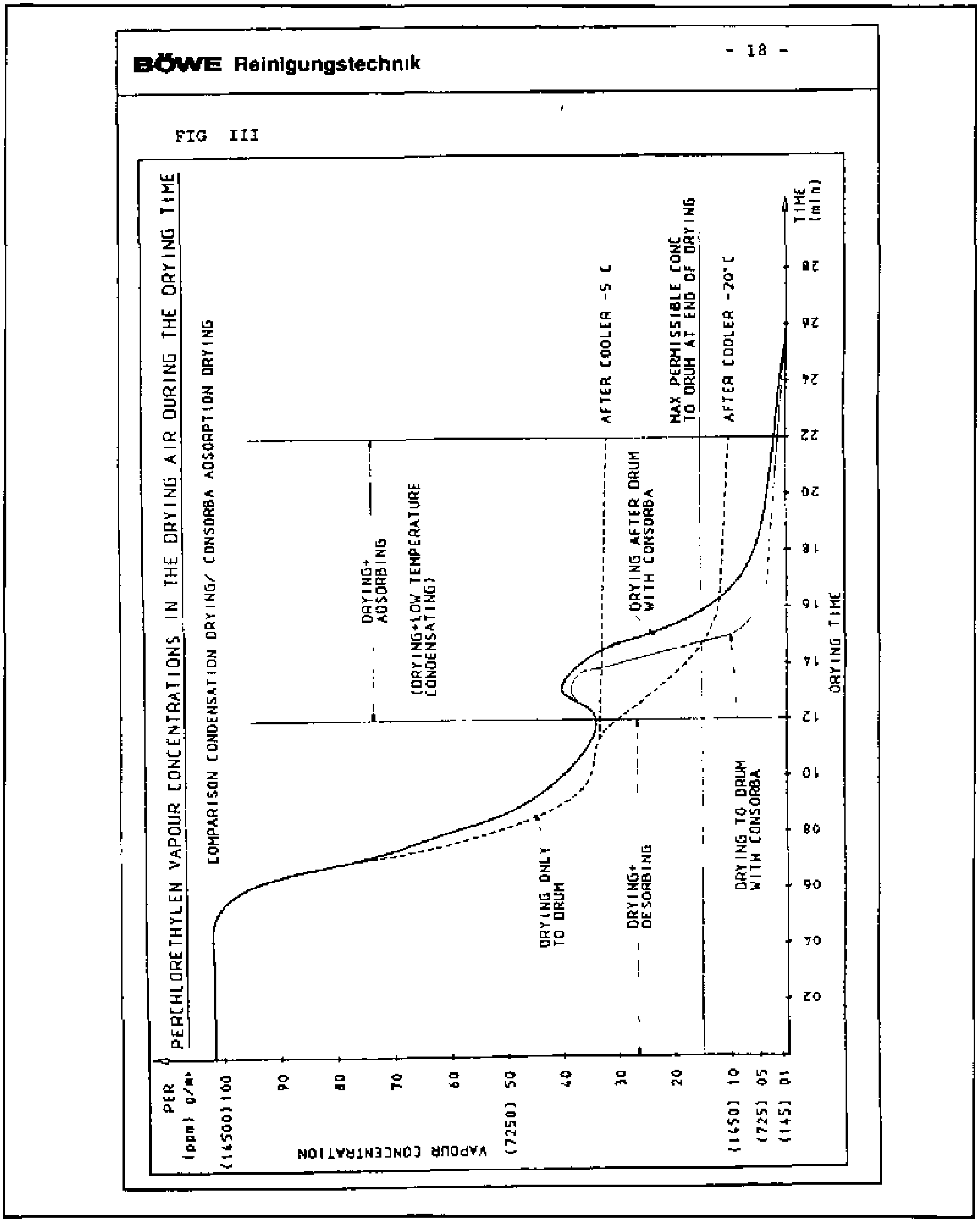

Figure 2 PERC cylinder concentration during vapor recovery (Used with permission of Boewe Passat, Wichita Falls, Texas)

switched the system to the cool down/deodorize step During this part of the cycle, the air was cooled to approximately 25 °F in the refrigerated condenser and then passed through the carbon absorber before returning to the drying drum The PERC concentration in the drum was below 290 ppm, and the residual solvent in the clothing was minimized This step relaxed the fabric fibers, helped to reduce wrinkles, and removed additional PERC

These machines each had an enclosed still cleaning device that eliminated the need to rake out the still on a daily basis Instead, still maintenance was performed every day, and the still was raked out approximately every three weeks Additionally, a dosing unit enabled the operator to perform waterproofing operations within the machine During a busy day, approximately eight loads of clothing were processed by each machine The machines had a cleaning cycle of 35 to 40 minutes, however, the drying cycle was often extended to ensure that the PERC concentration in the cylinder was sufficiently low The operator could determine the PERC concentration in the cylinder by reading a printout from the infrared photometer

Technical specifications for these machines can be seen in Table 1 In 1992, 46-pound machine base price was approximately $56,000, and the 36-pound machine base price was approximately $47,000 The Consorba® option was $16,000 The infrared photometer was $13,000 The enclosed still cleaning device was $4,500 The dosing unit was $1,400, and the drying monitor was $500

Table 1
Machine Technical Specifications

	Boewe® Model P546	Boewe® Model P536
Load Capacity	46 lbs	36 lbs
Cage Volume	400 liters (14 cubic feet)	323 liters (11 3 cubic feet)
Cleaning Speed	36 rpm	36 rpm
Extraction Speed	360 rpm	360 rpm
Tank Capacities	Tank 1 175 liters (46 24 gallons) Tank 2 240 liters (63 4 gallons)	Tank 1 193 liters (51 gallons) Tank 2 125 liters (33 gallons)

The clothing was weighed in a basket prior to loading into the machines The maximum capacities for the machines were 46 and 36 pounds of clothing, however, according to log sheets, the majority of loads placed into the machine were less than the machine capacity, (40 pounds in the larger machine and 30 pounds in the smaller machine) The weight of every load was logged onto a sheet of paper

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) At the start of the washing process, clothes at Brown's Cleaners were manually loaded through the front door into the cylinder of the machine After the door was closed, PERC was automatically pumped into the cylinder Water-based detergent was automatically injected into each 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 After the solvent was removed, the fabric was tumbled dry

Garments removed from the machine 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 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

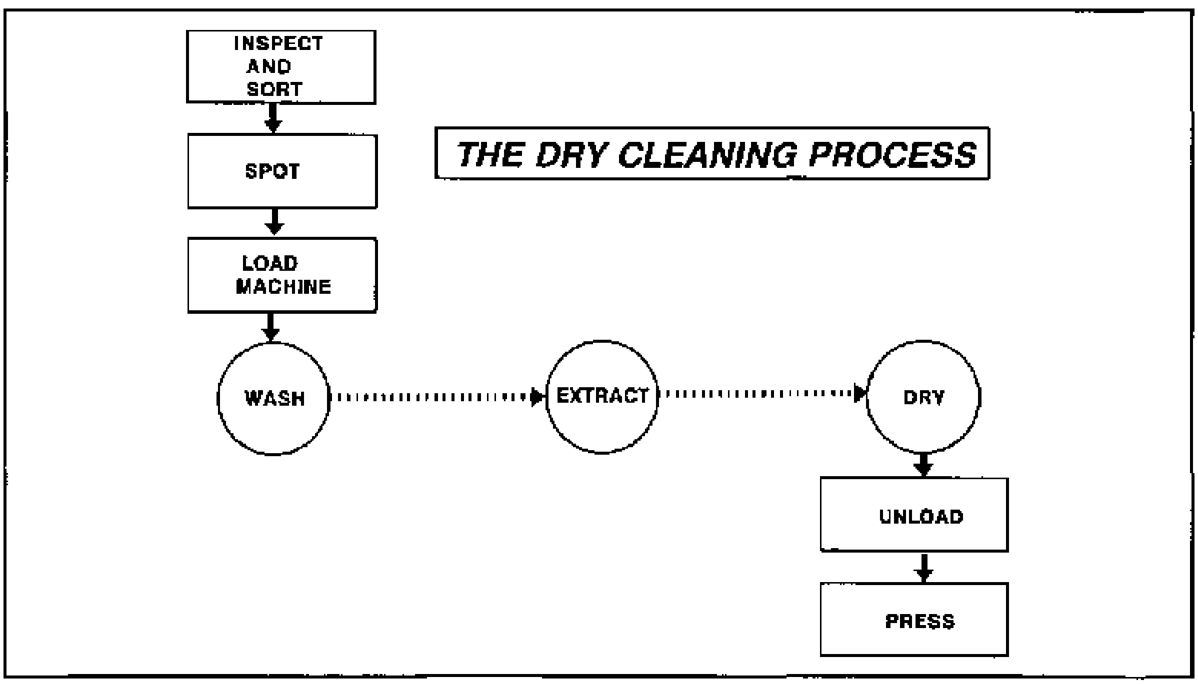

Figure 3 Process flow diagram

PERC, used in the wash cycle, was cleaned and recycled continuously by passing through a spin-disc filter filled with diatomaceous earth Filtration was used to remove the insoluble soils, and distillation was used to remove the soluble soils A filter maintenance program was run every Friday A local contractor supplied and delivered PERC as necessary The solvent was delivered by a truck through the rear door of the building and pumped directly into the machine's holding tank, which eliminated employee handling Approximately 55 gallons of PERC were purchased every nine months for both machines General dilution ventilation consisted of several fans located in the wall and ceiling near the dry cleaning and pressing areas

HAZARDS AND EVALUATION CRITERIA

POTENTIAL HAZARDS

Exposure to PERC is the primary health hazard for workers in dry cleaning facilities today Spotting involves the selective application of a wide variety of chemicals and steam to remove specific stains Individuals who perform the spotting process could be exposed to hazardous chemicals through skin or eye contact or inhalation of vapors 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 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

The objective of this site visit was to evaluate the effectiveness of the dry cleaning machines 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 period at 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]

Area samples were taken at various locations throughout the shop Air samples were collected in front of and behind both dry cleaning machines, at the spotting station, in the pressing area, tagging area, and inspection and bagging area (Figure 1) Full-shift TWA personal sampling was gathered for the machine operator and a presser TWA personal sampling results were compared to 25 ppm Area air sampling was also done at the spotting station for perchloroethylene, trichloroethylene, and petroleum naphtha Analysis was performed using NIOSH methods 1003, 1022, and 1550

VIDEO EXPOSURE MONITORING

Real-time monitoring was used to study 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 the machine, while others, such as cleaning the lint trap and still, were less often 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 vapor 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 videocamera 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 to compare vapor recovery efficiency of the machines This was accomplished by 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 emitted concentrations of PERC were monitored and recorded by using the MicroTIP® and Rustrak® datalogger The apparatus for measuring off-gassing can be seen in Figure 4

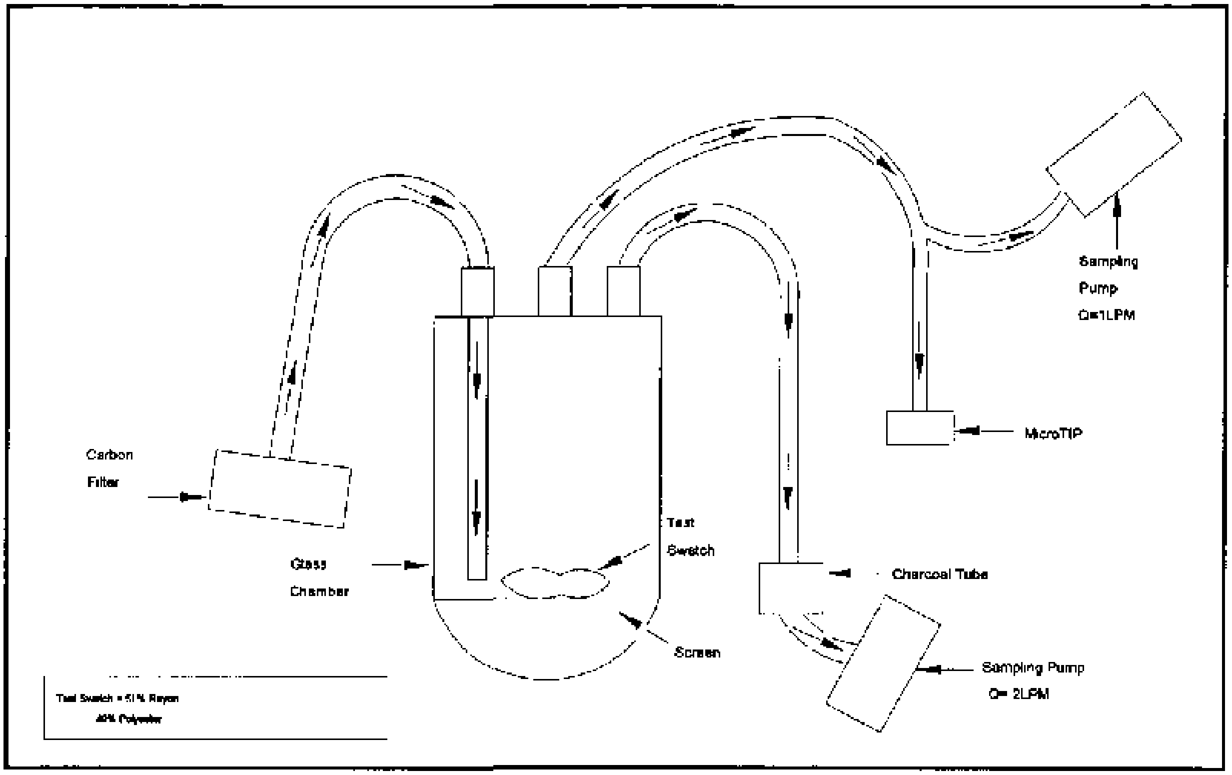

Figure 4 Apparatus for measuring off-gassing of garments and machine recovery

VENTILATION

General ventilation measurements were made with a Kurz® model 1440 velometer, with a measuring range from 0 to 6,000 feet per minute Turbulent airflow near the dry cleaning machine was qualitatively evaluated by using smoke tubes A mass airflow balance was performed for air entering and leaving the dry cleaning area The capacity and dimensions of general dilution ventilation systems were also recorded

RESULTS AND DISCUSSION

INDUSTRIAL HYGIENE SAMPLING

Results of the individual air samples can be seen in Appendix D Table 2 is a summary of personal air samples for each day All of the personal samples were well below 25 ppm The time-weighted average exposures would have been slightly lower if sampling had occurred for a full 8-hour shift, however, the dry cleaning machines typically operated between 5 and 7 5 hours during this survey The length of time the machine operated during the day decreased as the week progressed from Monday to Thursday

Table 2 Time-Weighted Average (TWA) PERC Exposures Over the Sampling Period					
Worker	Location (Fig 1)	Date	Number of Samples	Sampling Period (min)	TWA Concentration (ppm)
Operator	(1)	8/15/94	4	451	31
Presser	(2)	8/15/94	4	452	0
Operator	(1)	8/16/94	4	384	73
Presser	(2)	8/16/94	4	376	04
Operator	(1)	8/17/94	4	396	1 09
Presser	(2)	8/17/94	4	374	0
Operator	(1)	8/18/94	3	350	4 9
Presser	(2)	8/18/94	3	316	0

As expected, the operator of the machine had the highest exposure to PERC, which ranged from 0 31 to 4 9 ppm TWA on various days The bulk of exposure to PERC resulted from loading and unloading the machine and performing machine maintenance Almost all of the 2-hour samples of the operator were below 2 ppm, and most of them were below 1 ppm The only exception to these low exposures occurred during the last morning of sampling, when the operator cleaned the stills on both machines

Still cleaning occurred approximately once every three weeks and took 30 minutes or less During the last morning of sampling, the operator was exposed to approximately 12 ppm during a 2-hour period and 4 9 ppm full-shift TWA This TWA exposure was primarily due to cleaning the still that morning If cleaning the stills had not occurred, the TWA exposure probably would have been less than 2 ppm Exposures were higher when cleaning the still on the 46-pound machine This was probably due to a variety of factors, such as ventilation and still efficiency Operator exposures increased slightly as the week progressed

The presser did not work in as close proximity to the machines as the operator, (see Figure 1), however, the presser did work closely with dry cleaned clothing As a result, the presser was exposed to between 0 0 and 0 04 ppm TWA on various days Only one sample showed any PERC at all Concentrations this low indicate that there was very little, if any, PERC off-gassing from the clothing that was being pressed Additionally, PERC, originating from the machine, was isolated from other areas of the shop by the use of ventilation and barriers This was evidenced by the fact that the presser was exposed to 0 ppm during the day, while the operator was exposed to the maximum concentration of PERC All of the PERC concentrations measured near the presser's breathing zone, on each day, were at or below the limit of detection, which was 01 mg/sample

Results of area air sampling can be seen in Table 3 Area samples can be divided into two categories samples near the machine and samples away from the machine The samples near the machine include samples taken in front of the machines, behind the machines, and near the spotting board Samples away from the machine included those taken in the reception, pressing, hanging, and tagging areas There was almost no PERC detected away from the machines, except for a very small quantity detected in the reception area on the final day of sampling This nondetection of PERC can be attributed to the excellent ventilation in and around the machines Among the area samples taken in proximity to the machines, the highest concentrations were detected on samples located near the Model 546 machine These higher concentrations were true for samples taken in front of the machines as well as behind the machines where concentrations were generally higher No vapor leaks were detected The concentrations in front of the machines probably originated from the residual gases in the cylinder when the machine door was opened and closed

In general, exposures appeared to be higher near the end of the week rather than the beginning There was no clear trend between exposures in the morning and in the afternoon, with the exception of the final morning of sampling when still cleaning occurred The area air samples taken near the spotting station were also analyzed for trichloroethylene and petroleum naphtha in addition to PERC All of the two-hour trichloroethylene samples were at or below 8 ppm and all of the two-hour petroleum naphtha samples were at or below 4 ppm The majority of trichloroethylene samples were below 1 ppm Bulk samples were taken of the water separator run-off, no PERC was detected

REAL-TIME MONITORING

Video recording and real-time monitoring were performed during unloading and loading the machine and during maintenance on the machines, such as cleaning the button traps and lint filter Real-time monitoring was also used to evaluate the effectiveness of the vapor recovery system by examining garment residual off-gassing The MicroTIP® was set for a measuring range between 0 to 200 ppm for most of the operations and 0 to 2,000 ppm during one unloading/loading operation

On a daily basis, the most significant source of exposure to the operator occurred during loading and unloading the machines Exposures during this procedure peaked at approximately 160 ppm Loading and unloading occurred approximately six to eight times per machine each day, depending on the amount of business Machine maintenance, such as cleaning the lint traps, normally occurred once a day and some tasks, such as cleaning the still, only occurred every three weeks

Figures 5, 6, and 7 show real-time data during loading and/or unloading the machine Figure 5 shows operator exposure during the first loading cycle of the day Figures 6 and 7 show operator exposure during unloading/loading the machines The process of unloading and loading both machines took between 36 and 52 seconds On average, unloading took 10 5 seconds and loading took 12 seconds

Table 3
Area Sample Concentrations of Perchloroethylene

Area	Location (Fig 1)	Day	Avg Sample Time (min)	Arithmetic Mean (ppm)	Std Dev (ppm)	Range (ppm)
Reception		8/15/94	113	0	0	0
Mach #1 (536)	(4)	8/15/94	110	12	12	0- 26
Bhd (536) Mach	(6)	8/15/94	110	16	11	0- 26
Mach #2 (546)	(3)	8/15/94	111	21	09	12- 35
Press Area	(7)	8/15/94	110	0	0	0
Waste Barrel	(5)	8/15/94	107	25	15	0- 37
Spotting	(9)	8/15/94	107	07	11	0- 26
Hanging	(0)	8/15/94	107	0	0	0
Tagging	(8)	8/15/94	107	0	0	0
Reception		8/16/94	96	0	0	0
Mach #1 (536)	(4)	8/16/94	98	15	10	0- 25
Bhd (536) Mach	(6)	8/16/94	96	21	22	0- 58
Mach #2 (546)	(3)	8/16/94	98	22	13	0- 37
Press Area	(7)	8/16/94	96	0	0	0
Waste barrel	(5)	8/16/94	97	49	48	0-1 3
Spotting	(9)	8/16/94	96	14	08	0- 20
Hanging	(0)	8/16/94	95	0	0	0
Tagging	(8)	8/16/94	96	0	0	0
Reception		8/17/94	99	0	0	0
Mach #1 (536)	(4)	8/17/94	99	25	19	0- 48
Bhd (536) Mach	(6)	8/17/94	99	15	13	0- 37
Mach #2 (546)	(3)	8/17/94	99	50	34	0- 81
Press Area	(7)	8/17/94	100	0	0	0
Waste barrel	(5)	8/17/94	99	36	22	0- 57
Spotting	(9)	8/17/94	119	15	05	12- 22
Hanging	(0)	8/17/94	98	0	0	0
Tagging	(8)	8/17/94	98	0	0	0
Reception		8/18/94	107	09	12	0- 26
Mach #1 (536)	(4)	8/18/94	115	81	78	12-1 9
Bhd (536) Mach	(6)	8/18/94	107	13	10	0- 24
Mach #2 (546)	(3)	8/18/94	116	17	12	0- 27
Press Area	(7)	8/18/94	92	0	0	0
Waste barrel	(5)	8/18/94	115	1 8	1 8	42-4 4
Spotting	(9)	8/18/94	104	1 3	0	0
Hanging	(0)	8/18/94	115	0	0	0
Tagging	(8)	8/18/94	108	0	0	0

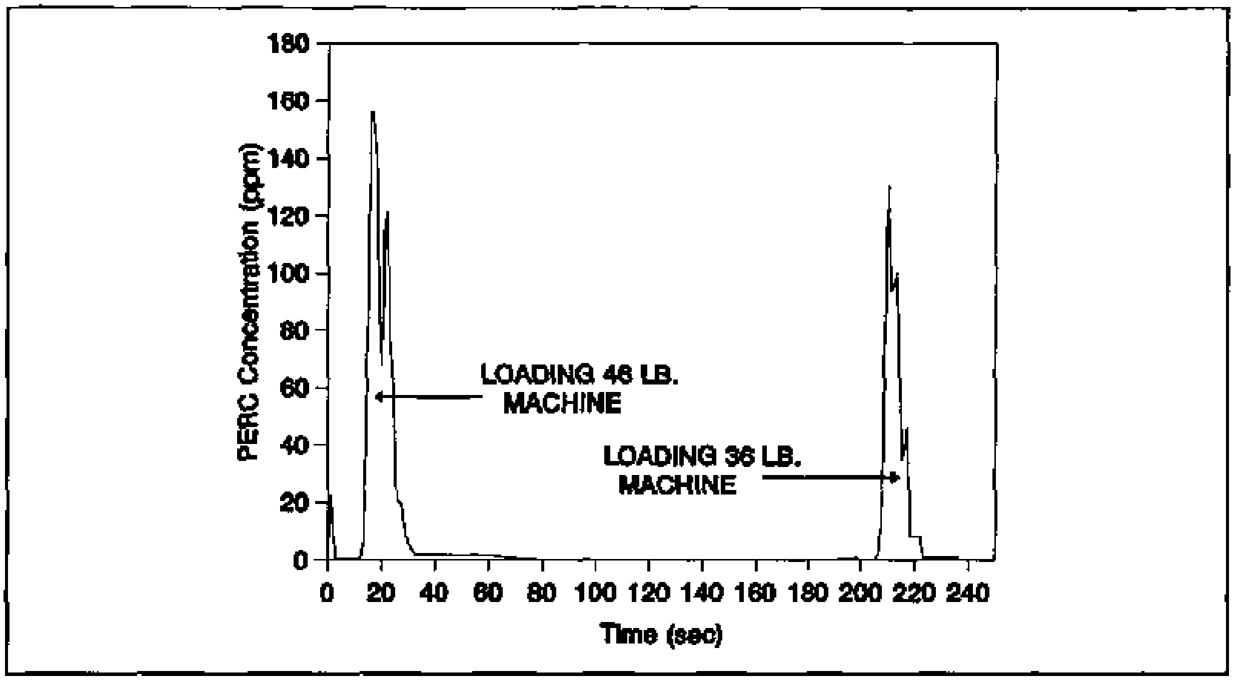

Figure 5 Operator exposure during first cycle of day

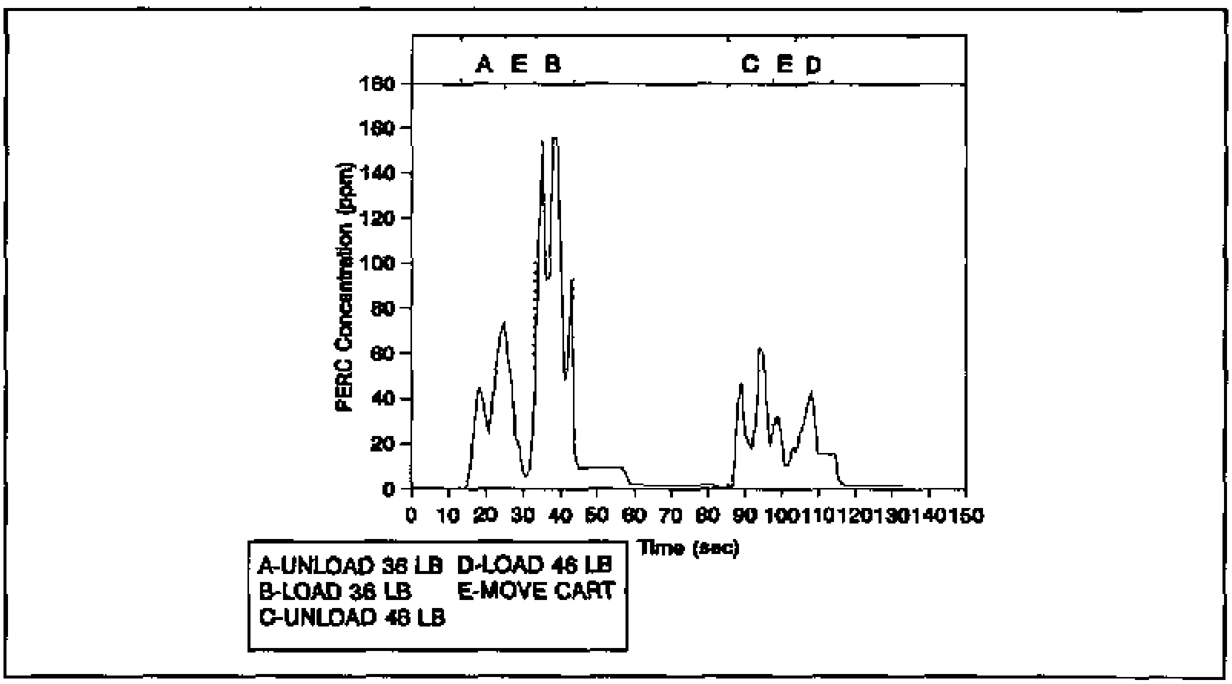

Figure 6 Operator exposure during unloading/loading

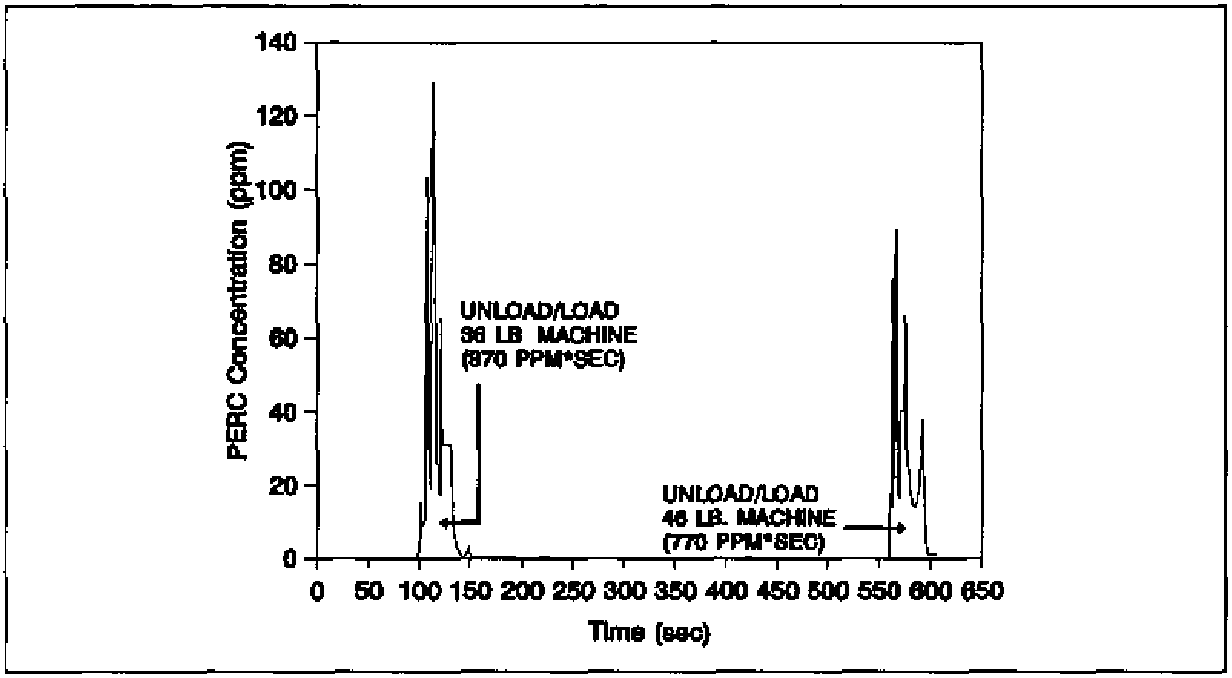

Figure 7 Operator exposure during unloading/loading

During 3 of 4 cycles, the average PERC exposure while the operator loaded the machine with dirty clothing was less than the average PERC exposure while the garments that had been cleaned in PERC were unloaded For the Model 536, the average exposure during loading was 58 7 ppm, the average exposure during unloading was 45 9 ppm For the Model 546, the average exposure during loading was 20 2 ppm, the average exposure during unloading was 35 4 ppm The total dose was usually higher during unloading than loading both machines, on average 466 ppm*sec versus 401 ppm*sec

During the cycles evaluated, there were inconsistencies in the results Variations between the time the dry cycle ended and the machine door was opened may have caused this problem Generally speaking, if the machine sat idle for a period of time before the door was opened, higher exposures occurred while the operator loaded the machine PERC vapors from the vapor loop were able to migrate down into the machine cylinder, and when the door was opened for clothes loading, air displacement forced residual vapors from the cylinder into the worker's breathing zone

Figure 5 shows real-time measurements taken at the operator's breathing zone during the first cycle of the day During this cycle, there was no unloading performed The empty machines had been turned on for a while and dirty clothing was added to the cylinder As can be seen in the figure, contaminated air was forced from the cylinder into the worker's breathing zone This is characterized by a rapid increase and almost instantaneous peak which approaches 160 ppm The concentration in the worker's breathing zone dissipates over the next ten to twenty seconds and then returns to zero This peak occurs because the machine cylinder, which is not fully isolated from the other sources of PERC within the machine, is not purged immediately prior to the door being opened PERC vapors move from the vapor loop, into the machine cylinder, and eventually out into the work environment due to air displacement during loading Operator exposure for loading the 46-pound machine was higher than for loading the 36-pound machine This may be due to differences in general ventilation near the machine doors, greater air displacement, and/or differences in the PERC concentrations within the machine cylinder

Figures 6 and 7 show exposure to the operator while performing unloading and loading on both machines During most of these activities, average operator exposure and total dose were higher during unloading than loading The exception to this general finding occurred during unloading and loading the Model 536 in Figure 5 During this activity, operator exposure for loading the machine was significantly higher than for unloading (avg exposure=101 ppm versus avg exposure= 34 6 ppm) Again in this instance, the machine sat idle for several minutes prior to the opening of the machine door Because of this inactive period, PERC was able to migrate down into the cylinder from the sources within the vapor loop Another reason for PERC leakage from the cylinder was that the centrifugal fan was unable to provide sufficient airflow at the machine door to prevent the escape of vapors

Figure 8 shows operator exposure during cleaning the stills on each machine Exposures during this procedure were higher for cleaning the still on the Model 546 than on the Model 536 Operator exposure while raking the Model 546 still averaged 156 ppm, and exposure while raking the Model 536 still averaged 35 ppm The exposure for cleaning the Model 546 still was actually greater, however, the instrument reached its upper measuring limit The shop owner noted that the still residue did not appear to be normal, and a machine malfunction may have allowed this abnormality to occur Another factor which could have affected the concentrations measured was the proximity of the Model 536 still to the fan in the wall This fan was moving 2,100 cfm of air No 5-minute peak or 15-minute short-term exposure levels were measured using sampling pumps, however, based on real-time data, it was unlikely that either the peak or short-term limits of 300 ppm and 200 ppm, respectively, were exceeded during this operation

Figure 9 shows exposures for cleaning the lint traps This task was done everyday or every other day and involved cleaning the lint/button traps and disposing of the hazardous waste Normally, lint traps were cleaned in the morning The highest exposure occurred for this task on the Model 546 The average exposure during maintenance on the Model 546 was approximately 44 ppm, and the average exposure during maintenance on the Model 536 was approximately 16 ppm

Finally, the garment off-gassing experiments are shown in Figures 10 and 11 During an average cycle, both machines were extremely effective at recovering solvent from the garments The total PERC, off-gassing from the test swatches, was 161 ppm*sec or 1 34 x 10^3 μg PERC/Kg cloth in the 46-pound machine and 346 ppm*sec or 2 89 x 10^3 μg PERC/Kg cloth in the 36-pound machine The average PERC concentrations were between 1 and 0 5 ppm for both machines

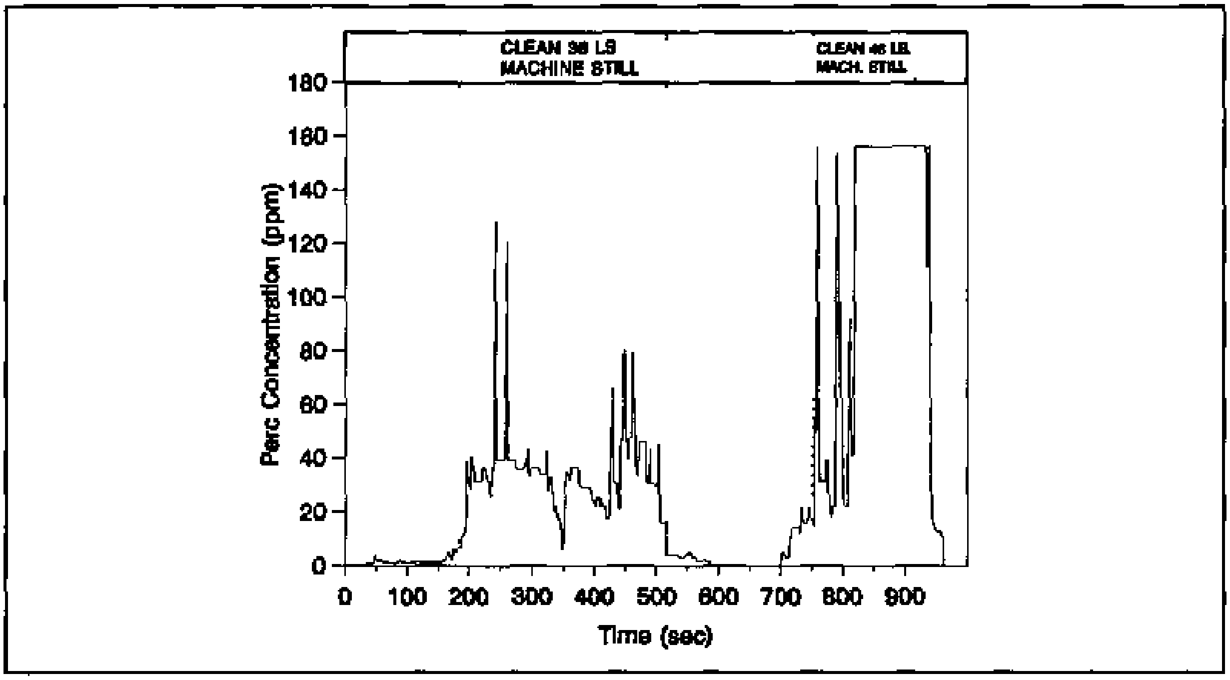

Figure 8 Operator exposure while cleaning the stills

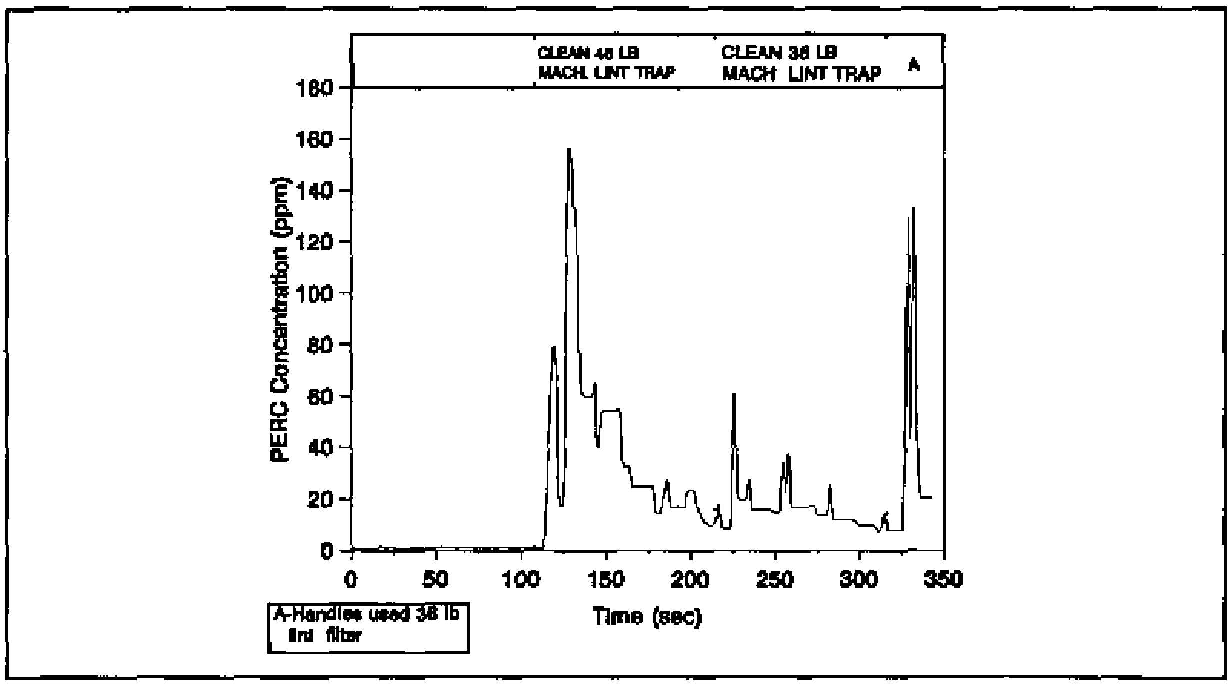

Figure 9 Operator exposure while cleaning lint traps

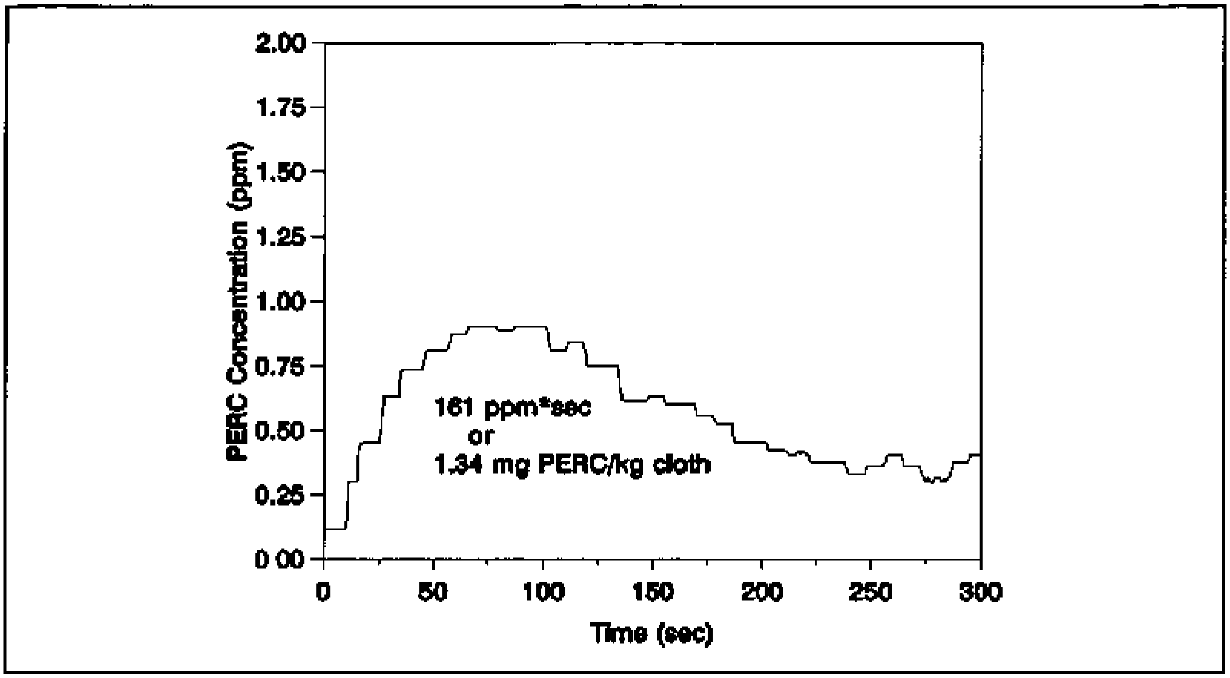

Figure 10 Typical off-gassing of swatch from 46 lb machine

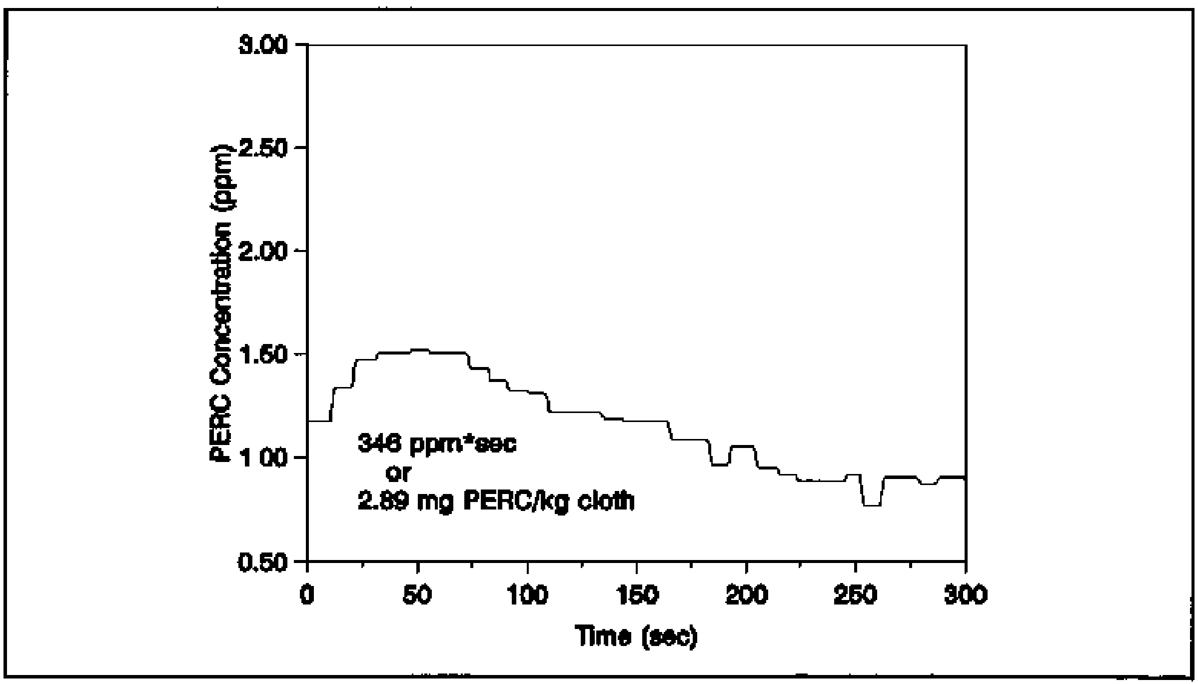

Figure 11 Typical off-gassing of swatch from 36 lb machine

VENTILATION MEASUREMENTS

Ventilation on the dry cleaning machine door at this shop was minimal Measurements taken with a Kurz® hot-wire velometer did not show an appreciable inward air velocity at the face of the machine door Smoke tubes indicated that there was only a very minor flow of air which was ineffective at preventing residuals in the cylinder from leaving through the door opening The airflow at the door was not exhausted from the machine, but it passed through the carbon absorber and into the button trap -The fan was activated by a microswitch on the door

Several propeller fans were located in the dry cleaning area to provide dilution ventilation Multiple air velocity measurements were taken approximately 6 inches in front of the supply fan in the wall and the exhaust fans in the ceiling The supply fan provided approximately 2,150 cfm of air The exhaust fan located in the ceiling above the dry cleaning machines exhausted 5,300 cfm of air, and the other exhaust fan located in the ceiling of the dry cleaning area exhausted 4,200 cfm of air Figure 12 and Table 4 show airflow measurements moving in and out of the dry cleaning area

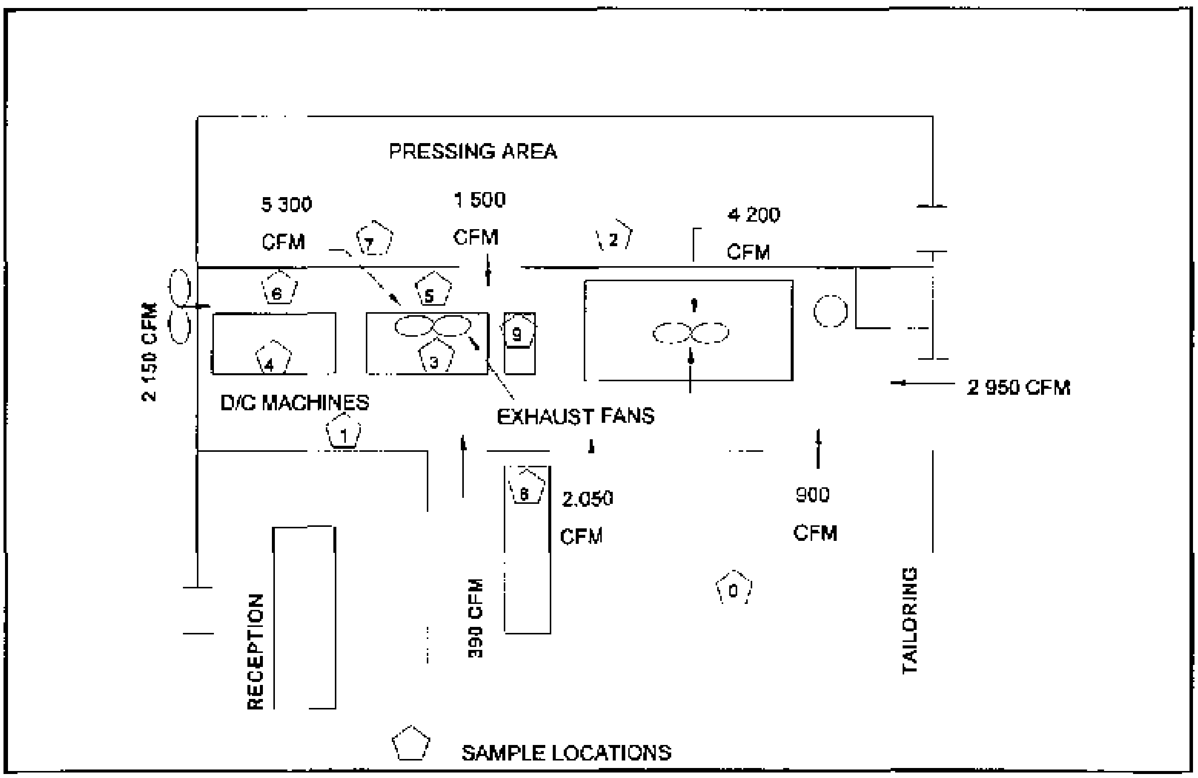

Figure 12 Airflow Balance In/Out of Dry-cleaning Room

Table 4			
Mass Balance of Airflow In/Out of Dry-cleaning Room (cfm)			
LOCATIONS	IN	LOCATIONS	OUT
Wall fan	2,150	Ceiling fan	4,200
From outside	2,950	Ceiling fan	5,300
From inspection area	2,050		
From pressing area	1,500		
From tagging	390		
From tailoring	900		
TOTALS	9,940		9,500

Smoke tubes used in and around the dry cleaning machines indicated that the general ventilation was effective at removing contaminated air originating from the machines Most of the contaminated air originating from the machines was isolated from other areas of the shop because the exhaust fans caused an inward flow of air through the door openings leading to and from the area This negative pressure prevented PERC vapors from diffusing throughout the building General ventilation principles require that fans should be arranged to move contaminated vapors away from the employees

OBSERVATIONS

The owners of this shop are members of the International Fabricare Institute and the California Fabricare Institute The shop has been visited by various federal, state, and city regulators to examine their state-of-the-art dry cleaning equipment

In addition to the clothing cleaned in the dry cleaning machines, 25 to 30 percent of the clothing brought into this shop was cleaned in water Water-based cleaning was either done in a machine or by hand Most of the clothing that was cleaned in water was not labeled "dry clean only "

Approximately 10 to 15 percent of clothing labeled "dry clean only" was cleaned in water Much of the clothing labelled "dry clean only" that was cleaned in water was very stained or soiled Some garments like these can be better cleaned in water than in solvent It is important to be very careful when doing this type of work to avoid color loss or shrinkage

Cleaning the machines' lint traps and stills was performed by the operator, but other more involved machine maintenance was performed by the manufacturer during annual services No solvent leaks were detected by NIOSH researchers This can probably be attributed to the fact that the equipment was relatively new A leak detector was not present at this shop, however, visual checks for leaks were performed and logged every week Additionally, when annual services are performed by the manufacturer, leaks will be identified

General maintenance and housekeeping appeared to be excellent Hazardous waste barrels were located outside of the shop Storage of hazardous waste outside of the building reduced the likelihood of employee exposure if a leak occurred Passive monitoring for PERC was not conducted at this shop because the Boewe® PMS 2000 infrared photometer provided instantaneous monitoring

Based upon a formula provided by the International Fabricare Institute (IFI), the capacity ratings for both machines were higher than recommended [7] IFI determines load capacity by multiplying cage volume in cubic feet by a load factor in pounds per cubic feet The load factor is 3 5 to 4 pounds per cubic feet for transfer equipment and 2 5 to 3 pounds per cubic feet for dry-to-dry equipment Based on this formula, the 46-pound machine should have a load capacity between 35 and 42 pounds, and the 36-pound machine should have a load capacity between 28 and 34 pounds This overrating might create a problem if the machines were consistently loaded to the full-rated capacity However, the machine operator weighed and logged each of the loads of clothing Most of the loads in the 46-pound machine weighed 40 pounds or less, and most of the loads in the 36-pound machine weighed 30 pounds or less

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment at this shop consisted of a respirator and gloves Personal protective equipment was stored on a shelf near the dry cleaning machines The respirator was an AO Safety® half-face respirator with organic vapor cartridges The cartridges were changed every two weeks Personal protective equipment training, qualitative respirator fit-testing, and a doctor's exam were performed The respirator and gloves were used by the operator when performing machine maintenance, such as cleaning the still and lint traps and during some spotting operations Latex surgical gloves were used at the spotting station if a garment was contaminated with body fluids When new employees were hired, management required them to sign a standard HAZCOM form, which explains the hazards present

CONCLUSIONS AND RECOMMENDATIONS

Brown's Cleaners had excellent controls that were able to maintain exposures well below 25 ppm, which is the level that OSHA encourages dry cleaners to follow NIOSH recommends controlling PERC to the lowest feasible concentration The highest TWA personal exposures were for the dry cleaning machine operator/spotter who was exposed to approximately 5 ppm TWA on the day he conducted still maintenance On other days, operator exposure was near or below 1 ppm TWA The presser was exposed to PERC concentrations at or below the limit of detection, 01 mg/sample

The primary source of exposure to the operator in this shop came from the dry cleaning machine Real-time evaluation showed that loading and unloading of the machines had the greatest impact upon daily exposures Therefore, if exposures are to be reduced further, loading and unloading operations demand the attention of management or machine manufacturers As is shown in Figures 4 and 5, there were several instances when the operator was exposed to significant PERC concentrations while loading the machines This could be better controlled by ensuring that contaminated air in the cylinder is purged by the carbon absorber immediately prior to opening the machine door

Another consideration for the manufacturer is modification of the machine design The machine cylinder could be isolated from vapor sources within the machine (i e the vapor loop and solvent loop), and sufficient ventilation, using a larger fan, could be provided to evacuate the cylinder and prevent displacement of contaminated air into the worker's breathing zone when the machine door is opened The contaminated air should be exhausted outside of the work environment The centrifugal fans, which activated when the machine doors were opened, provided insufficient air flow and were ineffective at controlling escape of residual PERC at the end of the dry cycle

Because these machines are already extremely effective at reducing operator exposure, the total reduction in ppm exposure would not be as great as other machines, however, the percentage reduction would still be substantial Theoretically, operator exposure could be reduced nearly 50 percent by eliminating exposure during loading Isolation of the dry cleaning area within this shop was excellent Process isolation practically eliminated exposure of other employees to PERC Ventilation and barriers effectively separated the dry cleaning area from other areas of the shop

Because the machines were relatively new, there were no visible liquid leaks Age of equipment may play a role in leakage As machines age, leaks may develop that should be repaired promptly Proper maintenance can be instrumental to reducing leakage Several devices can aid in leak detection These include halide torches, photo-ionization detectors, and pocket dosimeters

Because exposures were below the PEL at this shop, respirator usage is not required by OSHA However, when respirators are used, they must be used in accordance with Federal Regulation 29 CFR 1910 134 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 levels of PERC, must have the cartridges changed prior to breakthrough (approximately 130 minutes based on room concentrations) [8]

Where employees must wear respirators, an appropriate respiratory protection program in accordance with 29 CFR 1910 134 must be instituted This regulation 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 [9]

It is recommended that Brown's Cleaners continue to use respiratory protection when performing machine maintenance by the operator Proper gloves should also be worn

Gloves and goggles should be used to reduce exposure to hazardous chemicals such as PERC Latex gloves are effective at protecting the skin from biological agents, however, they do not give protection for most organic solvents 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 [10] A 1987 study showed that unsupported nitrile was impervious to PERC after a 2-hour challenge period [11] 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, softening of the gloves, or seepage of PERC into the glove is observed, the gloves should be replaced Gloves should also be regularly checked and discarded if perforations and cuts are found

Chemical splash goggles should be worn to prevent eye injury when workers use 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 and spotting Controls at this facility were excellent and capable of maintaining exposures well below 25 ppm TWA Engineering controls used at this facility were the most effective seen by the authors to-date

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 [12] 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 [13]

Some studies have shown that in addition to the numerous adverse health effects already known for PERC exposure, there is evidence of carcinogenicity [14] PERC is a known animal carcinogen,[15] but there is inadequate evidence of human carcinogenicity [16] 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 [17]

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 [18] More recent and comprehensive data gathered by the

International Fabricare Institute's (IFI) vapor monitoring service using passive monitoring badges is shown in Table 5

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 [19] 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 [20] This information has not been gathered exclusively for dry cleaning, and, additional research and analysis are needed

Table 5[21]

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

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 [22]

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 [23] 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 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[24] and a no filtration process[25] 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 [26] 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 depression of the central nervous system, damage to the liver and kidneys, impaired memory, confusion, dizziness, headache, drowsiness, and eye, nose, and throat irritation [23] Repeated dermal exposure may result in dry, scaly, and fissured dermatitis [27]

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,[28 29 30] esophageal,[27 31] and pancreatic cancer[32,33] 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 can be exposed to toxic chemicals through skin or eye contact, or through 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 the chemicals used and the intermittent nature and short duration of the task [12] During personal sampling by the Arthur D Little Company at the International Fabricare Institute's Analysis Laboratory,[34] PERC exposures during spotting were many times lower than OSHA standards and some chemicals being used were below detection limits [35] 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 can 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

APPENDIX D RAW AIR SAMPLING AND REAL-TIME DATA

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA

CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8-15-94	Operator	1	11909	CT500	0 1	120	12	0	0	0
8-15-94	Presser	1	11912	JW138	0 1	120	12	0	0	0
8-15-94	Reception	1	9060	JW132	0 1	120	12	0	0	0
8-15-94	Mach #1	1	9042	CT503	0 1	117	11 7	0	0	0
8-15-94	Behind Machs	1	11913	CT505	0 1	120	12	0 02	1 666666	0 245778
8-15-94	Mach #2	1	9049	CT506	0 1	118	11 8	0 01	0 847457	0 124971
8-15-94	Press area	1	11914	CT277	0 1	121	12 1	0	0	0
8-15-94	Waste barrel	1	9051	272	0 1	120	12	0 03	2 5	0 368667
8-15-94	Hanging	1	11910	279	0 1	120	12	0	0	0
8-15-94	Spotting	1	9055	278	0 1	120	12		0	0
8-15-94	Tagging	1	11982	271	0 1	120	12	0	0	0
8-15-94	Operator	2	11909	255	0 1	120	12	0 02	1 666666	0 245778
8-15-94	Presser	2	11912	507	0 1	118	11 8	0	0	0
8-15-94	Reception	2	9060	253	0 1	119	11 9	0	0	0
8-15-94	Mach #1	2	9042	270	0 1	115	11 5	0 02	1 739130	0 256464
8-15-94	Behind Machs	2	11913	252	0 1	113	11 3	0 02	1 769911	0 261003
8-15-94	Mach #2	2	9049	508	0 1	114	11 4	0 01	0 877192	0 129356
8-15-94	Press area	2	11914	276	0 1	113	11 3	0	0	0
8-15-94	Waste barrel	2	9051	JW130	0 1	112	11 2	0 02	1 785714	0 263333
8-15-94	Hanging	2	11910	275	0 1	108	10 8	0	0	0
8-15-94	Spotting	2	9055	274	0 1	113	11 3		0	0
8-15-94	Tagging	2	11982	CT501	0 1	113	11 3	0	0	0
8-15-94	Operator	3	11909	280	0 1	123	12 3	0 045	3 658536	0 539512
8-15-94	Presser	3	11912	289	0 1	124	12 4	0	0	0
8-15-94	Reception	3	9060	251	0 1	127	12 7	0	0	0
8-15-94	Mach #1	3	9042	258	0 1	126	12 6	0 02	1 587301	0 234074
8-15-94	Behind Machs	3	11913	250	0 1	120	12	0 01	0 833333	0 122889
8-15-94	Mach #2	3	9049	254	0 1	126	12 6	0 02	1 587301	0 234074
8-15-94	Press area	3	11914	283	0 1	123	12 3	0	0	0
8-15-94	Waste barrel	3	9051	256	0 1	113	11 3	0	0	0
8-15-94	Hanging	3	11910	287	0 1	114	11 4	0	0	0
8-15-94	Spotting	3	9055	259	0 1	112	11 2		0	0
8-15-94	Tagging	3	11982	288	0 1	111	11 1	0	0	0
8-15-94	Operator	4	11909	261	0 1	88	8 8	0 03	3 409090	0 502727

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA
CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8-15-94	Presser	4	11912	266	0 1	90	9	0	0	0
8-15-94	Reception	4	9060	282	0 1	87	8 7	0	0	0
8-15-94	Mach #1	4	9042	286	0 1	83	8 3	0	0	0
8-15-94	Behind Machs	4	11913	265	0 1	87	8 7	0	0	0
8-15-94	Mach #2	4	9049	262	0 1	84	8 4	0 02	2 380952	0 351111
8-15-94	Press area	4	11914	298	0 1	83	8 3	0	0	0
8-15-94	Waste barrel	4	9051	295	0,1	84	8 4	0 02	2 380952	0 351111
8-15-94	Hanging	4	11910	292	0 1	85	8 5	0	0	0
8-15-94	Spotting	4	9055	291	0 1	81	8 1		0	0
8-15-94	Tagging	4	11982	299	0 1	84	8 4	0	0	0
8-16-94	Operator	5	9055	542	0 1	113	11 3	0 082	7 256637	1 070113
8-16-94	Presser	5	11912	632	0.1	109	10 9	0	0	0
8-16-94	Reception	5	9060	628	0 1	116	11 6	0	0	0
8-16-94	Mach #1	5	9042	575	0 1	120	12	0 02	1 666666	0 245778
8-16-94	Behind Machs	5	11913	577	0 1	114	11 4	0 045	3 947368	0 582105
8-16-94	Mach #2	5	9049	296	0 1	121	12 1	0 02	1 652892	0 243746
8-16-94	Press area	5	11914	290	0 1	113	11 3	0	0	0
8-16-94	Waste barrel	5	9051	723	0 1	115	11 5	0 1	8 695652	1 282320
8-16-94	Hanging	5	11910	530	0 1	118	11 8	0	0	0
8-16-94	Spotting	5	11906	524	0 2	113	22 6		0	0
8-16-94	Tagging	5	11982	535	0 1	116	11 6	0	0	0
8-16-94	Operator	6	9055	538	0 1	119	11 9	0 056	4 705882	0 693961
8-16-94	Presser	6	11912	798	0 1	117	11 7	0 01	0 854700	0 126040
8-16-94	Reception	6	9060	539	0 1	116	11 6	0	0	0
8-16-94	Mach #1	6	9042	294	0 1	117	11 7	0 01	0 854700	0 126040
8-16-94	Behind Machs	6	11913	293	0 1	116	11 6	0 01	0 862068	0 127126
8-16-94	Mach #2	6	9049	797	0 1	116	11 6	0 02	1 724137	0 254253
8-16-94	Press area	6	11914	520	0 1	116	11 6	0	0	0
8-16-94	Waste barrel	6	9051	729	0 1	116	11 6	0 034	2 931034	0 432230
8-16-94	Hanging	6	11910	629	0 1	114	11 4	0	0	0
8-16-94	Spotting	6	11906	576	0 2	115	23		0	0
8-16-94	Tagging	6	11982	672	0 1	115	11 5	0	0	0
8-16-94	Operator	7	9055	175	0 1	118	11 8	0 052	4 406779	0 649853
8-16-94	Presser	7	11912	178	0 1	121	12 1	0	0	0

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA
CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8-16-94	Reception	7	9060	177	0 1	122	12 2	0	0	0
8-16-94	Mach #1	7	9042	534	0 1	121	12 1	0 02	1 652892	0 243746
8-16-94	Behind Machs	7	11913	297	0 1	122	12 2	0 01	0 819672	0 120874
8-16-94	Mach #2	7	9049	171	0 1	121	12 1	0 03	2 479338	0 365620
8-16-94	Press area	7	11914	173	0 1	121	12 1	0	0	0
8-16-94	Waste barrel	7	9051	174	0 1	122	12 2	0 02	1 639344	0 241748
8-16-94	Hanging	7	11910	728	0 1	121	12 1	0	0	0
8-16-94	Spotting	7	11906	724	0 2	121	24 2		0	0
8-16-94	Tagging	7	11982	179	0 1	123	12 3	0	0	0
8-16-94	Operator	8	9055	161	0 1	34	3 4	0	0	0
8-16-94	Presser	8	11912	170	0 1	29	2 9	0	0	0
8-16-94	Reception	8	9060	736	0 1	29	2 9	0	0	0
8-16-94	Mach #1	8	9042	165	0 1	34	3 4	0	0	0
8-16-94	Behind Machs	8	11913	176	0 1	33	3 3	0	0	0
8-16-94	Mach #2	8	9049	167	0 1	34	3 4	0	0	0
8-16-94	Press area	8	11914	166	0 1	32	3 2	0	0	0
8-16-94	Waste barrel	8	9051	172	0 1	33	3 3	0	0	0
8-16-94	Hanging	8	11910	164	0 1	27	2 7	0	0	0
8-16-94	Spotting	8	11906	163	0 2	35	7		0	0
8-16-94	Tagging	8	11982	162	0 1	28	2 8		0	0
8-17-94	Operator	9	9055	150	0 1	117	11 7	0 033	2 820512	0 415932
8-17-94	Presser	9	11912	153	0 1	106	10 6	0	0	0
8-17-94	Reception	9	9060	157	0 1	120	12	0	0	0
8-17-94	Mach #1	9	9042	156	0 1	118	11 8	0 01	0 847457	0 124971
8-17-94	Behind Machs	9	11913	152	0 1	119	11 9	0 03	2 521008	0 371765
8-17-94	Mach #2	9	9049	154	0 1	118	11 8	0 065	5 508474	0 812317
8-17-94	Press area	9	11914	205	0 1	119	11 9	0	0	0
8-17-94	Waste barrel	9	9051	151	0 1	117	11 7	0 045	3 846153	0 567180
8-17-94	Hanging	9	11910	155	0 1	123	12 3	0	0	0
8-17-94	Spotting	9	11906	169	0 2	123	24 6		0	0
8-17-94	Tagging	9	11982	160	0 1	121	12 1	0	0	0
8-17-94	Unk Blk		158	158	0 1	120	12	0	0	0
8-17-94	Unk Blk		159	159	0 1	120	12	0	0	0
8-17-94	Known Blk		215	215	0 1	120	12	0	0	0

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA
CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8-17-94	Known Blk		212	212	0 1	120	12	0	0	0
8-17-94	Operator	10	9055	204	0 1	120	12	0 16	13 33333	1 966224
8-17-94	Presser	10	11912	200	0 1	110	11	0	0	0
8-17-94	Reception	10	9060	203	0 1	120	12	0	0	0
8-17-94	Mach #1	10	9042	219	0 1	116	11 6	0 038	3 275862	0 483080
8-17-94	Behind Machs	10	11913	201	0 1	117	11 7	0 01	0 854700	0 126040
8-17-94	Mach #2	10	9049	206	0 1	116	11 6	0 064	5 517241	0 813610
8-17-94	Press area	10	11914	202	0 1	120	12	0	0	0
8-17-94	Waste barrel	10	9051	207	0 1	119	11 9	0 03	2 521008	0 371765
8-17-94	Hanging	10	11910	208	0 1	114	11 4	0	0	0
8-17-94	Spotting	10	11906	209	0 2	112	22 4		0	0
8-17-94	Tagging	10	11982	210	0 1	115	11 5	0	0	0
8-17-94	Operator	11	9055	216	0 1	121	12 1	0 055	4 545454	0 670303
8-17-94	Presser	11	11912	224	0 1	118	11 8	0	0	0
8-17-94	Reception	11	9060	222	0 1	119	11 9	0	0	0
8-17-94	Mach #1	11	9042	217	0 1	122	12 2	0	0	0
8-17-94	Behind Machs	11	11913	227	0 1	120	12	0 01	0 833333	0 122889
8-17-94	Mach #2	11	9049	221	0 1	122	12 2	0 03	2 459016	0 362623
8-17-94	Press area	11	11914	218	0 1	123	12 3	0	0	0
8-17-94	Waste barrel	11	9051	211	0 1	119	11 9	0 041	3 445378	0 508078
8-17-94	Hanging	11	11910	225	0 1	121	12 1	0	0	0
8-17-94	Spotting	11	11906	213	0 2	121	24 2		0	0
8-17-94	Tagging	11	11982	223	0 1	120	12	0	0	0
8-17-94	Operator	12	9055	238	0 1	38	3 8	0 044	11 57894	1 707510
8-17-94	Presser	12	11912	231	0 1	40	4	0	0	0
8-17-94	Reception	12	9060	228	0 1	36	3 6	0	0	0
8-17-94	Mach #1	12	9042	229	0 1	38	3 8	0 01	2 631578	0 388070
8-17-94	Behind Machs	12	11913	230	0 1	39	3 9	0	0	0
8-17-94	Mach #2	12	9049	234	0 1	38	3 8	0	0	0
8-17-94	Press area	12	11914	239	0 1	36	3 6	0	0	0
8-17-94	Waste barrel	12	9051	214	0 1	39	3 9	0	0	0
8-17-94	Hanging	12	11910	235	0 1	35	3 5		0	0
8-17-94	Spotting	12	11906	233	0 2	35	7		0	0
8-17-94	Tagging	12	11982	220	0 1	36	3 6	0	0	0

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA
CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8-18-94	Operator	13	11912	196	0 1	119	11 9	0 99	83 19327	12 26824
8-18-94	Presser	13	11909	194	0 1	92	9 2	0	0	0
8-18-94	Reception	13	9060	240	0 1	90	9	0	0	0
8-18-94	Mach #1	13	9042	249	0 1	116	11 6	0 15	12 93103	1 906898
8-18-94	Behind Machs	13	11913	242	0 1	90	9	0	0	0
8-18-94	Mach #2	13	9049	190	0 1	119	11 9	0	0	0
8-18-94	Press area	13	11914	198	0 1	92	9 2	0	0	0
8-18-94	Waste barrel	13	9051	195	0 1	114	11 4	0 34	29 82456	4 398133
8-18-94	Hanging	13	11910	193	0 1	115	11 5	0	0	0
8-18-94	Spotting	13	11906	248	0 2	104	20 8		0	0
8-18-94	Tagging	13	11982	197	0 1	90	9	0	0	0
8-18-94	Unknown Blk	13		245	0 1	100	10	0	0	0
8-18-94	Unknown Blk	13		244	0 1	105	10 5	0	0	0
8-18-94	Unknown Blk	13		243	0 1	110	11	0	0	0
8-18-94	Operator	14		180	0 1	120	12	0 11	9 166666	1 351779
8-18-94	Presser	14		187	0 1	113	11 3	0	0	0
8-18-94	Mach #1	14		186	0 1	118	11 8	0 01	0 847457	0 124971
8-18-94	Behind Mach	14		189	0 1	125	12 5	0 02	1 6	0 235946
8-18-94	Mach #2	14		181	0 1	119	11 9	0 02	1 680672	0 247843
8-18-94	Pressing	14		188	0 1	127	12 7	0	0	0
8-18-94	Reception	14		184	0 1	118	11 8	0	0	0
8-18-94	Waste Barrel	14		185	0 1	125	12 5	0 047	3 76	0 554475
8-18-94	Hanging	14		109	0 1	115	11 5	0	0	0
8-18-94	Tagging	14		182	0 1	120	12	0	0	0
8-18-94	Operator	15		104	0 1	111	11 1	0 063	5 675675	0 836973
8-18-94	Presser	15		111	0 1	111	11 1	0	0	0
8-18-94	Mach #1	15		108	0 1	112	11 2	0 03	2 678571	0 395000
8-18-94	Behind Mach	15		103	0 1	106	10 6	0 01	0 943396	0 139119
8-18-94	Mach #2	15		100	0 1	111	11 1	0 02	1 801801	0 265705
8-18-94	Pressing	15		118	0 1	103	10 3	0	0	0
8-18-94	Reception	15		183	0 1	113	11 3	0 02	1 769911	0 261003
8-18-94	Waste barrel	15		110	0 1	106	10 6	0 03	2 830188	0 417358
8-18-94	Hanging	15		117	0 1	115	11 5	0	0	0
8-18-94	Spotting	15		119	0 2	112	22 4	0	0	0

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Level	Sample size	Average	Median	Mode	Geometric mean
Scrape 536	154	34.5187	35.8729	39.5927	30.3237
Scrape 546	59	156.172	156.172	156.172	156.172
other	321	54.7363	30.7826	156.172	31.2203

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Scrape 536	269.290	16.4101	1.32236	3.84030	128.221
Scrape 546	0.00000	0.00000	0.00000	156.172	156.172
other	2832.54	53.2216	2.97054	1.28010	156.172

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Scrape 536	124.381	32.3037	38.4783	6.17460	2.53312
Scrape 546	0.00000	156.172	156.172	0.00000	-1.02628
other	154.892	22.1382	59.7882	37.6500	1.16508

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Scrape 536	12.8334	14.0334	35.5483	47.5396	5315.88
Scrape 546	-3.21822	-2.07143	-3.24781	0.00000	9214.16
other	8.52184	-0.24543	-0.89758	97.2326	17570.4

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Variable	BRNOGM11.Conc select (BRNOGM11._Count lt 300)
Sample size	299.
Average	1.15821
Median	1.17468
Mode	1.17468
Geometric mean	1 135553
Variance	0.052431
Standard deviation	0.228978
Standard error	0.013242
Minimum	0.76806
Maximum	1.52106
Range	0.753
Lower quartile	0.91866
Upper quartile	1.34034
Interquartile range	0.42168
Skewness	0.149571
Standardized skewness	1.055864
Kurtosis	-1.266248
Standardized kurtosis	-4.469396
Coeff. of variation	19.769959
Sum	346.3047

BROWN'S CLEANERS, SANTA MONICA, CALIFORNIA

CHARCOAL TUBE DATA

Date	Sample	Run	Pump	Tube	Flow (l/min)	Time (min)	Volume (l)	PERC Mass (mg)	PERC Conc (mg/m3)	PERC Conc (ppm)
8–18–94	Tagging	15		101	0 1	113	11 3	0	0	0