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IN-DEPTH SURVEY REPORT:

CHEMICAL EXPOSURES AND FIRE SAFETY IN COMMERCIAL DRY CLEANERS

at

A-One Cleaners
Cincinnati, Ohio

REPORT WRITTEN BY
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REPORT DATE
July 17, 1995

REPORT NO
ECTB 201-18a

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Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
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SIC CODE	7216
SURVEY DATE	January 23-27, 1995
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EXECUTIVE SUMMARY

A study was conducted at A-One Cleaners in Cincinnati, Ohio, to evaluate control of worker exposure to perchloroethylene (PERC) and mineral spirits and to provide recommendations to reduce exposures This study was also conducted to evaluate control of fire hazards Dry cleaning in this shop was performed using two dry-to-dry machines and a transfer unit Both dry-to-dry machines cleaned in PERC and had refrigerated condensers as their primary vapor recovery devices The secondary vapor recovery devices consisted of small, centrifugal fans that were ducted to carbon canisters When a dry-to-dry, machine door was opened, a micro switch energized the fan to draw PERC laden air from the cylinder through the activated carbon The transfer unit used mineral spirits and consisted of a washer and reclaimer The reclaimer was equipped with a refrigerated condenser to recover solvent vapors and did not have a secondary vapor recovery device

There were fifty-six employees at this shop Four workers, who worked in the dry cleaning room, were sampled the machine operator, dry cleaning manager, spotter, and a laundry worker Time-weighted average (TWA) personal samples for the machine operator ranged between 10 75 ppm and 30 62 ppm for PERC and 11 1 ppm and 32 86 ppm for mineral spirits The next highest exposures generally occurred to the spotter whose workstation was in proximity to the transfer machines The highest geometric mean area concentration was 87 ppm for PERC above the 80-pound dry-to-dry machine and 91 3 ppm for mineral spirits above the door of the reclaimer Both measurements were taken on the third day of the survey

Video recording and real-time monitoring were used to study machine emissions, and how emissions relate to worker exposure to PERC Video recording and real-time monitoring was performed during unloading and loading the machine and during machine maintenance The most significant source of machine emissions and ultimately exposure to the operator occurred during loading and unloading the machines This was primarily due to the frequency of the activity During all of the activities monitored with real-time instruments, operator instantaneous exposure to PERC was significantly higher than instantaneous exposure to mineral spirits This was because the vapor pressure of PERC is approximately seven times greater than the vapor pressure of mineral spirits The mineral spirits were at approximately room temperature during transfer, but PERC was heated and in the vapor state during unloading Although instantaneous exposures to PERC were higher than to mineral spirits, the TWA exposures were relatively similar There were several reasons for this, which are discussed in the text, including differences in time required to unload/load, air currents within the room, and the presence of multiple emission points for mineral spirits

Controls at A-One Cleaners maintained full-shift TWA exposures to PERC and mineral spirits below the OSHA permissible exposure limits (PEL) However, full-shift TWA PERC exposures exceeded 25 ppm on two days Twenty-five ppm is the exposure limit that OSHA encourages dry cleaners to remain beneath NIOSH recommends controlling PERC to the lowest feasible concentration Several measures which could be taken to reduce exposures further, such as modifications to the secondary vapor recovery device, use of local exhaust

ventilation, or improvements to general ventilation Personal protective equipment, such as a respirator and solvent resistant gloves, should be used during machine maintenance A respiratory protection program should also be established

This shop regularly passed all of its fire inspections because it was not required to comply with current codes Nevertheless, a number of measures could reduce the risk of injury and property damage due to fire Evaluation of fire protection found that a smoking policy needed to be established, and "NO SMOKING" signs should be posted Problems with the fire partition surrounding the dry cleaning room should be addressed The current method of transporting mineral spirits from the reclaimer to the washer should be eliminated and replaced with a pump and direct piping Areas where mineral spirits were able to evaporate directly to the work atmosphere should be eliminated An approved wet-pipe, automatic sprinkler system should be installed Proper egress from the basement and dry cleaning room needs further investigation

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 a technical report 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 A-One Cleaners located in Cincinnati, Ohio The primary purpose of this survey was to evaluate control of worker exposure to PERC and mineral spirits and to evaluate control of fire hazards for a dry-cleaner using mineral spirits Recommendations and conclusions are provided

PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

A-One Cleaners has been in operation since the early 1950s As A-One Cleaners' business grew, it needed additional space to operate Because of this expansion, A-One's owner purchased adjacent property The majority of the current shop had previously been a supermarket Other portions of the shop had been a restaurant and jewelry store A-One Cleaners is currently renovating The building had one main floor and a partial basement

Exterior walls of the building were constructed of concrete block Large windows were located across the front of the building A parapet fire wall bordered the north and south sides of the southern half of the building Interior walls were constructed of a variety of materials Most interior walls consisted of wood stud construction with plaster facing, however, some had a wallboard facing Floors were constructed of various materials Most of the building was built on a concrete slab, and the floors were covered with a ceramic tile The rear portion of the building, which was built over the partial basement, had wooden floors The roof frame was supported by steel joists The roof consisted of a steel deck, asphalt, and gravel

The shop layout is shown in Figures 1 and 2 The dry cleaning shop was divided into a southern-half and northern-half The southern-half consisted of clothing storage, dry cleaning presses, the break room, and tagging area The southern-half of the building was separated on the north and south side by a parapet fire wall There was a physical separation of approximately three feet between the dry clean pressing room and the area of the shop under construction The northern-half of the building contained the dry cleaning room, shirt laundry, shirt pressing area, alternations, offices, and an area being remodeled

The front of the store faced the road and had one set of double doors to pick-up and drop-off clothing The room next to the customer entrance was used for pressing dry-cleaned clothing There were approximately ten pressing stations in this room A motorized conveyor transported pressed clothing between the dry clean pressing area and the customer counter The rear portion of the southern-half of the building was primarily used for clothing storage and tagging Pressed clothing was hung on clothing racks in various areas throughout the building The largest clothing storage area appeared to be on racks behind the customer counter

The primary path of travel from the southern-half of the shop to the northern-half of the shop was through the dry cleaning room The dry cleaning room was bordered on two sides by a fire partition Because some of the dry cleaning was performed using mineral spirits, this room was considered a high hazard area Mineral spirits is a Class II, combustible liquid with a flashpoint of 120 degrees Fahrenheit One large propeller fan, providing general ventilation, was located in the rear wall of the dry cleaning room and exhausted outside of the building

The two doorways between the dry cleaning room and other areas of the shop had rolling fire doors with a 3-hour fire resistance rating There was one exit from the dry cleaning room leading out of the building and a garage door which was used for deliveries A side swinging, hinged door was located next to the 80-pound machine filters, however, it was blocked by the filter housing and unavailable for use This door had a 1-hour fire resistance rating

Adjacent to the dry cleaning room was a small room which contained a chiller and the main electrical control panel for the building One room near the front of the store was being remodeled The owner's office and clerical staff were located near the northern end of the building Several restrooms were located throughout the building Exterior doors were located in the rear and side of the shop for employees, maintenance, and deliveries

Access to the basement could be gained via an open stairwell near the clothing storage area in the rear of the shop The basement was divided into two rooms One room was used for storage of clothing and spare parts, and the other room was used for the boilers, a large vacuum, and an air compressor The gas-fired boilers provided heat for the presses, the dry cleaning machines, and to heat the building The basement, which was located below the clothing storage area in the rear of the shop had a single garage door

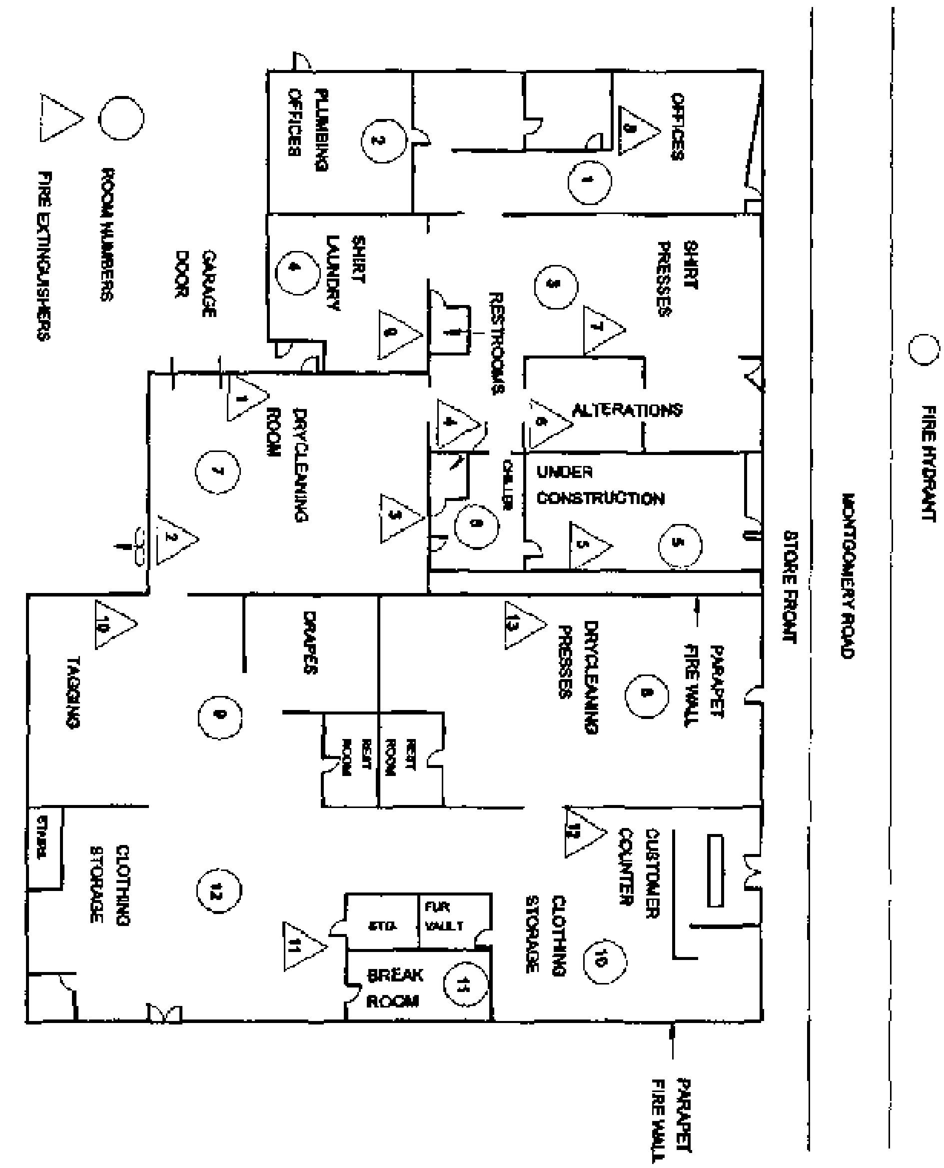

Figure 1. Layout of first floor

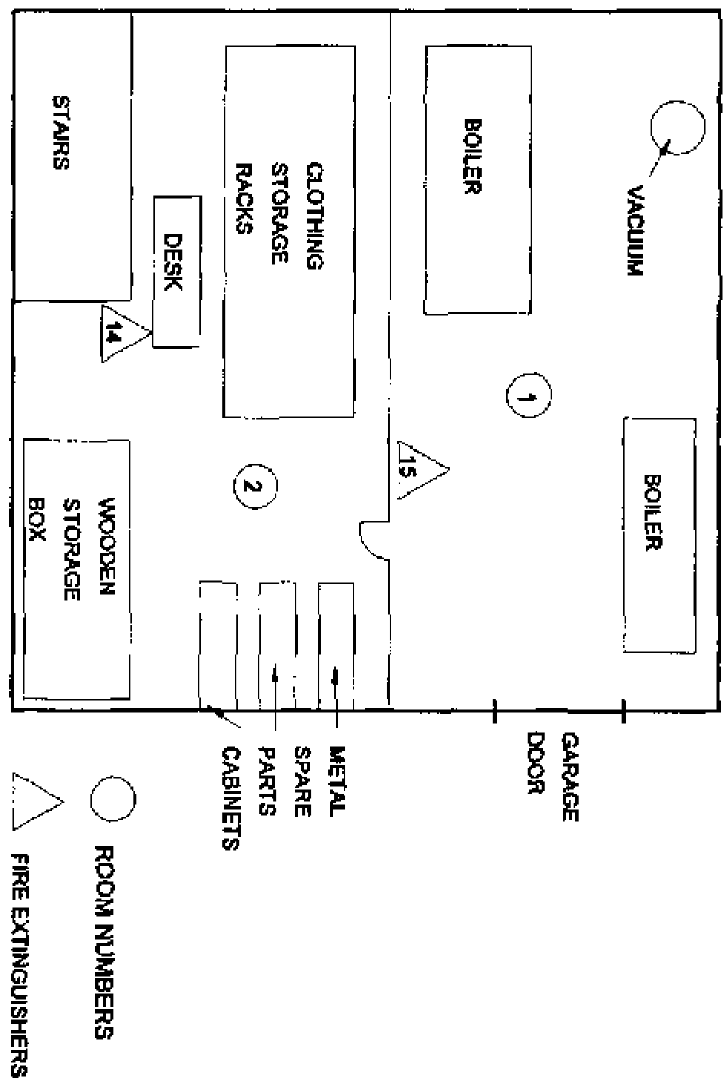

Figure 2 Layout of partial basement

PROCESS DESCRIPTION

Two different dry cleaning solvents were used in this shop PERC and mineral spirits PERC is a chlorinated hydrocarbon, and mineral spirits is a petroleum solvent Some of the most important characteristics of these two solvents, with respect to dry cleaning, are that PERC is nonflammable, toxic (permissible exposure limit is 100 ppm TWA), and an aggressive cleaning agent that readily removes oil and grease stains (Kauri-Butanol Value is 90) In contrast, mineral spirits is flammable (flashpoint is 120 degrees Fahrenheit), less toxic (permissible exposure limit is 500 ppm TWA), and a less aggressive cleaning agent (Kauri-Butanol Value ranges from 27-45)

At A-One Cleaners, dry cleaning was done using two PERC, dry-to-dry machines and a transfer unit consisting of a separate washer and dryer that used mineral spirits (Machine technical specifications are shown in Table 1) The dry-to-dry machines performed washing, extracting, and drying all in the same machine The dry-to-dry machines were Union® Models L80 and L116, which had a capacity of 80 pounds and 70 pounds, respectively The transfer machines performed washing and extracting in the washer and then required the operator to manually transfer the clothing to the reclaimer for drying The washer was a Marvel® Model "Fourteen-O", and the reclaimer was a Hoyt® Petromiser with a 62-pound capacity Because of the age of the washer, there was no documentation available at the shop or through the manufacturer Therefore, few technical specifications for the washer could be determined

Table 1
Machine Technical Specifications

	Hoyt® Petromiser	Marvel® 14-"O"	Union® L80	Union® L116
Load Capacity	62 lbs	Specs not available	80 lbs	70 lbs
Cage Volume	18 cubic feet		22 6 cubic feet	17 cubic feet
Cleaning Speed	39 rpm		28 rpm	28 rpm
Extraction Speed	NA		326 rpm	326 rpm
Tank Capacities	NA		Tanks 1,2,3 61, 61, 72 gallons	Tanks 1,2,3 61, 61, 72 gallons

Garments arrived at the customer counter and were transported to the tagging area where they were examined and tagged for identification They were also inspected and sorted according to weight, color, and finish At A-One Cleaners, typically, silks, sweaters, and red items were cleaned in mineral spirits Light and dark colored garments were cleaned in separate PERC dry-to-dry machines Garments with visible, localized stains were treated at the spotting station with either solvent-based liquids or water-based detergents These agents were held in small plastic squeeze bottles and applied to the stain when needed

Most spotting chemicals used today are purchased from a company that supplies proprietary products to the industry At A-One Cleaners, the majority of spotting agents were products from Laidlaw and R R Streets Some of the products used most frequently at this shop were Two-in-one®, POG®, Ban-Tan®, and Jinx Ink®. Two-in-one® is a mixture of trichlorethylene, hexylene glycol, and diacetone alcohol, POG® is a mixture of aromatic petroleum solvent, diacetone alcohol, PERC, and Pale oil, Ban-Tan® is a mixture of hexylene glycol and diacetone alcohol, and Jinx Ink® is primarily isopropyl acetate

The clothing was weighed in a basket, prior to loading into the dry cleaning machines The weight of every load placed in a PERC machine was logged onto a daily record According to log sheets, the majority of loads placed into the 70- and 80-pound PERC machines were approximately 55 pounds

Dry cleaning is a three-step process that involves washing, extracting, and drying A diagram of this process can be seen in Figure 3 To begin washing, clothes were manually loaded into the cylinder of the machines through the front door After the doors were closed, solvent was automatically pumped into the machine cylinder Water-based detergent was 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 In lieu of solvent distillation, clay and carbon filters were used to remove both soluble and insoluble soils from the solvents

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. Once the garments were completely pressed, they were wrapped in plastic and stored on the overhead rack to await customer pick-up

On a normal day, approximately eight loads of clothing were processed in each dry-to-dry machine, ten loads of clothing were processed in the transfer machines The shop dry-cleaned approximately 1,400 pounds of clothing per day, and approximately 5,000 pounds of shirts were laundered per week The shop was open for business from 7 00 a m to 6 00 p m Monday through Friday and Saturday 7 30 a m to 5 00 p m

The washer, which used mineral spirits, did not have an internal fire suppression system The reclaimer was Factory Mutual approved All of the

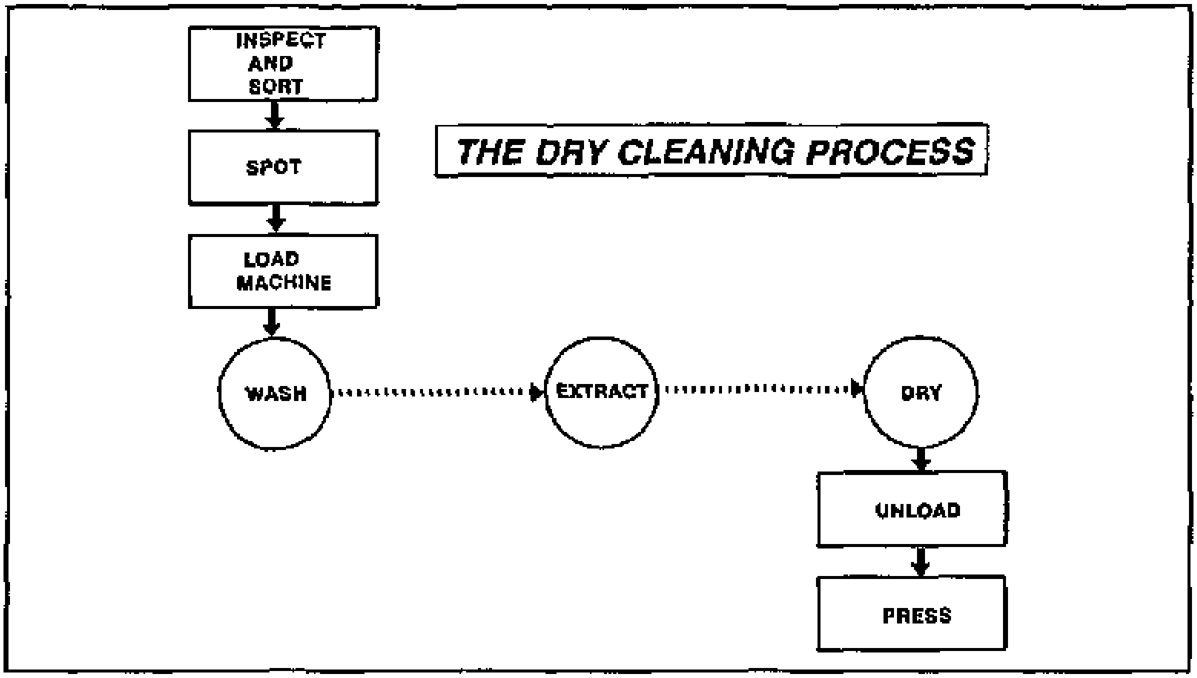

Figure 3 Process flow diagram

electrical controls on this machine were explosion-proof The reclaimer was equipped with an automatic steam injection fire extinguishing system and a high limit temperature control that safeguards against overheating In the event of an explosion within the machine, the blast would be released upwards through vents in the top of the machine while steam would automatically be injected into the cylinder

The reclaimer operated in two different phases solvent recovery (20-45 minutes) and cool-down (2-6 minutes) During the solvent recovery phase, mineral spirits were recovered from the drying air by passing the steam-heated airstream by a condenser The airstream passed through the tumbling load of clothing, a lint filter, and a condenser at approximately 625 cubic feet per minute (cfm) After partial removal of the solvent and water vapors, the airstream was passed through a steam chest for reheating The liquid mineral spirit and water mixture was condensed, and it was then piped to a separator From the separator the water and mineral spirits were directed into two different five-gallon buckets on the floor behind the machine The reclaimer utilized a cool-down phase to reduce excessive wrinkling, in which atmospheric air was drawn into the airstream with a flow rate of approximately 400 cfm When the machine door was opened, an exhaust fan pulled the ambient air through the dryer and exhausted outside of the building at approximately 750 cfm.[2]

Both dry-to-dry machines had refrigerated condensers as the primary vapor recovery device The refrigerated condenser used refrigerant to condense PERC vapors during the dry cycle The secondary vapor recovery device consisted of a 0 25 horsepower, centrifugal fan, that was ducted to an activated carbon canister The manufacturer recommended changing this canister approximately once every three months When the machine door was opened, a micro switch energized the fan to draw PERC laden air from the cylinder through the activated carbon This was designed to recover residual PERC vapors in the cylinder during loading and unloading

The drying process occurred in the same machine and consisted of two phases heat recovery and cool-down During heat recovery, warm air was recirculated to vaporize and recover the residual solvent Air was passed through the garments, a lint filter, cooling coils, and finally through a heating coil and back to the drum While passing through the cooling coil, PERC vapors condensed to liquid form and were directed to the separator where the water was removed Liquid PERC flowed back into the tank while the water was piped to an external container Unheated air was passed through the system during the cool-down cycle. During cool-down, the heating coil is by-passed and the temperature of the cooling coil is reduced to less than 0 °F This step relaxes the fabric fibers, helps to reduce wrinkles, and removes additional PERC

Approximately 200 gallons of mineral spirits were stored in a tank directly beneath the Marvel washer A 500-gallon, underground storage tank of mineral spirits was located just outside of the dry cleaning room Mineral spirits from this tank were pumped through an overhead piping system to the washer when needed The dry-to-dry machines held approximately 300 gallons of PERC A local contractor supplied and delivered PERC when needed PERC 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

HAZARDS AND EVALUATION CRITERIA

POTENTIAL HAZARDS

The two primary hazards in this dry cleaning shop were the fire hazard primarily from the use of mineral spirits and the health effects related to exposure to both PERC and mineral spirits 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 A

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.[3] OSHA had lowered the PEL to 25 ppm in 1989 under the Air Contaminants Standard [4] 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 [5] NIOSH considers PERC to be a potential occupational carcinogen and recommends that exposure be reduced to the lowest feasible concentration [6]

The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit (TLV) value for PERC is 50 ppm, based on health effects Because PERC and mineral spirits have some similar health effects (such as depression of the central nervous system) the additive effect of exposure was considered by computing a combined exposure (C_m)

$$C_m = C_1/T_1 + C_2/T_2$$

In this formula, C and T refers to the concentration and threshold limit values (TLV), respectively Combined exposures are acceptable when $C_m < 1$

The current OSHA PEL for mineral spirits is 500 ppm, 8-hour TWA There is no 15-minute short- term exposure limit nor a 5-minute peak [7] The NIOSH recommended exposure limit for mineral spirits is 350 mg/m^3 or approximately 66 ppm The TLV for mineral spirits is 100 ppm

The fire laws of the state, county, fire district, or community delegate general responsibility and authority to the fire officials involved in fire prevention activities The city of Cincinnati Fire Department has jurisdiction for A-One Cleaners The city of Cincinnati's Fire Prevention Code under Title XII of the Cincinnati Municipal Code has adopted the Building Officials and Code Administrators (BOCA) Basic Fire Prevention Code and the Ohio Fire Code Supplement with certain modifications

Additionally, the city of Cincinnati has adopted by reference a number of additional rules and regulations from national technical organizations Those that are particularly pertinent to this facility are the National Fire Protection Association (NFPA) 30--Flammable and Combustible Liquids Code and NFPA 32--Standard for Dry Cleaning Plants Recommendations in this report are based upon these adopted codes, as well as NFPA 101--The Life Safety Code

Because A-One Cleaners has been in operation prior to the adoption of many recent codes, they have been grandfathered and are not required to comply with many provisions in recent codes, however, code compliance would reduce the risk of property damage, injury, or death due to fire It may also reduce property insurance premiums According to NFPA 101, dry cleaning plants are classified as industrial occupancies According to NFPA 101 and the BOCA code for dry cleaning plants, A-One Cleaners' dry cleaning room is considered a high hazard area because there was greater than 60 gallons of mineral spirits

METHODOLOGY

INDUSTRIAL HYGIENE SAMPLING

The objective of industrial hygiene sampling was to evaluate the effectiveness of the dry cleaning machines for controlling worker exposure to PERC and mineral spirits Personal and area air sampling was conducted, using NIOSH Method 1003 for halogenated hydrocarbons and NIOSH Method 1550 for petroleum naphthas These methods call 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 these processes were 0 01 mg/sample for halogenated hydrocarbons and 0 1 mg/sample for petroleum naphthas [8]

Area samples were taken at various locations throughout the shop Air samples were collected in front of all dry cleaning machine doors, behind the PERC machines, near the folding table, and near the exhaust fan (Figure 4) Full-shift TWA personal sampling was conducted for the machine operator, the spotter, and several other workers who worked in the dry cleaning room

VIDEO EXPOSURE MONITORING

Real-time monitoring was used to study how specific manual tasks and maintenance operations affect worker exposure to PERC and mineral spirits Some of these procedures occurred frequently throughout the day, such as loading/unloading the machine, while others, such as cleaning the lint and button traps, were less often Most of these tasks took between 5 and 30 minutes Real-time monitoring of PERC exposures was 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 calibrated for both PERC and mineral spirits, using five bag standards of PERC vapor and five bag standards of mineral spirits vapor Instrument readings and actual concentrations were used to construct two calibration curves and find predictive equations 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 (ppm/volt)

Using the MicroTIP®, the information gathered 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 video camera was used to record worker activities This videotape was later used to analyze tasks, code data, and determine which work activities and movements resulted in the highest exposures

Real-time monitoring was also used to study off-gassing of garments and to compare vapor recovery efficiency of the machines. This was accomplished by placing a standard test swatch approximately 5 inches by 6 inches, made of 51 percent rayon and 49 percent polyester into a typical load of clothing

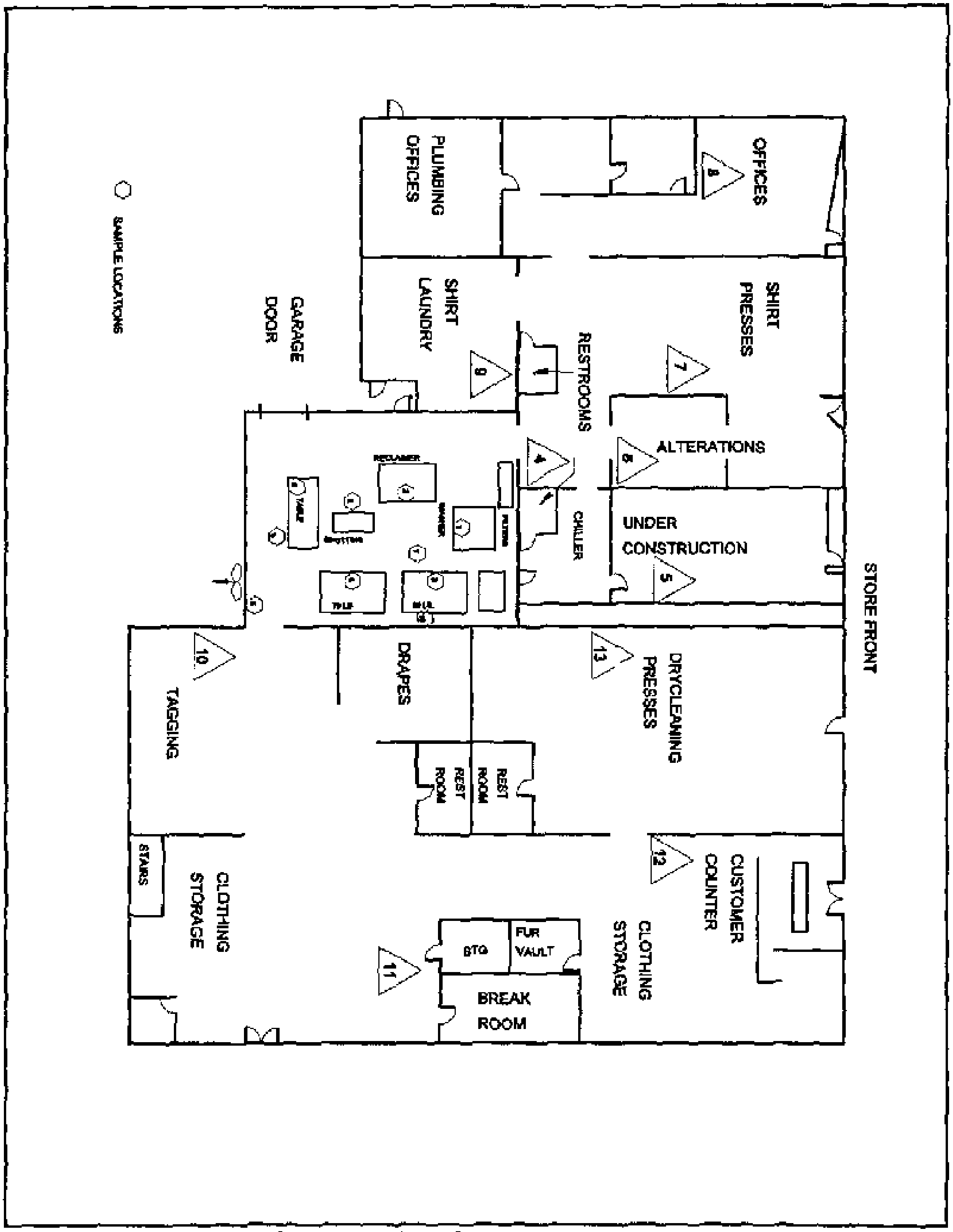

Figure 4. A-One Cleaners Sample Locations

When the dry cycle had ended, the test swatch was placed in a small glass test chamber As the PERC and mineral spirit residuals vaporized, the emitted concentrations were monitored and recorded by using the MicroTIP® and Rustrak® data logger The apparatus for measuring off-gassing can be seen in Figure 5

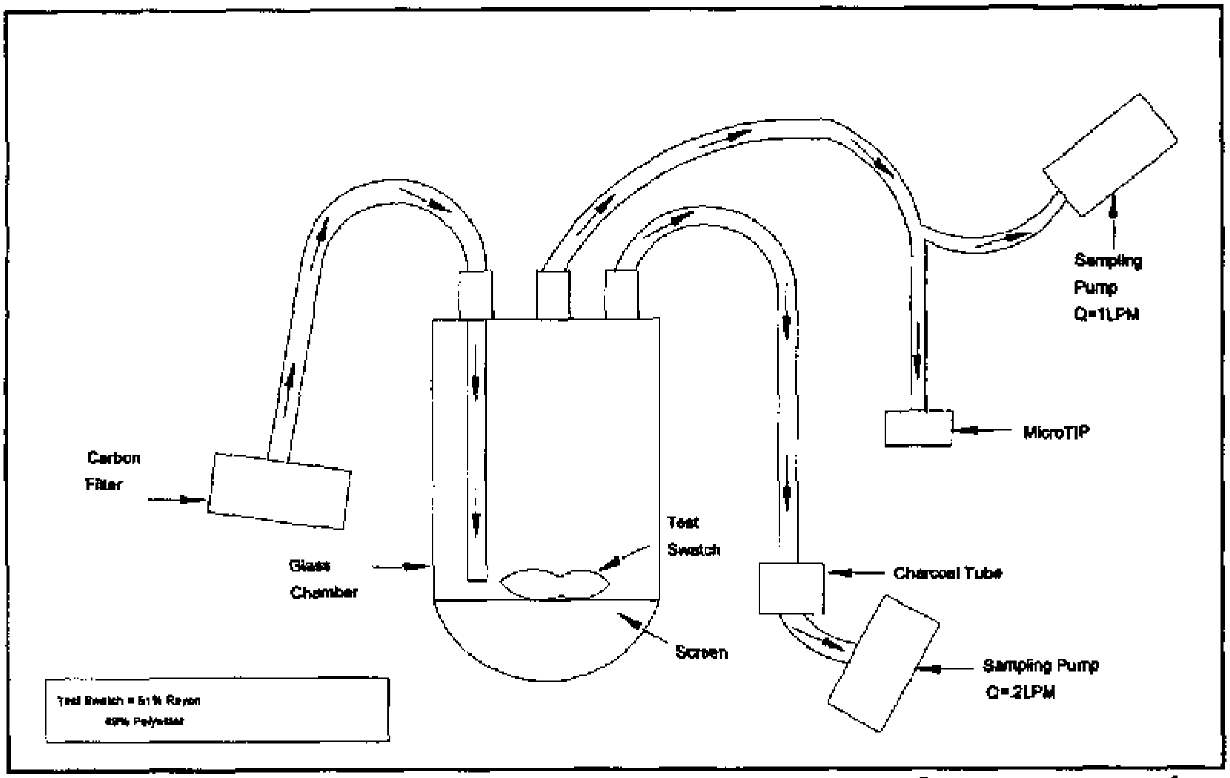

Figure 5 Apparatus for measuring off-gassing of garments and machine recovery

VENTILATION

General ventilation measurements were made with a Kurz® model 1440 hot wire anemometer, with a measuring range from 0 to 6,000 feet per minute (fpm) Airflow patterns in the dry cleaning room were qualitatively evaluated by using smoke tubes Face-velocity measurements were taken with each machines' door open 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 FINDINGS

FIRE SAFETY

Occupancy

A-One Cleaners had fifty-six able-bodied, adult employees Fifty of those employees worked on a full-time basis, and the other six employees worked on a part-time basis The building was occupied from approximately 5 00 a m to 6 00 p m Monday through Saturday During the evaluation, the number of people occupying the building, excluding survey participants, ranged from 35 to 45 people

There were approximately 4 people in the office area, 6 people working in the shirt pressing area, 3 people in the shirt laundry area, 5 people in the dry cleaning room, 3 people in alterations, 2 people in tagging, 10 people in the dry cleaning pressing area, and 3 people near the customer counter In addition to these workers, there were also a number of individuals that were in and out of the building Van drivers who picked up and delivered clothing to customers' homes, were in and out of the building throughout the day The break room also had a number of people in it at various times throughout the day

A-One Cleaners occupied approximately 8,500 square feet of floor space According to NFPA 101, industrial occupancies shall not have more than one person per 100 square feet of floor area [9] Based upon the floor area, this building may have up to 85 employees in the building at one time.

Heat Load

Heat or fire load refers to the severity of a fire that would be predicted in an occupancy, based upon the heat release rate of the combustible materials that are present divided by the fire area in square feet Typically, ordinary combustibles have a heat of combustion of approximately 8,000 BTU per lb Occupancies are traditionally divided into three categories [10]

Low fire load 100,000 BTU/ft^2
Moderate fire load. 100,000 BTU/ft^2 to 200,000 BTU/ft^2
High fire load 200,000 BTU/ft^2 to 400,000 BTU/ft^2

Heat load calculations were based upon building contents, construction, and heat of combustion Garment quantities and content mass were estimated Heat load calculations can be found in Appendix B According to the criteria outlined above, the heat load in this building was "low"

Egress

Egress calculations are shown in Appendix C There were three factors involved in egress analysis travel distance, occupancy load, and exit capacity NFPA 101 calls for a maximum travel distance of 75 feet to an exit [11] There were nine exits from the first floor Seven exits had a width of 2 5 feet, and the other two had a width of 5 0 feet Exit capacity is determined by considering the width of the exit and the number of occupants that may have to pass through the exit during a fire Results of the calculations indicate that sufficient exiting was provided

There was only one problem which may need further investigation According to NFPA 101, two remote exits are required for each level of a building and in high hazard areas There was only one approved exit from the basement and the dry-cleaning room In the case of the basement, a garage door is not an approved exit, and the current exit path passes through the first floor Again, in the case of the dry-cleaning room, the garage door and the two fire doors are not approved exits Exit paths must also be kept free and clear of obstructions or clutter This is particularly important at this shop since many items could potentially block an exit path

Fire extinguishers
Figures 1 and 2 depict the location of fire extinguishers throughout the building The corresponding fire extinguishers and their type, capacity, and date of last inspection is shown in Appendix D Class A extinguishers are for ordinary building protection and can use water, dry chemical, or halon Class B extinguishers are for flammable liquids and can use CO_2, dry chemical, halon, or AFFF Class C extinguishers are for fires in charged electrical equipment and use CO_2, dry chemical, or halon

There were 15 multi-purpose fire extinguishers located throughout the A-One Cleaners Two extinguishers were in the basement, and all of the other extinguishers were located on the main floor Most of those extinguishers were rated "BC" suitable for flammable liquids and fires in charged electrical equipment Based upon guidelines in the NFPA Handbook, the fire extinguishers present in this building were of adequate size, type, and distribution Table 5-23C of the NFPA handbook calls for a maximum travel distance of 30 feet to an extinguisher rated at 30-B in a high hazard area This would be appropriate for all of the extinguishers in the dry cleaning room which is a high hazard area For moderate hazard areas, extinguishers rated at 10-B and 20-B should have a maximum travel distance of between 30 and 50 feet, respectively

Fire detection and suppression systems
There was no automatic sprinkler system or fire detection system in this building Based upon the significant ignition sources and fire load within this building, a fire detection system should be installed to provide 24-hour notification to the fire department This system would be particularly important during hours when the building is unoccupied Due to the proximity of the fire department, rapid notification of fire would facilitate a quick response Photoelectric detectors that are most effective at detecting smoldering fires should be installed in the majority of the building with the exception of the dry cleaning room [11] This room should be equipped with an ionization detector to rapidly detect a fast flaming fire which typically occurs when a flammable/combustible liquid is ignited A wet-pipe automatic sprinkler system should be installed in accordance with the NFPA Code 32 for dry cleaning plants

Fire Department access
A-One Cleaners was under the protection of the Cincinnati Fire Department's Engine Company Number 8 Engine Company Number 8 was located only 0 6 miles from A-One Cleaners and could respond to a fire in a matter of minutes One fire hydrant was located directly across the street from A-One Cleaners, and several other hydrants were within 500 feet

INDUSTRIAL HYGIENE SAMPLING

Results of the individual air samples and statistical analysis can be seen in Appendix E Figure 4 shows the sample locations, and Table 2 is a summary of personal air samples for four different days Figure 6 shows the operator's time-weighted average (TWA) exposures for each day Because of the extremely cold weather during this survey, all of the doors leading to the outside were closed, and the primary air handling unit for the dry cleaning room was not operating This probably caused the concentrations of PERC and mineral spirits to be higher than other seasons of the year

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

Because PERC and mineral spirits have some similar health effects and significant exposures occurred to both chemicals, the additive effect of exposure was considered by computing a combined exposure (C_m)

$$C_1/T_1 + C_2/T_2 = C_m$$

In this formula, C and T refers to the concentration and threshold limit values (TLV), respectively Combined exposures are acceptable when $C_m < 1$ Results of this analysis can be seen in the final column of Table 2 No combined concentrations exceeded the combined TLVs

The full-shift, time-weighted average (TWA) personal samples ranged from 1 44 ppm to 30 62 ppm for PERC and 2 72 ppm to 32 86 ppm for mineral spirits The machine operator had the greatest TWA exposures which ranged between 10 75 ppm and 30 62 ppm for PERC and 11 1 ppm and 32 86 ppm for mineral spirits The operator's TWA exposure for all four days of sampling was 21 68 ppm PERC and 21 17 ppm mineral spirits Operator exposure to PERC was statistically significantly different from all other workers Operator exposure to mineral spirits was only significantly different from the laundry worker

The operator was exposed to slightly more mineral spirits than PERC on three of the four days The reason that the operator was generally exposed to slightly higher concentrations of mineral spirits was that much of the mineral

Table 2 Time-Weighted Average (TWA) PERC and Mineral Spirit Exposures

Worker	Date	Number of Samples	Sampling Period (minutes)	PERC TWA Conc (ppm)	Mineral Spirit TWA Conc (ppm)	Additive Exposures (C_a)
Spotter	1/24/95	4	479	5 45	10 04	21
Operator	1/24/95	4	510	19 66	11 1	50
Mgr T	1/24/95	4	405	1 44	2 72	06
Operator	1/25/95	4	506	10 75	13 29	35
Mgr S	1/25/95	4	448	7 9	13 78	30
Laundry wkr	1/25/95	4	473	5 11	8 01	18
Operator	1/26/95	4	496	30 62	32 86	94
Mgr S	1/26/95	4	495	15 01	20 82	51
Laundry wkr	1/26/95	4	479	9 45	13 66	33
Spotter	1/26/95	4	437	12 18	23 64	48
Operator	1/27/95	3	400	26 90	29 54	84
Spotter	1/27/95	3	358	7 17	17 52	32
Laundry wkr	1/27/95	3	415	7 14	11 98	26

spirits escaping from the transfer equipment tended to move toward the PERC machines. Therefore, when the operator was working near the PERC machines, he was being exposed to both PERC and mineral spirits When the operator worked near the transfer equipment he was primarily exposed to mineral spirits

As illustrated in Figure 8, there were significant concentrations of mineral spirits near the front of the 80-pound PERC machine (often the concentration of mineral spirits was 50 percent of the PERC concentration near the PERC machines), however, the concentrations of PERC around the transfer equipment was much lower (often only 20 to 25 percent)

The next highest exposures generally occurred to the spotter who worked in close proximity to the transfer machines The spotter's TWA exposures were consistently higher to mineral spirits than PERC The laundry worker was generally the farthest away from the dry cleaning machines The two managers who were sampled were in and out of the dry cleaning room throughout the day Exposures seemed to be greater on the last two days of sampling which was probably attributed to the fact that the volume of clothing needing dry-cleaned on those two days was greater.

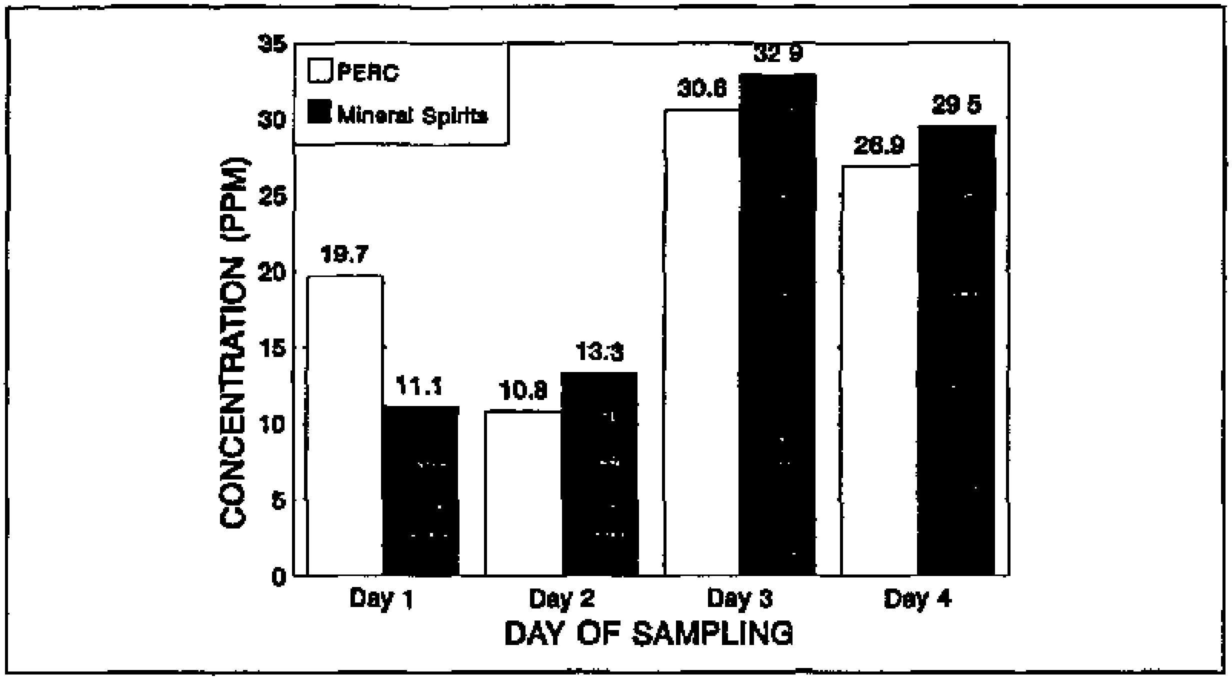

Figure 6. Operator TWA exposures to PERC and Mineral Spirits.

Results of all area air sampling can be seen in Appendix E, and Figures 7 and 8 show concentrations in front of each machine Area samples were taken throughout the dry cleaning room Area samples were taken above each of the dry cleaning machine doors because, based upon previous research, this is generally where the greatest exposures occur Samples were also taken behind the dry-to-dry machines where the secondary vapor recovery device exhausted and in two other locations within the dry-cleaning room

Among the area samples taken above the machine doors, the highest PERC concentrations were detected on samples located above the 80-pound dry-to-dry machine The highest geometric mean concentration, 87 ppm, was on the third day of sampling, above the 80-pound dry-to-dry machine Geometric mean PERC concentrations were consistently higher above the 80-pound machine than above the 70-pound machine, and there was a statistically significant difference between these concentrations On most of the days, the concentrations measured above the 80-pound machine door were two to three times greater than above the 70-pound machine door Part of this difference may be due to the proximity of the 70-pound machine to the exhaust fan A geometric mean concentration of 36 8 ppm PERC was measured on the last day of sampling behind the dry-to-dry machines, where the secondary vapor recovery device exhausted

The highest geometric mean concentrations of mineral spirits were measured above the door of the reclaimer This concentration was statistically significantly different from most other areas within the shop This was probably because the mineral spirits in the reclaimer were at a much higher

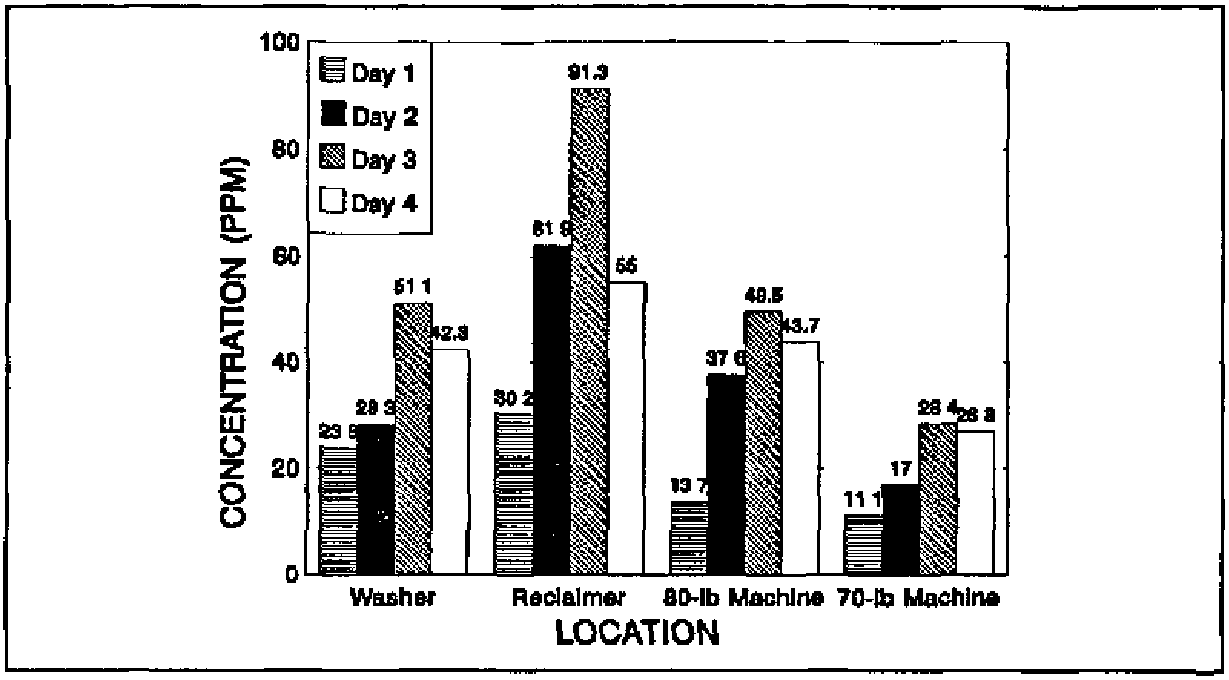

Figure 7. Geometric Means of Area Mineral Spirit Samples (ppm)

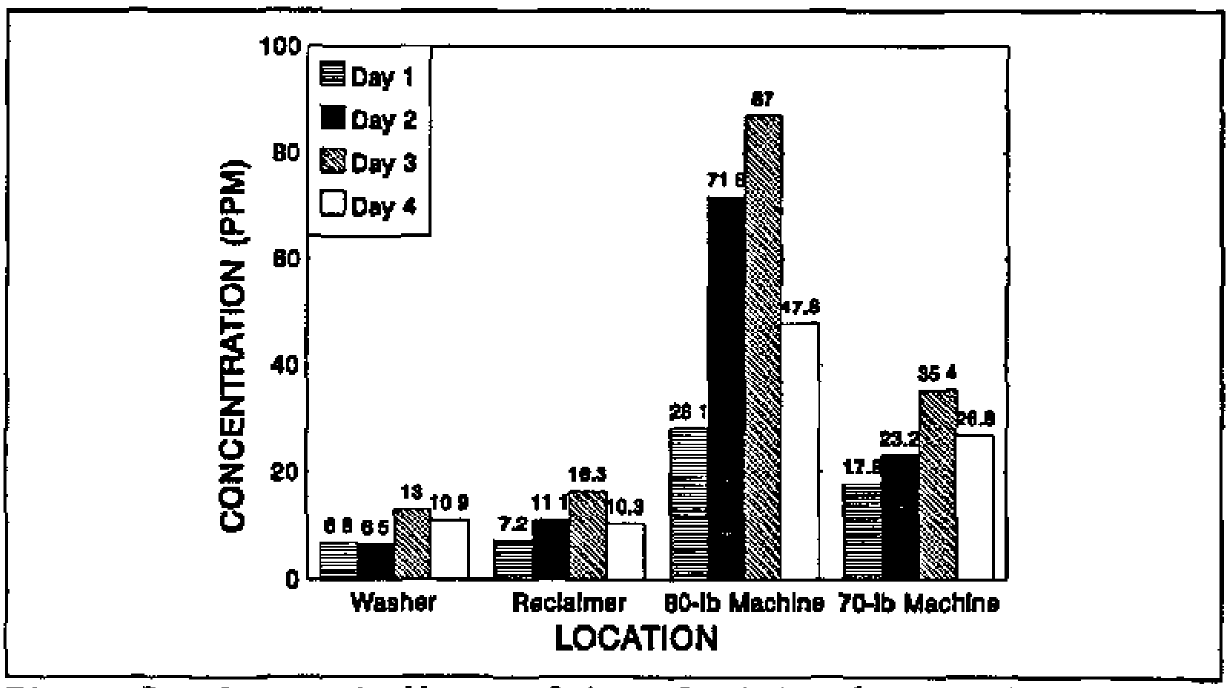

Figure 8. Geometric Means of Area PERC Samples (ppm)

temperature and in a vapor state during unloading The highest geometric mean concentration, 91 3 ppm mineral spirits, was measured on the third day of the survey The second highest concentrations were measured above the door of the washer, however, mineral spirit concentrations above the 80-pound machine door were virtually equivalent to those measured near the washer, and there was no statistically significant difference between these concentrations

Several doors leading to the solvent tank of the washer remained open throughout the day which permitted mineral spirits to vaporize into the work atmosphere A liquid leak was found around the door of the mineral spirit washer Concentrations measured in front of the machines resulted from residual gases in the cylinder escaping during unloading and loading In general, most concentrations appeared to be lowest on the first day of sampling when the smallest volume of garments were processed There was no clear relationship between exposure levels and time of the day

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 2,000 ppm

On a daily basis, the most significant source of exposure to the operator occurred during loading and unloading the machines Exposures during unloading approached full scale (2,000 ppm) for some of the PERC dry-to-dry machines More importantly, loading and unloading occurred frequently throughout the day, approximately eight times per day for each of the two dry-to-dry machines Transfers occurred approximately ten times per day Each transfer involved unloading the reclaimer, unloading the washer, loading the reclaimer and loading the washer Machine maintenance activities normally occurred only once a day per machine and some tasks, such as changing filters, occurred even less frequently

Figures 9 through 12 show real-time data during unloading, loading, and transfer from the machines During all of these activities, operator instantaneous exposure to PERC was significantly higher than to instantaneous exposure to mineral spirits This was the case in spite of the fact that the PERC machines were dry-to-dry, and the mineral spirit machines required transfer of solvent laden clothing There were two reasons why operator instantaneous exposures to PERC were higher than instantaneous exposures to mineral spirits First the vapor pressure of PERC is approximately seven times greater than the vapor pressure of mineral spirits (14 mm Hg at 68 degrees F versus 2 mm Hg at 68 degrees F) The second reasons is that when clothing from the mineral spirit washer was unloaded and transferred, the

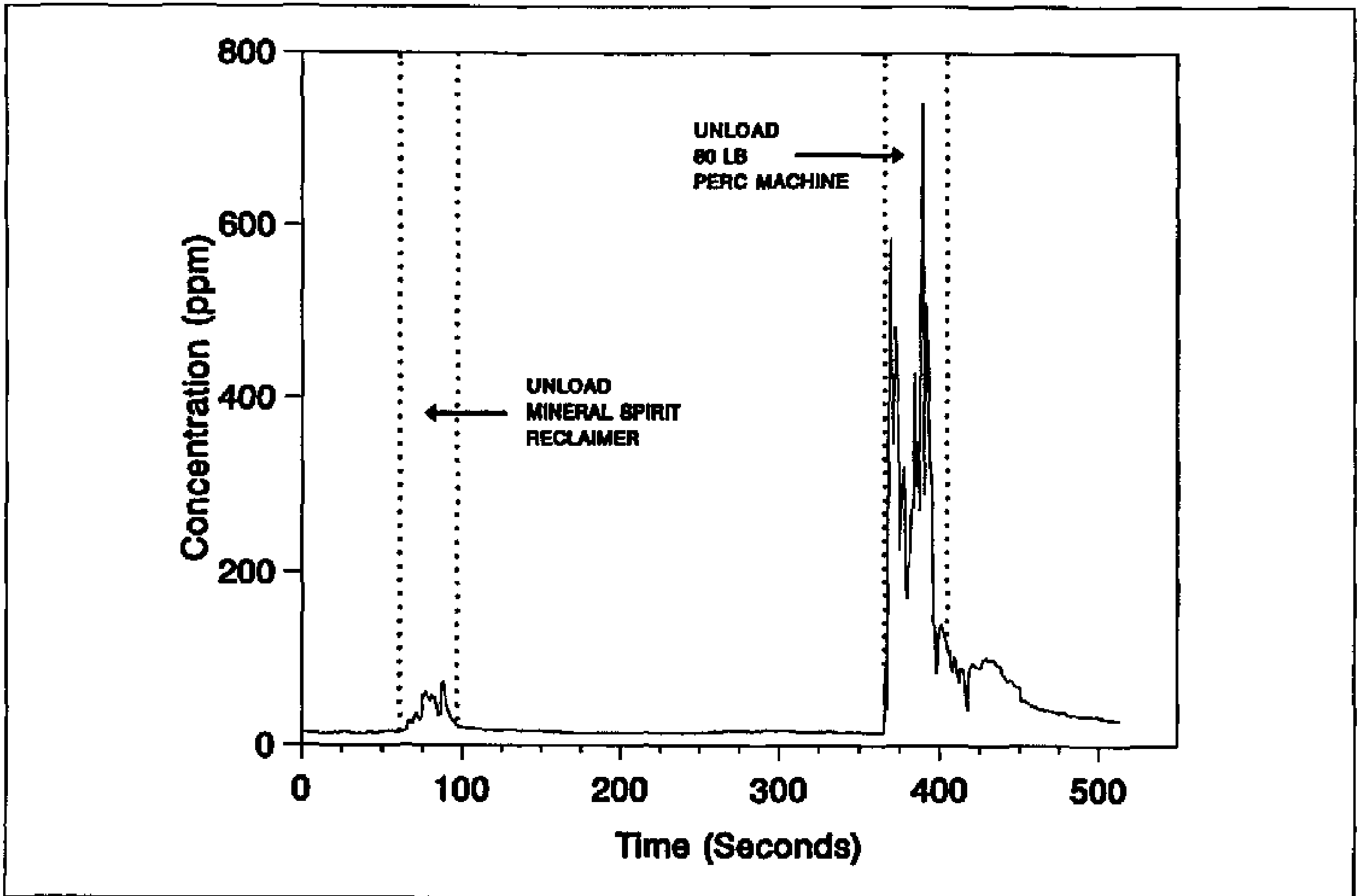

Figure 9. Exposure to mineral spirits and PERC while unloading two machines

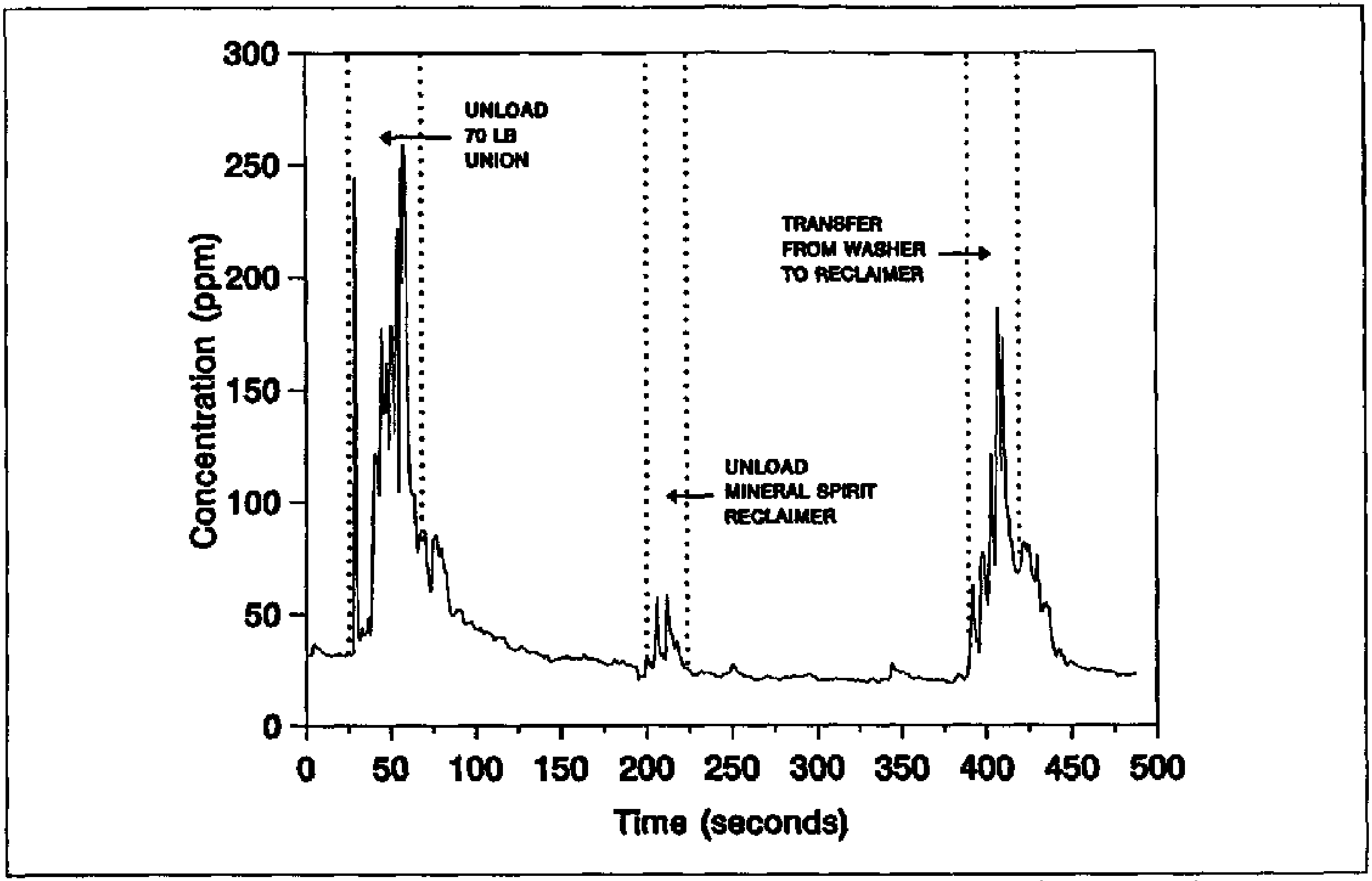

Figure 10. Exposure to PERC during unloading and exposure to mineral spirits during unloading and transfer.

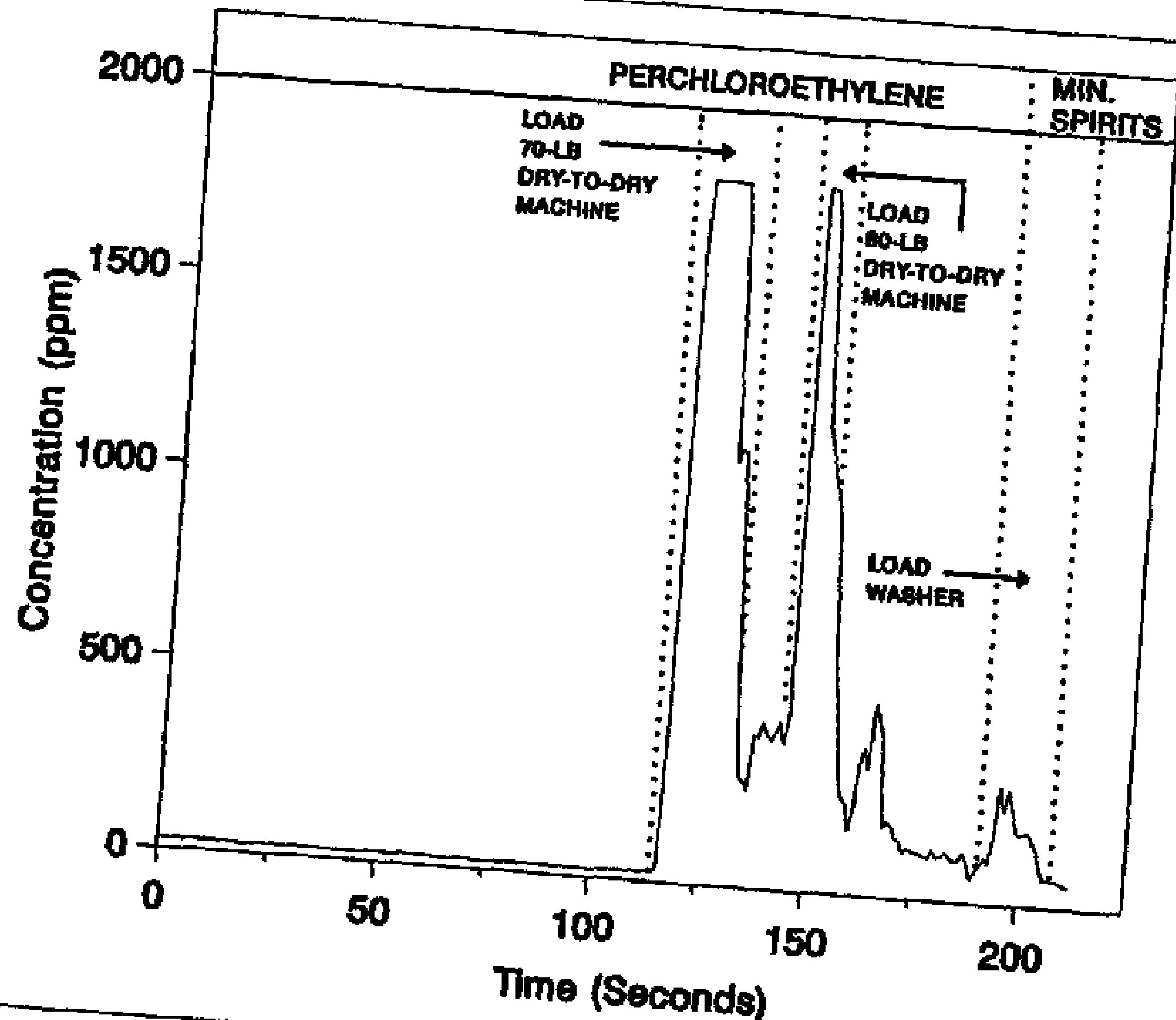

Figure 11. Exposure to PERC and mineral spirits while loading all three machines.

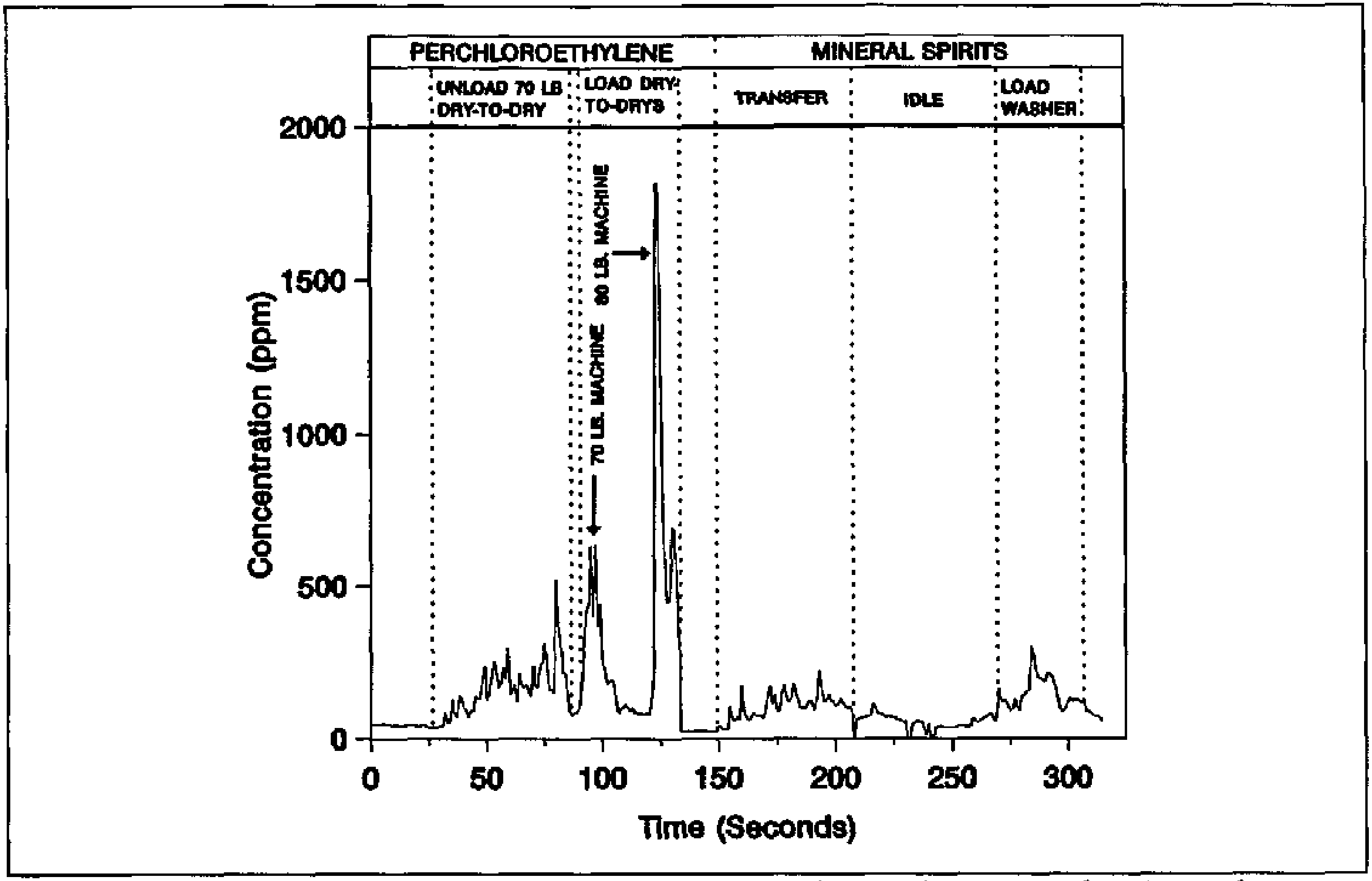

Figure 12. Exposure to PERC during unloading and loading and to mineral spirits during transfer.

mineral spirits were at approximately room temperature When the PERC machines were unloaded, the drying cycle had just ended, and the PERC in the cylinder was already in the vapor state

Figure 9 shows operator exposure during loading both dry-to-dry machines and the washer The average exposures during loading the 80-pound machine (1,317 ppm) and 70-pound machine (1,413 ppm) were relatively close However, the integrated exposure, while loading the 70-pound machine, was over twice as great because it took over twice as long to load (15 seconds versus 7 seconds)

Although instantaneous exposures to PERC were higher, the TWA exposures were relatively similar, which is clear from the air sampling results The reason for this was that loading and unloading the PERC machines occurred relatively quickly, but, transfer took more time A movement within the room also played a significant role When a dry-to-dry cycle ended, the machine could be quickly unloaded and loaded with no delay However, when the washer cycle ended, the clothing could be unloaded, but if the garments in the reclaimer still need to dry, the clothing could off-gas Part of this problem relates to the fact that the reclaimer cycle (approximately 30-35 minutes) is much longer than the washer cycle (approximately 10 minutes)

As observed during previous studies, average PERC exposure while loading the machine with dirty clothing was much higher than unloading garments that had been cleaned in PERC Instantaneous PERC exposures during loading approached 2,000 ppm, while during unloading, instantaneous exposures were less than half of that This was due to residuals being forced from the cylinder when a large quantity of uncleaned clothing was added to the empty cylinder This result indicates that the secondary control on this machine was ineffective

Although not shown with a figure, measurements taken near the carbon canister behind the machine showed that each time the machine door was opened, high concentrations of PERC were being blown into the work environment This was because the carbon in the canister was not capturing the PERC in the exhausted air The carbon canister was ineffective, due to a variety of factors Probably the most important factors were an insufficient flow rate and insufficient capacity of the carbon bed [13] A manufacturer's representative indicated that they recommend changing the small carbon canister approximately once every three months Based upon previous NIOSH in-depth studies, the quantity of activated carbon used for this type of machine would need to be changed on nearly a daily basis to be effective

Even if there was sufficient carbon in the canister and the machine operated at optimal efficiency, the PERC effluent would tend to remain in the 50-150 ppm range This concentration translates to approximately 95 to 99 percent efficiency When the working capacity of the carbon is approached, the concentration of PERC in the effluent stream increases dramatically This is called breakthrough

A general rule of thumb in dry cleaning is that one-half pound of carbon is needed to capture the PERC residuals from one load of clothing with no other recovery device [14] Carbon will absorb approximately 40 percent of its weight, and one gallon of PERC weighs approximately 13 5 pounds Additionally, the 0.25 horsepower, centrifugal fan was probably undersized for the intended purpose because it was unable to provide sufficient airflow at the machine door to prevent escape of PERC vapors

Figures 13 and 14 show worker exposure during machine maintenance on both dry-to-dry machines Machine maintenance was done on a daily basis and involved cleaning the lint and button traps and disposing of the hazardous waste Normally, the lint and button traps were cleaned at the end of the work day The lint and button traps were located behind the machines

Figure 13 shows that there was a fairly significant background level behind both dry-to-dry machines This background concentration can be attributed to exhaust from the secondary control device, located behind the machines Additionally, all of the normally used hazardous waste storage barrels were full Lint and other hazardous waste were being temporarily stored behind the machines in a cardboard cylinder The highest maintenance exposure occurred while cleaning the lint trap of the 80-pound machine The average exposure while cleaning the lint trap of the 80-pound machine was approximately 180 ppm, and the average exposure while cleaning the lint trap of the 70-pound machine was approximately 149 ppm There was no still to be cleaned on this machine

Finally, the garment off-gassing experiments are shown in Figures 15 through 17 During the cycles tested, it appeared that the 80-pound machine was most effective at recovering solvent from the garments, and the 70-pound machine was the least effective The total PERC off-gassing from the test swatch was 10 3 mg PERC/kg cloth for the 80-pound machine and 76 3 mg PERC/kg cloth for the 70-pound machine The total mineral spirits off-gassing from the test swatch that was dried in the reclaimer was 50 9 mg mineral spirits/kg cloth The quantity of PERC off-gassing from the test swatch placed in the 80-pound machine seems contradictory to results of area air sampling near the door of this machine For this reason, the low value may be due to having a smaller sized load during the individual cycle The area air sampling data is expected to be more representative than the off-gassing results because of the greater quantity of data

VENTILATION MEASUREMENTS

Ventilation on the dry-to-dry, dry-cleaning machines' doors at this shop was minimal Measurements, taken with a Kurz® hot-wire anemometer, did not show an appreciable inward air velocity at the face of the dry-to-dry machine doors 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 80-pound machine had a door face velocity of approximately 20 fpm and total air flow of approximately 170 cubic feet per minute (cfm) The 70-pound machine had a door face velocity of approximately 17 fpm and total air flow of approximately 140 cfm. Air drawn in through the open machines' doors was exhausted behind the machines

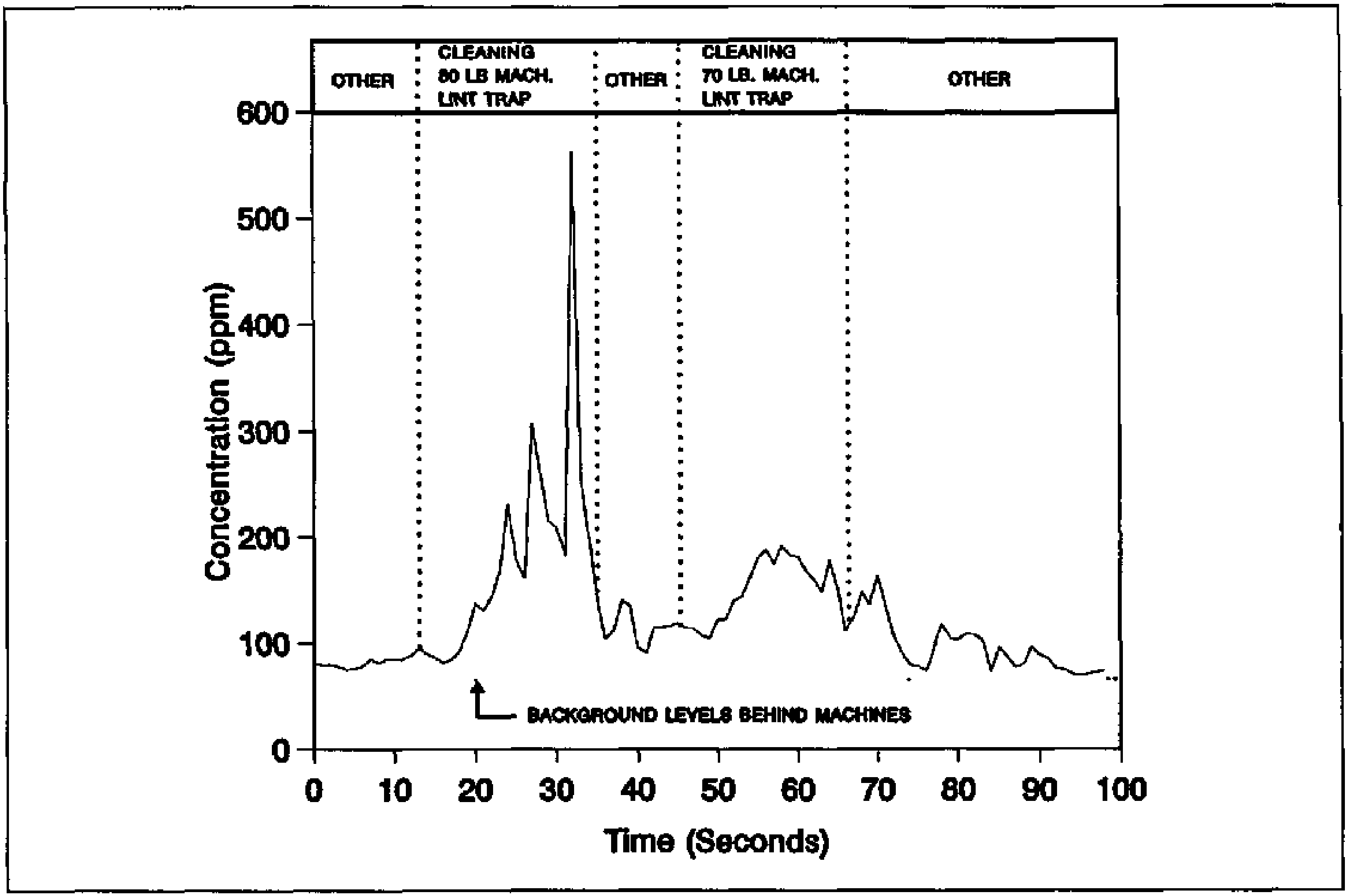

Figure 13 Exposure to PERC while cleaning lint traps

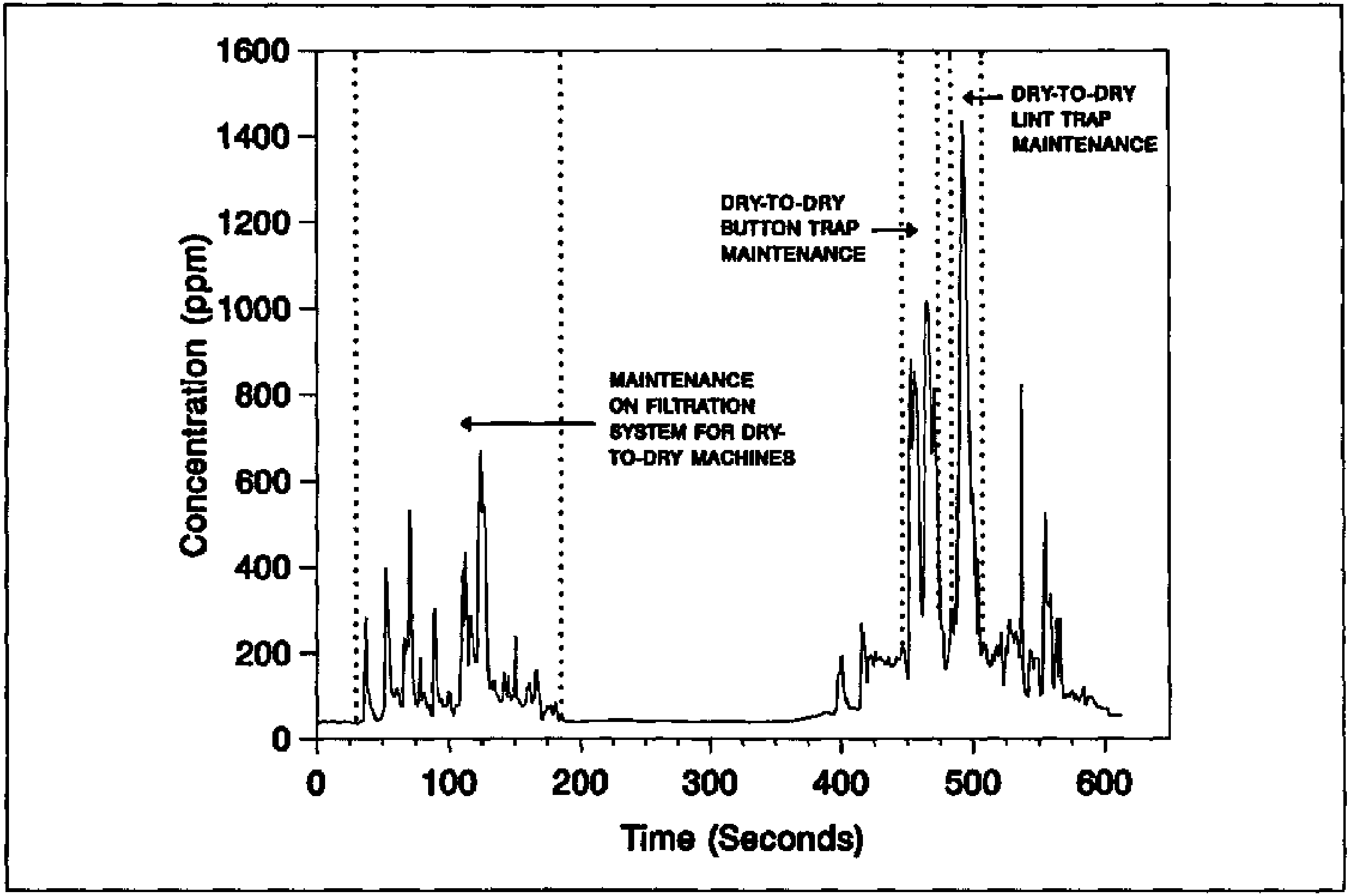

Figure 14. Exposure to PERC during machine maintenance activities.

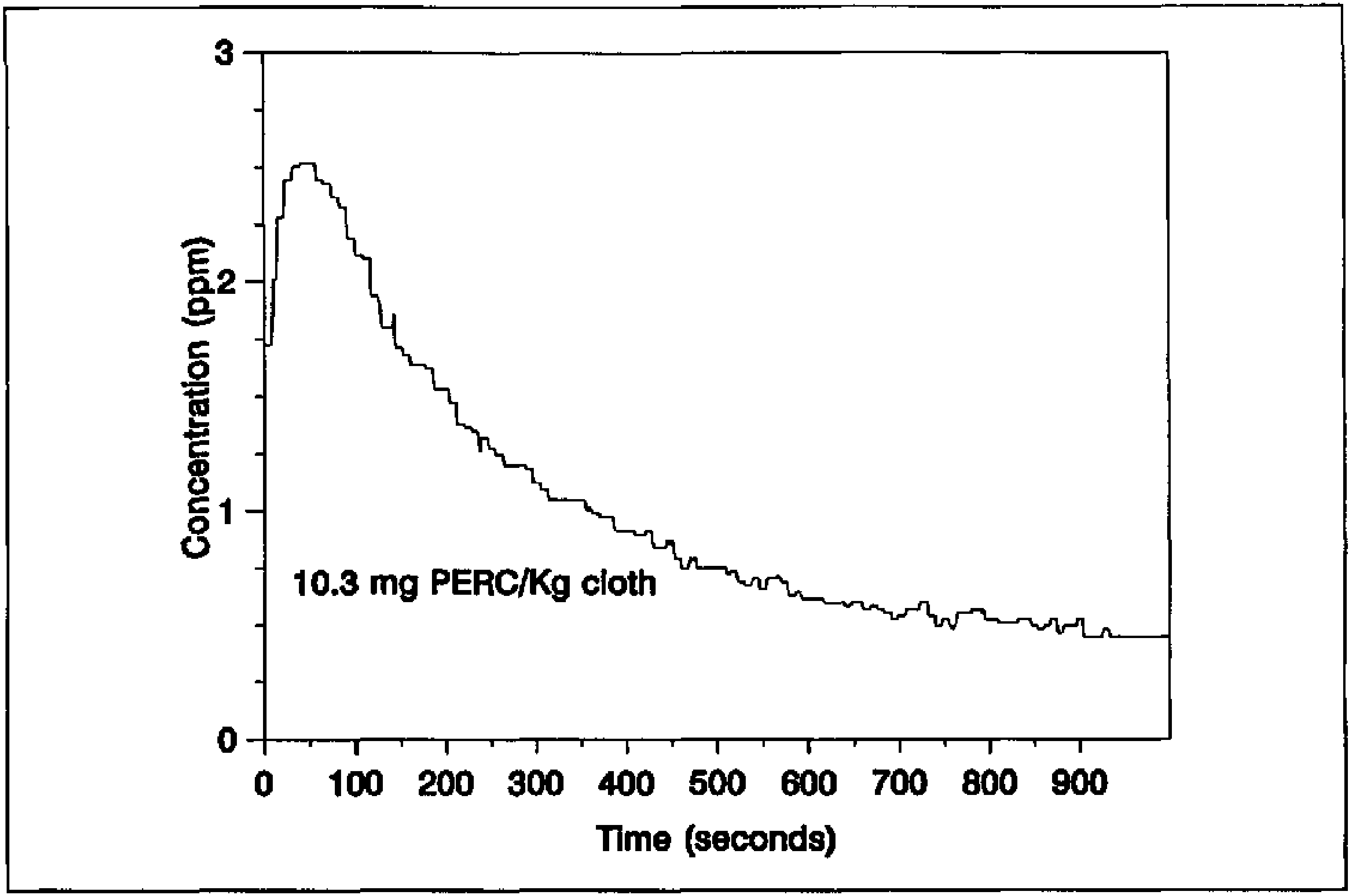

Figure 15. Typical off-gassing of PERC from test swatch from 80-pound machine.

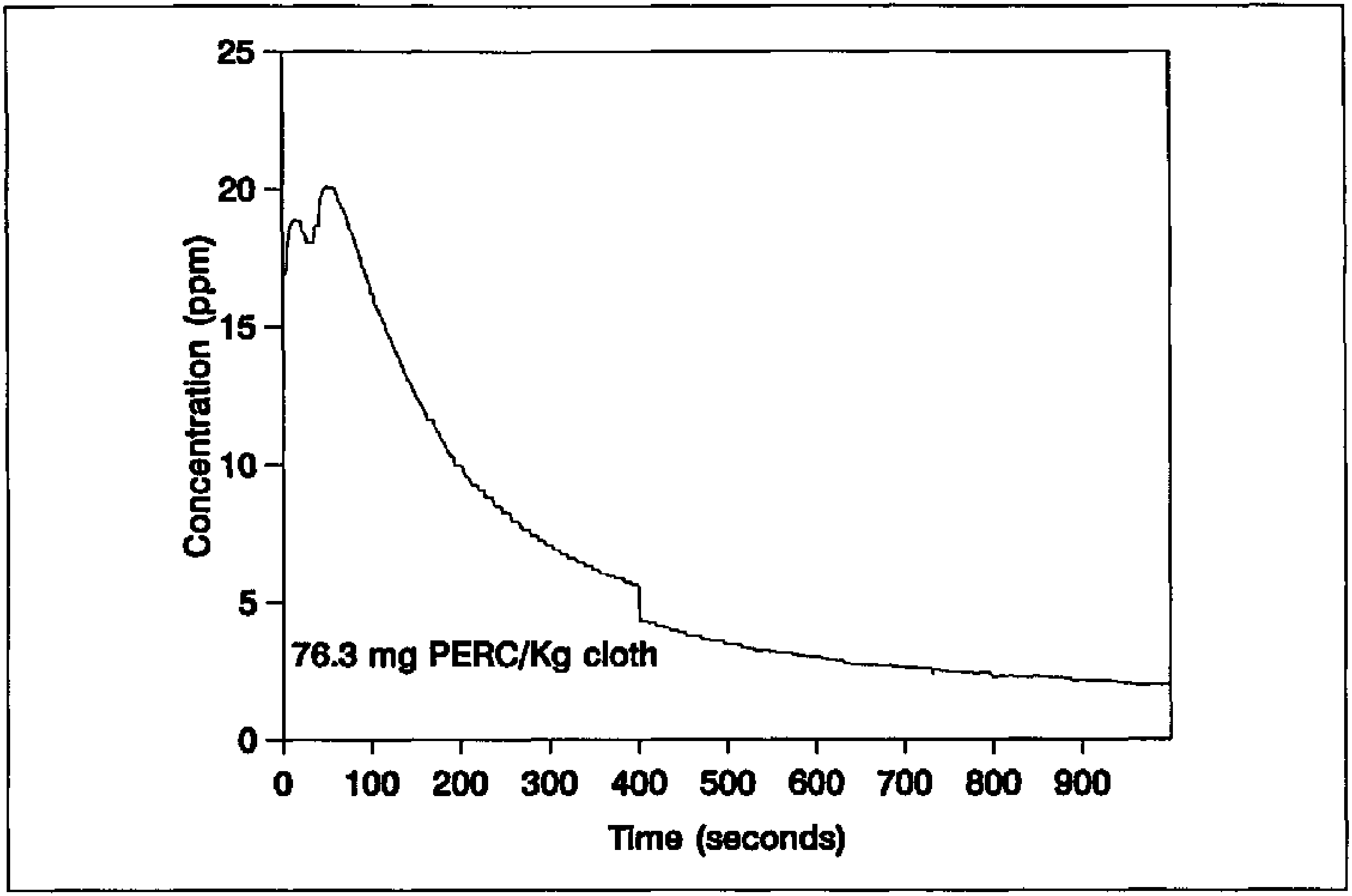

Figure 16. Typical off-gassing of PERC from test swatch from 70-pound machine.

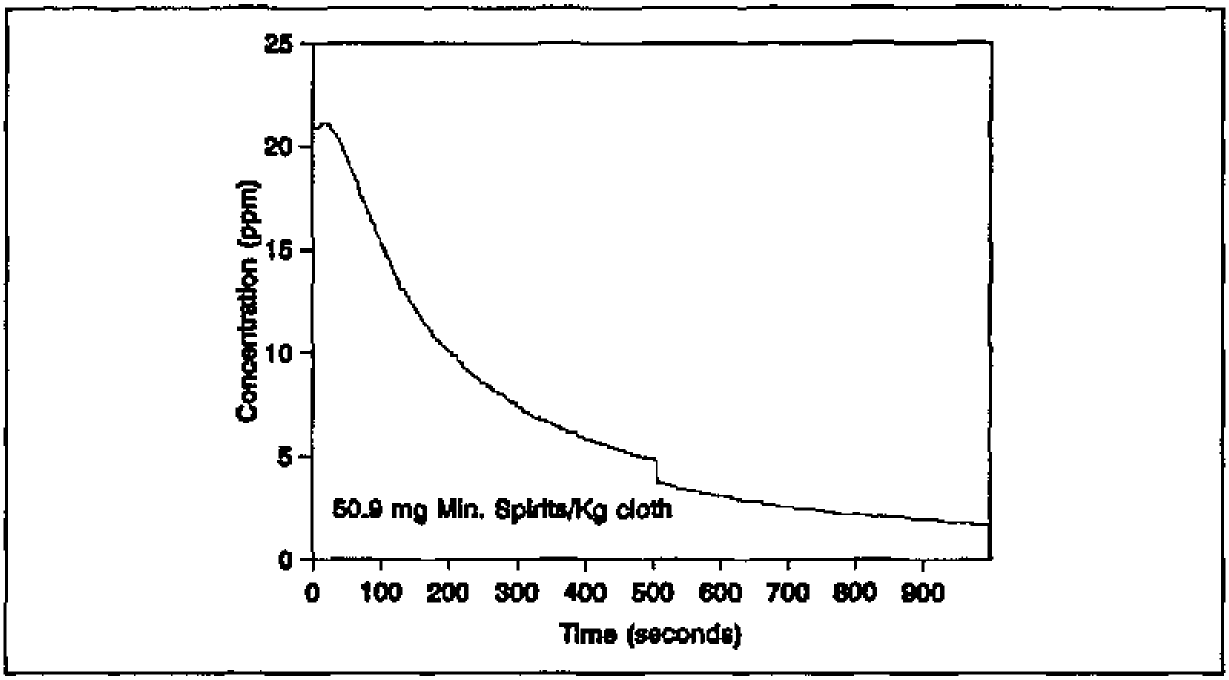

Figure 17. Typical off-gassing of mineral spirits from test swatch from reclaimer

The mineral spirit washer had no internal ventilation system However, the reclaimer had a fan which drew significant inward air flow at the face of the door Air velocity was approximately 170 fpm, and airflow was approximately 1,800 cfm This air was exhausted just above the roof line

A mass airflow balance was performed for the dry cleaning room Multiple air velocity measurements were taken approximately 6 inches in front of the wall fan, air handling unit vents, and the two openings leading to the rest of the shop Although the air handling unit was not operating, a significant amount of air was being drawn into the room through these vents Based upon results, air may have escaped from the room through leaks in the structure Air entering the room through the rear fire door was short circuited and exhausted by the wall fan Results of the air velocity measurements can be seen in the Table 3

Smoke tubes used in and around the dry cleaning machines indicated that there was very little air movement, however, some of the mineral spirits migrated towards the dry-to-dry machines Because much of the air was stagnant near the dry cleaning machines, this may have increased worker exposures to both PERC and mineral spirits originating from the machines Some of the air originating from the machines was able to escape to other areas of the shop through the fire door leading towards the alterations area

Table 3 Dry cleaning room airflow balance

LOCATION	SUPPLY (cfm)	EXHAUST (cfm)
Wall fan		5,300
Air handling unit	4,400	
Front fire door		1,100
Rear fire door	4,500	
Totals	8,900	6,400

OBSERVATIONS

The shop owner expressed a strong desire to comply with appropriate health and safety and environmental regulations, however, he stated that these were often difficult to follow because of their quantity and complexity There were a number of problems noted with maintenance and housekeeping A liquid mineral spirit leak was noted on the door of the washer Real-time measurements determined that the secondary vapor recovery device on the 70-pound dry-to-dry machine was not functioning properly Additionally, the operator indicated that at certain times the extraction cycle on the 70-pound machine was not functioning properly When these problems came to the attention of the owner, he quickly acted to address the problems

Hazardous waste storage barrels were located behind the washer in the dry cleaning room Because these barrels were filled to capacity, the machine operator temporarily stored hazardous waste in an unapproved cardboard container behind the dry-to-dry machines It was apparent that the cardboard had become saturated from solvent that was retained in the hazardous waste There were a number of locations within the dry cleaning room where mineral spirits remained open to the atmosphere and were able to vaporize This increased background levels of mineral spirits in the air and added to worker exposure Areas where mineral spirits were open to the atmosphere included two locations on the washer, an open barrel used for waterproofing, and a 5 gallon bucket used to catch mineral spirits recovered by the reclaimer

It was unclear whether an established smoking policy existed in this shop Several times throughout the week a worker passed through the dry cleaning room with a lit cigarette The owner indicated that he was planning on instituting either a no smoking policy or a policy which would restrict smoking to the break room

PERSONAL PROTECTIVE EQUIPMENT

There was no personal protective equipment used by the machine operator during this survey The operator indicated that at certain times he would wear a dust mask while working near the dry cleaning machines A first aid kit was located on the rear wall of the dry cleaning room where a half-face respirator with organic vapor cartridges and gloves were kept

CONCLUSIONS AND RECOMMENDATIONS

Controls at A-One Cleaners maintained full-shift TWA exposures to PERC and mineral spirits below the OSHA permissible exposure limits (PEL) However, operator, full-shift, TWA PERC exposures exceeded 25 ppm on two days Twenty-five ppm is the exposure limit that OSHA encourages dry cleaners to remain beneath NIOSH recommends controlling PERC to the lowest feasible concentration The highest TWA personal exposures to both PERC and mineral spirits occurred to the machine operator followed by the spotter

The primary sources of worker exposures to solvents in this shop were the dry cleaning machines Air sampling results demonstrated that the greatest concentrations of solvent were directly above the machine doors Real-time evaluation showed that loading and unloading of the machines had a major impact upon operator exposure, and in order to reduce exposures, emissions during loading and unloading should be better controlled Comparing the total TWA exposure to PERC during the day and total exposure due to loading and unloading, it appears that the operators exposure could be reduced nearly 65 percent by control of loading and unloading

Local exhaust ventilation could be used to significantly reduce exposures during loading and unloading On the dry-to-dry machines this could occur by modifying the current secondary vapor recovery device with a larger fan or carbon bed These changes would increase the airflow and reduce residuals escaping from the loading door, or improve PERC capture efficiency by providing more carbon Ducting the exhaust outside of the work environment would reduce background concentrations of PERC

A simpler option is to add inexpensive, external local ventilation system with a separate 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 [15]

Process isolation is another option to reduce worker exposure The majority of solvent emissions originate from the dry cleaning machines Isolating employees by either time or space will reduce exposures to the employee The owner should take a critical look at who is working inside the dry cleaning room and whether it is necessary for them to work there Minimizing the amount of time workers spend in the dry cleaning room would reduce exposure Because the dry cleaning room was the only internal route between the northern-half and southern half of the shop, many workers passed through this room who may not have had need to do so.

As machines age, leaks may develop and should be repaired promptly Proper maintenance is instrumental to reducing leakage Liquid leaks are more easily seen if proper maintenance and housekeeping is performed on a regular interval Lint and button trap residue should be immediately placed in a hazardous waste container At the beginning of the survey all of the hazardous waste storage barrels were full, and hazardous waste was improperly stored in a cardboard container. Hazardous waste should be stored in approved, leak-resistant, hazardous waste storage barrels Sufficient storage barrels should be available at all times to contain the hazardous waste that is produced

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 Occupational exposure could be further reduced through the proper use of respiratory protection

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.

- o a written standard operating procedure
- o respirator selection based upon hazards
- o instruction and training of the user concerning the proper use and limitations of respirators
- o regular cleaning, disinfection, and proper storage
- o medical review of the health and condition of the respirator user
- o use of certified respirators which have been designed according to standards established by competent authorities [16]

Proper respirators and gloves should be used during machine maintenance by the operator Gloves and goggles should be used to reduce exposure to hazardous chemicals such as PERC Gloves provide limited dermal protection and should be made of solvent resistant materials, such as Viton® fluoroelastomer, polyvinyl alcohol, or unsupported nitrile When a specific glove is chosen, factors such as permeation, durability, dexterity, and cost should be considered Viton® and polyvinyl alcohol have a PERC breakthrough time in excess of eight hours [17] A 1987 study showed that unsupported nitrile was impervious to PERC after a two-hour challenge period [18] 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

Based upon observations and review of pertinent fire codes, the following recommendations are offered to reduce the risk of fire A "No Smoking" policy should be established that restricts smoking to the break room or completely eliminates smoking within the building No smoking signs should be posted as appropriate [19,20]

The side-swinging hinged door, located between the dry cleaning room and the small room with the chiller, should be removed and replaced with either concrete block or a door with a greater fire resistance rating The door is not functional and has only a 1-hour fire resistance rating The dry cleaning room must be separated from the rest of the building by a wall with a 2-hour fire resistance rating.[21] The overhead rack which runs through the fire door on the north side of the building should be removed so that the door may be closed in the event of a fire

All open containers which contain mineral spirits should be closed to the atmosphere (ie washer tank, waterproofing barrel, water separator run-off from the reclaimer) The mineral spirits that flow from the water separator to the open bucket on the floor should be removed and the mineral spirits should be pumped directly to the washer [22,23] Rigid iron or steel pipe should be installed which transports mineral spirits from the underground storage tank directly to the tank of the washer [24,25]

The primary life safety feature of an industrial occupancy is an automatic sprinkler system At minimum, an approved wet-pipe sprinkler system should be installed in the dry cleaning room Automatic sprinkler systems have proven effective in preventing loss of life and controlling the spread of fire [26] Fire Codes indicate that the washer should have an integral, automatic carbon dioxide extinguishing system [27,28] Management should consider retrofitting an extinguishing system, or if the washer is to be replaced soon, the new washer should have an extinguishing system

Controls at this facility were capable of maintaining solvent exposures below the OSHA PEL for PERC and mineral spirits Control methods discussed previously could aid in reducing exposures further There were a number of areas where this shop was not in compliance with current fire codes Because A-One Cleaners has been in operation prior to the adoption of many recent codes, they were grandfathered and are not required to comply with many provisions in recent codes In spite of this, code compliance would reduce the risk of property damage, injury, or death due to fire Code compliance may also provide the benefit of reducing property insurance premiums

APPENDICES

APPENDIX A POTENTIAL HAZARDS

The two primary hazards in this dry cleaning shop were the fire hazard primarily from the use of mineral spirits and the health effects related to exposure to both PERC and mineral spirits Mineral spirits is a class II, combustible liquid with a flash point of 120 degrees Fahrenheit Its lower explosive limit is 0.7 percent or 7,000 ppm PERC is nonflammable, however, if it is heated sufficiently, thermal decomposition will result in the formation of hydrogen chloride and phosgene gases

Exposure to the products of combustion present numerous hazards to humans Most prominent among these are effects from heat, impaired vision due to smoke density or eye irritation, narcosis from inhalation of asphyxiants, and irritation of the upper or lower respiratory tracts These effects often occur simultaneously during a fire and may contribute to physical incapacitation, loss of motor coordination, faulty judgement, disorientation, restricted vision and panic Smoke and gases are responsible for approximately 70 percent of deaths during a fire [29]

Carbon monoxide is generally the most abundant toxic gas produced during a fire Carbon monoxide is produced in an accidental fire when some of the carbon present in organic materials is incompletely oxidized Due to the large number of textiles present in this facility, the production of hydrogen cyanide gas is another cause for concern during a fire Hydrogen cyanide is produced from burning materials that contain nitrogen Nitrogen is present in natural and synthetic materials such as wool, silk, acrylonitrile polymers, and nylons Hydrogen cyanide is a rapidly acting toxicant which is approximately 20 times more toxic than carbon monoxide [30]

At A-One Cleaners, the primary oxidizing agent was the air in and outside of the building Potential combustible materials included portions of the building itself, furniture, garments, lint, and combustible liquids such as mineral spirits Sources of ignition at this facility were heat energy produced primarily from chemical, electrical, and mechanical energy This heat energy could occur in the forms of a burning or smoldering cigarette, heat transfer from heated equipment on or near a press, friction due to moving parts, a frictional spark inside the reclaimer cage, or even static electricity that may build up within the reclaimer

PERC is a more toxic chemical than mineral spirits Sufficient quantities of mineral spirits can cause central nervous system depression Symptoms include inebriation followed by headache and nausea In severe cases, dizziness, convulsions, and unconsciousness occasionally result [31]

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 [2] 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 may 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 may 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. 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 B
HEAT LOADING

Table 4 Heat Loading (First Floor)

Room	Name	Heat Content (x10^6 Btu)	Area (Sq ft)	Fire Load (Btu/sq ft)
1	Offices	8	900	8,888 9
3	Shirt Presses	2 88	1584	1,818 2
4	Shirt Laundry	2 88	324	8,888 9
5	Under Construction	6 4	450	14,222
6	Chiller	1 6	180	8,888 9
7	Dry cleaning Room	78	729	106,995 9
8	Dry cleaning Press	5 44	1224	4,444 4
9	Tagging	8	720	33,333
10	Clothing storage I	33 4	1053	31,718 9
11	Break Room	4	225	17,777 8
12	Clothing Storage II	28	810	54,321
Total		183 2	8,523	21,484 8

(Basement)

Room	Name	Heat Content	Area	Fire Load
1	Boiler Room	None	486	None
2	Storage	12	486	24,691
Total		12	972	12,345 6

Heat of Combustion (approximate values)

(1) Wood 8000 Btu/lbs
(2) Mineral Spirits 20,000 Btu/lbs
(3) Paper 7000 Btu/lbs
(4) Garments 8000 Btu/lbs

Garment Load Calculations

10,000 shirts/week x 1 wk/7 days x 3 days x .5 lbs/shirt = 2,143 lbs of shirts in the building at a time

Unions	60 lb load x 2 machines x 8 loads/day	= 960 lbs
Marvel	40 lb load x 10 loads/day	= 400 lbs
		1,360 lbs/day

1,360 lbs/day x 3 days = 4,080 lbs of dry-cleaned clothing in building at a time

3,500 lbs of smoke damaged items at a time

Distribution

shirts	2/3 in clothing storage area	= 1,450 lbs shirts
	1/6 in shirt laundry area	= 360 lbs
	1/6 in shirt pressing area	= 360 lbs
dry cleaning		
	2/3 in clothing storage area	= 2,720 lbs
	1/6 in dry-cleaning room	= 680 lbs
	1/6 in dry-cleaning press area	= 680 lbs

APPENDIX C
EGRESS CALCULATIONS

TRAVEL DISTANCE

Average Recommended Maximum Travel Distance for an unsprinklered, high hazard, industrial occupancy   75 ft

Available Maximum Travel Distance
    For the first floor   Around 30 ft
    For the basement   Around 25 ft

Observation   The available travel distance to an exit is adequate

OCCUPANCY LOAD

Maximum Allowable Occupancy Load
    For Industrial Occupancy   100 ft^2/person

Present Occupancy Load
    For the first floor   8,523 ft^2/38 people= 224 ft^2/person
    For the basement   None

Observation   The present occupancy load is adequate.

EXIT CAPACITY

Available exits
    First Floor   Nine (Seven with an exit width of 2 5 ft and two with 5 0 ft)
    Basement   None

Capacity
    First floor   (7 doors x 30 inches + 2 doors x 60 inches)/ 2 = 1,650
    Basement   None

Actual Occupancy   approximately 38 people

Observation   The exiting capacity is much greater than required by NFPA 101

APPENDIX D
FIRE EXTINGUISHERS

TABLE 5 Fire Extinguishers

Location	Type	Capacity (lbs)	Date inspected
1	2A40BC Halon	13	January 95
2	2A40BC Halon	22	January 95
3	2A40BC Halon	22	January 95
4	2A10BC Badger	5	January 95
5	LL10F60 ABC	5	January 95
6	2A40 BC	10	January 95
7	2A40BC Halon	13	January 95
8	10BC Halon	10	January 95
9	4A60BC	10	January 95
10	Badger 2A10BC	5	January 95
11	Amerex 2A10BC	5	January 95
12	2A10BC Stfire	7	January 95
13	4BC CO2	5	January 95
14	10A60BC	5	January 95
15	2A10BC	18	January 95

APPENDIX E RAW AIR SAMPLING AND REAL-TIME DATA

Table 6 Area Sample Concentrations of Perchloroethylene and Mineral Spirits

Area	Location (Fig 1)	Day	Total Sample Time (min)	PERC Geo Mean (ppm)	PERC GSD (ppm)	PERC Range (ppm)	MS Geo Mean (ppm)	MS GSD (ppm)	MS Range (ppm)
Table	6	1/24	531	4 1	2 4	1 9-18 6	4 0	1 2	3 4-5 4
Washer	1	1/24	547	6 8	1 1	6 2-7 5	23 8	1 1	21 4-24 9
Reclaimer	2	1/24	525	7 1	1 3	3 6-10 5	30 2	1 6	14 6-63 5
Union (80-lb)	3	1/24	543	28 1	1 6	16 9-47 1	13 7	1 5	10 0-26 8
Union (70-lb)	4	1/24	523	17 8	1 3	14 4-27 9	11 1	1 3	8 7-17 9
Fan	5	1/24	533	12 8	1 2	10 3-16 6	7 4	1 4	6 1-12 7
Table	6	1/25	525	5 6	1 8	4 1-8 4	9 6	1 4	6 8-13 8
Washer	1	1/25	527	6 5	1 3	5 3-8 4	28 3	1 2	23 0-37 6
Reclaimer	2	1/25	529	11 1	1 3	7 9-16 3	61 9	1 8	33 4-133 9
Union (80-lb)	3	1/25	533	71 8	2 2	25 0-217 6	37 6	1 8	15 9-85 2
Union (70-lb)	4	1/25	531	23 2	1 4	16 1-36 3	17 0	1 4	10 1-22 5
Fan	5	1/25	525	10 5	1 3	4 0-18 9	12 0	1 3	8 8-17 2
Table	6	1/26	518	9 3	1 4	6 3-13 9	14 6	1 5	9 1-28 3
Washer	1	1/26	522	13 0	1 3	9 5-16 8	51 1	1 2	42 0-67 9
Reclaimer	2	1/26	521	16 3	1 2	12 8-10 4	91 3	1 3	65 8-132 5
Union (80-lb)	3	1/26	517	87 0	1 8	40 3-170 6	49 3	1 4	24 7-64 0
Union (70-lb)	4	1/26	516	35 4	1 3	27 7-48 3	28 4	1 3	19 1-39 6
Fan	5	1/26	517	23 1	1 1	20 9-24 2	19 1	1 4	14 9-34 0
Table	6	1/27	449	5 7	1 4	3 3-8 2	13 2	1 2	10 6-18 4
Washer	1	1/27	462	10 9	1 3	7 9-15 7	42 3	1 0	41 3-43 4
Reclaimer	2	1/27	460	10 3	1 3	7 2-13 1	55 0	1 3	39 8-77 3
Union (80-lb)	3	1/27	461	47 8	1 4	29 0-67 2	43 7	1 1	39 8-47 3
Union (70-lb)	4	1/27	460	26 8	1 7	12 5-47 4	26 8	1 1	23 5-29 1
Fan	5	1/27	449	16 8	1 5	9 0-27 4	20 0	1 2	14 3-25 3
Behind Union	10	1/27	460	36 8	1 3	25 3-52 0	33 4	1 1	29 1-36 4

DATE	TYPE	LOCATION	TIME (min)	PERCONC (ppm)	LNPERC (PPM)	MSCONC (ppm)	LNMS (PPM)
01/24/95	PERSONAL	SPOTTER	121 00	5 24	1 66	10 61	2 36
01/24/95	PERSONAL	OPERATOR	120 00	20 89	3 04	10 70	2 37
01/24/95	PERSONAL	MGR T	131 00	2 14	0 76	6 07	1 80
01/24/95	AREA	MARVEL	123 00	6.23	1 83	24.85	3 21
01/24/95	AREA	HOYT	122 00	10 52	2 35	63 46	4 15
01/24/95	AREA	UNION CORNEI	122 00	47 14	3 85	11.86	2 47
01/24/95	AREA	UNION FAN	121 00	15 84	2.76	10 44	2 35
01/24/95	AREA	FAN	120 00	10 32	2 33	6 28	1 84
01/24/95	AREA	TABLE	122 00	1 93	0 66	3.51	1 25
01/24/95	AREA	OFFGASSING	48 00	0 25	−1 38	1 78	0 58
01/24/95	PERSONAL	SPOTTER	120 00	4 92	1 59	9 34	2 23
01/24/95	PERSONAL	OPERATOR	120 00	14.75	2 69	10 70	2 37
01/24/95	PERSONAL	MGR T	128 00	0 63	−0 46	0 32	−1.14
01/24/95	AREA	MARVEL	124 00	6 18	1 82	21 36	3 06
01/24/95	AREA	HOYT	123 00	5 63	1.73	16 57	2 81
01/24/95	AREA	UNION CORNEI	123 00	17 98	2 89	11 10	2 41
01/24/95	AREA	UNION FAN	123 00	14 39	2 67	9 28	2 23
01/24/95	AREA	FAN	123 00	11 39	2 43	6 29	1.84
01/24/95	AREA	TABLE	121 00	2 44	0 89	3 87	1 35
01/24/95	AREA	OFFGASSING	27 00	0 36	−1 02	0 38	−0 97
01/24/95	PERSONAL	SPOTTER	146 00	5.35	1 68	9.77	2 28
01/24/95	PERSONAL	OPERATOR	122 00	22 97	3 13	12 19	2 50
01/24/95	PERSONAL	MGR T	146.00	1 52	0 42	1 81	0 60
01/24/95	AREA	MARVEL	131 00	7.32	1 99	24 89	3 21
01/24/95	AREA	HOYT	131 00	6 64	1 89	26 44	3.27
01/24/95	AREA	UNION CORNEI	131 00	16 89	2 83	9 95	2 30
01/24/95	AREA	UNION FAN	131 00	15 76	2 76	8 71	2 16
01/24/95	AREA	FAN	130 00	13 61	2 61	6 11	1 81
01/24/95	AREA	TABLE	127 00	18 58	2 92	3 37	1 21
01/24/95	AREA	OFFGASSING	131 00	0.00	ERR	0 00	ERR
01/24/95	PERSONAL	SPOTTER	92 00	6 57	1 88	10 63	2 36
01/24/95	PERSONAL	OPERATOR	148 00	19 93	2 99	10 88	2 39
01/24/95	AREA	MARVEL	169 00	7.50	2 02	24 11	3 18
01/24/95	AREA	HOYT	149.00	6 73	1.91	30.08	3 40
01/24/95	AREA	UNION CORNEI	167 00	43 27	3 77	26 84	3 29
01/24/95	AREA	UNION FAN	148 00	27 90	3 33	17.90	2.88
01/24/95	AREA	FAN	160 00	16.59	2.81	12 73	2 54
01/24/95	AREA	TABLE	161 00	3 30	1 19	5.44	1.69
01/25/95	AREA	MARVEL	123 00	5 28	1 66	24 85	3 21
01/25/95	AREA	HOYT	143 00	16 50	2 80	133.93	4.90
01/25/95	AREA	UNION CORNEI	149 00	83 14	4.42	38 29	3 65
01/25/95	AREA	UNION FAN	154 00	26.81	3.29	18 52	2 92
01/25/95	AREA	FAN	148 00	18 93	2 94	13 22	2 58
01/25/95	AREA	TABLE	150 00	8 36	2 12	10 59	2 36
01/25/95	PERSONAL	OPERATOR	135 00	16 39	2 80	11 77	2 47
01/25/95	PERSONAL	MGR S	132 00	4 36	1 47	5 09	1 63
01/25/95	PERSONAL	LAUNDRY WKR	119 00	6 69	1 90	6 51	1.87
01/25/95	AREA	MARVEL	124 00	5 47	1.70	23 00	3 14
01/25/95	AREA	HOYT	126 00	11.47	2 44	85 70	4 45

DATE	TYPE	LOCATION	TIME (min)	PERCONC (ppm)	LNPERC (PPM)	MSCONC (ppm)	LNMS (PPM)
01/25/95	AREA	UNION CORNEI	124.00	24 97	3 22	15 94	2 77
01/25/95	AREA	UNION FAN	119 00	16.11	2 78	10 10	2 31
01/25/95	AREA	FAN	127 00	13 93	2.63	8 82	2 18
01/25/95	AREA	TABLE	126 00	6 32	1.84	6.79	1 92
01/25/95	PERSONAL	OPERATOR	118 00	12 12	2.50	8 63	2 16
01/25/95	PERSONAL	MGR S	117 00	9 71	2.27	9 40	2 24
01/25/95	PERSONAL	LAUNDRY WKR	114 00	5.56	1.72	4 65	1.54
01/25/95	AREA	MARVEL	123 00	6 47	1.87	29 82	3 40
01/25/95	AREA	HOYT	122 00	7 86	2 06	33 40	3 51
01/25/95	AREA	UNION CORNEI	122 00	217 57	5 38	85.17	4 44
01/25/95	AREA	UNION FAN	122 00	36.26	3 59	20 04	3 00
01/25/95	AREA	FAN	120 00	11 55	2 45	10 19	2.32
01/25/95	AREA	TABLE	120 00	4 55	1 51	7 47	2 01
01/25/95	PERSONAL	OPERATOR	139 00	8.49	2 14	7 62	2 03
01/25/95	PERSONAL	MGR S	122 00	9 43	2 24	14 36	2 66
01/25/95	PERSONAL	LAUNDRY WKR	121 00	3 90	1 36	4 88	1 59
01/25/95	AREA	MARVEL	157 00	9 39	2 24	37 64	3 63
01/25/95	AREA	HOYT	138 00	10 04	2 31	38 39	3 65
01/25/95	AREA	UNION CORNEI	138 00	58 77	4 07	38 39	3 65
01/25/95	AREA	UNION FAN	136.00	18 43	2 91	22 47	3 11
01/25/95	AREA	FAN	130 00	3 97	1.38	17 24	2 85
01/25/95	AREA	TABLE	129 00	4 12	1 41	15 79	2 76
01/25/95	PERSONAL	OPERATOR	114 00	5 43	1 69	26 81	3 29
01/25/95	PERSONAL	MGR S	77 00	9 00	2 20	34 40	3 54
01/25/95	PERSONAL	LAUNDRY WKR	119 00	4 34	1.47	15 92	2 77
01/26/95	AREA	MARVEL	123 00	16 78	2 82	56 32	4 03
01/26/95	AREA	HOYT	123.00	20.38	3 01	132 52	4 89
01/26/95	AREA	UNION CORNEI	124 00	142 71	4 96	60 80	4 11
01/26/95	AREA	UNION FAN	125 00	42 47	3 75	29 34	3 38
01/26/95	AREA	FAN	124 00	23 78	3 17	16 43	2 80
01/26/95	AREA	TABLE	127 00	13 93	2 63	15 72	2 76
01/26/95	PERSONAL	OPERATOR	123 00	28 77	3 36	28 16	3 34
01/26/95	PERSONAL	MGR S	123 00	17 98	2 89	21 53	3 07
01/26/95	PERSONAL	LAUNDRY WKR	120 00	12 29	2 51	9 34	2 23
01/26/95	PERSONAL	SPOTTER	118 00	12 50	2 53	12 26	2.51
01/26/95	AREA	MARVEL	120 00	9 46	2 25	42 45	3 75
01/26/95	AREA	HOYT	119 00	18 59	2 92	99 31	4.60
01/26/95	AREA	UNION CORNEI	121 00	170.62	5 14	63 99	4 16
01/26/95	AREA	UNION FAN	119.00	48 33	3 88	29 11	3.37
01/26/95	AREA	FAN	122.00	24 17	3 19	16 03	2.77
01/26/95	AREA	TABLE	120 00	11.06	2.40	11 04	2.40
01/26/95	PERSONAL	OPERATOR	118 00	28 74	3.36	24 17	3.19
01/26/95	PERSONAL	MGR S	117.00	18.91	2.94	15 67	2 75
01/26/95	PERSONAL	LAUNDRY WKR	117 00	7 06	1 95	6.97	1.94
01/26/95	PERSONAL	SPOTTER	127 00	13 93	2 63	15 40	2.73
01/26/95	AREA	MARVEL	126 00	11 70	2 46	42 04	3.74
01/26/95	AREA	HOYT	127 00	12 77	2 55	65 78	4 19
01/26/95	AREA	UNION CORNEI	128 00	40 32	3 70	28 65	3 36
01/26/95	AREA	UNION FAN	128 00	27.65	3 32	19 10	2 95

DATE	TYPE	LOCATION	TIME (min)	PERCONC (ppm)	LNPERC (PPM)	MSCONC (ppm)	LNMS (PPM)
01/26/95	AREA	FAN	127 00	20 90	3 04	14.92	2 70
01/26/95	AREA	TABLE	127 00	6 27	1.84	9 14	2 21
01/26/95	PERSONAL	OPERATOR	131.00	28 14	3.34	26 44	3 27
01/26/95	PERSONAL	MGR S	130 00	13 61	2.61	13 48	2 60
01/26/95	PERSONAL	LAUNDRY WKR	118 00	10 75	2 37	16 58	2 81
01/26/95	PERSONAL	SPOTTER	120 00	9 95	2 30	32 26	3 47
01/26/95	AREA	MARVEL	153 00	15 42	2 74	67 92	4 22
01/26/95	AREA	HOYT	152 00	14.55	2.68	80 43	4 39
01/26/95	AREA	UNION CORNEI	144.00	58 37	4 07	53 77	3 98
01/26/95	AREA	UNION FAN	144 00	27 65	3 32	39 62	3 68
01/26/95	AREA	FAN	144 00	23.55	3 16	33 96	3 53
01/26/95	AREA	TABLE	144 00	7.58	2.03	28 30	3 34
01/26/95	PERSONAL	OPERATOR	124 00	36 87	3 61	52 58	3 96
01/26/95	PERSONAL	MGR S	125 00	9 91	2 29	32 60	3 48
01/26/95	PERSONAL	LAUNDRY WKR	124 00	7 73	2.05	21 36	3 06
01/26/95	PERSONAL	SPOTTER	72.00	12 29	2 51	42 45	3 75
01/27/95	AREA	MARVEL	114 00	12 03	2 49	41 11	3 72
01/27/95	AREA	HOYT	113 00	13 05	2 57	77.53	4 35
01/27/95	AREA	UNION CORNEI	112 00	67 15	4 21	47 30	3 86
01/27/95	AREA	UNION FAN	112 00	47 40	3 86	29 11	3 37
01/27/95	AREA	BEHIND UNION	110 00	40 22	3 69	33 34	3 51
01/27/95	AREA	FAN	109 00	20 29	3 01	18 32	2 91
01/27/95	AREA	TABLE	110.00	6 70	1.90	12 41	2 52
01/27/95	PERSONAL	OPERATOR	145 00	26 44	3 27	37 94	3 64
01/27/95	PERSONAL	SPOTTER	119 00	7 44	2 01	27 39	3 31
01/27/95	PERSONAL	LAUNDRY WKR	143 00	10 31	2 33	21.37	3 06
01/27/95	AREA	MARVEL	122 00	9 31	2 23	43 42	3 77
01/27/95	AREA	HOYT	121 00	10 24	2 33	62 30	4 13
01/27/95	AREA	UNION CORNEI	122 00	29 01	3 37	45 09	3 81
01/27/95	AREA	UNION FAN	121 00	24 37	3 19	26 94	3 29
01/27/95	AREA	BEHIND UNION	123 00	34 77	3 55	36 44	3 60
01/27/95	AREA	FAN	121 00	15 84	2 76	25 26	3 23
01/27/95	AREA	TABLE	122 00	5 68	1 74	18 37	2 91
01/27/95	PERSONAL	OPERATOR	138 00	38 47	3 65	26 58	3 28
01/27/95	PERSONAL	LAUNDRY WKR	138 00	7 91	2 07	7.83	2 06
01/27/95	PERSONAL	SPOTTER	124.00	9 75	2.28	13 47	2 60
01/27/95	AREA	MARVEL	122 00	15 71	2 75	41 75	3 73
01/27/95	AREA	HOYT	123 00	11 75	2 46	39 76	3 68
01/27/95	AREA	UNION CORNEI	123 00	53 95	3 99	39 76	3 68
01/27/95	AREA	UNION FAN	123 00	35 97	3.58	28 16	3.34
01/27/95	AREA	BEHIND UNION	122 00	51 98	3 95	35 07	3 56
01/27/95	AREA	FAN	124 00	27 35	3 31	21.36	3 06
01/27/95	AREA	TABLE	123 00	8 15	2 10	12 42	2 52
01/27/95	PERSONAL	OPERATOR	117 00	13 86	2 63	22 64	3 12
01/27/95	PERSONAL	LAUNDRY WKR	134 00	2 97	1 09	6 23	1.83
01/27/95	PERSONAL	SPOTTER	115 00	4 10	1.41	11 69	2 46
01/27/95	AREA	MARVEL	104 00	7 94	2 07	43 10	3 76
01/27/95	AREA	HOYT	103 00	7 16	1 97	47 48	3 86
01/27/95	AREA	UNION CORNEI	104.00	49 63	3 90	43 10	3 76

DATE	TYPE	LOCATION	TIME (min)	PERCONC (ppm)	LNPERC (PPM)	MSCONC (ppm)	LNMS (PPM)
01/27/95	AREA	UNION FAN	104 00	12 48	2 52	23 51	3 16
01/27/95	AREA	BEHIND UNION	105 00	25 28	3 23	29 11	3 37
01/27/95	AREA	FAN	95 00	9 00	2 20	16 30	2 79
01/27/95	AREA	TABLE	94 00	3 29	1 19	10 62	2 36

Multiple range analysis for A1SMPNEW LNPERC by A1SMPNEW LOCATION

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups
OFFGASSI	2	-1 1994840	X
MGR T	3	0 2398192	X
TABLE	16	1 7744152	X
LAUNDRY	11	1.8925446	XX
SPOTTER	11	2 0428504	XXX
MARVEL	16	2 1835060	XX
MGR S	8	2 3648674	XX
HOYT	16	2 3739078	XX
FAN	16	2 7137840	XX
OPERATOR	15	2.9463737	XX
UNION FA	16	3 2195765	XX
BEHIND U	4	3.6059580	XX
UNION CO	16	3 9851423	X

contrast		difference	+/- limits	
SPOTTER	- OPERATOR	-0 90352	0 39899	*
SPOTTER	- MGR T	1 80303	0 65467	*
SPOTTER	- MARVEL	-0 14066	0 39368	
SPOTTER	- HOYT	-0 33106	0.39368	
SPOTTER	- UNION CORNER	-1 94229	0 39368	*
SPOTTER	- UNION FAN	-1 17673	0 39368	*
SPOTTER	- FAN	-0 67093	0 39368	*
SPOTTER	- TABLE	0 26844	0 39368	
SPOTTER	- OFFGASSING	3 24233	0 77263	*
SPOTTER	- MGR S	-0 32202	0 46703	
SPOTTER	- LAUNDRY WKR	0 15031	0 42858	
SPOTTER	- BEHIND UNION	-1 56311	0 58686	*
OPERATOR	- MGR T	2 70655	0 63569	*
OPERATOR	- MARVEL	0 76287	0 36123	*
OPERATOR	- HOYT	0 57247	0 36123	*
OPERATOR	- UNION CORNER	-1 03877	0 36123	*
OPERATOR	- UNION FAN	-0 27320	0 36123	
OPERATOR	- FAN	0 23259	0 36123	
OPERATOR	- TABLE	1 17196	0 36123	*
OPERATOR	- OFFGASSING	4 14586	0 75662	*
OPERATOR	- MGR S	0 58151	0 44003	*
OPERATOR	- LAUNDRY WKR	1 05383	0 39899	*
OPERATOR	- BEHIND UNION	-0 65958	0 56561	*
MGR T	- MARVEL	-1 94369	0 63237	*
MGR T	- HOYT	-2 13409	0 63237	*
MGR T	- UNION CORNER	-3 74532	0 63237	*
MGR T	- UNION FAN	-2 97976	0 63237	*
MGR T	- FAN	-2 47396	0 63237	*
MGR T	- TABLE	-1 53460	0 63237	*
MGR T	- OFFGASSING	1 43930	0 91753	*
MGR T	- MGR S	-2.12505	0 68046	*
MGR T	- LAUNDRY WKR	-1 65273	0 65467	*
MGR T	- BEHIND UNION	-3 36614	0 76766	*
MARVEL	- HOYT	-0 19040	0 35536	
MARVEL	- UNION CORNER	-1.80164	0 35536	*
MARVEL	- UNION FAN	-1 03607	0 35536	*
MARVEL	- FAN	-0.53028	0 35536	*

* denotes a statistically significant difference

Multiple range analysis for A1SMPNEW LNPERC by A1SMPNEW LOCATION

Method 95 Percent LSD

Level Count Average Homogeneous Groups

MARVEL - TABLE	0 40909	0 35536	*
MARVEL - OFFGASSING	3 38299	0 75383	*
MARVEL - MGR S	-0 18136	0.43522	
MARVEL - LAUNDRY WKR	0 29096	0.39368	
MARVEL - BEHIND UNION	-1 42245	0 56187	*
HOYT - UNION CORNER	-1 61123	0 35536	*
HOYT - UNION FAN	-0 84567	0.35536	*
HOYT - FAN	-0 33988	0 35536	
HOYT - TABLE	0 59949	0 35536	*
HOYT - OFFGASSING	3 57339	0 75383	*
HOYT - MGR S	0 00904	0 43522	
HOYT - LAUNDRY WKR	0 48136	0 39368	*
HOYT - BEHIND UNION	-1 23205	0 56187	*
UNION CORNER - UNION FAN	0 76557	0 35536	*
UNION CORNER - FAN	1 27136	0 35536	*
UNION CORNER - TABLE	2 21073	0 35536	*
UNION CORNER - OFFGASSING	5 18463	0 75383	*
UNION CORNER - MGR S	1 62027	0 43522	*
UNION CORNER - LAUNDRY WKR	2 09260	0 39368	*
UNION CORNER - BEHIND UNION	0 37918	0 56187	
UNION FAN - FAN	0 50579	0 35536	*
UNION FAN - TABLE	1 44516	0 35536	*
UNION FAN - OFFGASSING	4 41906	0.75383	*
UNION FAN - MGR S	0 85471	0.43522	*
UNION FAN - LAUNDRY WKR	1 32703	0 39368	*
UNION FAN - BEHIND UNION	-0 38638	0 56187	
FAN - TABLE	0 93937	0.35536	*
FAN - OFFGASSING	3 91327	0 75383	*
FAN - MGR S	0 34892	0 43522	
FAN - LAUNDRY WKR	0 82124	0 39368	*
FAN - BEHIND UNION	-0 89217	0 56187	*
TABLE - OFFGASSING	2 97390	0 75383	*
TABLE - MGR S	-0 59045	0 43522	*
TABLE - LAUNDRY WKR	-0 11813	0.39368	
TABLE - BEHIND UNION	-1 83154	0 56187	*
OFFGASSING - MGR S	-3 56435	0 79461	*
OFFGASSING - LAUNDRY WKR	-3 09203	0 77263	*
OFFGASSING - BEHIND UNION	-4 80544	0 87045	*
MGR S - LAUNDRY WKR	0 47232	0 46703	*
MGR S - BEHIND UNION	-1 24109	0.61550	*
LAUNDRY WKR - BEHIND UNION	-1 71341	0.58686	*

* denotes a statistically significant difference

Multiple range analysis for A1SMPNEW LNMS by A1SMPNEW LOCATION

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups
OFFGASSI	2	-0 1982416	X
MGR T	3	0 4179167	X
TABLE	16	2.2242710	X
LAUNDRY	11	2 2506147	XX
FAN	16	2 6094311	XXX
SPOTTER	11	2 7337955	XX
MGR S	8	2 7473553	XX
OPERATOR	15	2 8909689	XX
UNION FA	16	2 9689381	XX
UNION CO	16	3 4807298	X
BEHIND U	4	3 5077289	XXX
MARVEL	16	3 5475986	XXX
HOYT	16	4 0140961	X X

contrast		difference	+/- limits	
SPOTTER	- OPERATOR	-0 15717	0 45444	
SPOTTER	- MGR T	2 31588	0 74566	*
SPOTTER	- MARVEL	-0 81380	0 44840	*
SPOTTER	- HOYT	-1 28030	0 44840	*
SPOTTER	- UNION CORNER	-0 74693	0 44840	*
SPOTTER	- UNION FAN	-0 23514	0 44840	
SPOTTER	- FAN	0 12436	0 44840	
SPOTTER	- TABLE	0 50952	0 44840	*
SPOTTER	- OFFGASSING	2 93204	0 88003	*
SPOTTER	- MGR S	-0 01356	0 53195	
SPOTTER	- LAUNDRY WKR	0 48318	0 48815	
SPOTTER	- BEHIND UNION	-0 77393	0 66843	*
OPERATOR	- MGR T	2 47305	0 72404	*
OPERATOR	- MARVEL	-0 65663	0 41144	*
OPERATOR	- HOYT	-1 12313	0 41144	*
OPERATOR	- UNION CORNER	-0 58976	0 41144	*
OPERATOR	- UNION FAN	-0 07797	0 41144	
OPERATOR	- FAN	0 28154	0 41144	
OPERATOR	- TABLE	0 66670	0 41144	*
OPERATOR	- OFFGASSING	3 08921	0 86179	*
OPERATOR	- MGR S	0 14361	0.50120	
OPERATOR	- LAUNDRY WKR	0 64035	0.45444	*
OPERATOR	- BEHIND UNION	-0 61676	0.64422	
MGR T	- MARVEL	-3 12968	0.72026	*
MGR T	- HOYT	-3 59618	0.72026	*
MGR T	- UNION CORNER	-3 06281	0 72026	*
MGR T	- UNION FAN	-2.55102	0.72026	*
MGR T	- FAN	-2 19151	0 72026	*
MGR T	- TABLE	-1 80635	0.72026	*
MGR T	- OFFGASSING	0 61616	1 04507	
MGR T	- MGR S	-2 32944	0 77504	*
MGR T	- LAUNDRY WKR	-1 83270	0 74566	*
MGR T	- BEHIND UNION	-3 08981	0 87437	*
MARVEL	- HOYT	-0 46650	0 40475	*
MARVEL	- UNION CORNER	0 06687	0 40475	
MARVEL	- UNION FAN	0 57866	0 40475	*
MARVEL	- FAN	0 93817	0 40475	*

* denotes a statistically significant difference

Multiple range analysis for A1SMPNEW LNMS by A1SMPNEW LOCATION

Method 95 Percent LSD

Level	Count	Average	Homogeneous Groups
MARVEL - TABLE	1.32333	0 40475 *	
MARVEL - OFFGASSING	3 74584	0 85861 *	
MARVEL - MGR S	0.80024	0 49572 *	
MARVEL - LAUNDRY WKR	1.29698	0.44840 *	
MARVEL - BEHIND UNION	0.03987	0 63997	
HOYT - UNION CORNER	0 53337	0.40475 *	
HOYT - UNION FAN	1.04516	0 40475 *	
HOYT - FAN	1.40466	0 40475 *	
HOYT - TABLE	1.78983	0 40475 *	
HOYT - OFFGASSING	4 21234	0.85861 *	
HOYT - MGR S	1 26674	0 49572 *	
HOYT - LAUNDRY WKR	1.76348	0 44840 *	
HOYT - BEHIND UNION	0.50637	0 63997	
UNION CORNER - UNION FAN	0 51179	0 40475 *	
UNION CORNER - FAN	0 87130	0 40475 *	
UNION CORNER - TABLE	1 25646	0 40475 *	
UNION CORNER - OFFGASSING	3.67897	0 85861 *	
UNION CORNER - MGR S	0 73337	0 49572 *	
UNION CORNER - LAUNDRY WKR	1 23012	0 44840 *	
UNION CORNER - BEHIND UNION	-0 02700	0 63997	
UNION FAN - FAN	0 35951	0 40475	
UNION FAN - TABLE	0 74467	0 40475 *	
UNION FAN - OFFGASSING	3 16718	0 85861 *	
UNION FAN - MGR S	0 22158	0 49572	
UNION FAN - LAUNDRY WKR	0 71832	0 44840 *	
UNION FAN - BEHIND UNION	-0.53879	0 63997	
FAN - TABLE	0.38516	0.40475	
FAN - OFFGASSING	2 80767	0 85861 *	
FAN - MGR S	-0 13792	0 49572	
FAN - LAUNDRY WKR	0 35882	0 44840	
FAN - BEHIND UNION	-0 89830	0.63997 *	
TABLE - OFFGASSING	2 42251	0 85861 *	
TABLE - MGR S	-0 52308	0 49572 *	
TABLE - LAUNDRY WKR	-0 02634	0 44840	
TABLE - BEHIND UNION	-1 28346	0 63997 *	
OFFGASSING - MGR S	-2 94560	0 90506 *	
OFFGASSING - LAUNDRY WKR	-2 44886	0 88003 *	
OFFGASSING - BEHIND UNION	-3.70597	0 99144 *	
MGR S - LAUNDRY WKR	0.49674	0.53195	
MGR S - BEHIND UNION	-0 76037	0.70105 *	
LAUNDRY WKR - BEHIND UNION	-1 25711	0.66843 *	

* denotes a statistically significant difference

Level	Sample size	Average	Median	Mode	Geometric mean
Load Union (FAN)	15	1413.44	1816.76	1816.76	914.184
Load Union (CORNER)	7	1317.40	1731.24	1816.93	1116.71
Load Marve	17	169.854	172.786	164.862	154.722
Other	79	249.113	124.149	24.4084	129.092

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Load Union	462630.	680.169	175.619	24.5840	1817.11
Load Union	425558.	652.348	246.565	379.296	1816.93
Load Marve	5283.84	72.6901	17.6299	60.0660	304.292
Other	83955.2	289.750	32.5994	22.4768	1154.57

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Load Union	1792.52	1093.99	1816.76	722.770	-1.48419
Load Union	1437.64	456.736	1816.93	1360.20	-0.85721
Load Marve	244.226	102.751	192.722	89.9712	0.45067
Other	1132.09	25.9888	385.442	359.453	1.85683

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Load Union	-2.34672	0.60078	0.47496	48.1215	21201.6
Load Union	-0.92589	-1.43324	-0.77404	49.5178	9221.81
Load Marve	0.75859	-0.52066	-0.43820	42.7957	2887.51
Other	6.73766	2.97314	5.39415	116.313	19679.9

Level	Sample size	Average	Median	Mode	Geometric mean
Unload Hoyt	35	38.4861	34.7616	34.3782	34.6675
Unload Uncover	31	338.806	316.080	298.344	299.428
Other	448	28.0044	16.1552	14.5748	21.7607

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Unload Hoy	287.518	16.9563	2.86615	14.3136	72.7182
Unload Unc	22805.9	151.016	27.1233	41.9684	741.734
Other	682.420	26.1232	1.23420	13.2912	141.534

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Unload Hoy	58.4046	26.8380	54.9540	28.1160	0.32971
Unload Unc	699.766	265.332	434.259	168.927	0.50690
Other	128.242	14.5748	29.5886	15.0138	2.29649

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Unload Hoy	0.79634	-0.98527	-1.18983	44.0584	1347.01
Unload Unc	1.15221	0.63167	0.71790	44.5730	10503.0
Other	19.8439	4.51768	19.5186	93.2825	12546.0

-vel	Sample size	Average	Median	Mode	Geometric mean
.load fun	60	163.580	156.547	151.192	140.508
ıtch car	5	104.833	87.2732	84.4636	99.6608
ɔad funio	12	371.935	383.335	298.696	341.975
:her	118	54.3203	46.5340	0.00000	0.00000
. cornerU	16	623.709	481.320	1816.93	397.024
:ansfer	59	103.862	103.135	101.601	94.7273
.mp bucke	7	68.5373	67.9896	63.3888	68.0295
ɔad Marve	39	146.043	124.861	121.282	138.396

evel	Variance	Standard deviation	Standard error	Minimum	Maximum
:load fun	7850.09	88.6007	11.4383	37.9296	522.586
ıtch car	1740.52	41.7195	18.6575	77.2640	178.410
ɔad funio	24241.7	155.698	44.9460	177.532	637.955
:her	900.803	30.0134	2.76295	0.00000	192.633
: cornerU	320137.	565.806	141.452	78.1420	1816.93
:ansfer	1664.96	40.8039	5.31221	25.5600	223.139
.mp bucke	81.1781	9.00989	3.40542	56.8710	79.7472
ɔad Marve	2672.13	51.6927	8.27745	87.0318	302.375

evel	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
nload fun	484.656	96.7556	214.495	117.740	1.30651
witch car	101.146	84.4636	96.7556	12.2920	2.08270
ɔad funio	460.423	234.689	439.176	204.486	0.49889
:her	192.633	38.3400	72.2070	33.8670	1.47513
d cornerU	1738.79	160.147	739.364	579.217	1.25268
ransfer	197.579	75.6576	126.650	50.9922	0.28187
:ump bucke	22.8762	60.1938	79.2360	19.0422	0.12210
oad Marve	215.343	114.381	185.182	70.8012	1.21602

.evel	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
.nload fun	4.13155	3.51504	5.55777	54.1635	9814.81
switch car	1.90124	4.44265	2.02779	39.7961	524.166
.oad funio	0.70554	-0.54082	-0.38242	41.8614	4463.23
:ther	6.54177	4.87951	10.8196	55.2526	6409.80
.d cornerU	2.04561	0.78661	0.64226	90.7164	9979.35
:ransfer	0.88389	0.32554	0.51042	39.2865	6127.88
:ump bucke	0.13188	-1.63451	-0.88274	13.1460	479.761
.oad Marve	3.10025	1.23368	1.57264	35.3956	5695.66

Level	Sample size	Average	Median	Mode	Geometric mean
corner lint trap	21	180.626	161.552	144.694	158.195
fan lint trap	21	148.591	148.031	142.938	145.587
other	57	98.9737	89.3804	85.6928	95.8403

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
corner lin	12032.4	109.692	23.9369	81.8296	563.325
fan lint t	914.465	30.2401	6.59893	105.009	191.931
other	742.521	27.2492	3.60925	68.8352	198.428

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
corner lin	481.495	95.5264	215.812	120.286	2.25844
fan lint t	86.9220	118.881	178.585	59.7040	-0.04418
other	129.593	78.4932	111.330	32.8372	1.41943

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
corner lin	4.22515	6.87417	6.43019	60.7292	3793.14
fan lint t	-0.08266	-1.64857	-1.54209	20.3512	3120.41
other	4.37497	2.16543	3.33715	27.5318	5641.50

,evel	Sample size	Average	Median	Mode	Geometric mean
'ilter mai	148	144.913	94.9996	84.9904	114.159
)ther	423	94.9232	44.4268	40.3880	70.3878
3trap cUni	23	653.713	685.894	676.938	567.017
.trap fUni	20	689.414	593.616	547.345	585.447

,evel	Variance	Standard deviation	Standard error	Minimum	Maximum
Filter mai	15038.1	122.630	10.0801	41.4416	673.250
Other	8547.51	92.4528	4.49521	35.9980	824.618
Btrap cUni	78916.3	280.920	58.5760	136.090	1018.66
ltrap fUni	152167.	390.085	87.2257	242.504	1437.64

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Filter mai	631.809	76.0348	168.488	92.4534	2.21823
Other	788.620	40.3880	128.012	87.6244	3.07357
Btrap cUni	882 566	439.527	864.303	424.776	-0.65663
ltrap fUni	1195.13	365.511	1034.37	668.860	0.58051

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Filter mai	11.0169	4.90519	12.1809	84.6233	21447.1
Other	25.8070	15.2093	63.8519	97.3974	40152.5
Btrap cUni	-1.28561	-0.75023	-0.73444	42.9731	15035.4
ltrap fUni	1.05987	-0.95664	-0.87329	56.5821	13788.3

Level	Sample size	Average	Median	Mode	Geometric mean
Open Union	4	85.3416	32.5738	31.7836	53.5820
Unload Uni	27	112.625	118.706	116.247	94.9232
End Unload	2	228.017	228.017	259.010	225.900
Close Unio	1	249.703	249.703	249.703	249.703
Other	308	32.7337	24.3459	20.3202	29.1120
Open Hoyt	2	21.2148	21.2148	22.2372	21.1901
Unload Hoy	22	34.3550	32.1417	31.0554	33.1006
End Unload	3	30.0330	30.1608	27.8604	29.9832
Close Hoyt	1	25.9434	25.9434	25.9434	25.9434
Open Marve	3	20.9166	21.3426	19.8090	20.9014
Transfer	31	83.7832	74.2518	68.1174	75.3221
Close Marv	1	74.7630	74.7630	74.7630	74.7630

Level	Variance	Standard deviation	Standard error	Minimum	Maximum
Open Union	11249.4	106.063	53.0316	31.7836	244.435
Unload Uni	3798.61	61.6329	11.8613	38.1052	249.176
End Unload	1921.18	43.8313	30.9934	197.023	259.010
Close Unio	0.00000	0.00000	0.00000	249.703	249.703
Other	386.855	19.6686	1.12072	18.6588	155.406
Open Hoyt	2.09060	1.44589	1.02240	20.1924	22.2372
Unload Hoy	101.023	10.0510	2.14289	21.5982	58.7880
End Unload	4.45887	2.11160	1.21913	27.8604	32.0778
Close Hoyt	0.00000	0.00000	0.00000	25.9434	25.9434
Open Marve	0.93642	0.96769	0.55869	19.8090	21.5982
Transfer	1642.63	40.5294	7.27930	32.0778	186.332
Close Marv	0.00000	0.00000	0.00000	74.7630	74.7630

Level	Range	Lower quartile	Upper quartile	Interquartile range	Skewness
Open Union	212.652	32.0470	138.636	106.589	1.99990
Unload Uni	211.071	44.0756	162.430	118.354	0.36027
End Unload	61.9868	197.023	259.010	61.9868	0.00000
Close Unio	0.00000	249.703	249.703	0.00000	0.00000
Other	136.747	20.5758	34.0664	13.4906	2.45239
Open Hoyt	2.04480	20.1924	22.2372	2.04480	0.00000
Unload Hoy	37.1898	28.6272	38.5956	9.96840	1.13025
End Unload	4.21740	27.8604	32.0778	4.21740	-0.27135
Close Hoyt	0.00000	25.9434	25.9434	0.00000	0.00000
Open Marve	1.78920	19.8090	21.5982	1.78920	-1.59710
Transfer	154.255	58.9158	98.4060	39.4902	1.09701
Close Marv	0.00000	74.7630	74.7630	0.00000	0.00000

Level	Standardized skewness	Kurtosis	Standardized kurtosis	Coefficient of variation	Sum
Open Union	1.63291	3.99967	1.63286	124.281	341.366
Unload Uni	0.76424	-0.72534	-0.76934	54.7241	3040.87
End Unload	0.00000	0.00000	0.00000	19.2228	456.033
Close Unio	0.00000	0.00000	0.00000	0.00000	249.703
Other	17.5707	7.15960	25.6483	60.0869	10082.0
Open Hoyt	0.00000	0.00000	0.00000	6.81549	42.4296
Unload Hoy	2.16427	1.20577	1.15444	29.2565	755.809
End Unload	-0.19188	0.00000	0.00000	7.03094	90.0990
Close Hoyt	0.00000	0.00000	0.00000	0.00000	25.9434
Open Marve	-1.12932	0.00000	0.00000	4.62640	62.7498
Transfer	2.49353	0.78452	0.89162	48.3742	2597.28
Close Marv	0.00000	0.00000	0.00000	0.00000	74.7630

ariable: HOYTOG.ppm

ample size	2839.
verage	2.745454
edian	1.00962
ode	0.3834
eometric mean	1.30689
ariance	17.64929
tandard deviation	4.201106
tandard error	0.078846
inimum	0.2556
aximum	21.3426
ange	21.087
ower quartile	0.5112
pper quartile	2.4921
nterquartile range	1.9809
kewness	2.657048
tandardized skewness	57.79716
urtosis	6.964402
tandardized kurtosis	75.746211
oeff. of variation	153.020455
um	7794.34308

Variable: UFANOG.ppm

Sample size	4210.
Average	2.17608
Median	0.945
Mode	0.6
Geometric mean	1.254172
Variance	11.925501
Standard deviation	3.453332
Standard error	0.053223
Minimum	0.345
Maximum	20.1
Range	19.755
Lower quartile	0.6
Upper quartile	1.845
Interquartile range	1.245
Skewness	3.462419
Standardized skewness	91.715996
Kurtosis	12.213439
Standardized kurtosis	161.760837
Coeff. of variation	158.69511
Sum	9161.295

Variable: UCORNOG.ppm

Sample size	1593.
Average	0.773992
Median	0.525
Mode	0.45
Geometric mean	0.639061
Variance	0.312296
Standard deviation	0.558835
Standard error	0.014002
Minimum	0.3
Maximum	2.52
Range	2.22
Lower quartile	0.45
Upper quartile	0.915
Interquartile range	0.465
Skewness	1.712911
Standardized skewness	27.910463
Kurtosis	2.045619
Standardized kurtosis	16.665832
Coeff. of variation	72.201555
Sum	1232.97

APPENDIX F REFERENCES

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