IN-DEPTH SURVEY REPORT

CONTROL OF PERCHLOROETHYLENE EXPOSURES IN COMMERCIAL DRY CLEANERS

AT

Appearance Plus Cleaners
Cincinnati, Ohio

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Public Health Service
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4676 Columbia Parkway, R5
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PLANT SURVEYED	Appearance Plus Cleaners 6812 Clough Pike Cincinnati, Ohio 45244
SIC CODE	7216
SURVEY DATE	March 30-31, 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 Appearance Plus Cleaners located in Cincinnati, Ohio, to evaluate control of worker exposure to perchloroethylene (PERC) and provide recommendations to reduce exposure Two un-vented, refrigerated, dry-to-dry machines, each less than five years old, were used at this shop a Boewe® Permac Model P540, 46-pound dry-to-dry machine and a Fluormatic® Model M242, 30-pound dry-to-dry machine Both had a refrigerated condenser as the primary vapor recovery device Both machines were connected to a Rite-Temp® Model RTR1003AWC Chiller using R-22 refrigerant to chill the water used for reclamation, distillation, and maintaining proper solvent temperature There were no secondary recovery devices Each machine was used to clean approximately ten loads of clothing daily

There were approximately twenty-five employees at this shop Three workers were sampled the machine operator, a presser, and a clothing inspector The machine operator was exposed to 7 8 ppm TWA perchloroethylene Nearly half of this exposure resulted from loading and unloading The presser and inspector, who did not work in close proximity to the machines, but did work closely with dry cleaned clothing, were exposed to less than 1 ppm TWA The highest area samples, 5 4 and 5 7 ppm PERC, were taken above the door of the dry cleaning machines The next highest concentrations were behind the machines The concentrations above the machine were probably a result of loading and unloading the machine Garment off-gassing experiments showed that the 30-pound machine was not as effective at removing solvent from clothing as the 46-pound machine However, general ventilation near the 30-pound machine was better than near the 46-pound machine due to the large propeller fan located directly behind the 30-pound machine

Real-time monitoring showed that during loading/unloading the 46-pound machine, total dose of PERC was higher during unloading (1,955 ppm-sec vs 1,572 ppm-sec), however, the average exposure was actually higher during loading (98 ppm vs 89 ppm) The difference is more profound when examining the median exposure during loading (147 ppm) vs unloading (98 ppm) Operator exposure could be cut nearly in half by eliminating exposure during loading and unloading Theoretically, if exposure during loading/unloading could be reduced to 0, then the operator's total TWA exposure for the day would be approximately 3 9 ppm The average exposures during all of the maintenance on both machines was slightly over 38 ppm The highest maintenance exposures occurred while cleaning the lint trap on the Fluormatic®

Controls at Appearance Plus Cleaners maintained exposures well below 25 ppm, which is the exposure limit that OSHA encourages dry cleaners to follow NIOSH recommends controlling PERC to the lowest feasible concentration There are several measures which could be taken to reduce exposures further, such as improved vapor recovery or local exhaust ventilation Wet cleaning methods might also be used to reduce the total quantity of clothing which requires dry cleaning Personal protective equipment such as chemical splash goggles and protective gloves should be used at the spotting station to reduce dermal exposure to hazardous chemicals A proper respirator 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 the Appearance Plus Cleaners, located in Cincinnati, Ohio The primary purpose of this survey was to evaluate control of worker exposure to PERC from two non-vented, refrigerated, dry-to-dry machines and provide recommendations for improvement

PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

Appearance Plus Cleaners is a commercial dry cleaner, located in Cincinnati, Ohio There are three shops located throughout the city Two of the shops are "dry stores" where no dry cleaning occurs These two dry shops receive garments needing cleaned from the customers After examination and tagging for identification, the garments are transported to the main store for cleaning, then later, the dry cleaned clothing is returned and held until customer pickup The focus of this in-depth study was at the main shop where all of the dry cleaning occurs

Dry cleaning has been done at Appearance Plus Cleaners since 1984 The shop is located in a single story building that stands alone. The shop layout is shown in Figure 1 The front of the store faces the road and has three doors One entrance is for customers dropping off or picking up clothing, and the other entrances are to either the offices or storage area A worker transports clothing between this shop and the two dry stores and uses the entrance to the storage area to enter and depart

Two dry cleaning machines are located along the center of the rear wall of the building The boiler room is located directly behind the dry cleaning machines and three large propeller fans, which provide general ventilation,

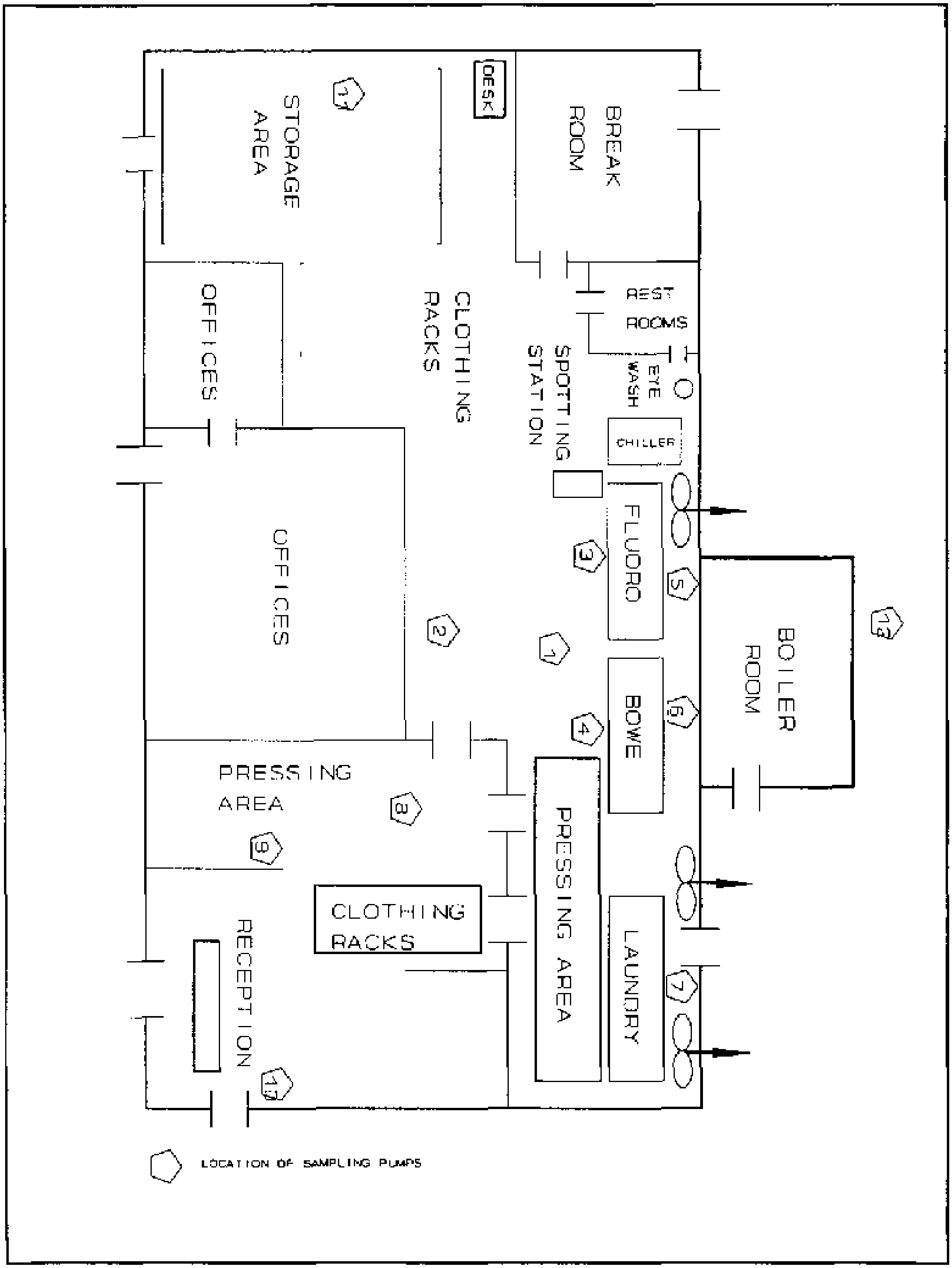

Figure 1 Shop Layout of Appearance Plus Cleaners

are in the wall Spotting is done on a spotting board just to the front side of the Fluormatic® machine Pressed and unpressed clothing is hung on the clothing racks in front of the dry cleaning machines Clothing racks behind the reception area are used for clothing which is ready for customer pickup Laundry and pressing of dress shirts are done in one of the rear corners of the building, and a break room is located in the other corner

The shop consumes an average of 30 gallons of PERC every 2 to 2 5 months On a typical day, each machine processes approximately ten loads of clothing for a total of approximately 600 pounds of clothing a day The shop processes between 160,000 and 190,000 pounds of clothing annually There are approximately 25 employees at this shop, of which most work on a full-time basis (8 hours per day and 5 days per week) The shop is open for business from 7 00 a m to 8 00 p m , Monday through Friday and Saturday 8 00 a m to 6 00 p m

PROCESS DESCRIPTION

Garments arrive at the shop from two sources customers who brought their clothing directly to the shop or via a van which transported the clothing from the dry shops Garments that arrived at the customer counter 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 near the Fluormatic® dry cleaning machine Both machine operation and spotting were done by one person whose job title was "operator " Various chemicals were used depending on the type of stain Spotting may be done before or after being cleaned in the machine Post-spotting is being used more frequently today because it reduces the amount of spotting required, which is very labor intensive

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 Appearance Plus, the majority of spotting agents were products from FabriTEC International's Stamford® line or Adco Chemical The three products used most frequently at this shop were Stamford's SPOL®, PROTEEN®, and POG® SPOL® is a mixture of hexylene glycol, amyl acetate, and nonylphenol PROTEEN® is a mixture of aqueous ammonia and ammonium hydroxide POG® is a mixture of aromatic petroleum solvent, n-butoxyethanol, ethylene glycol monobutylether acetate, and amyl acetate

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 Recent German regulations require a vacuum device to carry away dangerous or noxious gases and vapors This was not being used at this shop In regards to the solvents used, the German Federal Emission Protection Law forbids the use halogenated solvents outside the machine and, therefore, cannot be used for spotting [2]

There were two different dry cleaning machines at this shop A Boewe® Permac Model P540, 46-pound dry-to-dry machine and a Fluormatic® Model M242, 30-pound dry-to-dry machine Both of these machines had a refrigerated condenser as the primary vapor recovery device The refrigerated condensers used R-22 to condense PERC vapors during the dry cycle Additionally, both machines were connected to a Rite-Temp® Model RTR1003AWC Chiller using R-22 refrigerant to chill water used for heat removal during cool-down, condensing vapors in the still, and cooling solvent in the base tank [3] The chiller was added to reduce the water bill and improve the cleaning ability of PERC, especially during the summer months There were no secondary recovery devices Both machines were less than five years old The 30-pound machine had a 35 minute cycle and the 46-pound machine had a 45 minute cycle Technical specifications for these machines can be seen in Table 1 The 46-pound machine cost approximately $50,000 and the 30-pound machine cost approximately $30,000 The Rite-Temp® Chiller cost approximately $11,000

The clothing was weighed in a basket, prior to loading into the machines The maximum load for the 46-pound machine was 45 pounds of clothing, and 30 pounds for the 30-pound machine The weight of every load was logged onto a weekly 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 2 (See Appendix B for dry cleaning technology) To begin washing, clothes were manually loaded into the cylinder of the machine through the front door After the door was closed, PERC was automatically pumped into the cylinder Water-based detergent was automatically injected into 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 the solvent had been removed, the fabric was tumbled dry The drying process occurred in the same machine Recirculated warm air was used to vaporize the residual solvent Unheated air was then passed through the system during the cool-down cycle This step helped to reduce wrinkles

When the garments had been removed from the machine, they were pressed to remove wrinkles and to restore their original shape The garments were placed

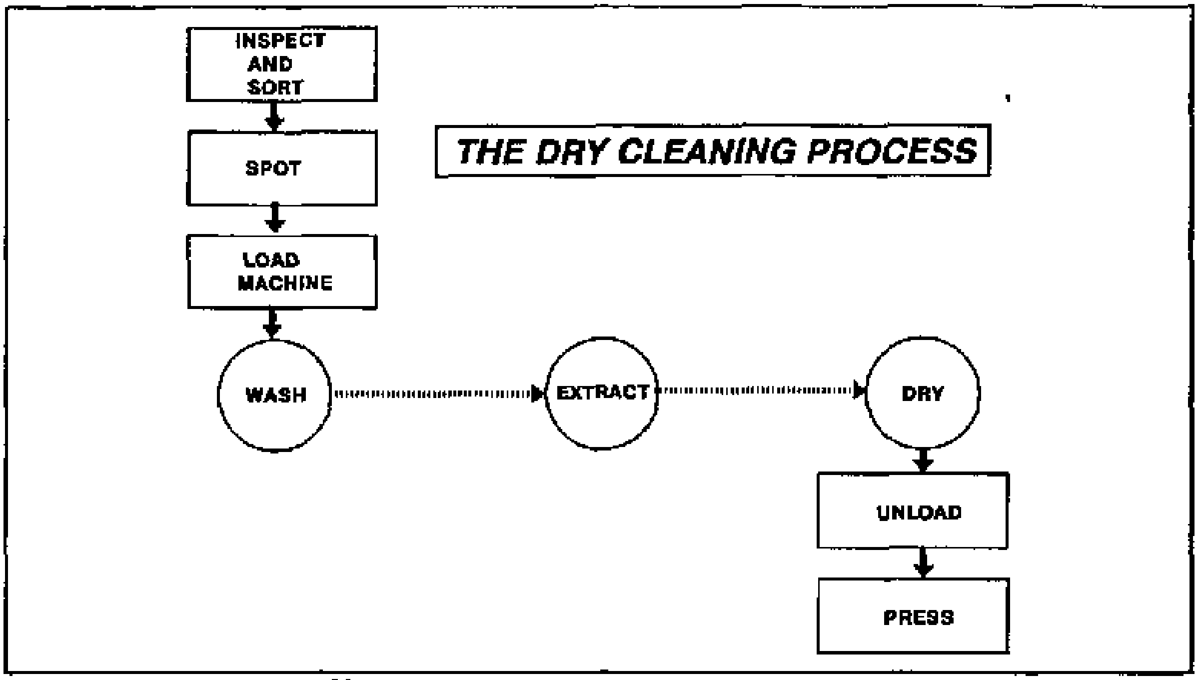

Figure 2 (Process flow diagram)

Table 1
Machine Technical Specifications

	Boewe® MODEL P540	Fluormatic® MODEL M242
Load Capacity	46 lbs	30 lbs
Cage Volume	400 liters (14 cubic feet)	8 8 cubic feet
Cleaning Speed	36 rpm	37 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 28 5 gallons tank 2 57 gallons
Cooling Water (Drying)	60 liters (15 85 gal/cycle)	24 gal/cycle

on specialized pressing equipment, coming in a variety of shapes and sizes and uses steam heated to temperatures around 300 °F

The utility presses were manufactured by Forenta®, and the shirt presses were manufactured by Unimac® When the garments were properly situated, they were pressed between two surfaces, at least one of which was hot, to remove any wrinkles Some of the equipment that was 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 returned to the overhead rack to await customer pickup

A local contractor supplied and delivered PERC when needed The solvent was pumped directly into the machine's holding tank, which eliminates employee handling PERC used in the wash cycle was cleaned continuously by passing through a filtration system The 46-pound machine used powder filters with diatomaceous earth that were changed approximately every 74 loads The Fluormatic® machine used eight Puritan® carbon cartridges that were changed approximately every four months Distillation was also used to help maintain solvent purity The 46-pound machine's still was cleaned every morning and the Fluormatic® still was cleaned each Saturday morning Filtration removes most of the insoluble soils, and distillation removes most of the soluble soils

Ventilation consisted of three large, propeller fans located in the rear wall One was located behind the 30-pound machine, and the other two were located near the right rear corner of the building The air was exhausted outside of the building Air conditioning ducts were located in the front of the building in the offices, the pressing area, and the reception area Several comfort fans were located throughout the pressing area to circulate air

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 five minutes in any three-hour period [4] OSHA had lowered the PEL to 25 ppm in 1989 under the Air Contaminants Standard [5] 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[6] NIOSH considers PERC to be a potential occupational carcinogen and recommends that exposure be reduced to the lowest feasible concentration[7]

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 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[8]

Area samples were taken at various locations throughout the shop Air samples were collected in front of and behind the dry cleaning machines in the pressing area, in the storage 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 a presser and garment inspector TWA personal sampling results were compared to 25 ppm No air sampling was done for the spotting chemicals Bulk samples were gathered from the still residue and water separator run-off and analyzed for PERC content

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 the machine, while others were less often, such as machine maintenance Most of these tasks took between 5 and 30 minutes Real-time monitoring of PERC exposures were performed using a MicroTIP® HL200® (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 concentration 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® data logger (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 between 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® data logger The apparatus for measuring off-gassing can be seen in Figure 3

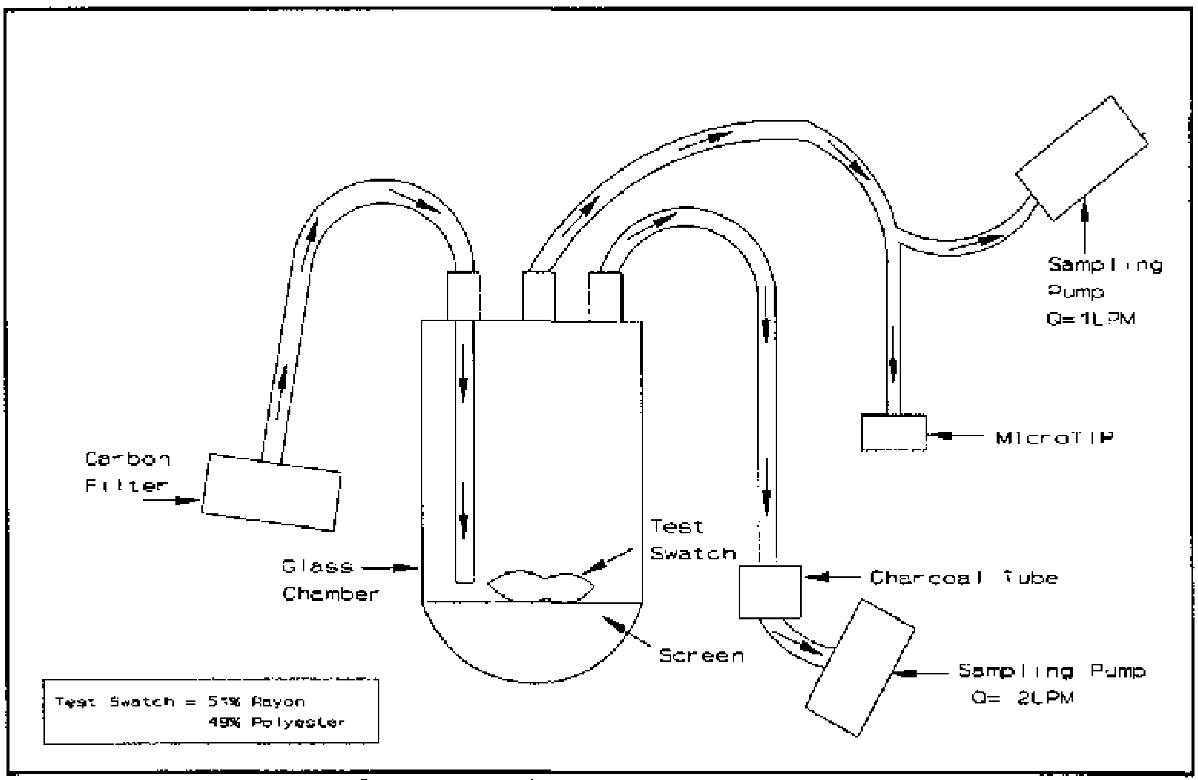

Figure 3 Apparatus for measuring off-gassing of garments and machine recovery

VENTILATION

General ventilation measurements were taken with a Kurz® model 1440 velometer with a measuring range from 0 to 6,000 feet per minute Turbulent airflow near the dry cleaning machines was qualitatively evaluated using smoke tubes The capacity and dimensions of general dilution ventilation systems were also recorded

RESULTS

INDUSTRIAL HYGIENE SAMPLING

Results of the individual air samples can be seen in Appendix E A summary of personal and area air samples for each day can be seen in Tables 2 and 3 The numbers in parenthesis in Tables 2 and 3 refer to the sample locations in Figure 1 All of the personal samples taken at this shop were well below 25 ppm The time-weighted average exposures would have been even lower if sampling had occurred for a full eight hour shift, however, the dry cleaning machines were not operated for a complete eight hours during this survey

As expected, the operator of the machine had the highest exposure to PERC which was 7 8 ppm TWA The bulk of this exposure resulted from loading and unloading the machine and performing maintenance The presser and inspector, who did not work in close proximity to the machine (see Figure 1), but did work closely with dry cleaned clothing, were exposed to less than 1 ppm TWA

Results of area sampling can be seen in Table 3 The highest area samples were taken above the dry cleaning machines The next highest concentrations were behind the machines The concentrations above the machine probably came from the machine when the door was opened and closed Although there were higher residuals in the clothing cleaned in the 30-pound machine, and

Table 2
Time-Weighted Average (TWA) Exposures Over the Sampling Period

Worker	Date	Sample Period (min)	TWA Concentration (ppm)
Presser (8)	3/30/94	419	52
Operator (1)	3/30/94	425	7 8
Inspector (2)	3/30/94	419	39
Presser (8)	3/31/94	405	70
Operator (1)	3/31/94	421	7 81
Inspector (2)	3/31/94	388	67

Table 3
Area Sample Concentrations of perchlorethylene in (ppm)

Area	Date	Average Sampling Time (min)	Geometric Mean (ppm)	Geometric Standard Deviation (ppm)	Range (ppm)
Above Bowe (4)	3/30/94	104 80	5 7	1 9	2 5-13 5
Behind Bowe (6)	3/30/94	105 80	0 2	1 6	0 1-0 4
Above Fl (3)	3/30/94	104 80	2 3	8 4	0 1-8 5
Reception (10)	3/30/94	103 00	0 4	1 6	0 3-0 7
Pressing (9)	3/30/94	103 00	0 6	2 1	0 3-1 5
Storage (11)	3/30/94	102 50	0 5	1 4	0 4-0 8
Behind Fl (5)	3/30/94	97 70	3 1	1 4	2 2-5 0
Outside (12)	3/30/94	103 50	0 3	1 1	0 0-0 3
Above Bowe (4)	3/31/94	101 50	3 1	1 3	2 3-5 0
Behind Bowe (6)	3/31/94	104 40	0 4	1 5	0 3-0 9
Above Fl (3)	3/31/94	106 30	5 4	1 1	4 7-6 2
Reception (10)	3/31/94	98 00	0 4	2 5	0 1-0 9
Pressing (9)	3/31/94	128 00	0 4	2 5	0 1-1 8
Behind Fl (5)	3/31/94	101 00	1 5	1 3	1 0-2 3
Outside (12)	3/31/94	99 00	0 4	1 3	0 0-0 5

presumably from the machine's cylinder during loading and unloading, this was not clear from the air samples measured above the machine This could be due to the large fan located directly behind the 30-pound machine which was able to remove vapors originating from this machine

There were two containers exposed to the atmosphere behind the machine the 30-pound machine's water separator run-off and the 46-pound machine's still rake-out bin PERC concentrations behind the machine may have originated from these two sources, primarily the still rake-out residue Analysis of the residue in the Boewe® rake-out bin showed that it was 20 percent PERC (w/w) Analysis of the Fluormatic® separator run-off showed that it was 029 percent PERC (w/w) PERC concentrations were clearly lower behind the 46-pound machine than behind the 30-pound machine

REAL-TIME MONITORING

Video recording and real-time monitoring was performed during loading and unloading the machine, hanging clothing, and performing maintenance on the machines such as cleaning the still and lint/button traps Real-time monitoring was also used to evaluate garment residual off-gassing Because the MicroTIP® was set for a measuring range between 0 and 200 ppm and a correction factor from the calibration curve was used, concentrations above approximately 150 ppm are not shown

Clearly, the most significant source of exposure to the operator occurred during loading and unloading the machines Concentrations during this procedure were over 140 ppm More importantly, loading and unloading occurred approximately ten times a day for each machine Machine maintenance normally occurred only once a day and some tasks were much less frequent

Figures 4 and 5 show operator exposure during loading and unloading of both machines and hanging clothing Loading and unloading the 46-pound machine took 61 seconds Loading and unloading the 30-pound machine took only 32 seconds This difference in time is expected because of the difference in capacities Hanging the clothing took approximately nine minutes Surprisingly, for both of these machines, average PERC exposure while loading the machine with dirty clothing was almost the same as unloading garments that had been cleaned in PERC This may be due to residuals being forced from the cylinder when a large quantity of uncleaned clothing is added to an empty cylinder

Average exposure from loading and unloading the 30-pound machine was slightly higher than that from the 46-pound machine There are two factors at work here Part may be due to less efficient solvent recovery which can be seen during the off-gassing experiment However, the large fan behind the Fluormatic® was able to compensate for less efficient recovery and carry away some of the PERC escaping from the Fluormatic® cylinder

Average exposure while hanging the clothing was approximately 5 ppm By viewing the video, it was apparent that the operator was being exposed to higher PERC concentrations when hanging bulky items which may not have completely dried This is shown in Figure 4 by examining peaks which occur while hanging clothing

Figure 6 shows a detailed plot of loading and unloading the 46-pound machine following a different machine cycle than in Figure 4 During this cycle, total dose was higher during unloading (1,955 ppm-sec vs 1,572 ppm-sec), however, the average exposure was actually higher during loading (98 ppm vs 89 ppm) The difference is more profound when examining the median exposure during loading (147 ppm) vs unloading (98 ppm)

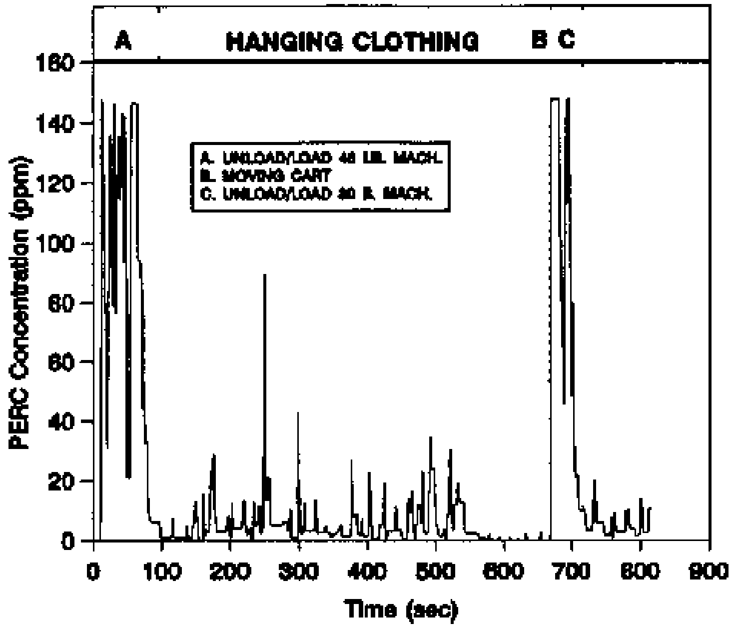

Figure 4 Unloading/loading 46- and 30-pound Machines

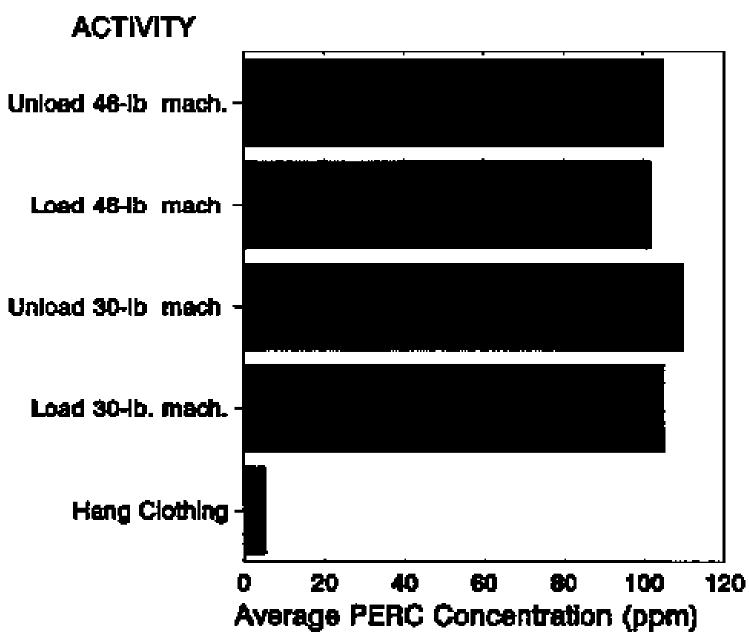

Figure 5 Summary of Exposures during various Activities

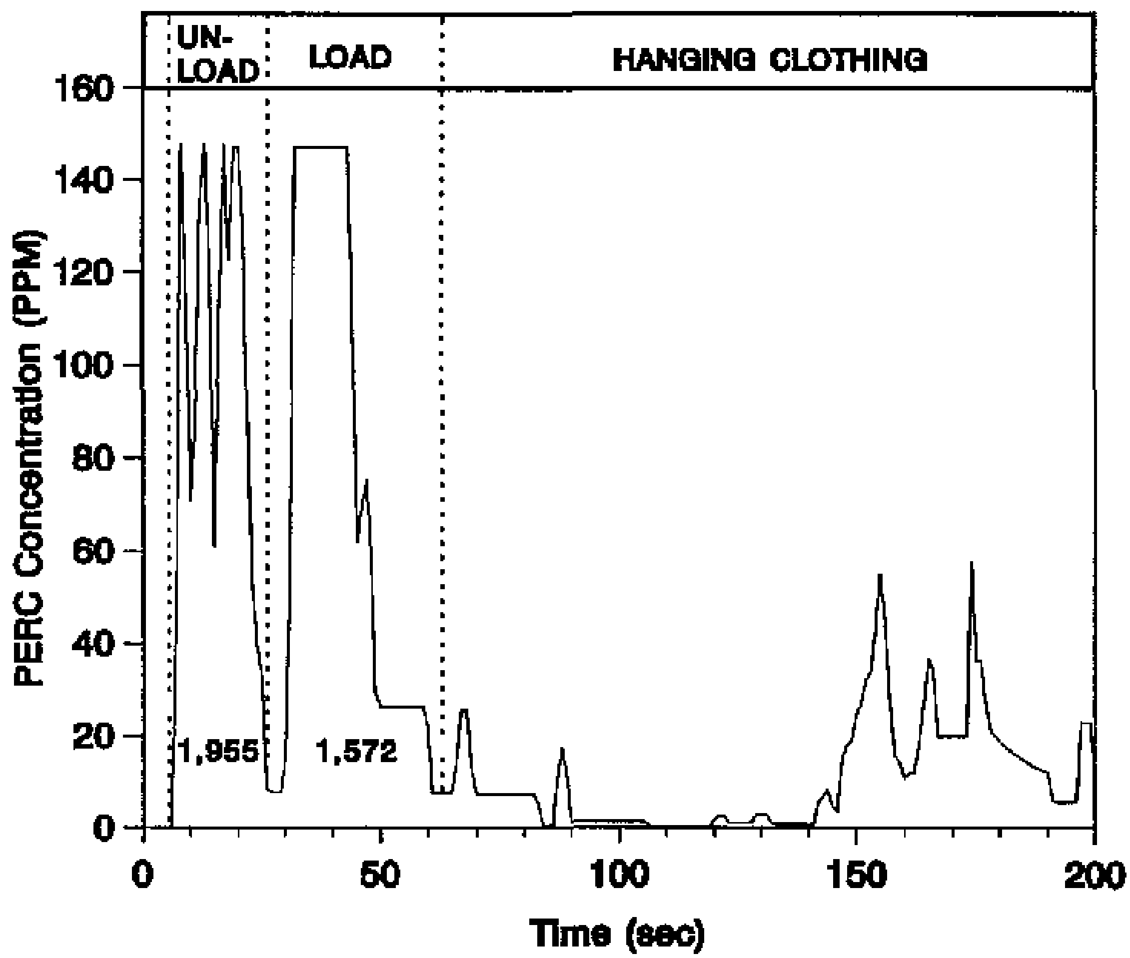

Figure 6 Loading, Unloading, and hanging clothing from 46-pound Machine

Operator exposure could be cut nearly in half by eliminating exposure during loading and unloading This can be seen by determining the operator total exposure in ppm*seconds during the workday from air sampling (25,380 seconds * 7 8 ppm = 198,000 ppm*sec) and comparing this to the operator total exposure during loading/unloading from real-time measurements (loading/unloading 46-pound machine 610 sec *103 5 ppm = 63,000 ppm*sec) and (loading/unloading 30-pound machine 320 sec * 107 5 ppm = 34,400 ppm*sec) If exposure during loading/unloading were reduced close to 0, then the operator's total TWA exposure for the day would be approximately 3 9 ppm

Figures 7 and 8 show exposures during machine maintenance It is important to mention that these exposures may have been higher than normal because the boiler had been on for approximately 15 minutes before performing this maintenance This enabled the machines and PERC residue to begin warming up Normally, maintenance is performed on the machine before the boiler has heated up in the morning The still from the 46-pound machine is cleaned every morning, but the 30-pound machine's still is normally only cleaned on Saturday mornings Figures 7 and 8 show that the highest exposures occurred during cleaning the lint trap on the Fluormatic® The average exposures during all of the maintenance on this machine was slightly over 38 ppm

Finally, the garment off-gassing experiment in Figures 9 and 10 showed that during an average cycle, the 46-pound machine was more effective at recovering solvent from the garments The total PERC off-gassing from the test swatch in the 30-pound machine was nearly twice as great than the swatch in the 46-pound machine The average PERC concentration from the 30-pound machine was 15 ppm and less than 6 ppm for the 46-pound machine

VENTILATION MEASUREMENTS

No ventilation was provided for the dry cleaning machines' doors at this shop The 46-pound machine did have a small duct inside the top edge of the doorway that drew a minimal amount of air This airflow was not exhausted outside of the machine Rather, it was returned to the machine via the button trap, so that the net airflow through this duct was 0 Three large propeller fans located in the rear wall of the building provided dilution ventilation Nine air velocity measurements were taken approximately 6 inches in front of each of the fans in the wall The fan behind the Fluormatic® machine provided approximately 8,800 cfm, the center fan provided approximately 9,400 cfm, and the fan near the laundry area was not operating

Smoke tubes indicated that the fan located behind the Fluormatic® machine appeared to be effective at exhausting contaminated air that could be originating from the front or behind the machine Smoke tubes used around the 46-pound machine indicated that the fans in the wall were ineffective at removing any PERC originating from this machine Rather, PERC originating from this machine was able to diffuse throughout the building General ventilation principles require that fans should be arranged to move contaminated vapors away from the employees Figure 3 shows the airflow currents near the machines

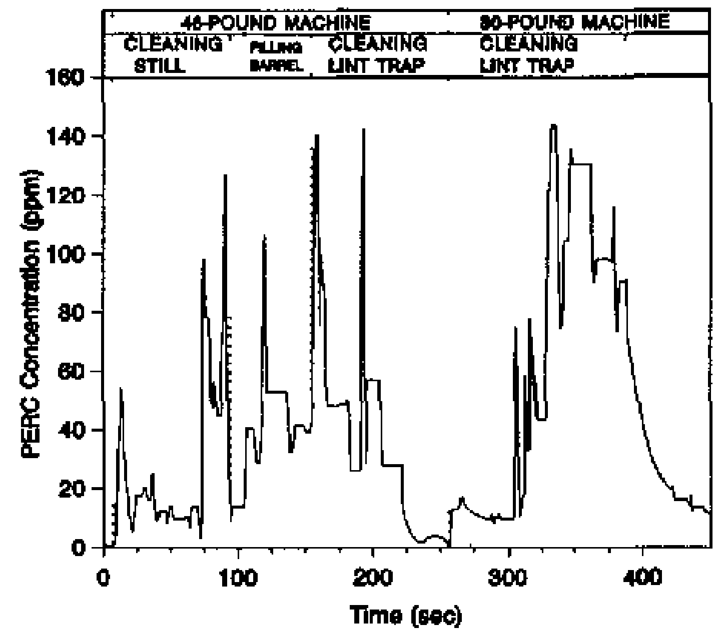

Figure 7   Exposures during Maintenance on the Stills and Lint Traps

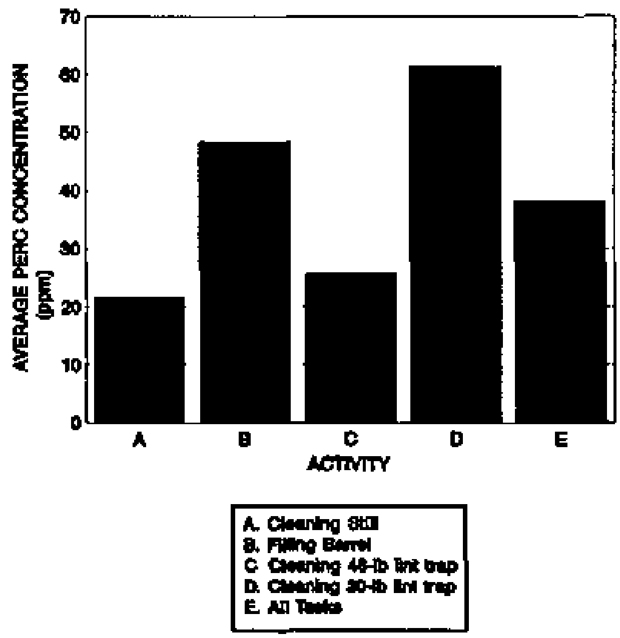

Figure 8   Average Exposure during Machine Maintenance

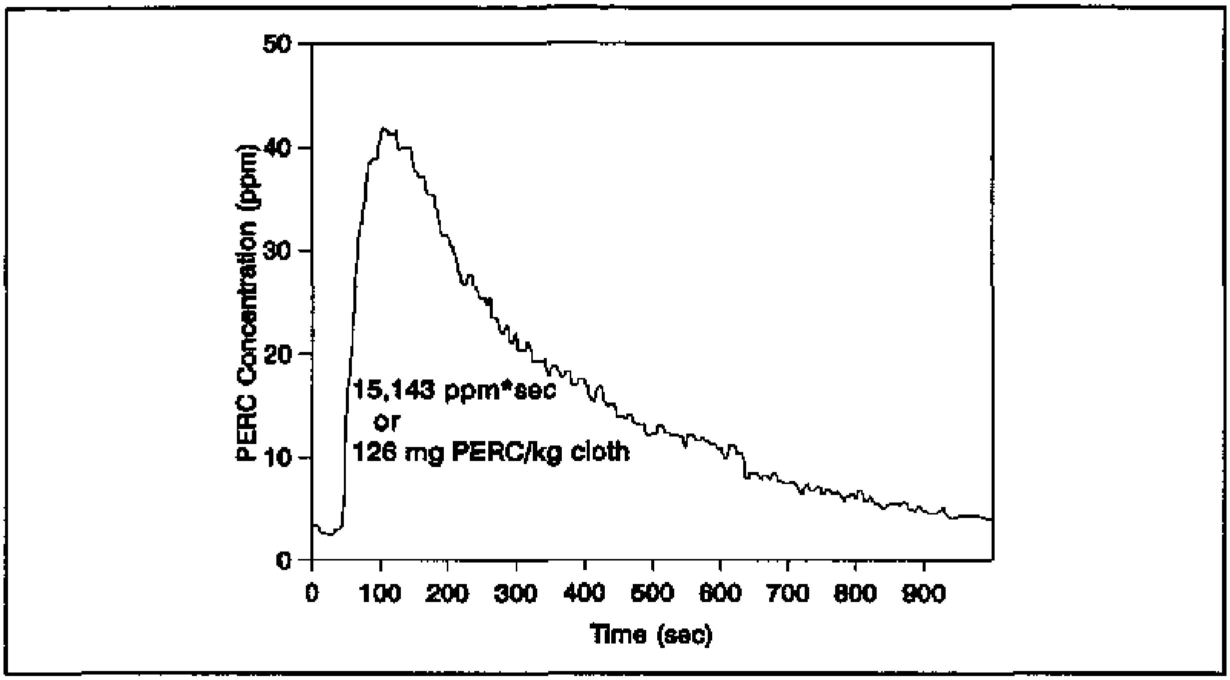

Figure 9 Typical off-gassing of swatch from 30-pound machine

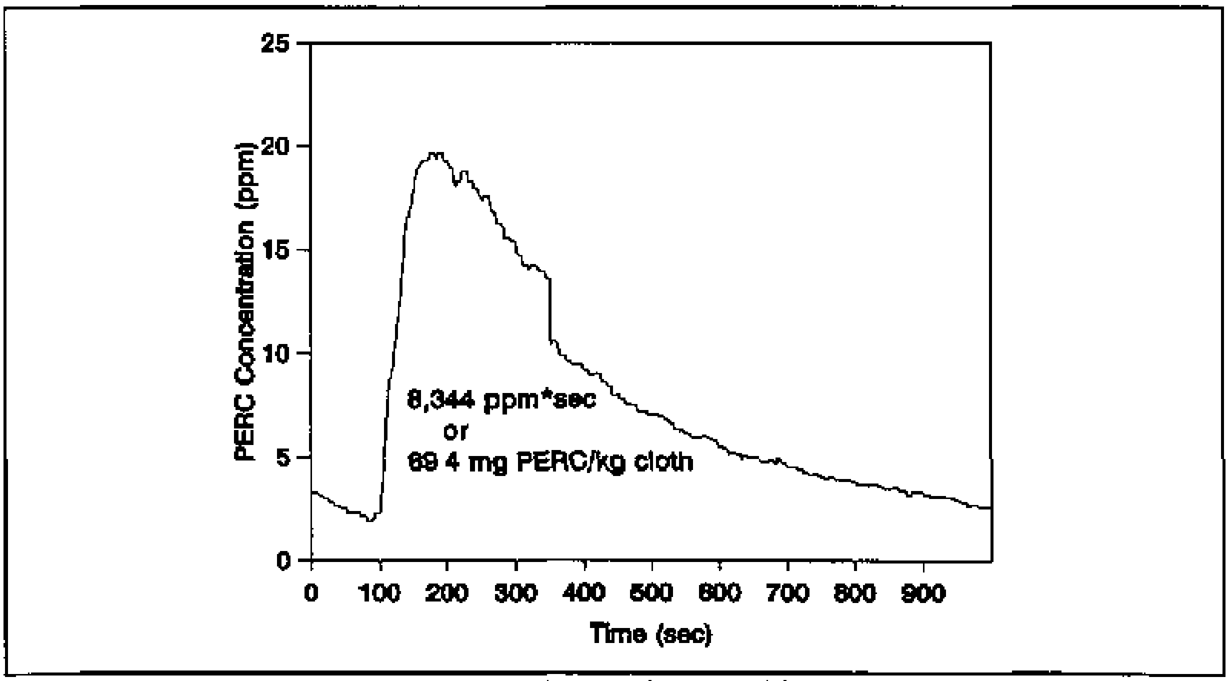

Figure 10 Typical off-gassing of Swatch from 46-pound Machine

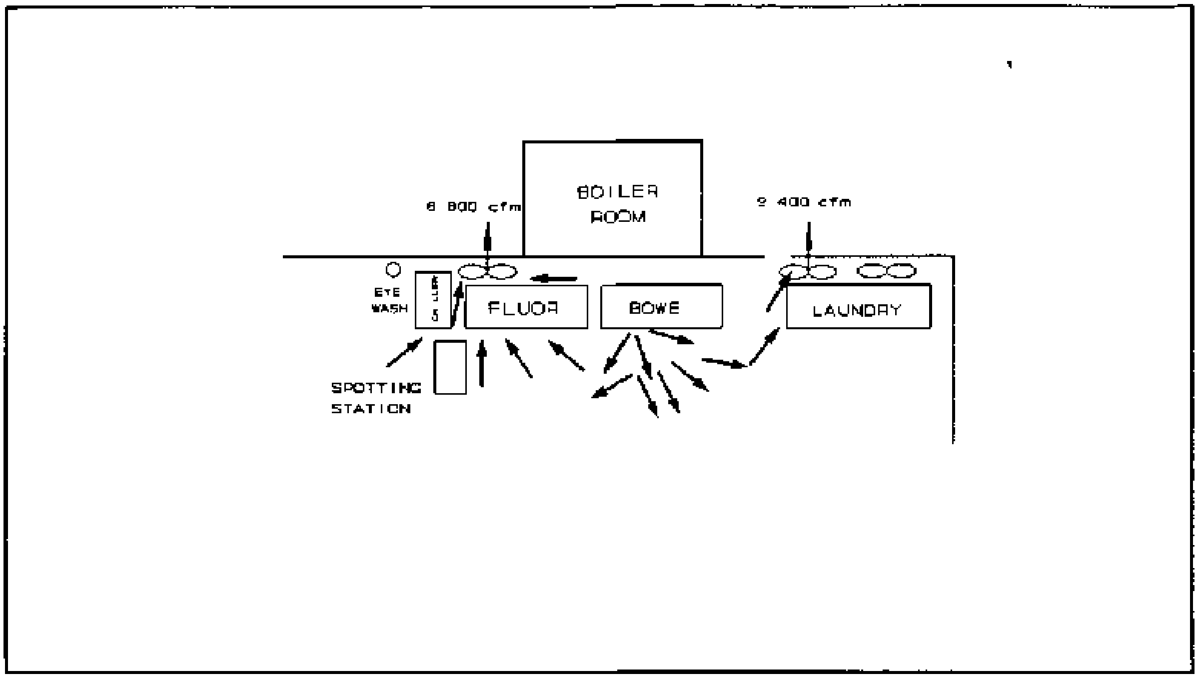

Figure 11 Airflow currents near the machines

OBSERVATIONS

The General Manager and the Production Supervisor of this shop seemed to be very concerned with environmental and health and safety issues Both have recently studied for and taken the International Fabricare Institute's Certification test They also conduct passive monitoring for PERC semi-annually Appearance Plus had a policy where the operator would be given three days off without pay if the machines were overloaded

No liquid solvent leaks were detected in this shop during the visit This can probably be attributed to the fact that the equipment was relatively new There were no open containers with solvent or solvent contaminated items observed Hazardous waste barrels were located between the dry cleaning machines and the rear wall of the building

A halogen leak detector was not available, however, visual checks for leakage were performed on a weekly basis and logged General maintenance and housekeeping appeared to be adequate Many shops like this one have a lack of adequate space for the large amounts of equipment, clothing, and workers

Based upon a formula provided by the International Fabricare Institute, the capacity rating for both of these machines is higher than recommended [9] 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 30-pound machine should have a capacity between 22 and 26 4 pounds instead of 30 pounds

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment was used by the operator when performing machine maintenance such as still cleaning, filter cleaning, or lint and button trap cleaning Personal protective equipment consisted of gloves and a respirator The respirator was a 3M® Model 8712 organic vapor respirator The gloves were thick black Viton® gloves provided by Safety Kleen There was no personal protective equipment training and no respirator fit testing The operator had a mustache and beard which could interfere with a proper respirator fit Personal protective equipment was not used while spotting clothing The owner requires all new employees to sign a standard HAZCOM form, which explains the hazards present, when they begin work

CONCLUSIONS AND RECOMMENDATIONS

Appearance Plus Cleaners had adequate controls to maintain 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 concentration The highest TWA personal exposures were for the dry cleaning machine operator/spotter who was exposed to approximately 7 8 ppm TWA The other two workers who were sampled were exposed to less than 1 ppm TWA

The primary source of exposure to the workers in this shop was the dry cleaning machines Real-time evaluation showed that loading and unloading of the machines had the greatest impact upon exposures Therefore, if management or machine manufacturers desired to reduce exposures even further, they should first examine exposures during loading and unloading By examining the total exposure during the day and total exposure due to loading and unloading, it appears that the operators exposure could be reduced nearly 50 percent by control of loading and unloading

There are a number of different measures which could be taken to reduce exposures during loading and unloading One approach is to improve vapor recovery There are four primary factors which effect vapor recovery [10] machine maintenance, cooling coil efficiency, size of load, and length of dry cycle Some of these factors could possibly reduce exposures during loading and unloading even further

Another approach which could significantly reduce exposures during loading and unloading would be to add a simple, inexpensive, external local ventilation system using an exhaust fan, ductwork, and hood 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 [11]

Process isolation can be examined from two perspectives between shops and with the main shop Appearance Plus Cleaners had two "dry stores" where no dry cleaning occurred Workers at the "dry stores" were isolated from significant exposures to PERC Process isolation was not used within the main shop and would be difficult to do because of limited floor space If solvent emissions became a significant problem, process isolation could help to reduce the number of employees exposed 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 majority of PERC emissions originate from the machine Isolating employees by either time or space will reduce exposures to the employee

Because the machines were relatively new, there were no visible leaks, however, as machines age, leaks may develop and should be repaired promptly Proper maintenance can be instrumental in reducing leakage Leaks are more easily seen if proper maintenance and housekeeping is performed within the shop Lint buildup 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 Several devices can aid in leak detection These include the following the halide torch, photo-ionization detector, and pocket dosimeters The passive exposure monitoring devices used every six months in this shop will not aid in leak detection but will alert management when an exposure problem exists [12]

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 currently used respirators (half-mask facepiece with organic vapor cartridges), may be used for short-term exposures to low concentrations of PERC At a minimum, the cartridges must be changed prior to breakthrough (approximately 130 minutes based on room concentrations) [13] Regular cartridge changes are important because the odor threshold of PERC is 27 ppm Because of this low odor threshold, a worker may not smell PERC until significant breakthrough and exposure has occurred [14]

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 C, 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[15]

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 deciding on a specific glove to use, 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 [16] A 1987 study showed that unsupported nitrile was impervious to PERC after a two hour challenge period [17] 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 still cleaning and spotting Additionally, an unobstructed eyewash station should be in the vicinity of the spotting area to provide prompt eye irrigation in the event it is needed If chemical contamination of the eye does occur, prompt irrigation for at least fifteen minutes can play a deciding role in limiting the extent of damage

Controls at this facility were capable of maintaining exposures below 25 ppm TWA Control methods discussed previously could aid in reducing exposures even further

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 [18] 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 [19]

Some studies have shown that in addition to the numerous adverse health effects already known for PERC exposure, there is evidence of carcinogenicity [20] PERC is a known animal carcinogen,[21] but there is inadequate evidence of human carcinogenicity [22] 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 [23]

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 [24] More recent and comprehensive data gathered by the

International Fabricare Institute's (IFI) vapor monitoring service using passive monitoring badges is shown in Table 4

Table 4[25]
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 [26] 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 [27] 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 [26]

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 [3] 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 adsorber and the refrigerated condenser Carbon adsorbers 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 adsorber 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 adsorber 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 adsorber

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[29] and a no filtration process[30] 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 [31] 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 [3] Repeated dermal exposure may result in dry, scaly, and fissured dermatitis [32]

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,[33,34,35] esophageal,[32,36] and pancreatic cancer[37 38] 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 [18] During personal sampling by the Arthur D Little Company at the International Fabricare Institute's Analysis Laboratory,[39] PERC exposures during spotting were many times lower than OSHA standards and some chemicals being used were below detection limits [40] 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

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

(c) 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 1/2-inch green stripe completely around the canister near the bottom
Chlorine gas	White with 1/2-inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gases	Green with 1/2-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 1/2-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 1/2-inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with 1/2-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

APPEARANCE PLUS CLEANERS AIR SAMPLING DATA

DATE	DAY	SAMPLE NUMBER	TYPE	SAMPLE LOCATION	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	PERC DET LIMIT	PERC MASS (mg)	PERC CONC (mg/m3)	PERC CONC (ppm)
03/30/94	MAR_30	658 00	PERSONAL	PRESSER	130 00	0 1	13 0	0 01	0 03	2 3	0 34
03/30/94	MAR_30	753 00	PERSONAL	OPERATOR	125 00	0 1	12 5	0 01	0'50	40 0	5 90
03/30/94	MAR_30	689 00	AREA	ABOVE BOWE	125 00	0 1	12 5	0 01	0 37	29 6	4 37
03/30/94	MAR_30	602 00	PERSONAL	INSPECTOR	125 00	0 1	12 5	0 01	0 03	2 4	0 35
03/30/94	MAR_30	558 00	AREA	BEHIND BOW	131 00	0 1	13 1	0 01	0 01	0 8	0 11
03/30/94	MAR_30	503 00	AREA	ABOVE FL	120 00	0 1	12 0	0 01	0 69	57 5	8 48
03/30/94	MAR_30	687 00	AREA	RECEPTION	115 00	0 1	11 5	0 01	0 02	1 7	0 26
03/30/94	MAR_30	501 00	AREA	PRESSING	117 00	0 1	11 7	0 01	0 02	1 7	0 25
03/30/94	MAR_30	704 00	AREA	STORAGE	126 00	0 1	12 6	0 01	0 03	2 4	0 35
03/30/94	MAR_30	605 00	AREA	BEHIND FL	110 00	0 1	11 0	0 01	0 37	33 6	4 96
03/30/94	MAR_30	525 00	PERSONAL	PRESSER	110 00	0 1	11 0	0 01	0 03	3 1	0 46
03/30/94	MAR_30	608 00	PERSONAL	OPERATOR	109 00	0 1	10 9	0 01	0 87	79 8	11 77
03/30/94	MAR_30	606 00	AREA	ABOVE BOW	109 00	0 1	10 9	0 01	0 55	50 5	7 44
03/30/94	MAR_30	740 00	PERSONAL	INSPECTOR	118 00	0 1	11 8	0 01	0 05	3 9	0 57
03/30/94	MAR_30	506 00	AREA	BEHIND BOW	108 00	0 1	10 8	0 01	0 01	0 9	0 14
03/30/94	MAR_30	551 00	AREA	ABOVE FL	114 00	0 1	11 4	0 01	0 59	51 8	7 63
03/30/94	MAR_30	690 00	AREA	RECEPTION		0 1	0 0	0 01	0 00	ERR	ERR
03/30/94	MAR_30	654 00	AREA	PRESSING	109 00	0 1	10 9	0 01	0 04	3 4	0 50
03/30/94	MAR_30	660 00	AREA	OUTSIDE	108 00	0 1	10 8	0 01	0 02	1 9	0 27
03/30/94	MAR_30	598 00	AREA	NEAR DOOR	105 00	0 1	10 5	0 01		0 0	0 00
03/30/94	MAR_30	800 00	AREA	STORAGE	111 00	0 1	11 1	0 01	0 06	5 6	0 82
03/30/94	MAR_30	705 00	AREA	BEHIND FL	119 00	0 1	11 9	0 01	0 21	17 6	2 60
03/30/94	MAR_30	708 00	PERSONAL	PRESSER	126 00	0 1	12 6	0 01	0 08	6 6	0 97
03/30/94	MAR_30	548 00	PERSONAL	OPERATOR	130 00	0 1	13 0	0 01	0 71	54 6	8 05
03/30/94	MAR_30	626 00	AREA	ABOVE BOW	131 00	0 1	13 1	0 01	1 20	91 6	13 51
03/30/94	MAR_30	509 00	PERSONAL	INSPECTOR	124 00	0 1	12 4	0 01	0 04	2 9	0 43
03/30/94	MAR_30	504 00	AREA	BEHIND BOW	124 00	0 1	12 4	0 01	0 03	2 4	0 36
03/30/94	MAR_30	553 00	AREA	ABOVE FL	128 00	0 1	12 8	0 01	0 67	52 3	7 72
03/30/94	MAR_30	726 00	AREA	RECEPTION	131 00	0 1	13 1	0 01	0 06	4 4	0 65
03/30/94	MAR_30	989 00	AREA	PRESSING	131 00	0 1	13 1	0 01	0 13	9 9	1 46
03/30/94	MAR_30	761 00	AREA	OUTSIDE	129 00	0 1	12 9	0 01	0 03	2 3	0 34
03/30/94	MAR_30	650 00	AREA	STORAGE	129 00	0 1	12 9	0 01	0 05	3 6	0 54
03/30/94	MAR_30	556 00	AREA	BEHIND FL	64 00	0 1	6 4	0 01	0 10	15 0	2 21
03/30/94	MAR_30	531 00	PERSONAL	OPERATOR	61 00	0 1	6 1	0 01	0 11	18 0	2 66
03/30/94	MAR_30	748 00	AREA	ABOVE BOW	54 00	0 1	5 4	0 01	0 09	16 9	2 49
03/30/94	MAR_30	528 00	AREA	BEHIND BOW	60 00	0 1	6 0	0 01	0 01	1 7	0 25
03/30/94	MAR_30	771 00	AREA	ABOVE FL	57 00	0 1	5 7	0 01	0 40	0 4	0 06
03/31/94	MAR_31	512 00	PERSONAL	OPERATOR	119 00	0 1	11 9	0 01	0 48	40 3	5 95
03/31/94	MAR_31	641 00	PERSONAL	INSPECTOR	118 00	0 1	11 8	0 01	0 06	4 7	0 69
03/31/94	MAR_31	764 00	AREA	ABOVE FL	114 00	0 1	11 4	0 01	0 43	37 7	5 56
03/31/94	MAR_31	568 00	AREA	ABOVE BOW	113 00	0 1	11 3	0 01	0 18	15 9	2 35
03/31/94	MAR_31	618 00	AREA	BEHIND FL	111 00	0 1	11 1	0 01	0 17	15 3	2 26
03/31/94	MAR_31	664 00	AREA	BEHIND BOW	108 00	0 1	10 8	0 01	0 02	1 9	0 27
03/31/94	MAR_31	564 00	PERSONAL	PRESSER	108 00	0 1	10 8	0 01	0 02	1 9	0 27
03/31/94	MAR_31	899 00	AREA	OUTSIDE	106 00	0 1	10 6	0 01	0 03	2 8	0 42
03/31/94	MAR_31	590 00	AREA	PRESSING	102 00	0 1	10 2	0 01	0 01	1 0	0 14
03/31/94	MAR_31	765 00	AREA	RECEPTION	102 00	0 1	10 2	0 01	0 01	1 0	0 14
03/31/94	MAR_31	597 00	PERSONAL	OPERATOR	116 00	0 1	11 6	0 01	0 61	52 6	7 75
03/31/94	MAR_31	586 00	PERSONAL	INSPECTOR	120 00	0 1	12 0	0 01	0 06	4 9	0 73
03/31/94	MAR_31	759 00	AREA	ABOVE FL	122 00	0 1	12 2	0 01	0 51	41 8	6 16
03/31/94	MAR_31	717 00	AREA	ABOVE BOW	123 00	0 1	12 3	0 01	0 25	20 3	3 00
03/31/94	MAR_31	563 00	AREA	BEHIND FL	122 00	0 1	12 2	0 01	0 14	11 5	1 69
03/31/94	MAR_31	776 00	AREA	BEHIND BOW	122 00	0 1	12 2	0 01	0 03	2 5	0 36
03/31/94	MAR_31	768 00	PERSONAL	PRESSER	122 00	0 1	12 2	0 01	0 06	4 8	0 71
03/31/94	MAR_31	614 00	AREA	OUTSIDE	124 00	0 1	12 4	0 01	0 04	3 1	0 45
03/31/94	MAR_31	677 00	AREA	H20 BY DOOR	123 00	0 1	12 3	0 01	0 01	0 8	0 12
03/31/94	MAR_31	511 00	AREA	PRESSING	124 00	0 1	12 4	0 01	0 04	3 0	0 44
03/31/94	MAR_31	763 00	AREA	RECEPTION	125 00	0 1	12 5	0 01	0 07	5 9	0 87
03/31/94	MAR_31	507 00	AREA	OFF GAS OUT	81 00	0 1	8 1	0 01	5 00	617 3	91 03
03/31/94	MAR_31	578 00	PERSONAL	OPERATOR	120 00	0 1	12 0	0 01	0 45	37 5	5 53
03/31/94	MAR_31	750 00	PERSONAL	INSPECTOR	115 00	0 1	11 5	0 01	0 05	4 4	0 65
03/31/94	MAR_31	745 00	AREA	ABOVE FL	117 00	0 1	11 7	0 01	0 37	31 6	4 66
03/31/94	MAR_31	559 00	AREA	ABOVE BOW	117 00	0 1	11 7	0 01	0 22	18 8	2 77
03/31/94	MAR_31	732 00	AREA	BEHIND FL	120 00	0 1	12 0	0 01	0 11	9 2	1 35
03/31/94	MAR_31	527 00	AREA	BEHIND BOW	119 00	0 1	11 9	0 01	0 04	3 1	0 46
03/31/94	MAR_31	581 00	PERSONAL	PRESSER	120 00	0 1	12 0	0 01	0 09	7 8	1 16
03/31/94	MAR_31	585 00	AREA	OUTSIDE	123 00	0 1	12 3	0 01	0 02	1 6	0 24

APPEARANCE PLUS CLEANERS AIR SAMPLING DATA

DATE	DAY	SAMPLE NUMBER	TYPE	SAMPLE LOCATION	SAMPLE TIME (min)	FLOW RATE (LPM)	VOLUME (liters)	PERC DET LIMIT	PERC MASS (mg)	PERC CONC (mg/m3)	PERC CONC (ppm)
03/31/94	MAR_31	508 00	AREA	H20 BY DOOR	123 00	0 1	12 3	0 01	0 01	0 8	0 12
03/31/94	MAR_31	594 00	AREA	PRESSING	117 00	0 1	11 7	0 01	0 14	12 0	1 76
03/31/94	MAR_31	694 00	AREA	RECEPTION	118 00	0 1	11 8	0 01	0 05	4 3	0 64
03/31/94	MAR_31	637 00	PERSONAL	OPERATOR	66 00	0 1	6 6	0 01	0 69	104 5	15 42
03/31/94	MAR_31	505 00	PERSONAL	INSPECTOR	35 00	0 1	3 5	0 01	0 01	2 9	0 42
03/31/94	MAR_31	517 00	AREA	ABOVE BOW	53 00	0 1	5 3	0 01	0 18	34 0	5 01
03/31/94	MAR_31	665 00	AREA	BEHIND FL	51 00	0 1	5 1	0 01	0 04	7 1	1 04
03/31/94	MAR_31	612 00	AREA	BEHIND BOW	51 00	0 1	5 1	0 01	0 03	5 9	0 87
03/31/94	MAR_31	557 00	PERSONAL	PRESSER	55 00	0 1	5 5	0 01	0 02	3 6	0 54
03/31/94	MAR_31	570 00	AREA	PRESSING	169 00	0 1	16 9	0 01	0 03	1 8	0 26
03/31/94	MAR_31	725 00	AREA	OFF GAS OUT	46 00	0 1	4 6	0 01	6 30	1369 6	201 97
03/31/94	MAR_31	733 00	AREA	QC	110 00	0 1	0 1	0 01	0 22	2200 0	324 43
03/31/94	MAR_31	734 00	AREA	QC	115 00	0 1	0 1	0 01	0 21	2100 0	309 68
03/31/94	MAR_31	579 00	AREA	QC	121 00	0 1	0 1	0 01	0 16	1600 0	235 95
03/31/94	MAR_31	591 00	AREA	QC	112 00	0 1	0 1	0 01	0 41	4100 0	604 61
03/31/94	MAR_31	635 00	AREA	QC	105 00	0 1	0 1	0 01	0 41	4100 0	604 61

Level	Sample size	Average	Median	Mode	Geometric mean
Open Bowe	3	0.00000	0.00000	0.00000	0.00000
Unload Bow	37	105.052	117.400	143.224	0.00000
Load Bowe	24	102.060	125.356	146.153	82.8189
Close Door	5	50.7569	44.5086	44.5086	48.2442
Hang Cloth	546	5.24532	3.14262	2.44584	0.00000
Open Fluor	3	0.00000	0.00000	0.00000	0.00000
Unload Flu	17	110.271	147.646	147.646	0.00000
Load Fluor	15	105.453	113.163	147.703	97.5403
Close Fluo	1	137.792	137.792	137.792	137.792
Hang Cloth	93	5.00666	3.34170	2.92932	4.02027
Other	73	12.5637	6.44166	0.00000	0.00000

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Open Bowe	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Bow	1464.99	38.2752	6.29241	0.00000	147.746
Load Bowe	2504.76	50.0476	10.2159	21.1736	146.153
Close Door	381.269	19.5261	8.73235	32.7487	84.1397
Hang Cloth	51.1161	7.14955	0.30597	0.00000	89.3443
Open Fluor	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Flu	3994.32	63.2006	15.3284	0.00000	147.675
Load Fluor	1502.83	38.7664	10.0094	45.5751	147.703
Close Fluo	0.00000	0.00000	0.00000	137.792	137.792
Hang Cloth	13.3958	3.66003	0.37953	1.02384	20.0929
Other	393.286	19.8314	2.32110	-0.00023	87.9649

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Open Bowe	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Bow	147.746	79.8737	135.360	55.4864	-1.02999
Load Bowe	124.980	65.4547	146.153	80.6985	-0.75250
Close Door	51.3911	44.5086	47.8787	3.37014	1.72666
Hang Cloth	89.3443	1.22292	6.15726	4.93434	4.45631
Open Fluor	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Flu	147.675	97.0373	147.646	50.6090	-1.26151
Load Fluor	102.128	78.6793	147.177	68.4977	-0.34824
Close Fluo	0.00000	137.792	137.792	0.00000	0.00000
Hang Cloth	19.0690	2.81556	6.07194	3.25638	1.63798
Other	87.9652	0.00812	10.1815	10.1734	2.31238

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Open Bowe	0.00000	0.00000	0.00000		0.00000
Unload Bow	-2.55775	0.54234	0.67339	36.4347	3886.91
Load Bowe	-1.50500	-1.05238	-1.05238	49.0372	2449.45
Close Door	1.57622	3.61040	1.64791	38.4699	253.784
Hang Cloth	42.5105	37.6929	179.784	136.303	2863.95
Open Fluor	0.00000	0.00000	0.00000		0.00000
Unload Flu	-2.12344	-0.35145	-0.29579	57.3139	1874.61
Load Fluor	-0.55061	-1.28702	-1.01748	36.7619	1581.79
Close Fluo	0.00000	0.00000	0.00000	0.00000	137.792
Hang Cloth	6.44875	2.74143	5.39651	73.1032	465.620
Other	8.06575	5.06927	8.84099	157.847	917.150

Level	Sample size	Average	Median	Mode	Geometric mean
Open door	3	0.00000	0.00000	0.00000	0.00000
Unload Bo	22	88.8640	97.8336	0.00000	0.00000
Load Bo	16	98.2780	147.063	147.063	57.7683
Close door	4	118.158	131.734	147.063	111.819
Hang Cloth	220	9.79172	7.63614	0.58302	0.00000
Other	17	31.6362	26.2359	26.2359	0.00000

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Open door	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Bo	2770.12	52.6319	11.2212	0.00000	147.675
Load Bo	4350.88	65.9612	16.4903	7.76412	147.063
Close door	1605.58	40.0697	20.0348	62.0987	147.063
Hang Cloth	113.085	10.6342	0.71695	-0.81054	57.4346
Other	355.155	18.8455	4.57072	0.00000	75.3660

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Open door	0.00000	0.00000	0.00000	0.00000	0.00000
Unload Bo	147.675	46.1866	134.749	88.5622	-0.45280
Load Bo	139.299	11.6320	147.063	135.431	-0.65022
Close door	84.9645	89.2518	147.063	57.8114	-1.32506
Hang Cloth	58.2451	1.10205	14.5400	13.4379	1.73175
Other	75.3660	26.2359	26.2359	0.00000	1.32521

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Open door	0.00000	0.00000	0.00000		0.00000
Unload Bo	-0.86705	-1.17758	-1.12744	59.2275	1955.01
Load Bo	-1.06180	-1.73495	-1.41658	67.1170	1572.45
Close door	-1.08190	1.07541	0.43903	33.9121	472.630
Hang Cloth	10.4863	3.63027	10.9912	108.603	2154.18
Other	2.23066	1.71323	1.44190	59.5697	537.815

Level	Sample size	Average	Median	Mode	Geometric mean
Open still	8	0.78210	0.65412	0.65412	0.75262
Scrape sti	69	21.5855	13.7792	9.75492	15.7371
Close stil	12	13.9249	14.1062	14.1062	13.7956
Open barre	10	36.3861	38.9415	40.5697	36.0255
Pour sludg	38	48.3237	44.1673	52.9268	46.6855
Close barr	5	81.5972	89.9273	89.9273	79.1895
Open lt tr	17	48.6993	48.2058	48.2058	48.0167
Clean trap	85	25.7211	25.7524	27.7432	13.0882
Close lt t	8	53.4796	67.3388	12.9686	39.5038
Vacuum tra	129	61.3380	44.0678	130.653	41.5183
Other	101	27.9292	11.9021	9.42786	17.4162

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Open still	0.06916	0.26297	0.09298	0.65412	1.37934
Scrape sti	453.622	21.2984	2.56403	3.12840	98.5019
Close stil	3.29545	1.81534	0.52404	8.87328	17.1493
Open barre	27.2700	5.22207	1.65136	29.1510	40.5697
Pour sludg	210.736	14.5167	2.35493	29.1510	106.750
Close barr	400.919	20.0230	8.95454	48.2058	100.208
Open lt tr	94.0912	9.70006	2.35261	43.3994	83.2581
Clean trap	646.044	25.4174	2.75690	0.49770	142.186
Close lt t	1206.38	34.7329	12.2800	12.9686	90.5103
Vacuum tra	2218.04	47.0961	4.14658	10.7361	143.665
Other	972.789	31.1896	3.10348	0.65412	140.408

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Open still	0.72522	0.65412	0.80343	0.14931	2.15157
Scrape sti	95.3735	9.75492	19.4956	9.74070	2.10736
Close stil	8.27604	14.1062	14.1062	0.00000	-1.73839
Open barre	11.4187	29.1510	40.5697	11.4187	-0.75033
Pour sludg	77.5985	39.4178	52.9268	13.5090	2.34657
Close barr	52.0025	79.7173	89.9273	10.2100	-1.53819
Open lt tr	39.8587	43.3994	48.2058	4.80636	3.19282
Clean trap	141.688	3.71142	45.0347	41.3233	1.65162
Close lt t	77.5417	12.9686	81.8717	68.9030	-0.38496
Vacuum tra	132.929	15.9691	98.2175	82.2485	0.35620
Other	139.754	9.61272	41.2096	31.5968	2.01857

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Open still	2.48442	4.39751	2.53890	33.6241	6.25680
Scrape sti	7.14639	3.58464	6.07805	98.6697	1489.40
Close stil	-2.45846	6.98439	4.93871	13.0366	167.099
Open barre	-0.96867	-1.47689	-0.95333	14.3518	363.861
Pour sludg	5.90540	7.57757	9.53491	30.0407	1836.30
Close barr	-1.40417	2.67599	1.22142	24.5388	407.986
Open lt tr	5.37432	11.1732	9.40365	19.9183	827.888
Clean trap	6.21646	4.66640	8.78185	98.8191	2186.30
Close lt t	-0.44451	-2.05606	-1.18707	64.9461	427.837
Vacuum tra	1.65165	-1.50021	-3.47809	76.7813	7912.61
Other	8.28190	3.79485	7.78483	111.674	2820.85

APPENDIX F REFERENCES

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