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FINAL REPORT

South Coast Air Quality Management District Contract No. 99050

Developing Additional Technologies to Monitor and Reduce Fugitive Perchloroethylene Emissions at Dry Cleaners

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EXECUTIVE SUMMARY

The California Air Toxic "Hot Spots" Information and Assessment Act (AB 2588) requires facilities whose emissions of perchloroethylene (perc) or other air toxic chemicals that exceed certain thresholds to conduct an inventory of their emissions and, depending on the level of emissions, to prepare and submit health risk assessments to the State.

Most small perc dry cleaners were included in a 1990 industrywide survey to quantify perc emissions. The resulting emissions data provided the basis for AB 2588 health risk assessments which, along with the inventories, became public information.

Facilities identified by an air pollution control district or air quality management district as having the potential to present a "significant risk" to the public were required to develop and implement a plan to reduce their risk below the significant level set by that district. Under this process, only the largest perc dry cleaners were required to perform AB 2588 risk assessments. Air districts may themselves conduct industrywide emissions inventories of perc dry cleaners that qualify as small businesses and meet other criteria.

Recognizing that vapor and liquid leaks contribute significantly to perc emissions released to the atmosphere, the South Coast Air Quality Management District (AQMD) awarded a contract to AVES, an Affiliate of ATC Associates Inc. (ATC) and its subcontractor, Pacific Environmental Services, Inc. (PES) to "Develop Additional User-Friendly and Cost-Effective Technologies to Monitor and Reduce Fugitive Emissions at Perchloroethylene Dry Cleaners."

The overall objectives of this project were:

- To identify and/or develop additional ways to monitor and reduce perc emissions; and
- To simplify, reduce, or eliminate costly monitoring by dry cleaner operators subject to the State Airborne Toxic Control Measure (ATCM).

AVES/PES performed the following seven (7) tasks to achieve these objectives:

Task 1 – Gathering and evaluating available leak data from local air pollution control districts (APCDs)

- Compiling, reviewing, and analyzing inspection and enforcement data on fugitive perc emissions; and
- Converting the existing data into a standard electronic format, using Microsoft Excel™ to perform statistical calculations and summarizing the results.

<u>Results</u>

Survey results from 110 facilities identified the five components of perc dry cleaning machines most likely to leak as the front loading door (55%), still (33%), lint trap (25%), button trap (14%), and water separator (12%).

Task 2 – Surveying dry cleaning equipment manufacturers on design criteria and recommended maintenance practices

- Gathering baseline data from manufacturers and other interested parties regarding equipment/process design criteria; and
- Recommending practices for ensuring reduced perc emissions from dry cleaning operations.

Results

Engineering studies revealed that newer dry cleaning machines have a lower potential to release fugitive emissions. Higher quality gaskets and improved maintenance on these newer dry cleaning machines are thought to be responsible for this difference. Older dry cleaning machines have a greater potential to release fugitive emissions due to normal wear, vibration and/or lack of necessary maintenance. However, perc dry cleaning machine operators can be effective in reducing fugitive emissions by changing these gaskets on an annual basis.

Task 3 – Developing or refining emission factors and achievable leak rates, and estimating or measuring mass emissions as a function of relative perc concentrations

- Conducting a review of professional and trade publications to identify and determine the relative merits of methodologies for estimating or measuring mass emissions;
- Reviewing findings on various dry cleaning waste products, including filters, clothing, still bottoms, and lint;
- Quantifying mass perc emissions from vapor leaks by enclosing a dry cleaning machine with a temporary total enclosure and measuring continuously the emissions from the enclosure; and
- Continuously monitoring the concentration of vapor leaks from various components of the dry cleaning machine.

Results

The temporary total enclosure (TTE) approach proved to be a practical, effective method for measuring fugitive emissions from the operation of a perc dry cleaning machine. The two machines tested may reasonably be considered to represent devices at opposite ends of a spectrum of "poor" to "excellent" maintenance practices and emission controls. The Douglas Square Cleaners machine had fugitive emissions of about 0.23 lb of perc per cleaning cycle, and approximately 5.6 lb of perc per 1,000 lb of clothes cleaned. The Gordon Ranch Cleaners machine had fugitive emissions of about 0.023 lb of perc per cleaning cycle, and about 0.57 lb of perc per 1,000 lb of clothes cleaned (an emission rate of about 10 percent of that of the Douglas Square Cleaners machine).

A screening risk analysis provided approximate lower and upper bounds for individual cancer risk in areas surrounding such "best" and "worst" case facilities.

For the "best" case, the individual cancer risk:

- Does not exceed 10 in 1 million at any point outside the facility.
- Does not exceed 1 in 1 million risk beyond approximately 51 meters (167 feet).

For the "worst" case, the individual cancer risk:

- Exceeds 10 in 1 million out to a distance of 65 meters (213 feet) from the facility.
- Exceeds 1 in 1 million out to 305 meters (1,000 feet).

Task 4 – Surveying perc leak monitoring equipment, determining the likelihood of leaks, and proposing monitoring options which ensure high compliance levels, minimize cost, and are simple to perform

- Determining the relative likelihood of leaks in components in decreasing order of frequency of citation for leaks;
- Evaluating monitoring equipment and monitoring needs at dry cleaners; and
- Identifying and proposing monitoring options and solutions that are cost-effective and user-friendly.

Results

Halogenated hydrocarbon detectors developed for the refrigeration and air conditioning industry are calibrated to provide a visual or audible signal for refrigerant leaks exceeding ¼ ounce per year. Halogen leak detectors used with a soap solution can help to pinpoint, but not quantify, a leak source. Quantifiable emission concentration data requires the use of a portable direct-reading photo ionization detector (PID). However, the high cost of the least expensive direct-reading PID (approximately $1300) represents a substantial financial burden for many small business dry cleaners.

Task 5 – Performing an engineering study of several dry cleaning machines to determine causes of leaks, and recommending technological and maintenance/operational solutions

- Performing an empirical engineering study of the causes of leaks in a representative sample of perc dry cleaning equipment, and
- Developing cost-effective, user-friendly technological "fixes" to improve the ability of dry cleaner operators to detect equipment leaks and reduce fugitive perc emissions.

Results

New and tighter machine designs significantly reduce fugitive emissions. Perc recovery is especially efficient in dry cleaning machines equipped with spin filters or disc filtration systems. This new design results in less waste generated, lower perc emissions during waste removal, reduced operator exposure to perc, lower overall perc loss, and potentially lower hazardous waste disposal costs. New machines are equipped with a perc-drying sensor that runs through the microprocessor and monitors perc concentrations in the clothes. The sensor monitors perc returning from the condenser during the drying cycle. When properly programmed, the sensor prevents operators from short-cycling loads, with the inherent loss of perc to the atmosphere and the exposure of operators to excess vapors.

Improving housekeeping practices is often the easiest, quickest, and least expensive way to reduce fugitive emissions and waste. Good housekeeping includes effective inventory control and efficient operating procedures; properly labeling all perc and waste containers; and using spigots, pumps and funnels when transferring perc and waste materials.

Task 6 – Recommending changes to the State ATCM with respect to leak limits, maintenance and operational practices and monitoring requirements

- Based on observations and findings, proposing reasonable, justifiable, cost-effective, and achievable leak limits, monitoring requirements, and maintenance and operational practices; and
- Recommending how proposed changes can be incorporated into the State ATCM and implemented throughout the State of California.

Recommendations

Based on observations and findings, the following changes to the State ATCM are proposed with respect to leak limits, operating and maintenance practices, monitoring, report, recordkeeping, and reporting requirements:

- If the State ATCM perc leak limit concentration were increased from 25 ppm expressed as perc to 100 ppm expressed as perc[1], simple sensing instruments such as halogenated hydrocarbon detectors could be modified to detect leaks exceeding this revised threshold. This change would provide dry cleaner operators with a low-cost option to maintain compliance with State ATCM requirements. By requiring all dry cleaner operators to purchase and use the detectors daily to test for leaks, manufacturers of leak detectors would be encouraged to produce leak detectors calibrated for perc and fugitive emissions could be measured and reduced.

[1] Assuming, for AQMD purposes, that associated risk levels do not exceed those specified in recently amended AQMD Rule 1402.

- Dry cleaning machines should be tested daily by the dry cleaning machine operator using a halogen leak detector and soap solution to detect perc leaks. Any perc leaks found should be repaired immediately. Dry cleaning facilities should maintain sufficient spare gaskets and seals on the premises for each dry cleaning machine to repair leaks at the front loading door, still, lint trap, button trap, and water separator. Additionally, dry cleaner operators should replace the gaskets for the loading doors, stills, lint traps, button traps, and water separators of their equipment on an annual basis.
- Since some hoses and tubing are not impervious to perc, rigid piping and appropriate flex joints should be used to reduce the potential of releasing perc into the environment.
- If a leak is found, the date and type of repair should be listed on a service and repair log. If a leak cannot be repaired immediately, the leaking component should be tagged and the date noted on a service and repair log. Parts should be ordered within two working days of the date when the leak was detected, and the order date should be recorded on the service and repair log. Once the part is received, it should be installed within five working days after receipt. If not repaired by the end of the 5th working day, a leaking piece of equipment should not be operated without a leak repair extension from AQMD. Dates on which the parts are received and the repairs completed must be recorded on the service and repair log. Standardized logs and checklists should be developed and implemented by perc dry cleaner operators. These logs and checklists should be available upon request by AQMD inspectors, and copies should be submitted to AQMD with each facility's annual emissions report.
- Two distinct dry cleaner personnel classifications (Dry Cleaner Owner/Manager and Dry Cleaner Equipment Operator) and two distinct training requirements (Environmental and Equipment) should be established. To satisfy Environmental and Equipment requirements, Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should receive environmental training from certifying agencies/schools/individuals. Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should be required to complete an annual refresher course.

Task 7 – Developing a streamlined, user-friendly guidance manual for use by dry cleaners to reduce overall perc emissions

- Compiling a streamlined, user-friendly guidance manual for use by dry cleaners with recommendations for:
  - ✓ Operating and maintaining dry cleaning and control equipment;
  - ✓ Performing frequent equipment leak detection and repair;
  - ✓ Storing perc solvent and perc-containing wastes;
  - ✓ Handling of cartridge filters and solvent reuse; and
  - ✓ Complying with recordkeeping and reporting requirements.

Results

A streamlined, user-friendly manual is included as Appendix A of this comprehensive report.

1.0 DRY CLEANER PERCHLOROETHYLENE LEAKAGE DATA

Task 1 of this report focused on compiling available leak data from local APCDs by

- Compiling, reviewing, and analyzing inspection and enforcement data on fugitive perc emissions; and
- Converting the existing data into a standard electronic format, using Microsoft Excel™ to perform statistical calculations and summarize the results.

In 1997 the CAPCOA Enforcement Managers' ATCM Dry Cleaners Subcommittee began examining problems associated with implementing the airborne toxic control measure (ATCM) for perc emissions from dry cleaning. As part of that effort, several local and regional air quality agencies assembled leak data from previous inspections, and/or conducted special field surveys to obtain more information on frequencies and reasons for violations of the ATCM, vapor leak concentrations, and identification of leaking components. For Task 1, AVES/PES compiled, reviewed, and analyzed inspection data from six of these agencies.

AVES/PES received dry cleaning equipment leak data from the six agencies listed in Table 1-1 (see following page). AVES/PES also received incomplete data from the Sacramento Metropolitan Air Quality Management District. The only other agency contacted was the Mojave Desert Air Quality Management District, which reported that it did not have any information useful to this study. The types of information requested included:

- Machine manufacturer
- Machine model
- Machine type
- Machine capacity
- Identification of leaking component(s)
- Operating phase (e.g., wash or dry)
- Vapor concentration reading at leak point

No agency supplied all seven types of information. The types supplied by each agency are shown in Table 1-1. All data were entered into a Microsoft Access™ database created for this project.

Table 1-1 Sources of Perc Dry Cleaner Fugitive Emissions Data

APCD or AQMD	# Leaks	Data Categories Provided						
		Mfr	Model	Type	Capacity	Component ID	Oper. Phase	VOC Data
Bay Area	146	X		X	X	X		X
San Diego County	30	X	X	X	X	X		X
San Joaquin Valley Unified	230	X	X	X	X	X		X
Santa Barbara County	32	X	X	X		X	X	X
South Coast	6	X	X	X	X	X		X
Ventura County	10	X	X	X		X		
Approximate Total	454							

1.1 LEAK POINT AND DEVICE CLASSIFICATION

To analyze the fugitive emissions data, it was first necessary to define a "standard" set of names for the dry cleaning machine components for which leaks were detected. AVES/PES devised a classification scheme using a three-level hierarchy:

- "Primary leak point" -- a major subsystem within the dry cleaning machine, such as the still or the refrigerated condenser.
- "Secondary leak point" -- an integral part of a primary leak point; e.g., the sight glass on a still.
- "Tertiary leak point" --- a component of a secondary leak point; e.g., the gasket on the sight glass on the still.

Many leaks were reported for secondary or secondary and tertiary leak points only; the major subsystem with which they were associated was unknown. Table 1-1 lists the classification scheme used to analyze the agency data.

The agency data submittals contained a wide variety of descriptions for machine type. In many cases, it was impossible to determine whether a particular machine had been converted or was of original equipment manufacture. Furthermore, the types of controls could not be determined from the information provided. AVES/PES was therefore unable to use device type in the analyses presented in Section 4. The machine types reported (and the abbreviations used in the Microsoft Access™ database) were as follows:

CCL	Converted closed loop (no other information)
CCLF	Converted closed loop, fugitive control system
CERC	Converted closed loop, external refrigerated condenser
CL	Closed loop (no other information)

CLSC	Closed loop, add-on secondary control
CNF	Converted closed loop, no fugitive control
CP	Converted closed loop, primary control
CPSF	Closed loop, primary, secondary and fugitive control
IRC	Closed loop, internal refrigerated condenser
IRCF	Closed loop, internal refrigerated condenser, fugitive control system

1.2 IDENTIFICATION OF MOST IMPORTANT LEAK POINTS

Table 1-2 lists major cleaning machine components in decreasing order of the number of reported leaks. Although no single component type predominated, the components appeared to fall into three clusters. Those most frequently reported to leak were the still and the loading door, which together accounted for about one-third the reported leaks. A second group comprised the button trap, lint trap, water separator, refrigerated condenser and filter, which included about 43 percent of the leaks. The remaining eight major components accounted for the last 22 percent.

Major components ranked highest in reported leak frequency were not necessarily responsible for the most emissions. For example, loading doors placed high on the list in Table 1-2 but had relatively low VOC leak rates. The relationship between reported leak frequency and emissions is discussed later in this section.

Table 1-2 Ranking of Major Components by Number of Leaks Reported

Major Component	Number	Percent	Cumulative Percent
Still	65	17.7	17.7
Loading Door	54	14.6	32.3
Button Trap	38	10.4	42.7
Lint Trap	35	9.5	52.2
Water Separator	35	9.5	61.7
Refrigerated Condensor	34	9.2	70.9
Filter	28	7.6	78.5
Solvent Tank or Base Tanks	19	5.2	83.7
Condenser	18	4.9	88.6
Hazardous Waste Container	14	3.8	92.4
Solvent Recirculating Pump	12	3.3	95.7
Drum (other than Loading Door)	7	1.9	97.6
Wastewater Container	7	1.9	99.5
Dip Tank	1	0.2	99.7
Pump	1	0.3	100.0

Table 1-3 shows the most frequently reported leak points for the six most frequently reported leaking major components. For example, most of the leaks associated with stills were detected at the sight glass. Sight glasses and gaskets were very commonly cited as leak points. Note that the same leak observation on a given major component may have included two leak points. For example, 14 of the "sight glass" leaks on stills were for sight glasses on the still cover. These leak points are included in Table 1-2 in both the "Cover or Door" and "Sight Glass" columns.

Table 1-3 Important Leak Points on Major Components

Major Component	Leak Point						
	Cover or Door	Sight Glass	Gasket	Steam Line	Temp Gauge	Other	Not Specified
Still	23	32		13		2	2
Loading Door			37				17
Button Trap	1	2	4			2	30
Lint Trap		1	4				30
Water Separator		1				1	40
Refrigerated Condenser	2				19	4	9

1.3 LEAK CONCENTRATION DATA

Leak concentration values reported by different agencies were obtained with various instruments. Some detectors were calibrated with isobutylene, while others were calibrated directly with perc. Only nonzero leak values were considered in the analysis, and readings reported as "less than" or "more than" values (inequalities) were analyzed as equalities (e.g., <1000 was treated as 1,000).

1.4 CHARACTERISTICS OF THE POOLED DATA SET

Reported leak concentrations varied from a few parts per million (ppm) to 10,000 ppm. The data appeared to be distributed lognormally, with a mean and median of 95 and 100 ppm, respectively. Figure 1.1 shows the cumulative distribution of the concentrations. Note that the horizontal scale is logarithmic.

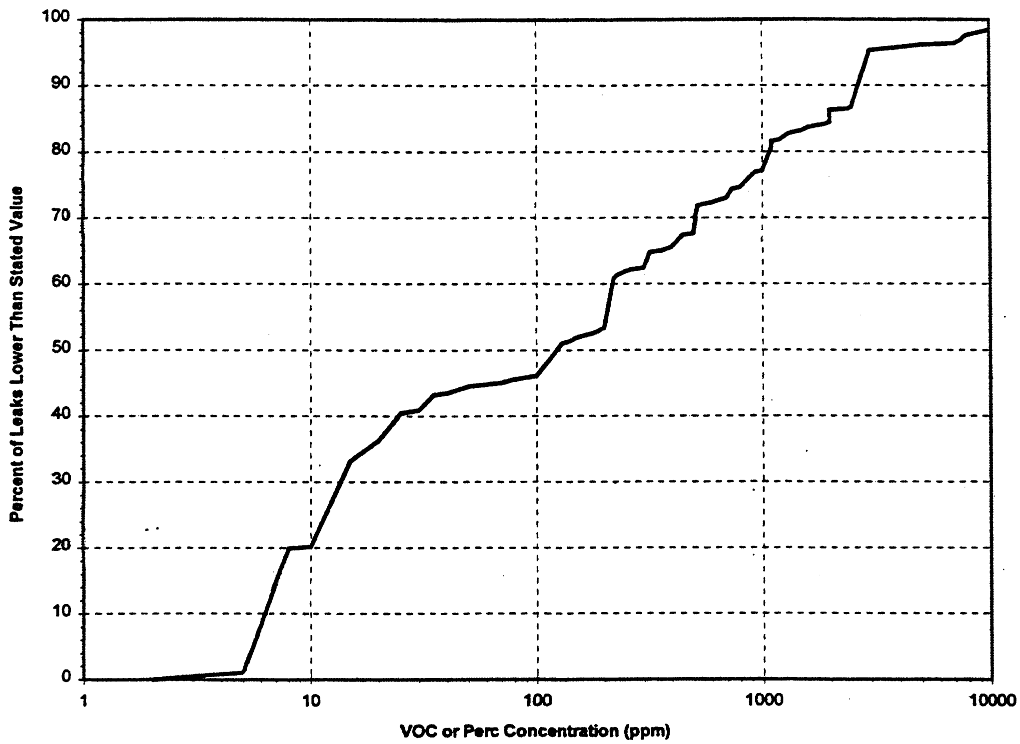


Figure 1.1 Cumulative Distribution of All Reported Leak Concentrations.

1.5 LEAK CONCENTRATIONS FOR MAJOR COMPONENTS

Figure 1.2 shows the cumulative leak concentration frequency distributions for each of the major dry cleaning machine components. The median leak concentration value differed markedly among the machine components. The lowest was for loading doors (35 ppm expressed as perc) and the highest was for stills (600 ppm expressed as perc).

All the leaks reported for refrigerated condensers were above 100 ppm expressed as perc. Since the cumulative distribution above 300 ppm expressed as perc followed the same general pattern as those for the other machine components, it is likely that leaks lower than 100 ppm expressed as perc simply were not reported for the refrigerated condensers.

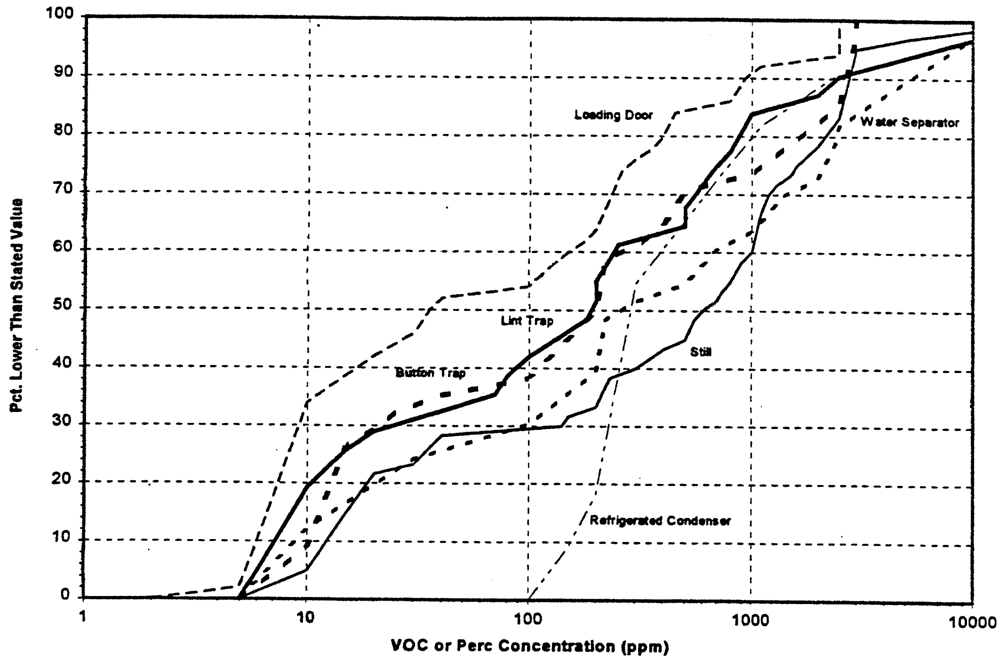


Figure 1.2 Cumulative Distributions of Leak Concentration, by Major Machine Component.

1.6 IMPLICATIONS FOR THE REST OF THE STUDY

Although major components varied little with respect to the frequency of reported leaks, they varied substantially with respect to median leak concentration. To determine which components are responsible for the most fugitive emissions, however, one also needs to know the duration of emissions from each one. For example, the loading door has the lowest median leak concentration, but functions throughout the dry cleaning cycle. In contrast, the still has the highest median leak concentration, but typically operates for a relatively small fraction of the time. Careful attention was paid to the duration of activity of each component during the Task 3 tests.

2.0 DRY CLEANER MANUFACTURERS DESIGN AND MAINTENANCE CRITERIA

Task 2 of this report focused on surveying manufacturers on design criteria and recommended maintenance practices. AVES/PES was tasked with:

- Gathering baseline data from manufacturers and other interested parties regarding equipment/process design criteria; and
- Recommending practices for ensuring reduced perc emissions from dry cleaning operations.

Two comprehensive survey forms were prepared: one for dry cleaning equipment manufacturers/vendors, and the other for dry cleaners. Survey participants included:

- Dry cleaning equipment manufacturers and vendors;
- Environmental regulatory agencies;
- Dry cleaners; and
- Trade associations.

2.1 SOURCES OF SURVEY

Dry cleaning equipment manufacturers and dry cleaners were contacted by phone and mail. Some of the facilities provided verbal feedback only. With the help of the California Cleaners Association, 170 dry cleaning facilities and 8 dry cleaning equipment manufacturers were contacted. Thirty survey forms were completed by dry cleaner facilities and three forms were completed by equipment manufacturers. AQMD also conducted an independent survey of 80 facilities.

2.2 SURVEY RESULTS

2.2.1 Dry Cleaners

Surveys solicited responses to questions regarding typical dry cleaning practices. Tables 2-1, 2-2, and 2-3 summarize survey results obtained by AVES/PES and AQMD.

2.2.2 Dry Cleaning Equipment Manufacturers

AVES/PES reviewed operational, service, and maintenance specifications for dry cleaning machine care from the following manufacturers:

- Lindus
- Frigosec
- Columbia
- Union
- Multimatic

Three manufacturers responded to survey questions about the characteristics and maintenance of their dry cleaning equipment. Survey results are summarized in Table 2-4.

All machines manufactured by these three vendors are microprocessor controlled and equipped with secondary control devices. Machines are normally sold without a perc detector to keep costs competitive. One manufacturer's machines are tested for leakage before leaving the factory. Service specifications were based on either a calendar or cyclic approach. Calendar service was recommended on a daily, weekly, monthly, quarterly, biannual and/or annual basis. Cyclic service was recommended after completion of 4, 8, 50, 200, 300, 1800 and/or 3000 operating cycles. Summaries of these manufacturers' maintenance recommendations are shown in Tables 2-5a, 2-5b, and 2-6.

Table 2-1 Ranking of Major Dry Cleaning Machine Leaking Components by Survey

Major Component	AQMD Survey		AVES/PES Survey	
	Number	Percentage	Number	Percentage
Loading Door	47	34%	14	29%
Still	30	22%	6	12%
Lint Trap	18	13%	9	18%
Button Trap	12	9%	3	6%
Water Separator	9	6%	4	8%
Drum (Other Than Loading Door)	4	3%	1	2%
Condenser	3	2%	2	4%
Solvent Pump	3	2%		
Filter	2	1%	1	2%
Discharge Vent	2	1%	2	4%
Solvent Tank	2	1%		
Wastewater Container	1	1%	4	8%
Dry Sensor	1	1%		
Filter Gasket	1	1%		
Sludge Storage Drum	1	1%		
Temperature Gauge	1	1%		
Connection Valves	1	1%		
Steam Line	1	1%		
Refrigerated Condenser			1	2%
Lint Filter Doors			2	4%
TOTAL	**139**	**100%**	**49**	**100%**

Results are from 80 facilities surveyed by AQMD; 30 facilities surveyed by AVES/PES.

Table 2-2 Perchloroethylene Usage vs. Waste Disposal by Survey

Perchloroethylene Usage (gallons)	AQMD Survey Sludge* (gallons)	Clothes Cleaned Per Year (pounds)	AVES/PES Survey Sludge* (gallons)
0-50	0-20 (4) 21-50 (7) 51-100 (4) 101-150 (1)	=<10,000 (0) 10,001-20,000 (4) 20,001-30,000 (3) 30,001-40,000 (2) >40,001 (2)	0-20 (1) 21-50 (1) 51-100 (1) 101-150 (0)
51-100	0-20 (6) 21-50(11) 51-100 (6) 101-150(3) 151-300 (1)	=<10,000 (3) 10,001-20,000 (0) 20,001-30,000 (2) 30,001-40,000 (5) 40,001-50,000 (3) >50,001 (4)	0-20 (0) 21-50(6) 51-100 (1) 101-150(1) 151-300 (1)
101-200	0-20 (3) 21-50 (4) 51-100 (2) 101-150 (1) 151-200 (1) =>700 (1)	=<10,000 (1) 10,001-20,000 (1) 20,001-30,000 (3) 30,001-40,000 (2) 40,001-50,000 (0) >50,001 (5)	0-20 (1) 21-50 (3) 51-100 (2) 101-150 (3) 151-200 (0) =>700 (0)
201-300	0-20 (2) 21-50 (0) 51-100 (0) 101-150 (0) 151-200 (3)	>200,000 (1)	0-20 (0) 21-50 (2) 51-100 (1) 101-150 (0) 151-200 (2)
301-400	=>600 (1)	>200,000 (1)	=>400 (1)
401-500	=>600 (1)	>200,000 (1)	=>200 (1)
501-600	=>600 (1)	>200,000 (1)	=>300 (1)

Results are from 80 facilities surveyed by AQMD; 30 facilities surveyed by AVES/PES .
* This is the sludge volume. Data provided in pounds were converted to gallons by dividing 13.55.

Table 2-3 Perchloroethylene Usage vs. Cartridge Filter Disposal by Survey

Perchloroethylene Usage (gallons)	AQMD Survey		AVES/PES Survey	
	Filters	Number of Times Per Year	Filters	Number of Times Per Year
0-50	0-4 (1)	0-1 (5)	0-4 (0)	0-1 (2)
	5-8 (8)	1.1-2 (4)	5-8 (0)	1.1-2 (0)
	9-12 (1)	2.1-3 (0)	9-12 (1)	2.1-3 (0)
	13-20 (0)	3.1-4 (1)	13-20 (1)	3.1-4 (1)
	>21 (1)		>20 (1)	5.1-6 (1)
51-100	0-4 (3)	0-1 (5)	0-4 (0)	0-1 (1)
	5-8 (5)	1.1-2 (10)	5-8 (1)	1.1-2 (1)
	9-12 (6)	2.1-3 (1)	16-20 (1)	2.1-3 (3)
	13-20 (5)	3.1-4 (8)	21-24 (2)	3.1-4 (0)
	21-24 (3)	4.1-5 (0)	25-30(1)	5.1-6 (1)
	25-30(1)	5.1-6 (1)	>30 (2)	
101-200	0-4(2)	0-1 (0)	0-4(0)	0-1 (1)
	5-8(1)	1.1-2 (3)	5-8(3)	1.1-2 (4)
	9-12(1)	2.1-3 (1)	9-12(2)	2.1-3 (0)
	13-20(2)	3.1-4 (5)	13-20(1)	3.1-4 (1)
	36-40(1)	4.1-5 (0)	21-25(1)	5.1-6 (2)
	41-45(1)	11-12 (1)	>90 (1)	>10 (1)
201-300	5-8(1)	*	>20 (3)	4.1-5 (1)
	21-24 (1)			5.1-6 (1)
301-600	>80 (1)	3.1-4 (1)	13-20 (1)	1.1-2 (1)
			21-25 (1)	3.1-4 (1)
			>70 (1)	5.1-6 (1)

Results are from 80 facilities surveyed by AQMD; 30 facilities surveyed by AVES/PES.
* No data

Table 2-4 Survey of Dry Cleaning Equipment Manufacturers

Survey question	Union Dry cleaning Products	Wyatt-Bennett Equipment Co.	Western Multitex
How many models?	4	1	9
Recommended perc capacity (gal)?	150-300	35-80	
Pounds of clothes per load?	25-95	35-80	30-65
Operating temp. (deg. C)	28	50	57
Typical cycle length (minutes)?	55	50	
How is the machine controlled?	Microprocessor	Microprocessor	Computer
Any secondary control device?	Yes	Standard	Yes
How often are waste bottoms removed?	2 times per week (Automatic)	1-2 times a week	1-2 times/week
How often does the lint filter need to be cleaned?	After 2-3 Loads	Every 3-4 loads	Each Day
Do you normally sell a perc detector with your machine	No	No	No
Is some other method used to monitor for perc?	Yes. Machines are tested for perc concentration before they are out of manufacture.	No	Yes. Secondary control units have built-in perc sensors.
How can the odor of perc be minimized?	Lockout for 30 seconds before the door can be opened.	Secondary Control. The odor will be minimized to be below 30 ppm	Run through complete program including secondary control cycle and OSHA fan operating when door is open.
How do you know when to replace the filters?		When certain poundage level on gauge is reached.	Filter pressure indication and poundage cleaned for reference
How often does the gasket in the door need to be replaced?		Only when the perc detector detects a leak.	3-4 months
How are perc charge rates established?		From the soap company	Cost and distribution factors and make-ups
What is routinely monitored for the machines?	Temperature, Pressure	Temperature and Pressure	Temperature
Any possible material upgrades for valves, fittings, door lid, gasket?	Yes. We have Viton gaskets for almost every glass.	No. The valves and gasket have proven to be good	Yes. Viton is used where is necessary.
Do you receive any complaints regarding the machines?	No	No. We have an excellent machine that has proven itself over the last 15 years. We also have an extensive parts department, service department and technical support.	Yes. On occasion-As with any machine-air leak, solvent leaks, tune-up adjustments. Nothing major.

Table 2-5a Maintenance Requirements: Forenta and Western Multitex Dry Cleaning Machines

Frequency	Forenta, Model D-345, Clos. 45 lbs	Western Multitex Corporation.
Every 4th Load	Clean button trap.	
Daily	Drain compressed air filter. Empty water separator, skim water container. Clean pre-lint filter. Check filter pressure, drain still residue.	Check lint trap and button trap after each load and clean, if necessary. Check heat sensor probe for linting, located under lint trap in air outlet. Check still for cleanliness. Turn grease cup half-turn daily on bearing housing.
Weekly	Clean lint filter housing. Clean interior lint screen. Check air pressure. Check compressed air lubricant level. Check lubricant feed. Clean still residues.	Remove any lint that may have collected in the air duct between basket and recovery sections by reaching down through lint trap access door. Check still for cleanliness. If distillation rate has slowed, check proper operation of steam traps and make sure no residue has caked on heating surfaces. Steam traps equipped with strainers must be checked and cleaned weekly as described above.
Monthly	Check belt tension. Check hoses and gaskets. Remove reclaiming housing hand hole cover and extract lint using hand or shop vac.	Check tension of V-belts and retighten, if necessary.
Every 3 Months	(1) Open separator drain valve, drain separator. (2) Remove bolts holding separator sight glass retaining flange. (3) Remove flange glass and check gaskets for damage (be sure to remove any damaged gaskets or other debris from the sealing faces on flange, glass, and separator. (4) Using a rag and water, wipe the separator interior clean. (5) If necessary, replace the sight glass gaskets then reassemble. (6) Close the separator drain valve.	
Every 6 Months		Remove and clean lint from air heater and air cooler. Clean lint from all air drying passage. Drain water separator, clean and refill it with clean solvent. Check and clean steam trap strainers (if present).
Every 12 Months	Annual preventive maintenance check.	Check solvent tanks for contamination and clean them, if necessary.

Table 2-5b Maintenance Requirements: ILSA and Union Dry Cleaning Machines

Frequency	ILSA (Columbia), MEC 200-360	UNION U2000-L	UNION L740-L760	UNION P735
Every 4th Load		Clean and remove residues from button trap. Remove and clean primary air filter.	Clean and remove residues from button trap. Remove and clean primary air filter.	Clean air filter. Clean buttontrap.
Daily	Clean air and lint filter. Drain the condensation from the compressed air maintenance unit. Drain waste water from the water tank. Remove distillation sludge from the still and fill neutralizing additive. Clean the drying control device. Clean the gaskets. Check doping container. Check the machine to verify the presence of gas leaks using a leak finder. Check nitrogen.	Clean dry control. Clean the still (without idromatic system). Drain separator water.	Clean dry control. Clean the still (without idromatic system). Drain separator water. Drain double separator water.	Separator maintenance. Clean dry control. Continuous distillation.
Weekly	Drain separator water.	Disassemble and clean the impurities filter. Empty and clean the water separator and fill separator. Remove residues from pump strainer.	Run the pump strainer cleanout program. Empty and clean the water separator and fill separator. Remove primary filter and wash sponge with water. Remove and clean secondary air filter. Disassemble and clean impurities filter.	Check lubrication.
Monthly	Clean the water separator. Clean the water tank.	Remove primary filter and wash the sponge with water.		Separator maintenance. Check ecological filter. Check powder filter.
Every 3 Months		Replace solvent filter cartridge.	Check the drive belt of the drum basket.	Deco filter.
		Check the drive belt of the drum basket.	Replace solvent filter cartridge.	
		Replace carbon in the decofilter basket.	Replace carbon in the decofilter basket.	
Every 6 Months				
Every 12 Months	Annual check by an ILSA authorized engineer.	Annual preventive check.	Annual preventive check.	Annual preventive check.

Table 2-6 Maintenance Requirements: Wyatt-Bennett Lindus Dry Cleaning Machine

Frequency	Maintenance Operation
Every 4 complete cycles	Clean the button trap.
Every 8 complete cycles	Clean the safety filter of the button trap basket.
Every 50 complete cycles	Clean the air lubricator and check the oil level.
Every 300 complete cycles	Clean the button trap level controls.
Every 300 complete cycles	Clean the still safety valve.
Every 300 complete cycles	Clean the drain valve of the carbon canister.
Every 200 complete cycles	Clean separator.
Every 1000 complete cycles	Clean the air tunnel cooling/heating coil.
Every 1800 complete cycles	Clean the ducts in the filter/drum area.
Every 3600 complete cycles	Clean the tanks.
Every time pressure reaches 1.2 to 1.3 BAR	Clean the ecological filter.
Every time pressure reaches 1.8 to 2 BAR	Clean the powder filter.
At the end of every working day	If the distillation is continuous, drain out the greasy residues. Clean the still (partial cleaning).
Every 300 complete cycles	Clean the still (complete cleaning).
Every 10 complete cycles	Check out all safety devices fitted on the machine.
Every 250/300 complete cycles	Carbon replacement in the container of pressure compensation.
Every 20/30 regenerations	Carbon replacement REGENAIR E D40.

2.3 IMPLICATIONS FOR THE REST OF THE STUDY

Survey results from 110 facilities identified the five components most likely to leak as the front loading door (55%), still (33%), lint trap (25%), button trap (14%), and water separator (12%). Higher quality gaskets on newer dry cleaning machines may be responsible for a lower potential to release fugitive emissions. Older dry cleaning machines have a greater potential to release fugitive emissions from the button trap, water separator, still, carbon filter, drum door, lint filter, and other areas where gaskets are found due to normal wear, vibration and lack of necessary maintenance. Dry cleaning machine operators can reduce fugitive emissions from these areas, however, by changing gaskets annually. Determining vapor leak concentrations of each component was the next step in Task 3.

3.0 PERCHLOROETHYLENE (PERC) EMISSION FACTORS AND LEAK RATES

Task 3 of this report focused on developing or refining emission factors and achievable leak rates, and estimating or measuring mass emissions as a function of relative perc concentrations. Specifically, AVES/PES was tasked with:

- Conducting reviews of professional and trade publications to identify and determine the relative merits of methodologies for estimating or measuring mass emissions;
- Reviewing findings on various dry cleaning waste products, including filters, clothing, still bottoms, and lint;
- Constructing temporary total enclosures around a dry cleaning machine, allowing access to the machine by dry cleaning personnel and for equipment maintenance; and
- Continuously monitoring the dry cleaning machine for fugitive perc emissions.

The primary objective of Task 3 was to develop an accurate, readily applicable procedure for estimating fugitive emission release rates for individual perc dry cleaning facilities. The secondary objective was to attempt to find a relationship between observed vapor leak values, as measured in the indoor ambient air at various leak points, and mass emission rates. Three questions were addressed:

(1) How much perc is emitted from fugitive sources during each phase of the perc dry cleaning cycle?

(2) Can any combination(s) of process variables (e.g., temperature, pressure) be related to fugitive emission rates?

(3) Is there a scientifically supportable relationship between vapor leak concentrations and the mass rate of fugitive emissions?

Answers to the second and third questions were expected to help improve compliance monitoring procedures. For example, establishing a reliable relationship between fugitive emissions and easily measurable process variables (i.e., drum temperature or pressure), would mean process variable measurements could be substituted for concentration measurements. Establishing a reliable relationship between fugitive emissions and vapor leak concentrations would enable the magnitude of those concentrations to determine the performance specifications for perc leak detection devices used for monitoring purposes.

In the past, vapor leak rate studies have attempted to correlate ambient air concentration measurements with measured mass emission rates from individual components. Leak rates are measured by enclosing a leaking component in a bag, and letting the bag fill with vapor for a known amount of time (Epperson et al., 1996). Before or after filling the bag, the pollutant concentration is measured at a given distance from the leak source. Using many such measurements, a statistical correlation can be obtained between the concentration and mass emission rate values. This approach has yielded good data for the petroleum and chemical industries. However, it would be difficult to implement on a perc dry cleaning machine. One of the most serious problems would be enclosing the door to the drum.

Realizing the difficulties of using standard methods, AVES/PES used a temporary total enclosure (TTE) approach. A temporary enclosure constructed around a perc dry cleaning machine allowed access to the machine by shop personnel and for equipment maintenance. Air to the TTE was supplied at a known rate with temporary ductwork and a blower. Exhaust air containing fugitive perc from the dry cleaning machine was routed to a single exhaust. While the machine was operating, perc emissions were continuously monitored with a flame ionization analyzer (FIA), and vapor leak concentrations were measured with a hand-held photoionization detector (PID). Tests were conducted at two dry cleaning facilities: Douglas Square Cleaners in Oceanside, CA and Gordon Ranch Cleaners in Chino Hills, CA.

3.1 TESTS AT DOUGLAS SQUARE CLEANERS

Douglas Square Cleaners occupies about 15,000 square feet in a shopping center at 650 Douglas Drive in Oceanside, CA. Although the area is predominantly residential, the nearest residence is approximately 0.25 mile away. The one-story facility has one perc dry cleaning machine and several wet washers and dryers. Normal operating hours are 7 a.m. to 6 p.m. Monday through Friday. Most of the five to six loads of dry cleaning per day are run before noon.

The dry cleaning machine tested was a Lindus Model 40, Type 1812 HPV, with a capacity of 40 pounds (lbs) of clothes. Table 3-1 lists some of its characteristics. Manufactured in 1988, the machine has a refrigerated condenser but no secondary controls.

Table 3-1 Characteristics of the Lindus 40 Dry Cleaning Machine

Parameter	Value
Manufacturer	Lindus
Type	1812 HPV
Serial No.	2200
Manufacture Date	1988
Dimensions	85 in.. wide x 42 in deep x 79 in. high
Solvent Capacity	175 gallons
Loading Door Diameter	26 in.
Drum Speed	40 RPM
Centrifuge Speed	410 RPM

The operating cycle of the Lindus 40 at Douglas Square Cleaners is pre-programmed on a punched card, which is then read by an electronic controller on the front of the machine. Table 3-2 lists typical times for the components of the cleaning cycle, according to the facility operator. In general, dark-colored fabrics require longer cycles than light-colored fabrics, and heavy fabrics require higher drum speeds than lightweight fabrics.

Table 3-2 Typical Times for Components of the Lindus 40 Operating Cycle

Activity	Typical Time (Min)	Notes
Charging	1-2	Charged with 25-30 gallons perc
Wash	8-10	
Solvent Filtering	1-2	Removes lint from perc
Solvent Draining	2-3	
Extraction	3-5	Drum rotation increases to 1,000 RPM
Drying	12-15	Drum rotation alternates direction until liquid sensor no longer detects perc
Cool Down	8-12	Drum at high speed
Deodorization	3-5	Drum at low speed

3.2 PRE-TEST OBSERVATIONS

On March 2, 1999, Dr. Eddy Huang and Mr. Dennis Becvar of AVES/PES visited Douglas Square Cleaners to verify that the facility was suitable for the emissions test. Using a MiniRAE hand-held photoionization detector (PID) calibrated with isobutylene, vapor leaks were measured at various points on the Lindus 40. Detected concentrations are shown in Table 3-3. These results were used to scope the emissions tests.

Table 3-3 Vapor Leak Measurements During Pre-Test Site Visit

Site of Vapor Leak	PID Reading (ppm)
Sight glass below prefilter	600
Carbon filter gasket	400
Button trap gasket	285
Water separator gasket	150
Drum door gasket	140
Lint filter gasket	110
Prefilter gasket	80
Refrigerated condenser	14
Background in shop	2

3.3 TEMPORARY TOTAL ENCLOSURE

3.3.1 Configuration

Figures 3.1 and 3.2 contain diagrams of the temporary total enclosure (TTE) used for the tests. The TTE consisted of clear plastic sheeting supported by 1.5-inch poly-vinyl chloride (PVC) pipe (see Figure 3.3). The TTE surrounded the dry cleaning machine housing and various components external to the housing (filter cartridge cases, still, etc). The dry cleaning machine operator entered and exited the TTE through a 36-inch wide resealable plastic flap on the north wall, near the loading door (see Figure 3.4). "Fresh" shop air entered the TTE through two pairs of perpendicular slits in the south wall. Air from the TTE was exhausted through a 3-inch diameter PVC duct. At Douglas Square Cleaners the TTE did not contain a fan or other air-mixing device.

Front View

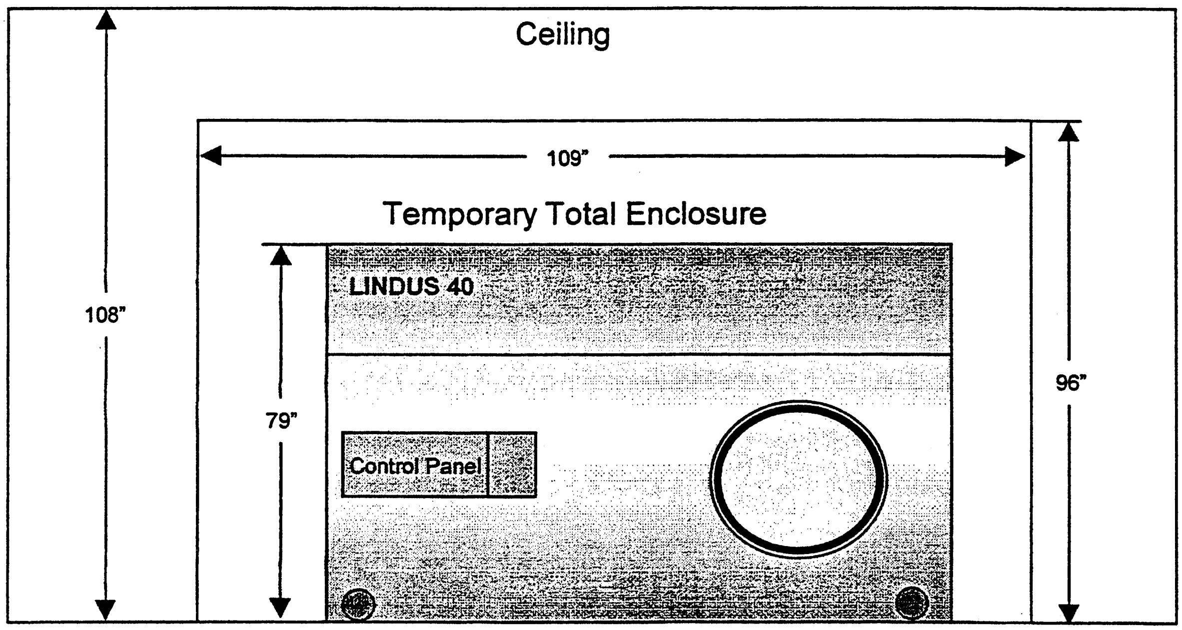


Figure 3.1 Diagram of Temporary Total Enclosure at Douglas Square Cleaners

3.3.2 Flow Rates

The average volumetric air flow rate at the TTE exhaust was about 100 standard cubic feet per minute (scfm). The enclosure gross volume was 617.7 cubic feet (ft^3). The volume occupied by the dry cleaning machine and ancillary equipment was about 163.2 ft^3. Therefore, the net open volume in the TTE was about 455 ft^3. If mixing is assumed to be uniform, the residence time in the TTE was 455/100 = 4.6 minutes, and the ventilation rate was about 13 air changes per hour.

Side View

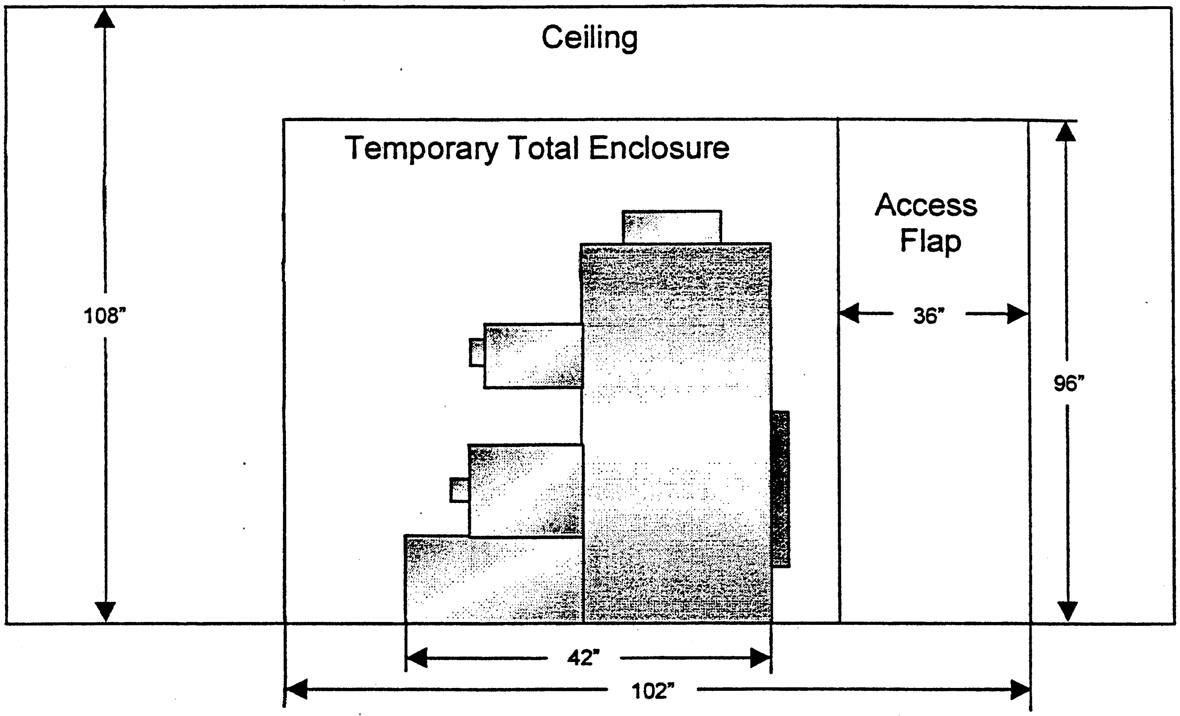


Figure 3.2 Diagram of Temporary Total Enclosure at Douglas Square Cleaners

3.3.3 Performance Criteria

The TTE design had to meet U.S. Environmental Protection Agency (EPA) performance criteria (Method 204) as specified below:

> *Natural draft openings (NDOs) must be at least four equivalent diameters from the nearest VOC emitting point.* The only NDOs were the two pairs of perpendicular slits mentioned above. The equivalent diameter of each slit was about 4 inches. Given space constraints, it was not possible to locate the slits at least 16 inches from the nearest suspected VOC vapor leak source. However, smoke tests confirmed that all air flow through the slits was into the enclosure.

> *The total area of the NDOs must be less than 5 percent of the total surface area of the TTE.* The total surface area of the TTE (not counting the floor) was 358.5 ft^2. The inlet slit area was 0.175 ft^2. Therefore, this criterion was met.

> *The net negative flow rate into the enclosure must be at least 200 feet per minute (fpm).* Given the average volumetric flow rate through the enclosure (for all the runs) of about 100 cubic feet per minute (cfm), and the NDO area of 0.175 ft^2, the average flow rate into the enclosure was about 570 fpm. Therefore this criterion was met.

> *All access openings to the enclosure must normally be closed.* The access door was opened and closed immediately before and after each run, so that clothes

could be taken out and added to the machine. In addition, on several runs, the person who was monitoring VOC leak concentrations inside the TTE had to exit the TTE during the run, to avoid exposure to high perc levels.

All exhausts from the enclosure must be vented outdoors. A flexible hose conveyed all exhausts from the TTE through an exterior doorway at the rear of the shop.

All other openings and connections to the TTE must be verified for negative pressure using smoke tubes and plastic streamers. Smoke tests conducted before the VOC measurements confirmed the integrity of the seal of the TTE.

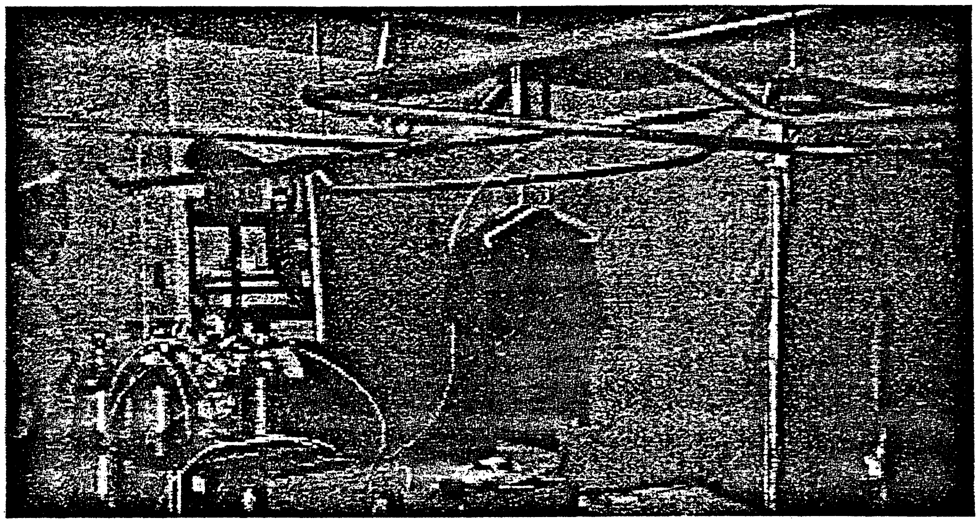


Figure 3.3 Side of Temporary Total Enclosure. Perchloroethylene Monitoring Equipment Shown at Left

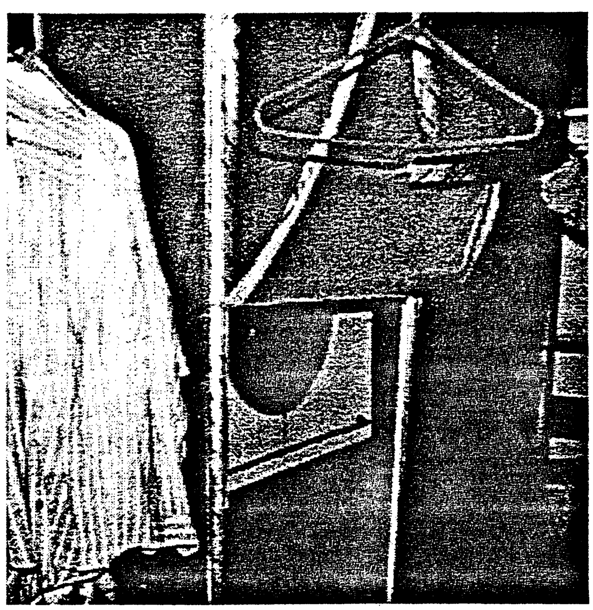


Figure 3.4 North End of TTE, Showing Access Flap

3.3.4 Definition of Test Runs

Table 3-4 defines the eight sampling runs at this facility. The AVES/PES test plan was to seal the leak points identified on the March 2, 1999 pre-test visit, and then unseal one leak at a time. To measure the maximum emission rate a test (Run 0) was first conducted with no leaks sealed. Perc concentrations in the TTE were found to be considerably higher than expected. When questioned, the facility operator reported that liquid perc had spilled onto the floor the previous night, and he had transferred it to the 5-gallon container that normally collects water from the perc-water separator. Emissions from the wastewater container were contributing to the dry cleaning machine emissions. AVES/PES sealed the wastewater collection container and then conducted another test (Run 1) with all fugitive emission points unsealed. During test Run 3, only the loading door was allowed to leak. During test Run 4, all known leak points were sealed. Information on the remaining runs is reported in Table 3-4.

For testing purposes the maximum load was 40 lbs of clothes. All loads were of similar clothing type and materials (military uniforms).

Table 3-4 Test Run Schedule at Douglas Square Cleaners March 11, 1999

Run	Allowed to Leak	Start Time	End Time	Run Time
0	Everything, including liquid	9:43	10:25	0:42
1	Everything	10:38	11:20	0:42
2	Loading Door	11:39	12:18	0:39
3	Nothing	12:31	13:10	0:39
4	Button Trap	31:21	14:03	0:42
5	Lint Trap	14:15	14:54	0:39
6	Prefilter	15:04	15:34	0:30
7	Charcoal Filter	15:44	16:16	0:32

3.3.4.1 Flow Measurement

Exhaust air flow velocity was measured with a TSI Model 8350 Velocicalc portable air velocity meter (TSI Inc., St. Paul, MN) temperature-compensated hot-wire anemometer. Before Run 0, velocities were measured at four points along each of two perpendicular diameters. On subsequent runs, the velocity was measured roughly every ten minutes at a single point. The exhaust temperature was measured shortly after the start of each run with the same hot-wire anemometer. The inlet air volumetric flow rate was assumed to equal the outlet rate.

3.3.4.2 Inlet and Exhaust VOC Concentration

EPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer" was used to determine the perc concentrations in the TTE inlet and exhaust. The monitoring system included the following components:

- A stainless steel probe (0.3875 inches OD), connected to a heated Teflon® sample line, approximately 25 feet long, and maintained at a temperature of 250°F;
- Two JUM Model VE7 heated total hydrocarbon analyzers equipped with flame ionization detectors (FIDs); and
- A data acquisition system.

The hydrocarbon analyzers were operated at a full scale of 100 ppm volume per volume (v/v) and were multi-point calibrated with known concentrations of perc contained in compressed gas cylinders. Concentrations of 10, 50 and 100 ppm (v/v) perc were used to calibrate the instrument. The calibration gases for the tests at this facility were prepared by Praxair Distribution, Inc. (Cudahy, CA), and were certified accurate to 2 percent. A diagram of the monitoring system is presented in Figure 3.5.

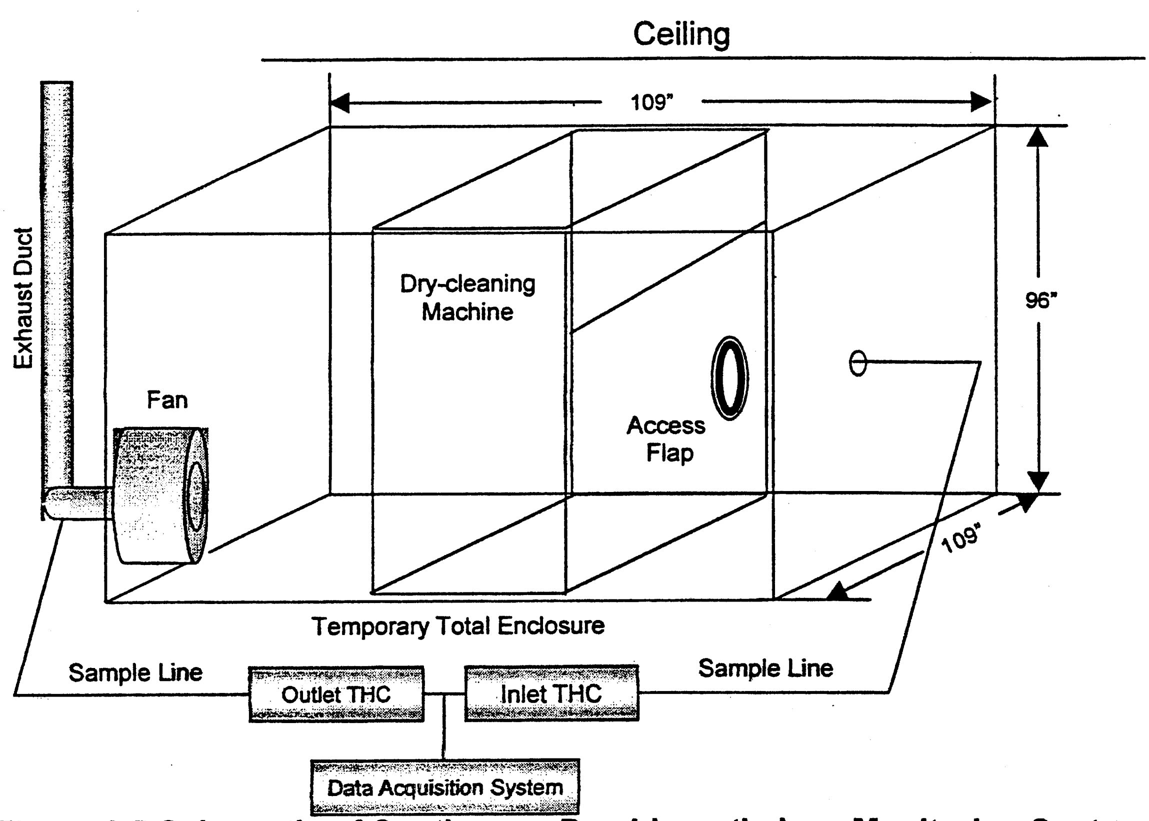


Figure 3.5 Schematic of Continuous Perchloroethylene Monitoring System

The analog output of the instruments was connected to a strip chart recorder and computer-based data acquisition system. The data acquisition system was comprised of a

National Instruments analog-to-digital converter installed in a computer, and can monitor eight channels of data simultaneously. Each channel was scanned every second. The data acquisition system converted the scanned data into 10-second and 1-minute averages. The 1-minute averages were downloaded into Microsoft Excel™ spreadsheets for additional data analysis and graphics.

3.3.4.3 Perchloroethylene Vapor Leak Monitoring

Before, during and after each emission test run, AVES/PES used a MiniRAE PID calibrated with isobutylene to monitor volatile organic compound (VOC) concentrations at various points inside the TTE. The following points were monitored:

- Background concentration inside the TTE (5.5 feet above the floor)
- Loading door
- Button trap
- Lint trap
- Water separator
- Carbon filter
- Still
- Pre-filter

During each test run, the monitoring focused on the dry cleaning machine component that was being allowed to leak. Testing plans required measurements to be made every one or two minutes. However, the perc concentrations inside the TTE frequently reached levels that made it too dangerous and/or uncomfortable for the PID operator to remain. Therefore, a maximum of four vapor leak measurements were obtained during test runs 2, 4, 5, 6, and 7.

3.3.4.4 Quality Assurance

To ensure that the results of its emissions tests would be credible and supportable, AVES/PES followed standard quality assurance (QA) procedures. QA procedures that apply specifically to the perc dry cleaners emissions tests are described below.

Use of Standard Test Procedures
EPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer" (USEPA, 1995a) was used to determine the perc concentrations in the TTE inlet and exhaust. A procedure must be thoroughly studied under various conditions in order to be designated as an EPA reference method. Results of many executions of the procedure are compared to demonstrate accuracy and repeatability before adoption of the procedure as a source testing method.

Use of Trained Test Personnel
Because of the complexity of typical source testing methods, testers should be trained and experienced with the test procedures in order to assure reliable results. Personnel used for the dry cleaner emissions tests had received professional training and routinely conduct source tests using EPA Method 25A.

Equipment Maintenance and Calibration

JUM Model JE-1 total hydrocarbon analyzers were used for continuous monitoring of perc at the inlet and outlet of the TTE. Table 3-5 summarizes the quality control objectives for these instruments. The analyzers were calibrated with zero and calibration gases prepared by Praxair Distribution, Inc. (Cudahy, CA).

At the beginning of the test, a multi-point calibration was performed for each instrument. Span gases were introduced at the probe and were delivered through Teflon tubing directly connected to each instrument. The concentrations of the calibration gases were selected to produce an instrument response at approximately 90, 50 and 0 percent of applicable full scale. The instruments were adjusted to match the digital display on the data acquisition system to the value of the known span gas.

A calibration error (linearity) of less than or equal to 2 percent of full scale was maintained. After completion of each test run, zero and span gases were re-introduced to check for zero and span drift. The span gases were chosen to give responses close to values observed during testing. Analyzer zero and span drift were maintained at less than 3 percent of full scale. An instrument response of ± 5 percent of instrument full scale was considered acceptable. This procedure determines if the sample delivery system has any effects on the measured concentrations of the pollutants of interest.

Table 3-5 Quality Control Objectives for Continuous Emissions Monitoring

Data Quality Parameter	Frequency	Requirement
Linearity	Before test	≥ 2%
Calibration Error	Before and after each test run	± 2% of span value
Sampling System Bias	Once per test run	± 5% of span value
Calibration Drift	After each test run	± 3% of span value
Calibration Gases	Not applicable	EPA Protocol 1; ± 1% of gas concentration

Thorough Recordkeeping

All data relating to the operation of the flame ionization analyzers (FIAs) were immediately recorded to ensure that they were not lost or misinterpreted. Any unusual occurrences in the process operation, unusual test instrument readings, or any other items that could affect the test results were also noted.

3.4 RESULTS

3.4.1 Net Perchloroethylene Emissions

Net perc emissions (outlet minus inlet) were calculated by a method described in Appendix A. Minute-by-minute fugitive emission results are presented in Appendix B. Table 3-6 shows the minimum and maximum one-minute average perc concentrations in the TTE inlet and exhaust. For all runs after Run 0 (when liquid perc was evaporating), the maximum one-minute average concentration in the TTE exhaust was 221 ppm.

Table 3-7 summarizes the emission results for the eight test runs. As seen in the table, the mean rate of air flow through the TTE ranged from 97 to 102 standard cubic feet per minute (scfm) and did not significantly vary from minute to minute during any run. The average inlet perc concentration, representing the ambient concentration in the dry cleaning plant, ranged from 2.4 to 5.4 ppm. Measured exhaust perc concentrations ranged from 94 to 163 ppm. These results represent conditions immediately around the dry cleaning machine.

The net emissions of perc (for all runs except the one with the liquid leak) ranged from 0.126 to 0.226 lb per dry cleaning cycle. Because the cycle times varied from run to run, all rates were also normalized to one hour.[2] These normalized rates varied from 0.235 to 0.323 lb./hr., for all runs except Run 0. Finally, an emission factor was calculated *for machine operation only.* For all the runs except Run 0, the emission factor ranged from 3.1 to 5.6 lb of perc per 1,000 lb of clothes cleaned.

Table 3-6 One-Minute Average Concentrations in TTE Inlet and Exhaust

Run	Allowed to Leak	Perc Concentration (ppm)			
		Inlet		Outlet	
		Minimum	Maximum	Minimum	Maximum
0	Everything, including liquid	0.9	9.2	16	324
1	Everything	2.2	9.2	6	213
2	Loading Door	1.6	9.2	30	178
3	Nothing	2.4	9.5	30	192
4	Button Trap	1.8	9.5	24	200
5	Lint Trap	1.6	7.6	14	197
6	Prefilter	1.6	7	30	170
7	Charcoal Filter	1	5	10	221

As exhibited in Table 3-7, the Douglas Square Cleaners dry cleaning machine emitted a significant amount of perc (0.187 lb for the cycle) even when all known leak points were sealed. Table 3-8 compares the hourly emission rates in Runs 4 through 7 with that of the Run 3. When the loading door, prefilter and charcoal filter were each allowed to leak, the hourly emission rate decreased, rather than increased.

[2] Hourly rate = (emissions per cycle/minutes per cycle) x 60. Note that, since no runs exceeded 42 minutes, the true hourly average emission rate would be lower.

3.4.2 Temporal Pattern of Emissions

During all runs, net emissions increased to a maximum rate during the midpoint of the test run and then decreased. For example, Figure 3.6 shows the variation of net emissions with time for Runs 1, 3 and 4. In all three cases, emissions suddenly decreased and then almost immediately increased. A review of field data sheets led AVES/PES to conclude that these changes in emission rates were the result of a sudden dilution of the TTE air when the person measuring component leaks entered or exited the TTE during a run.

Table 3-7 Emission Results

Run	Allowed to Leak	Run Time (min)	Mean Flow Rate (scfm)	Average Perc Concentration		Net Mass Emissions	Emission Rate	Emission Factor (lb/1000 lb)
				Inlet (ppm)	Outlet (ppm)			
0	Everything, including liquid	42	97.2	3.6	162.7	0.284	0.406	7.1
1	Everything	42	102.3	4.7	125.0	0.226	0.323	5.6
2	Loading Door	39	98.5	4.6	110.0	0.177	0.272	4.4
3	Nothing	39	99.4	5.4	116.1	0.187	0.288	4.7
4	Button Trap	42	100.0	5.1	118.6	0.208	0.297	5.2
5	Lint Trap	39	102.3	3.8	115.6	0.194	0.299	4.9
6	Prefilter	30	101.1	3.1	109.2	0.141	0.282	3.5
7	Charcoal Filter	32	98.7	2.4	93.6	0.126	0.235	3.1

Table 3-8 Comparison of Hourly Emission Rates "Nothing Allowed To Leak" Case

Run	Allowed to Leak	Emission Rate (lb/hr)	Increase or Decrease from Run 3 (lb/hr)
0	Everything, including liquid	0.406	0.118
1	Everything	0.323	0.035
2	Loading Door	0.272	-0.016
4	Button Trap	0.297	0.009
5	Lint Trap	0.299	0.011
6	Prefilter	0.282	-0.006
7	Charcoal Filter	0.235	-0.053

3.4.3 Leaks Detected

Table 3-9 indicates the measured VOC concentrations inside the TTE during each of the test runs. The maximum concentration at which the PID was calibrated was 1,000 ppm expressed as isobutylene. Therefore any reading at or above this value should be considered as "greater than 1,000 ppm expressed as isobutylene."

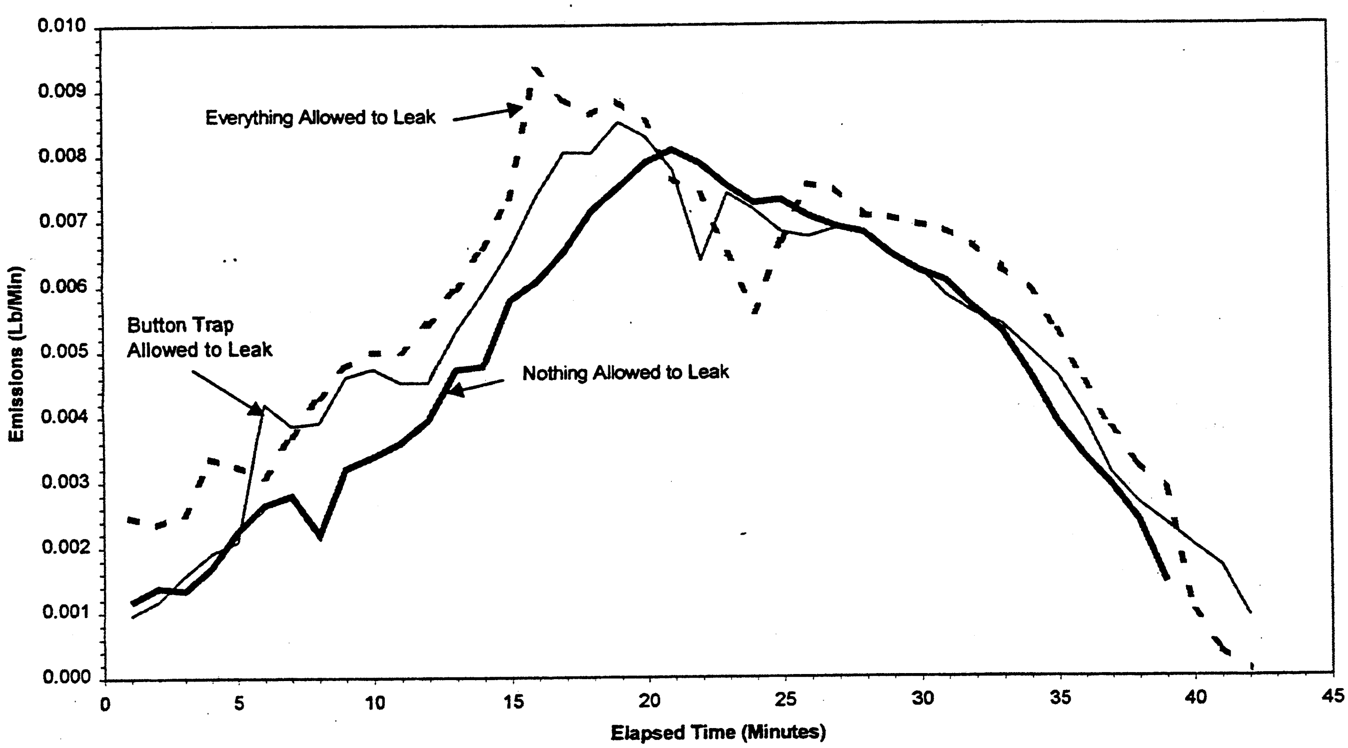


Figure 3.6 Variation of Net Emission Rate for Three Runs

3.4.4 Correlation of Emissions with Leaks

The secondary objective of Task 3 was to determine whether vapor leak measurements made with a portable instrument such as a PID could be correlated with mass fugitive emission rates. AVES/PES planned to obtain a large number of vapor leak values for each run. However, it was not possible for the field technician to remain in the TTE long enough to make the desired number of measurements. The analysis was limited, therefore, to Run 4 (button trap allowed to leak), for which four leak data values were obtained. Even in that case, one leak measurement (1,000 ppm expressed as isobutylene) is suspect, for the reason given above.

Because the residence time of perc in the TTE was at least several minutes, the analysis assumed a lag between the leak measurement and an emission value. The general model used was a simple linear regression with a time delay:

$$E_t = \beta_o + \beta_1 C_{t-n} + \varepsilon$$

Table 3-9 Results of PID Measurements Inside the TTE (in ppm as Isobutylene)

Run	Time	Loading Door	Button Trap	Lint Trap	Water Separator	Carbon Filter	Still	Pre-Filter	TTE Background
0	9:45	500							80
	9:50	150							185
	9:53				150			225	150
	9:57		310	250		300			375
	10:10				212				420
	10:12								130
	10:18	175							
1	10:40	800							90
	10:43							130	
	10:45		1000						
	10:48			300-700	170				
	10:49		2000[a]						
	10:50								170
	10:54					300			
	10:55								250
	10:58	170							
	11:00						175		1000
	11:05			240					400
	11:06		240		250	290		240	240
2	11:45		60						70,50
	11:46								175
	11:47								150
	11:48								220
	11:49								260
	11:50								180
	11:54	100-150							145
	11:58								150
	12:00	200-400							
	12:18								232
3	12:45								120
	12:46								300
	13:12								110
4	13:24		270						
	13:25		1000						120
	13:32	100							100
	13:35		450						140
	13:40		130						130
5	14:17			1000					
	14:23								50
	14:26								150
	14:30			150					
	14:56								120
6	15:05							70	90
	15:10	25							
	15:38								50
7	15:45								40
	15:50					80			80-90
	15:55								60
	15:57					260			
	15:58					280			

[a]PID readings at or above 1000 ppm may not be reliable.

In the equation, E_t is the emission rate at time t, C_{t-n} is the leak concentration n minutes before, β_o and β_1 are regression parameters, and ε is the error of the regression. The four concentration values and their respective measurement times are shown in Table 3-9. Using StatMost™ for Windows™ (Dataxiom Software Inc., Los Angeles, CA) the linear regression model was run for lag times ranging from 10 to 20 minutes. Figure 3-7 shows the coefficient of determination of regression for each run. The lag time resulting in the highest coefficient of determination was 12 minutes. The regression equation determined by StatMost™ was:

$$E_t \quad = \quad 0.00591616281 + 0.000000415\, C_{t-12}$$

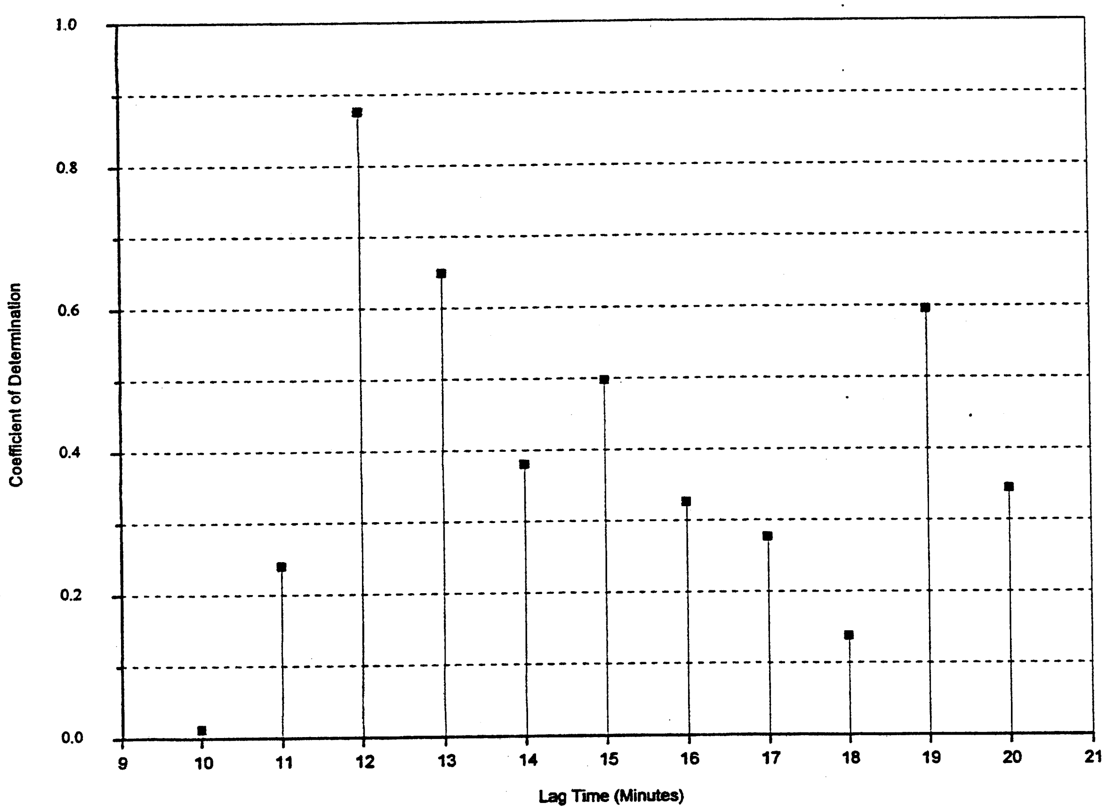


Figure 3.7 Coefficient of Determination of Regression for Run 4 (Button Trap Leak).

The coefficient of determination (r^2) for this equation is 0.876. This means that 88 percent of the variation in E_t can be explained by variation in the concentration 12 minutes earlier. Using other results from the regression analysis, AVES/PES determined lower and upper 95-percent confidence limits for the regression line. These are shown in Figure 3.8, along with the four data points from the test. Although there is apparently an excellent fit between the data and the regression line, it should be noted that the slope of the line is not significantly different from zero at the 95-percent confidence level. Additionally, the lowest PID reading incorporated in the analysis was 130 ppm expressed as isobutylene. The prediction equation therefore is not useful for PID readings below that value.

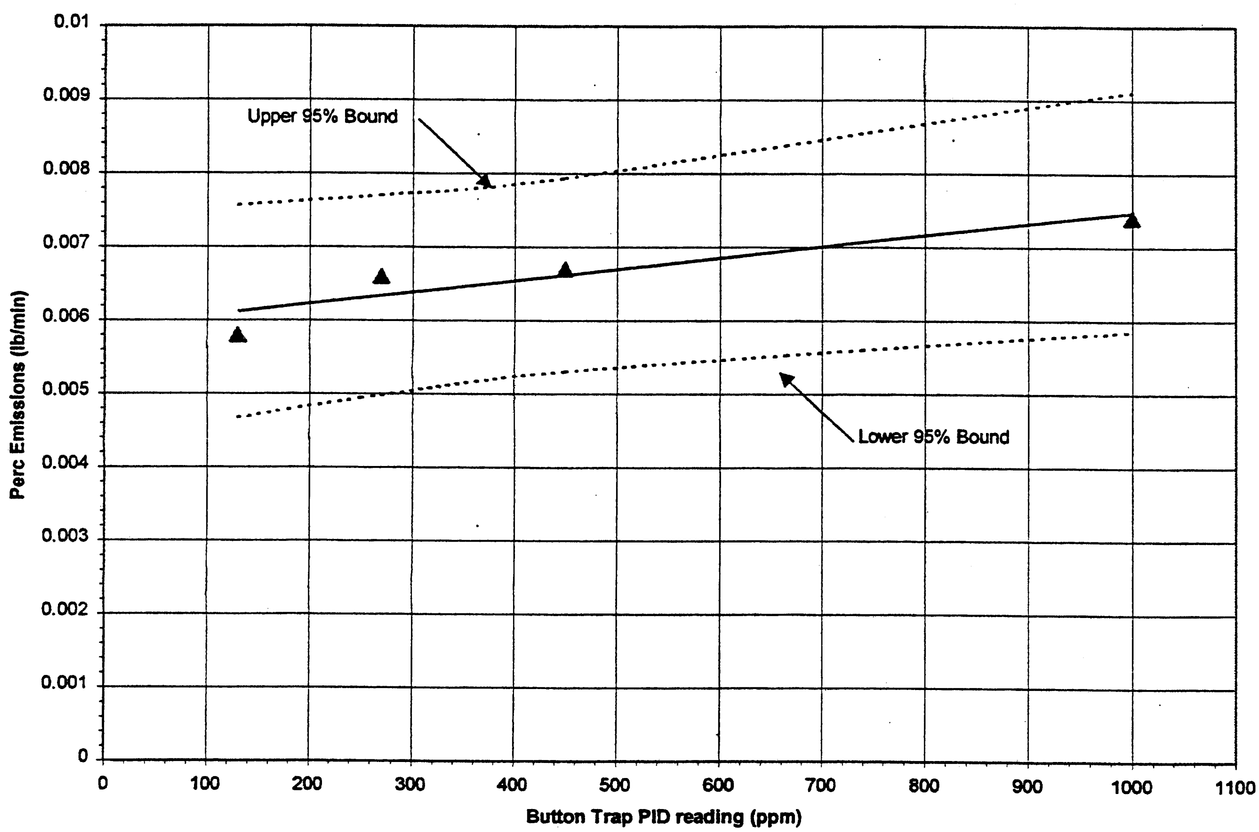


Figure 3.8 Upper and Lower Regression Limits

AVES/PES performed a multiple regression analysis to ascertain the relationship, if any, between perc emissions and the "leak status" of five dry cleaning machine components: the loading door (LD), button trap (BT), lint trap (LT), pre-filter (PF), and charcoal filter (CF). The "leak status" was set to 1 when the component was allowed to leak and 0 when it was sealed. The data set for the analysis consisted of Runs 1 through 7, and the dependent variable was average perc emissions for the run, in lb/hr (LBHR). The resulting multiple regression equation was:

$$\begin{aligned} LBHR = {} & 0.2719 + 0.00416\,LD + 0.02957\,BT + 0.03112\,LT \\ & + 0.01436\,PF - 0.03241\,CF \end{aligned}$$

The coefficient of determination (r^2) for this equation is 0.917. The problem, however, is that the Student's t value for each of the coefficients is low. In fact, the probability that each coefficient is not different from zero ranges from 0.15 to 0.68. Thus the simple linear regression equation presented above would be more useful for predicting emissions.

3.5 DISCUSSION

A perplexing result from these tests was the small difference in emissions between the cases of "everything allowed to leak" and "nothing allowed to leak." AVES/PES believes that the most likely explanation for this finding was that the machine had one or more significant, unidentified leak sources. In support is the observation that the minute-by-minute emissions pattern was similar for all runs; any contribution from known leaking components was superimposed upon the general pattern of emissions from the unknown source. Because the exterior of the machine and all its appurtenances were thoroughly checked, we believe the unidentified leak was located in an inaccessible area beneath the machine. In addition it is possible that one of the unidentified leak sources was evaporation of liquid perc from the spill that had occurred the night before the test.

The only identified leaking components whose emissions exceeded those of the unidentified leak source(s) were the button trap and the lint trap. Their net emissions exceeded those of the "nothing allowed to leak" case by 0.009 and 0.011 lb/hr, respectively. Emissions from these two sources probably comprised most of the gap between the "everything allowed to leak" and "nothing allowed to leak" cases.

As seen in Table 3-9, the general background VOC concentrations in the TTE were frequently higher than the leak concentrations measured near various "leaking" machine components. This observation raises the question of whether measurements at specific points (e.g., at the lint trap) are valid in a relatively small enclosure. The correlation between the button trap leaks and the TTE emissions may have been due to the fact that the "leaks" used as independent variables in the regression analyses were actually TTE background concentrations, which should be directly proportional to emissions. Given this possibility, we decided to perform leak measurements outside the TTE for the Gordon Ranch Cleaners tests.

The pronounced "dips" in the emissions when the technician opened and closed the door to the TTE indicate poor mixing in the enclosure. In this case, relatively clean shop air moved directly from the door to the TTE exhaust, bypassing the leaking equipment. After this experience, it was decided to incorporate a fan in the TTE for the Gordon Ranch Cleaners tests.

3.6 TESTS AT GORDON RANCH CLEANERS

Gordon Ranch Cleaners and Laundry is located in a shopping center at 2587 Chino Hills Parkway, in Chino Hills, CA. The one-story facility has one perc dry cleaning machine and several washers and dryers. Normal operating hours are 7 a.m. to 7 p.m. The machine cleans eight to ten loads per day on Monday and Tuesday, and six to eight loads per day on Wednesday through Friday.

The dry cleaning machine tested was a four-year-old "Frigosec" by Union, Model P95, with a capacity of 45 lbs of clothes per load. Table 3-10 lists some of its characteristics, and Table 3-11 shows the times for components of a typical operating cycle. It should be noted that the machine is equipped with the following unique retrofit features that further minimize fugitive perc emissions:

- A built-in carbon adsorber consisting of 2 units, each having 10.5 lbs of activated carbon to control fugitive leaks when the loading door is opened;
- Pressure sensors in the lint filter and button trap, which shut the system down if leaks are detected; and
- A "wedge lock" with a crank on the front loading door, which allows the gasket-lined door to be tightened around the opening.

As will be discussed below, these features made it impossible to "create" controlled leaks during the emissions tests.

3.7 PRE-TEST OBSERVATIONS

On May 28, 1999, Dr. Eddy Huang and Dennis Becvar of AVES/PES inspected the equipment at the Gordon Ranch Cleaners. Dr. Huang measured leak concentrations with a MiniRAE hand-held PID calibrated with isobutylene. Table 3-12 shows the detected concentrations.

Table 3-10 Characteristics of the Frigosec Model P95 Dry Cleaning Machine

Parameter	Value
Manufacturer	Union/Frigosec
Type	P95
Serial No.	01G5650
Manufacture Date	1995
Dimensions	49 in.. wide x 80 in deep x 87 in. high
Solvent Capacity	93 gallons
Loading Door Diameter	20 in.
Drum Speed	40 RPM
Centrifuge Speed	Not applicable[a]

[a]This machine has a gravity separator instead of a centrifuge.

Table 3-11 Typical Times for Components of the Frigosec Model P45 Operating Cycle

Activity	Typical Time (Min)
Soak	3
Cleaning	8
Draining	1
Solvent Extraction	3
Drying	10-15
Cool Down	2

Table 3-12 Vapor Leak Measurements During Pre-Test Site Visit

Site of Vapor Leak	PID Reading (ppm)
Still	130
Lint filter gasket	120
Clothes unloading	30
Button trap gasket	18
Water separator gasket	10
Drum door gasket	10
Background in shop	0

3.8 METHODS

3.8.1 Temporary Total Enclosure Design

Configuration

The TTE used for the tests at Gordon Ranch Cleaners consisted of clear plastic sheeting supported by 2-inch PVC pipe. The TTE surrounded the dry cleaning machine housing and various components external to the housing (filter cartridge cases, still, etc.). An oscillating fan was placed inside and near the rear of the TTE to assure thorough air mixing. The dry cleaning machine operator entered and left the TTE through a 30-inch wide resealable plastic flap on the north wall, directly in front of the loading door. "Fresh" shop air entered the TTE through two 4-in. diameter circular holes on the north side. (One hole was on the access flap.) Air from the TTE was exhausted through a 4-inch outside diameter (3.94 inches inside diameter) PVC duct leading from the wall opposite the inlet. Because a day care center was located on the property immediately to the south of the dry cleaning shop, the TTE exhaust duct made a 90-degree vertical bend after exiting the building. The exhaust point was about 21 feet above the ground.

Flow Rates

As will be discussed in Section 3.4, the average volumetric air flow rate at the TTE exhaust was about 139.5 standard cubic feet per minute (scfm). The enclosure gross volume was 437.25 cubic feet (ft^3). The volume occupied by the dry cleaning machine and ancillary equipment was about 197.36 ft^3. The net open volume in the TTE was about 239.89 ft^3. If mixing is assumed to be uniform, the residence time in the TTE was 239.89/139.5 = 1.7 minutes, and the ventilation rate was about 35 air changes per hour.

Performance Criteria

The TTE design had to meet U.S. Environmental Protection Agency (EPA) performance criteria (Method 204) as specified below:

Natural draft openings (NDOs) must be at least four equivalent diameters from the nearest VOC emitting point. The only NDOs were the two pairs of perpendicular slits mentioned above. The equivalent diameter of each slit was about 4 inches. Given space constraints, it was not possible to locate the slits at least 16 inches from the nearest suspected VOC vapor leak source. However, smoke tests confirmed that all air flow through the slits was into the enclosure.

The total area of the NDOs must be less than 5 percent of the total surface area of the TTE. The total surface area of the TTE (not counting the floor) was 358.5 ft^2. The inlet slit area was 0.175 ft^2. Therefore, this criterion was met.

The net negative flow rate into the enclosure must be at least 200 feet per minute (fpm). Given the average volumetric flow rate through the enclosure (for all the runs) of about 100 cubic feet per minute (cfm), and the NDO area of 0.175 ft^2, the average flow rate into the enclosure was about 570 fpm. Therefore this criterion was met.

All access openings to the enclosure must normally be closed. The access door was opened and closed immediately before and after each run to allow clothes to be taken from and added to the machine. In addition, on several runs, the person who was monitoring VOC leak concentrations inside the TTE had to exit the TTE during the run to avoid exposure to high perc levels.

All exhausts from the enclosure must be vented outdoors. A flexible hose conveyed all exhausts from the TTE through an exterior doorway at the rear of the shop.

All other openings and connections to the TTE must be verified for negative pressure using smoke tubes and plastic streamers. Smoke tests conducted before the VOC measurements confirmed the integrity of the seal of the TTE.

3.8.2 Definition of Test Runs

As discussed in Section 3.5, a major problem with the Douglas Square Cleaners tests was it was often difficult to isolate "leak" concentrations at specific points from the general background perc concentration in the TTE. To avoid this problem, the emissions measurements were uncoupled from the fugitive leak measurements. The plan was to induce minor leaks at specific points in the system and then to measure emissions. After the emissions tests were completed, the TTE was removed and leak concentrations were continuously monitored at the same induced-leak points. Two problems were encountered. First, because of the machine's vapor interlocks, it was extremely difficult to induce leaks. Second, the facility ran out of clothes to wash before all planned tests could be completed. Table 3-13 describes the tests performed. In test Runs 1 and 2, 40 lbs of clothes were cleaned. In test Run 3 the load was 35 lbs.

Table 3-13 Test Run Schedule At Gordon Ranch Cleaners June 10, 1999

Run	Induced Leak Point	Start Time	End Time	Run Time
1	None	9:15	9:59	0:44
2	Button Trap	10:10	10:55	0:45
3	Lint Trap	11:07	11:54	0:47
4	Button Trap and Lint Trap (No TTE)	12:20	12:54	0:34

3.8.3 Flow Measurement

AVES/PES used SCAQMD Method 1.2, "Sample and Velocity Traverse for Stationary Sources With Small Stacks or Ducts," to specify traverse points at the outlet to the TTE. The flow sampling location was eight duct diameters downstream, and two duct diameters downstream from the nearest flow disturbance. The team conducted an initial traverse of eight points, through two ports oriented 90 degrees to one another.

SCAQMD Method 2.3, "Determination of Gas Velocity and Volumetric Flow Rate From Small Stacks or Ducts," was followed to determine the exhaust gas velocity and volumetric flow rate through the TTE exhaust duct. A standard micro Pitot tube and type-K (chromal-alumel) thermocouple were positioned at each traverse point, and the velocity head and temperature were recorded for each point. The Pitot tube was connected to a Dwyer 0.5-in. H_2O magnehelic differential pressure gauge (PES ID No. GF-17) and the thermocouple was connected to a Fischer digital temperature readout. The Pitot tube, thermocouple and readout devices were calibrated prior to field use. After the initial traverse, the velocity pressure and exhaust temperature was measured three times during each emissions test at a reference point on the horizontal traverse diameter.

The molecular weight of the exhaust gas was assumed to equal that of ambient air since there was no combustion source. Moisture was determined by psychrometry (wet bulb-dry bulb). Methods used to calculate the exhaust flow rate are available upon request.

3.8.4 Inlet and Exhaust VOC Concentration

EPA Method 25A, "Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer" was used to determine the perc concentrations in the TTE inlet and exhaust. The monitoring system was comprised of the following components:

- A stainless steel probe (0.3875 inches OD), connected to a heated Teflon sample line, approximately 25 feet long, and maintained at a temperature of 250°F;
- Two JUM Model VE7 heated total hydrocarbon analyzers equipped with flame ionization detectors (FIDs); and
- A data acquisition system.

The hydrocarbon analyzers were operated at full scale of 100 ppm (v/v) and were multi-point calibrated with known concentrations of perc contained in compressed gas cylinders. Concentrations of 10, 50 and 100 ppm (v/v) perc were used to calibrate the instrument. All calibration gases for this project were prepared by Praxair, Inc., and were certified accurate to 2 percent. A diagram of the monitoring system was presented in Figure 3.6.

The analog output of the instruments was connected to a strip chart recorder and computer-based data acquisition system. Comprised of a National Instruments analog-to-digital converter installed in a computer, the data acquisition system can monitor eight channels of data simultaneously. Each channel was scanned every second. The data acquisition system converted the scanned data into 10-second and 1-minute averages. The 1-minute averages were downloaded into Microsoft Excel™ spreadsheets for additional data analysis and graphics.

3.8.5 Perchloroethylene Vapor Leak Monitoring

Although leak monitoring for correlation of leaks with emissions was to take place after removal of the TTE, leaks were monitored inside the TTE during test Runs 1 through 3. AVES/PES used a portable MiniRAE PID calibrated with isobutylene to monitor VOC concentrations at the button trap, and also measured background concentrations in the TTE and compared them with instantaneous readings from the continuous VOC analyzers.

Test Run 4 consisted solely of vapor leak monitoring of the lint trap and still, without the TTE. AVES/PES used the same EPA Method 25A monitoring system as was used in the emissions tests. During this run, at least four attempts were made to induce a steady leak from the lint trap by jamming a necktie in the access cover.

3.8.6 Quality Assurance

AVES/PES followed the same quality assurance procedures that were described in Section 2.3.6. In addition, the magnehelic differential pressure gauge was calibrated in accordance with AQMD requirements (SCAQMD, 1989).

3.9 RESULTS

3.9.1 Net Perchloroethylene Emissions

Table 3-14 summarizes the one-minute average perc concentrations for Runs 1 through 3. For the outlet maximum and average concentrations, the data were divided into two sets, one corresponding to normal operations and one corresponding to times in which attempts were made to induce a leak. For Run 1, the entire data set corresponded to normal operations, since no leaks were induced. For Runs 2 and 3, the normal operating time comprised two intervals:

(1) From the start of the test run until the start of leak.

(2) From the point where the vapor concentration returned to pre-leak value to end of the test run.

The TTE inlet concentration averaged 1.5 ppm, which represents the concentration in the general facility air. For normal operating conditions, the mean outlet concentration averaged 7.1 ppm for the three runs. Because the air in the TTE was well mixed, and outlet concentrations consistently exceeded inlet values, it is clear that fugitive vapor leaks were occurring. When leaks were induced, the one-minute average perc concentration in the TTE exhaust reached 131 ppm. (Note: this peak value was lower than all the average exhaust perc concentrations in the tests at Douglas Square Cleaners.) The average exhaust concentration for the two induced leak runs was 33.6 ppm.

Table 3-14 One-Minute Average Perchloroethylene Concentrations

Run	Perchloroethylene Concentration (ppm)								
	Inlet			Outlet					
				Normal Operation			Induced Leak		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
1	1.0	3.8	1.3	2.4	30.5	9.8			
2	0.5	2.8	1.3	0.7	8.0	5.1	8.6	60.3	28.0
3	0.9	14.0	2.0	3.1	9.2	6.4	10.5	131.0	39.2
For 3 runs	0.5	14.0	1.5	0.7	30.5	7.1	8.6	131.0	33.6

Table 3-15 summarizes the net perc emissions from the TTE. For the normal operating time intervals, the emission rate (normalized to lb/hr for comparison of runs) ranged from 0.014 to 0.031 lb/hr. These values are 5 to 11 percent of those for the "nothing allowed to leak" case at Douglas Square Cleaners. When leaks were induced at the button trap and the lint trap, the normalized emission rates were 0.097 and 0.130 lb/hr, respectively. These values are lower than the minimum fugitive emission rate at Douglas Square Cleaners.

Table 3-15 Net Perchloroethylene Emissions from the TTE

Run	Induced Leak	Mean Flow Rate (scfm)	Normal Operations				Induced Leak		
			Run Time (min)	Net Mass Emissions (lb)	Emission Rate (lb/hr)	Emission Factor (lb/1000 lb clothes	Run Time (min)	Net Mass Emissions (lb)	Emission Rate (lb/hr)
1	None	138.8	44	0.023	0.031	0.57			
2	Button Trap	139.9	34	0.008	0.014	0.20	11	0.018	0.097
3	Lint Trap	139.7	29	0.010	0.020	0.27	18	0.039	0.130

3.9.2 Temporal Pattern of Emissions

Figure 3.9 shows the net TTE emission rate (expressed in pounds per minute) for each minute of test Run 1. The emission rate decreased from 0.00175 lb/min at the start of the run to 0.0000651 lb/min near the end. The high initial value was likely due to the presence of residual perc in the TTE after a previous load of clothing had been removed from the machine. The jump in the emission rate at the end of the run was probably a result of the opening of the loading door and removal of the load while the analyzer was still recording perc concentrations.

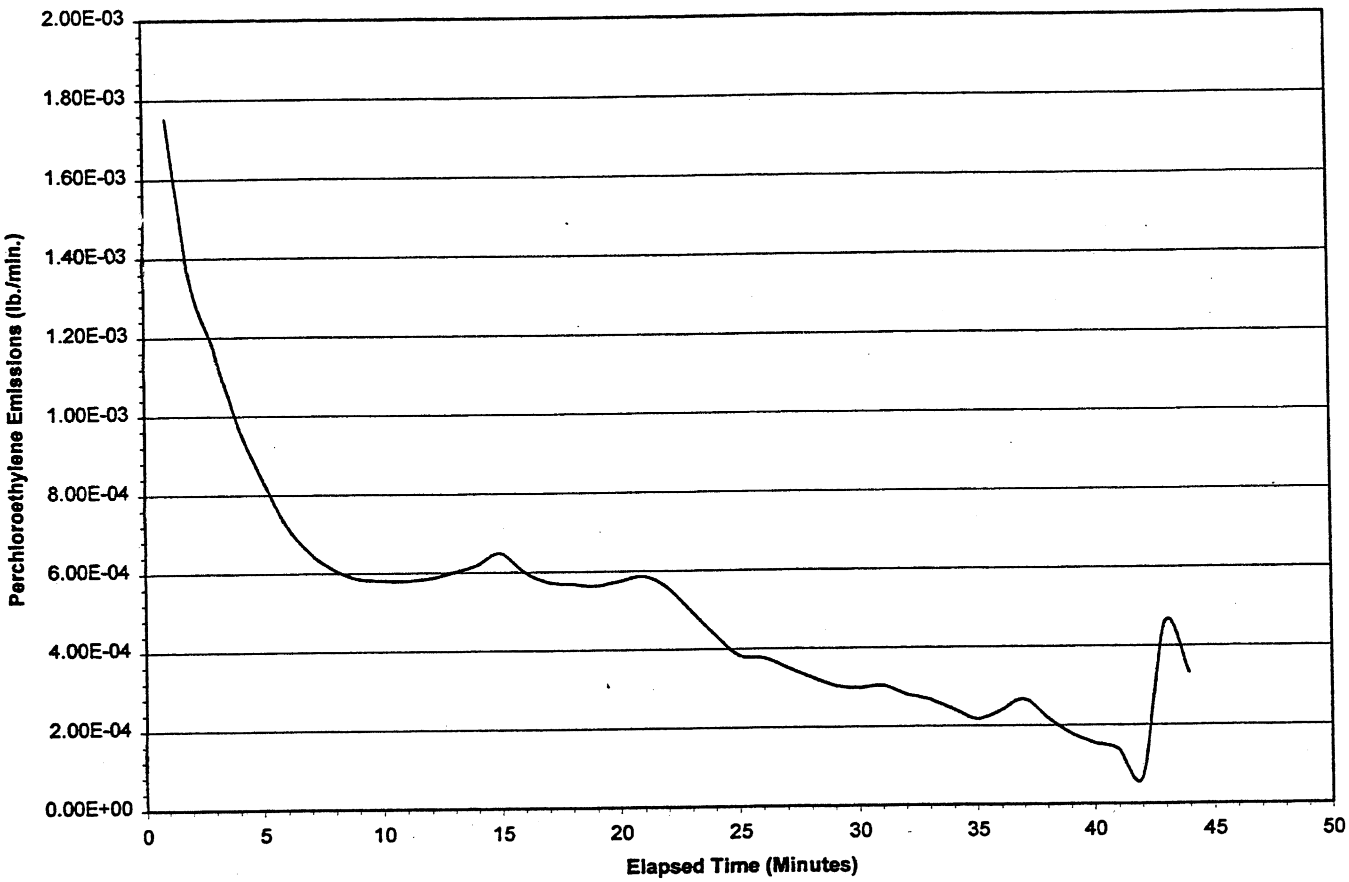


Figure 3.9 Net TTE Emission Rate

The minute-by-minute emission rate for test Run 2 is shown in Figure 3.10. During "normal" operations, the net perc emission rate was generally below 0.001 lb/min. The peak emission rate when the leak was induced was 0.00356 lb/min. Because of the safeguards mentioned in Section 3.1, it was not possible to maintain the button trap leak without shutting down the dry cleaning machine. As seen in Figure 3.10, it took about ten minutes for the emission rate to return to its pre-leak induction value.

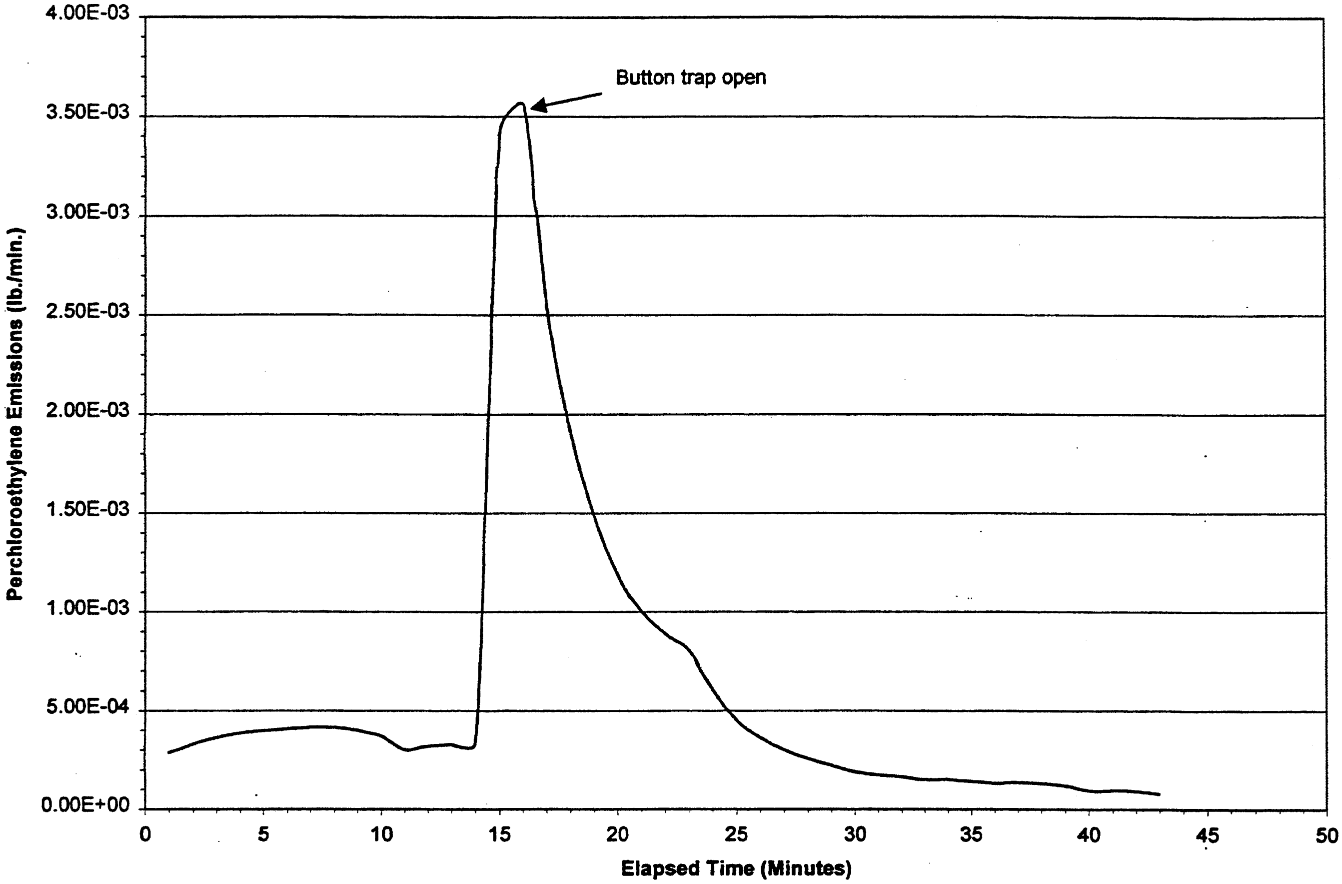


Figure 3.10 Minute-by-Minute Emission Rate for Run 2

Figure 3.11 shows the minute-by-minute emission rate for test Run 3. The pattern is similar to that of test Run 2, except that the attempt to introduce a leak occurred later in the cycle. The maximum net perc emission rate was 0.00712 lb/min. Again, it took about ten minutes for the emission rate to return to its pre-leak induction value.

In test Run 1, the high initial perc levels probably masked any variation in the emission rate with phase of the cleaning cycle. In test Run 2, the leak was induced near the end of the solvent extraction phase of the cleaning cycle. The emissions data show no trend that can be clearly correlated with phases of the cycle. In test Run 3, the leak was induced during the drying phase. Again, no clear trend can be discerned, with the exception of a slight rise of emissions during the beginning of the drying cycle.

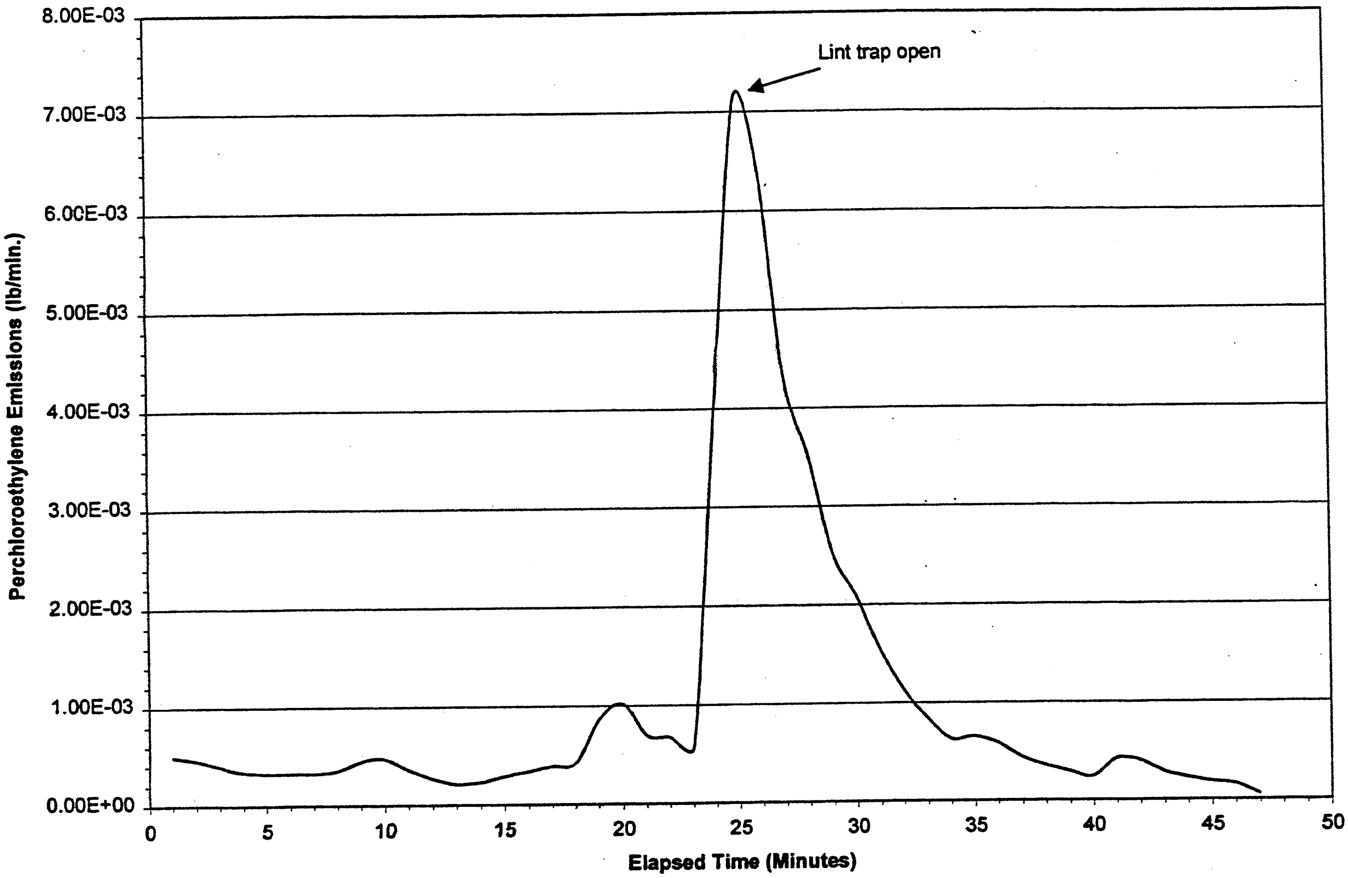


Figure 3.11 Minute-by-Minute Emission Rate for Run 3

3.9.3 Leak Monitoring Results

Limited leak monitoring was conducted inside the TTE during Runs 1 through 3. In general, MiniRAE readings were within a few ppm of the instantaneous readouts from the flame ionization analyzer that was sampling the TTE outlet. In test Run 2 when attempts were made to induce a leak in the button trap, the perc concentration inside the TTE ranged from about 50 to 600 ppm; averaged readings were around 150 ppm.

Figure 3.12 illustrates the one-minute average leak concentrations at the still door from the start of the washing cycle until the cleaned clothes were unloaded from the machine. Until the loading door was opened, the leak concentration was constant. The mean value was 5.6 ppm, and a 95-percent confidence interval about the mean was 5.4 ppm to 5.9 ppm. When the loading door was opened, the perc concentration reached a maximum 10-second average of 1,350 ppm and a maximum one-minute average of 598 ppm. It should be noted that the dry cleaning machine's still is directly beneath the loading door.

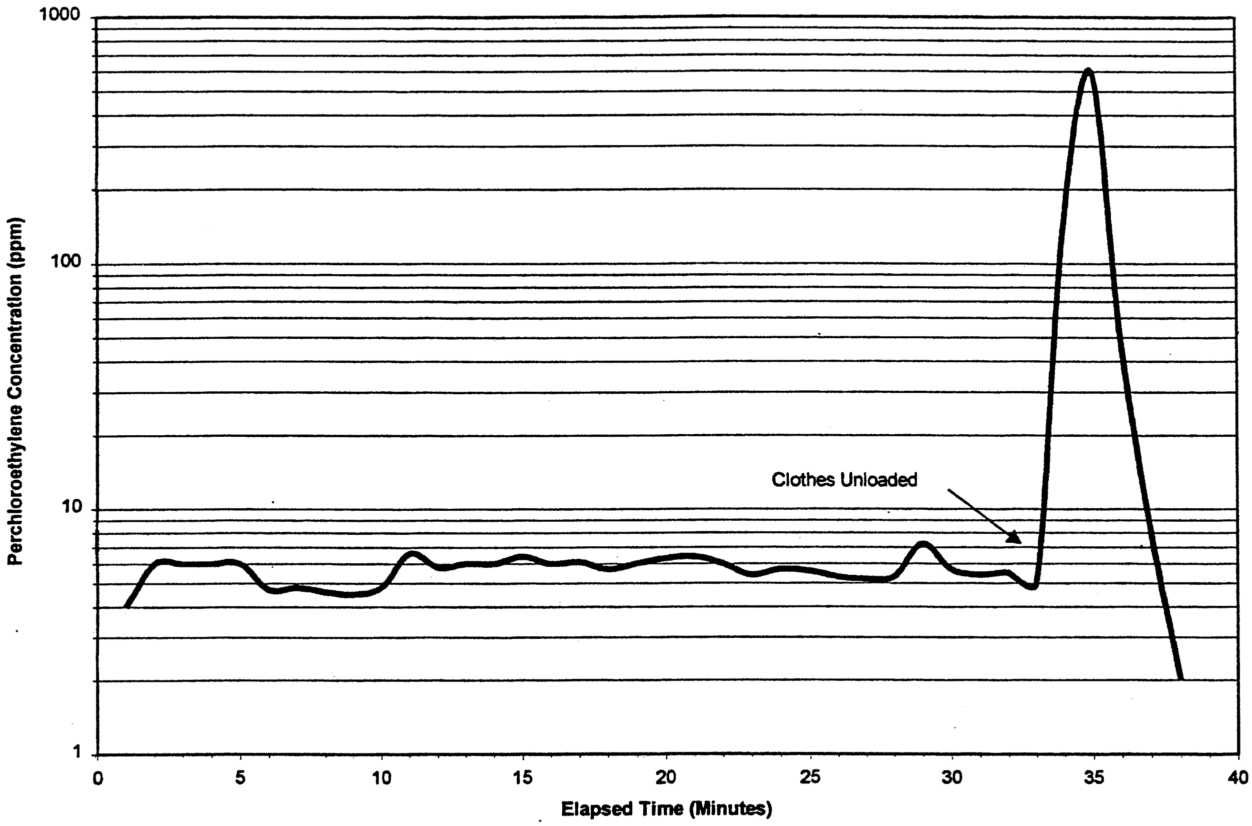


Figure 3.12 One-Minute Average Leak Concentrations at the Still Door

Figure 3.13 shows the one-minute average concentrations at the lint trap during the same time interval as was shown for the still door monitoring. The many peaks in the graph represent attempts to force a leak. The highest 10-second average value was about 13,500 ppm; its corresponding one-minute average value was 12,000 ppm. The troughs in the graph are more representative of "normal" leaks. For those times, the mean leak concentration was 4.3 ppm, and a 95-percent confidence interval about the mean was 3.1 ppm to 5.5 ppm.

3.10 DISCUSSION

Perc emission rates and vapor leak concentrations at this facility were significantly lower than those measured at Douglas Square Cleaners. AVES/PES believes that the special leak prevention features on the equipment, as well as an excellent maintenance program, contributed to the low emission rate.

3.11 SCREENING RISK ASSESSMENT

A major goal of the California Air Resources Board's Airborne Toxic Control Measure for perc emissions from dry cleaning is to reduce health risks to the community surrounding dry cleaning facilities. To obtain a better understanding of the impacts of changes in dry cleaning equipment and/or maintenance practices on public health, AVES/PES performed a screening risk assessment for two cases, corresponding to the two source tests performed under this Task. The equipment at Douglas Square Cleaners in Oceanside was considered to represent a nearly worst case (i.e., a very leaky, poorly maintained machine). The equipment at Gordon Ranch Cleaners represents the other, best case extreme: an unusually well-maintained "fourth generation" perc machine with custom-designed emission controls. The objective of the screening risk assessment was to measure the decrease in cancer risk that would result from going from the "worst case" to the "best case."

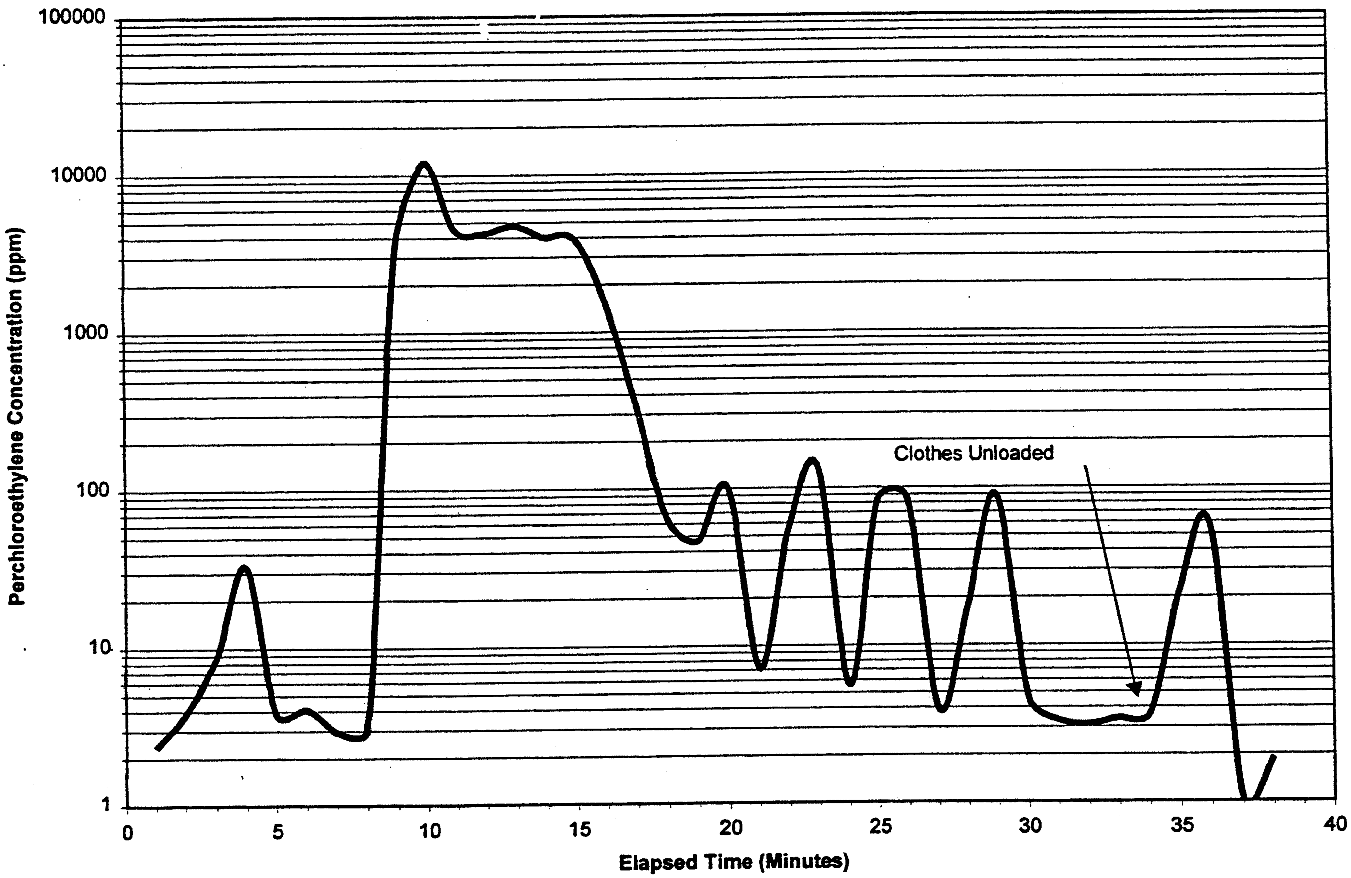


Figure 3.13 One-Minute Average Leak Concentrations at the Lint Trap

3.12 METHODS

The U.S. Environmental Protection Agency's SCREEN3 model, Version 96043 (USEPA, 1995b), predicts hourly average perc concentrations at various distances from a source. AVES/PES used this model for the screening risk assessment. Since the dry cleaning machine has no exhaust stack, it was modeled as a "volume source," with dimensions corresponding to those of the store. For the purpose of this assessment, it was assumed that each building is 100 ft wide, 150 feet long and 15 ft high. Table 3-16 shows other model parameters.

Table 3-16 Parameters Used in SCREEN3 Modeling

Parameter	Value
Source Height	2.29 m
Initial Lateral Dimension (σ_y)	3.54 m
Initial Lateral Dimension (σ_z)	2.13 m
Receptor Height	0 m
Urban/Rural Option	Urban
Meteorology	Full
Building Downwash	No

Cancer risk was calculated by the following equation:

$$R = C \times URF$$

where

C = Annual average perc concentration in $\mu g/m^3$

URF = Unit risk factor for perc

The hourly average concentrations predicted by SCREEN3 were multiplied by 0.08 to obtain annual average values. The unit risk factor for perc is 5.9×10^{-6} $(\mu g/m^3)^{-1}$ (CAPCOA, 1993). To save computation, the emission *input* to the model was multiplied by 0.08 URF, or 4.2×10^{-7}, so that the output of the model was the cancer risk.

3.13 RESULTS

Table 3-17 summarizes some of the results from the modeling. Figures 3.14 and 3.15 show the predicted cancer risk from fugitive emissions of perc as a function of distance from the plant, for Douglas Square Cleaners and Gordon Ranch Cleaners, respectively.

Table 3-17 Results of Screening Risk Assessment

Model Result	Douglas Square, Everything Allowed to Leak	Gordon Ranch, Run 2 (No-Leak Portion)
Maximum Risk	4.2×10^{-5}	3.1×10^{-6}
Distance to Maximum Risk	10 m	10 m
Risk at 100 m from Plant	5.6×10^{-6}	4.2×10^{-7}
Distance to 10 in 1 million	65 m	Not Applicable
Distance to 1 in 1 million	305 m	50.6 m

In general, it should be noted that SCREEN3 provides more conservative values (i.e., higher concentrations) than a model using actual hourly meteorological data. Thus, the risk values reported here are higher than if a model such as the Industrial Source Complex Short Term (ISCST) model had been used.

These model results give a picture of the lower and upper bounds of risk from dry cleaning machine fugitive perc emissions. At one end of the spectrum is the poorly maintained machine at Douglas Square Cleaners. Receptors out to 305 meters are subject to risks exceeding 1 in 1 million. At the opposite end of the spectrum is the dry cleaning machine at Gordon Ranch Cleaners with advanced emission controls and that is well maintained. Emissions from that machine are probably as low as may be achievable. The predicted cancer risk from the Gordon Ranch facility is about an order of magnitude lower than that from the Oceanside plant. At no point does the risk exceed 10 in 1 million, and the radius of the 1 in 1 million risk is about 51 meters, rather than 305.

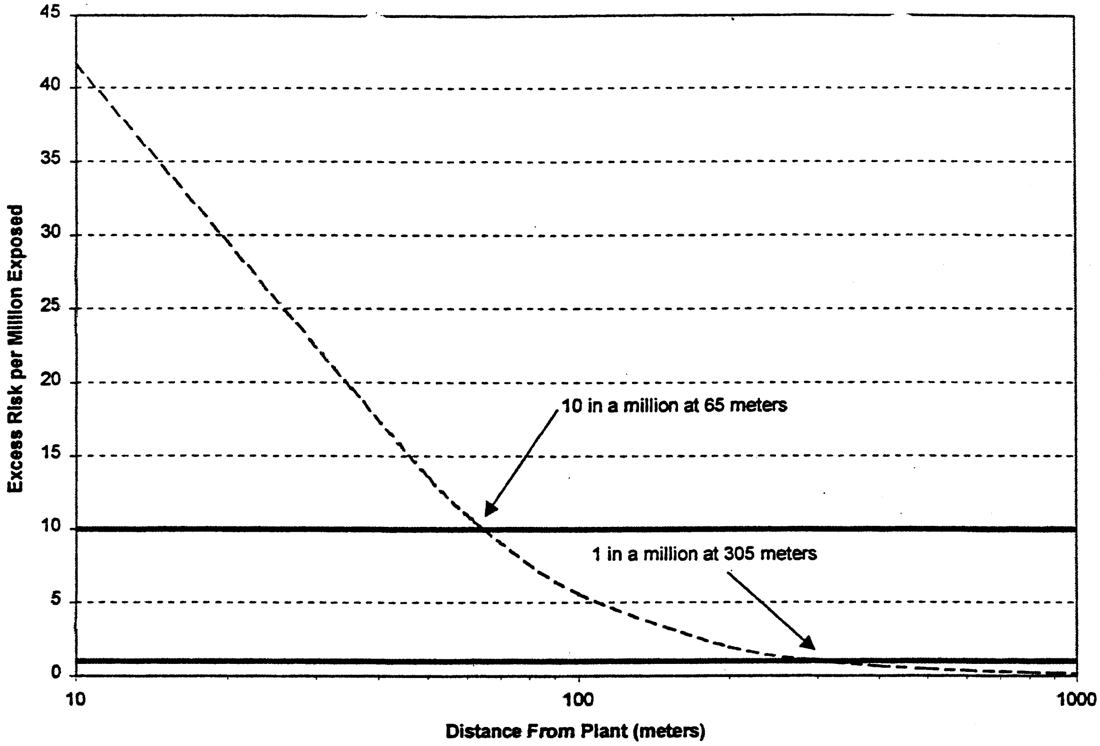


Figure 3.14 Predicted Cancer Risk from Fugitive Emissions for Douglas Square Cleaners

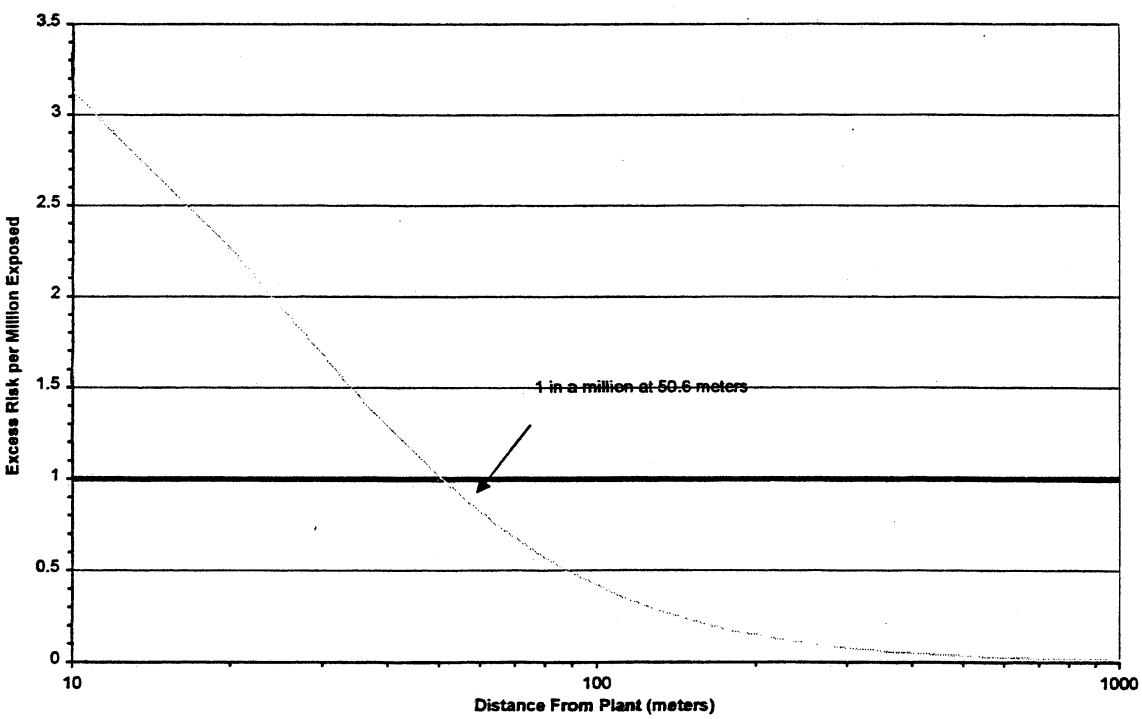


Figure 3.15 Predicted Cancer Risk from Fugitive Emissions for Douglas Square Cleaners

4.0 DRY CLEANING MACHINE LEAK MONITORING EQUIPMENT

Task 4 activities included surveying perc leak monitoring equipment, determining the likelihood of leaks, and proposing simple-to-perform monitoring options to ensure high compliance levels and minimize cost. Specifically, AVES/PES was tasked with:

- Determining the relative likelihood of leaks in components in decreasing order of frequency of citation for leaks;
- Evaluating monitoring equipment and monitoring needs at dry cleaners; and
- Identifying and proposing monitoring options and solutions that are cost-effective and user-friendly.

AVES/PES worked closely with representatives from dry cleaning and related industries to identify monitoring equipment manufacturers and vendors that could furnish technical support to meet the needs of this task. For dry cleaning monitoring issues, AVES/PES contacted the following sources to investigate new or improved cost-effective, user-friendly monitoring technologies:

- California Air Resources Board, Stationary Source Division
- Kelleher Equipment Company
- Orange County Korean Dry Cleaners Association
- SKC West, Inc.
- TIF Instruments, Inc.
- Yokogawa Corporation of America
- ZeroWaste/VacExtract

4.1 RELATIVE LIKELIHOOD OF LEAKS

Survey results from 110 dry cleaning facility owners (80 facilities surveyed by the SCAQMD and 30 facilities surveyed by AVES/PES) showed that the front leading door, still, lint trap, button trap, and water separator were the components most likely to leak. Survey findings are rank-ordered and summarized in Table 4.1.

Table 4-1 Ranking of Major Dry Cleaning Machine Leaking Components

Major Component	RELATIVE LIKELIHOOD OF LEAKS	
	Ranking	Leaking Percentage
Loading Door	1	55%
Still	2	33%
Lint Trap	3	25%
Button Trap	4	14%
Water Separator	5	12%
Drum (Other Than Loading Door)	6	5%
Condenser	6	5%
Wastewater Container	6	5%
Discharge Vent	9	4%
Solvent Pump	10	3%
Filter	10	3%
Lint Filter Doors	12	2%
Solvent Tank	12	2%
Dry Sensor	14	1%
Filter Gasket	14	1%
Sludge Storage Drum	14	1%
Temperature Gauge	14	1%
Connection Valves	14	1%
Steam Line	14	1%
Refrigerated Condenser	14	1%

4.2 MONITORING EQUIPMENT AND NEEDS

AQMD Rule 1421 requires daily monitoring of perc vapor leaks at dry cleaners. Approximately 3,000 dry cleaning facilities in the South Coast Air Basin are subject to this rule. While leaks can often be detected by smell, sight, and sound, the Air Toxic Control Measure (ATCM) requires each facility to use a portable halogenated hydrocarbon detector, a portable gas analyzer, or an alternative method approved by the district to locate vapor leaks at components such as the machine door, pumps, compressors, vapor recovery systems, and filter housings.

A vapor leak is an emission of perc vapor from unintended openings in the dry cleaning system. A vapor leak is indicated by a rapid audible or visual signal from a halogenated hydrocarbon detector, or a concentration of perc exceeding 50 ppmv as methane as indicated by a portable analyzer. The ATCM also requires liquid leaks to be repaired. AQMD considers one drop of liquid solvent from any one component in three minutes to be a violation, and any liquid or vapor leak must be repaired within 24 hours of detection.

TIF Instruments, Inc. offers the most commonly used low-cost halogen detectors (e.g., the TIF 5050A) in the dry cleaning industry. However, halogen detectors are designed for refrigerant leak detection and are not calibrated for perc. This generation of low-cost halogen detectors is sensitive but does not yield the quantitative data necessary to determine which leaks require repair. Dry cleaners interviewed by AVES/PES felt that the detectors were not accurate and could not be used for daily monitoring.

Yokogawa Corporation of America manufactures several industrial halogen leak detectors which utilize heated diode sensors to detect halogen-based gases. These halogen detectors were mainly designed for refrigerant leak detection and are not calibrated for perc. Prices range from $475 (Model H-10PM) to $4995 (Model H25C). A vapor leak is indicated by a rapid audible signal and a visual signal (red light) from those detectors, but neither digital readout nor gas concentration levels are provided by these industrial halogen leak detectors.

Although Yokogawa Refrigerant Monitoring Systems (RMS) equipment can register direct digital readings from 0 to 1000 ppm, the high cost ($5950 for Model HGM50WT) prevents this technology from being considered as an improved cost-effective, user-friendly monitoring option.

SKC West, Inc. offers several portable direct reading photo ionization detectors (PIDs) from RAE Systems. While AQMD inspectors currently use direct reading PIDs such as the MiniRAE for compliance purposes, the cost of this equipment (around $3495) represents a substantial financial burden for small business dry cleaners. RAE Systems also manufactures a lower cost real-time reading PID (ToxiRAE) for about $1300. The ToxiRAE's response time (T_{90}) is 10 seconds (compared to a 2-second response time for the MiniRAE), and the detection range is from 0 to 2000 ppm with a correction factor of 0.58 for perc. Since the ToxiRAE is a more cost-effective alternative to the well-accepted MiniRAE currently used by AQMD and the San Diego APCD, AVES/PES chose the ToxiRAE to conduct comparison testing with the MiniRAE in the actual field environment. Test results are presented later in this chapter.

In March 1999, the San Joaquin Valley Air Pollution Control District conducted a study to evaluate the effectiveness of using a halogenated hydrocarbon detector (HHD) and Snoop vs. soap solutions with a Toxic Vapor Analyzer (TVA) to verify perc leaks. Results demonstrated that the use of an HHD with a soap solution (but not with a Snoop solution) is a reliable method for determining compliance.

4.3 TEST RESULTS

A ToxiRAE provided by SKC West, Inc., was tested side by side with a MiniRAE provided by AQMD on June 10, 1999 at Gordon Ranch Cleaners. Test results are summarized in Table 4-2.

Table 4-2 Comparison of Two Direct-Reading PIDs

Sources	MiniRAE	ToxiRAE
	Perc Conc. (ppm)	Perc Conc. (ppm)
Loading Door (unloading clothes)	120	108
Lint Trap (Created Leaks)	60	50
Button Trap (Created Leaks)	150-270	120-236
Inside Temporary Total Enclosure	7	6
Indoor Background	0.1-0.3	0.1-0.3

The ToxiRAE is a diffusive sampler while the MiniRAE is an active sampler. Both the ToxiRAE and the MiniRAE have a built-in correction factor for perc. Test results showed that the ToxiRAE and MiniRAE PIDs have similar monitoring capabilities, but that the ToxiRAE PID had a slower response time. The lower reading results may be due to different calibration practices (the ToxiRAE was calibrated by SKC West; the MiniRAE was calibrated by AQMD staff) and the nature of created leaks (the ToxiRAE may not respond fast enough to show the peaks of vapor leaks). Overall, the ToxiRAE is considered a cost-effective, user-friendly perc monitoring option.

4.4 COST ANALYSIS

A brief summary of several manufacturers' leak detector specifications and approximate costs are shown in Table 4.3 below:

Table 4-3 Summary of Leak Detector Specifications and Costs

Manufacturer or Brand Name	Model No.	Sensitivity Range	Signal Type		Display		Estimated Average Cost
			Audible	Visual	Digital	Analog	
Yokogawa Corporation of America	H-10PM	< ¼ oz Refrigerant per year	Alarm	Neon Lamp	N/A	N/A	$4,995.00
Yokogawa Corporation of America	HGM-50WT	0-1000 ppm	Alarm	N/A	0-1000 ppm	N/A	$5,950.00
Leybold Inficon	Ecotec II	< ¼ oz Refrigerant per year	Alarm	Green and Red Light Emitting Diodes	N/A	N/A	$2,395.00
Leybold Inficon	TEK-Mate	< ¼ oz Refrigerant per year	Alarm	N/A	N/A	N/A	$375.00
Davis Instruments	RFC Refrigerant Leak Detector	< .5oz Refrigerant per year	Tic Noise	N/A	N/A	N/A	$299.95
Robinair	Robinair	< ¼ oz Refrigerant per year	Tic Noise	Light Emitting Diodes	N/A	N/A	$225.00

Manufacturer or Brand Name	Model No.	Sensitivity Range	Signal Type		Display		Estimated Average Cost
			Audible	Visual	Digital	Analog	
TIF	Halogen Hawk	< ¼ oz Refrigerant per year	N/A	Tricolor Light Emitting Diode Display	N/A	N/A	$395.00
TIF	TIF 5750A	< ¼ oz Refrigerant per year	Beep	N/A	N/A	N/A	$325.00
ToxiRAE	PGM-35	0-1000 ppm	Buzzer	Liquid Crystal Display	0-1000 ppm	N/A	$1,295.00
ToxiRAE	PGM-30 MiniRAE	0-2000 ppm	Buzzer	Liquid Crystal Display	0-2000 ppm	N/A	$3,495.00

4.5 IMPLICATIONS FOR THE REST OF THE STUDY

When used with a soap solution, halogenated hydrocarbon detectors have been demonstrated to be capable of detecting perc vapor leaks. However, this method does not yield the quantitative data necessary to determine which leaks require repair. Even though the ToxiRAE is the lowest-priced direct-reading PID, its cost ($1295) may still be a financial burden for most dry cleaners. If the leak limit concentration were increased, the alarm threshold of simple sensing instruments (such as the TIF) could be modified to help keep dry cleaners in compliance. This and other recommendations will be addressed in the discussion of Task 6.

5.0 ENGINEERING STUDIES OF DRY CLEANING MACHINE LEAKS

Task 5 of this project included two elements:

- Performing an empirical engineering study of the causes of leaks in a representative sample of perc dry cleaning equipment, and
- Developing cost effective, user-friendly technological "fixes" to improve the ability of dry cleaner operators to detect equipment leaks and reduce fugitive perc emissions.

Vapor and liquid leaks contribute significantly to perc emissions released to the atmosphere. Fugitive perc emissions from leaks in dry cleaning machines can occur wherever parts are mechanically connected. To establish the most frequent leak points, AVES used dry cleaner survey data for the identification of dry cleaning system components and determination of their relative likelihood to leak. AVES also conducted fugitive emission monitoring at two dry cleaning facilities using temporary total enclosures (TTEs) around dry cleaning machines and system components.

With the help of Bay Area Air Quality Management District (Bay Area) staff, AVES/PES staff conducted emissions testing at nine perc dry cleaning facilities in the metropolitan San Francisco area. Three types of facilities using various fugitive emission controls were tested: Local Ventilation (LVS), Partial Vapor Room (PVR) and Vapor Barrier Room (VBR).

AVES/PES determined mass emissions of perc from exhaust stacks and indoor air. To complete a mass balance for each facility, AVES collected wastewater, sludge, and filters and analyzed the collected samples using EPA/SW-846-ED-3. Test results indicated that the use of secondary controls is associated with a higher percentage of perc in the waste stream than when no secondary controls are used.

AVES/PES reviewed operational, service, and maintenance specifications for dry cleaning machine care from the following manufacturers:

- Lindus
- Frigosec
- Columbia
- Union
- Multimatic

Service specifications were based on either a calendar or cyclic approach. Calendar service was recommended on a daily, weekly, monthly, quarterly, biannual and/or annual basis. Cyclic service was recommended after completion of 4, 8, 50, 200, 300, 1800 and/or 3000 operating cycles.

Based on contacts with dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel, AVES/PES compiled user-friendly, cost-effective operational, service, and maintenance recommendations which will improve the ability of dry cleaners to detect equipment leaks and reduce fugitive perc emissions by reducing the frequency/probability of leaks and spills. AVES/PES further developed housekeeping practices based on dry cleaner owners' and operators' recommendations for the reduction of fugitive emissions.

5.1 DETECTION OF PERCHLOROETHYLENE LEAKS

Due to the presence of co-residential dry cleaning facilities in the Bay Area Air Basin, the Bay Area AQMD (Bay Area) has adopted stringent rules governing perc dry cleaning operations. With the help of Bay Area staff, AVES/PES staff selected nine perc dry cleaning facilities in the Bay Area Air Basin for its engineering analysis.

5.1.1 Engineering Analysis for Perchloroethylene Use in Dry Cleaners

Each of the nine perc dry cleaning facilities selected by AVES/PES for testing employed one of the following fugitive emission controls:

- Local Ventilation Systems (LVS): Local Ventilation Systems use physical structures (fume hoods, flexible walls, and shrouds) designed to capture fugitive emissions near the machine.

- Partial Vapor Rooms (PVR): Partial Vapor Rooms enclose the back of a dry cleaning machine in a small room with the front panel and loading door exposed for convenient loading and unloading.

- Vapor Barrier Rooms (VBR): A Vapor Barrier Room completely surrounds a dry cleaning machine and is constructed of material resistant to diffusion of solvent vapors, seams and gaps and sealed with metalized tape to eliminate transport.

AVES/PES determined mass emissions of perc from exhaust stacks and indoor air. To complete a mass balance for each facility, AVES/PES collected wastewater, sludge, and filters and analyzed the collected samples using EPA/SW-846-ED-3. Test results showed that the use of secondary controls is associated with a higher percentage of perc in the waste stream than when no secondary controls are used.

5.1.1.1 Number of Samples Collected

Table 5-1 summarizes the test matrix and the number of samples collected.

Table 5-1 Test Matrix for Dry Cleaning Facilities

Sources	Samples per Facility	No. of Facilities	Total Samples
Stack Air	4	9	36
Indoor Ambient	3	9	27
Wastewater	2	9	18
Sludge	3	9	27
Filter Cartridge*	3	9	27
Fabric	3	9	27
Lint	2	9	18
Total	**20**	**9**	**180**

*Where filter cartridge data were unavailable, empirical data were supplied by Bay Area.

5.1.1.2 Sampling and Analysis Methods

Methods used to sample and analyze perc at the nine facilities tested by AVES/PES are presented in Table 5-2. AVES/PES followed the procedures outlined in each of the referenced tests with exceptions as noted.

Table 5-2 Reference Test Methods

Measurement	Source	Test Methods
Flow Rate	Room Enclosure Ventilation Stack	ARB Method 1 and 2
Concentration	Ventilation Stack	EPA TO-14/ARB Method 422[1]
Concentration	Ambient Air[2]	NIOSH Method 1003[3]
Concentration	Wastewater, Sludge	EPA Method 8260
Concentration	Clothing, Fabric, Lint	NIOSH Method 1003
Weight	Filters	Gravimetric Method

Remarks:
1. Sampling method followed EPA TO-14 (used a Summa Canister instead of Tedlar Bag to prevent sample loss during shipping). Analytical method followed ARB Method 422.
2. Inside the facility.
3. Sample collection followed NIOSH Method 1003. Samples were analyzed by electron capture detection (ECD) instead of FID.

5.1.1.3 Emission Sampling from Exhaust Stacks

AVES/PES determined mass emissions of perc from the exhaust stacks. Three test runs were performed on exhaust stacks during dry cleaning cycles (one stack sample per dry cleaning cycle). The team collected the exhaust stack perc emissions through a stainless steel sample probe inserted directly into an evacuated SUMMA canister in accordance with procedures described later in this section.

The specific sampling location within the stack was determined after the velocity of the exhaust stack's effluent gas stream had been profiled. The velocity of the gas stream from the ventilation stack was measured in accordance to the procedures specified in CARB Reference Methods 1 and 2. The stack diameter and sampling location were different for each of the test sites. During the site visits, staff determined that the stacks connected to the particular ventilation device were accessible and would meet the criteria for sampling in accordance to the referenced test methods (CARB Methods 1 and 2).

During the test two holes were drilled in the stacks to measure the velocity of the gas stream. Since the composition of the air stream was primarily ambient room air, ambient levels of O_2, CO_2, and moisture content were used to calculate the molecular weight of the effluent air stream as permitted in CARB Reference Test Method 2. The molecular weight of 29.0 along with the velocity measurements were used to calculate the volumetric flow rate of the effluent air stream emanating from the exhaust stack, in accordance with the calculations presented in CARB Method 2.

A single point for measuring the effluent concentrations of perc was determined for the ventilation stack at each facility after the profile of the gas stream had been determined. The basis for sample point selection required that it be a "representative" point along a traverse with respect to the velocity or any potential cyclonic nature of the effluent gas stream.

5.1.1.4 Wastewater, Sludge, Fabrics and Lint

Wastewater, sludge, and filters from the two dry cleaning facilities were collected using EPA/SW-846-ED-3 as the guideline. All samples were stored in a cold box and shipped to the laboratory within 7 days of collection. The samples were analyzed within 7 days of receipt and within 14 days of collection to meet EPA requirements. A chain-of-custody form was included with each set of samples.

Wastewater

Wastewater was collected in a clean container from the machine separator during the sampling period on each day. The wastewater was gently swirled in the container so that it was mixed. A glass thief was used to transfer liquid from the container to volatile analysis vials. When collecting the wastewater samples, the liquid was carefully introduced into the vials to reduce any agitation that could drive off volatile compounds. In general, liquid samples were poured into the vial without introducing any air bubbles within the vial as it was being filled. The vials were filled to the top at the time of sampling, so that when the septum cap was fitted and sealed and the vial inverted, no headspace was visible. The samples were refrigerated during shipping and storage. To monitor possible contamination, a trip bla... prepared from organic-free re...gent water was carried throughout the sampling, storage, and shipping process.

Sludge

Sludge from still bottoms was collected using a clean container at the end of each sampling period. One sludge sample was collected for every dry cleaning cycle. The sludge was gently swirled in the container so that it was mixed. Vials with samples that had solid or semi-solid matrices (e.g., sludge) were completely filled as best as possible. The vials were tapped slightly as they were filled to eliminate as much free air space as possible.

All vials were labeled immediately at the point at which the sample was collected. The vials were then sealed in separate plastic bags to prevent cross-contamination between samples. The samples were refrigerated during shipping and storage.

Fabrics

Residual perc content for several fabric types was quantified as part of this project. Three fabric types were selected: wool blends, rayon and silk. The fabrics were weighed before testing, then added into the load as test coupons. At the end of the cleaning cycle, the test coupons were removed, immediately sealed in a double bag, and sent to the laboratory for analysis. At the lab, the test coupons were extracted using methanol and analyzed using NIOSH Method 1003.

Lint

At the end of the cleaning cycle, lint samples were collected from the lint filter. The samples were double-bagged for shipping. Analysis was performed at the laboratory using NIOSH Method 1003. The total amount of lint generated during the sampling period was weighed and recorded.

5.1.1.5 Ambient Air Sampling inside the Dry Cleaning Facilities

Ambient air monitoring was performed inside the dry cleaning facilities at various locations to provide a baseline for worker exposure. It is believed that personal monitoring systems are more appropriate for indoor air quality measurement and much more cost-effective to determine worker exposure. Calibrated personal sampling pumps were attached to the wall at locations closest to the emission sources (i.e., dry cleaning machines and recently dry cleaned clothes). The calibrated personal sampling pump drew air through a charcoal sorbent tube, which was analyzed at a laboratory to determine average employee exposure to perc during the sampling period. NIOSH Method 1003 was used for the analysis. All of the samples were analyzed within 14 days to meet EPA's shelf life requirement. Ventilation systems and dry cleaning machine types for the nine facilities selected for source testing are summarized on the following page in Table 5-3.

Table 5-3 Facility List for Source Test

Test Site	Type	Machine Type
Facility 1	VBR	Secondary Control
Facility 2	VBR	Secondary Control
Facility 3	VBR	Closed Loop with Fugitive Control
Facility 4	PVR	Closed Loop and Secondary Control
Facility 5	PVR	Secondary Control
Facility 6	PVR	Closed Loop with Fugitive Control
Facility 7	LVS	Closed Loop and Secondary Control
Facility 8	LVS	Closed Loop
Facility 9	LVS	Closed Loop

5.2 SOURCE TEST DATA AND MASS BALANCE

The parameters for measurement of the test program were selected to calculate a mass balance for perc usage at each facility and to calculate the capture efficiency of each ventilation system. Theoretically, the perc consumption of the dry cleaning machine is equal to the sum of stack emissions, fugitive emissions, and residual perc in the clothes and in the waste streams (wastewater, sludge and lint).

Each dry cleaning facility keeps logs and records showing site-specific data for perc use, pounds of materials cleaned, and waste. However, some of the facilities maintained very poor records. For those dry cleaning facilities with logs and records showing site-specific data, perc daily consumption and waste streams were back-calculated by the consumption of perc in a certain period of time divided by the number of operating days during that time period. Perc daily consumption was also back calculated by the consumption of perc in a certain period of time divided by the weight of clothes cleaned during that time period. Where site-specific data were not available, empirical data were used to conduct mass balance calculations.

Test data for the nine facilities are summarized below in Tables 5-4a, 5-4b, 5-5a, and 5-5b.

Table 5-4a Facility Source Test Data: Perchloroethylene Usage - Mass Balance (grams/day)

Facility	Clothes	Lint	Sludge	Water	Stack	Air	Filter	Total
Facility 1	4.12	0.00	318.58	0.00	15.26	0.16	30.76	368.88
Facility 2	16.07	0.00	634.98	0.11	129.58	1.86	61.52	844.12
Facility 3	1.25	0.00	125.58	0.08	147.01	0.83	61.52	336.26
Facility 4	16.46	0.00	2.66	0.00	1154.99	32.32	164.05	1370.48
Facility 5	4.41	0.00	23.85	0.07	12.07	0.65	123.03	164.07
Facility 6	11.11	0.00	928.02	0.62	1032.18	1.10	0.00	1973.04
Facility 7	19.25	0.00	1059.96	0.53	616.23	9.09	574.16	2279.21
Facility 8	6.43	0.00	63.33	0.24	1038.42	0.81	0.00	1109.24
Facility 9	10.39	0.00	13.39	1.67	524.95	0.53	820.23	1371.16

Table 5-4b Facility Source Test Data: Perchloroethylene Usage - Mass Balance (lbs/yr)

Facility	Clothes	Lint	Sludge	Water	Stack	Air	Filter	Total
Facility 1	2.72	0.00	210.52	0.00	10.08	0.11	20.33	243.75
Facility 2	10.62	0.00	419.59	0.07	85.63	1.23	40.65	557.79
Facility 3	0.83	0.00	82.98	0.05	97.14	0.55	40.65	222.20
Facility 4	10 88	0.00	1.76	0.00	763.21	21.36	108.40	905.60
Facility 5	2.91	0.00	15.76	0.05	7.98	0.43	81.30	108.42
Facility 6	7.34	0.00	613.23	0.41	682.06	0.73	0.00	1303.77
Facility 7	12.72	0.00	700.41	0.35	407.20	6.01	379.40	1506.09
Facility 8	4.25	0.00	41.85	0.16	686.18	0.54	0.00	732.98
Facility 9	6.87	0.00	8.85	1.10	346.88	0.35	542.00	906.05

Note: Facility mass balance data were converted from grams/day to lbs/yr assuming 300 operating days per year.

Table 5-5a Facility Source Test Data: Fugitive Emissions of Perchloroethylene (grams/day)

Facility	Machine Type	Clothes	Stack	Air	Total Fugitive Emissions	Source Test Total
Facility 1	Secondary Control	4.12	15.26	0.16	19.54	368.88
Facility 2	Secondary Control	16.07	129.58	1.86	147.51	844.12
Facility 3	Closed Loop with Fugitive Control	1.25	147.01	0.83	149.09	336.26
Facility 4	Closed Loop and Secondary Control	16.46	1154.99	32.32	1203.77	1370.48
Facility 5	Secondary Control	4.41	12.07	0.65	17.12	164.07
Facility 6	Closed Loop with Fugitive Control	11.11	1032.18	1.10	1044.39	1973.04
Facility 7	Closed Loop and Secondary Control	19.25	616.23	9.09	644.57	2279.21
Facility 8	Closed Loop	6.43	1038.42	0.81	1045.67	1109.24
Facility 9	Closed Loop	10.39	524.95	0.53	535.88	1371.16

Table 5-5b Facility Source Test Data: Fugitive Emissions of Perchloroethylene (lbs/yr)

Facility	Machine Type	Clothes	Stack	Air	Total Fugitive Emissions	Source Test Total
Facility 1	Secondary Control	2.72	10.08	0.11	13.01	243.75
Facility 2	Secondary Control	10.62	85.63	1.23	97.48	557.79
Facility 3	Closed Loop with Fugitive Control	0.83	97.14	0.55	98.52	222.20
Facility 4	Closed Loop and Secondary Control	10.88	763.21	21.36	795.44	905.60
Facility 5	Secondary Control	2.91	7.98	0.43	11.31	108.42
Facility 6	Closed Loop with Fugitive Control	7.34	682.06	0.73	690.13	1303.77
Facility 7	Closed Loop and Secondary Control	12.72	407.20	6.01	425.93	1506.09
Facility 8	Closed Loop	4.25	686.18	0.54	690.97	732.98
Facility 9	Closed Loop	6.87	346.88	0.35	354.10	906.05

Note: Facility fugitive emissions data were converted from grams/day to lbs/yr assuming 300 operating days per year.

5.2.1 Statistical Data An.. sis

Data collected for this test program included perc concentrations in indoor air, stack air, fabrics and waste streams. Site-specific data such as perc usage, waste volume, mass of clothes cleaned per batch and number of cleaning batches were also collected. Because of the small size of the study population, only basic summary statistics were calculated.

5.2.2 Analysis of Perchloroethylene Use

The purpose of this analysis was to determine whether the use of secondary controls would result in the partitioning of a higher fraction of the perc in waste products than occurs without secondary controls. Table 5-6 shows the amounts of perc that accumulated in three types of dry cleaner waste materials (sludge, lint, and filters) at six of the facilities[3]. Table 5-6 also shows the waste as a percentage of the total perc accounted for.

Table 5-6 Mass Balance Summary: Bay Area Dry Cleaner Study

		Ventilation Type			Perchloroethylene Used (lbs/yr.)		
Machine Number	Secondary Control?	Total Enclosure	Partial Enclosure	Local Ventilation	Total Used	Total Waste	Total Emissions
1	Yes	XXX			243.8	230.8 (95%)	10.2 (4%)
2	Yes	XXX			557.8	460.3 (83%)	86.9 (16%)
3	No	XXX			222.2	123.7 (56%)	97.7 (44%)
4	Yes/No[1]		XXX		905.6	110.2 (12%)[2]	784.6 (87%)
5	Yes		XXX		108.4	97.1 (90%)	8.4 (8%)
6	No		XXX		1303.8	613.6 (47%)	682.8 (52%)
7	Yes/No[1]			XXX	1506.1	1080.2 (72%)	413.2 (27%)
8	No			XXX	732.9	42.0 (6%)[3]	686.7 (94%)
9	No			XXX	906.0	552.0 (61%)[4]	347.2 (38%)

Note 1: There are two types of machines (one secondary control, one closed-loop).
Note 2: This is a special leather care dry cleaner (minimum sludge volume).
Note 3: This machine does not have disposable filters.
Note 4: This facility reported 88 disposable filters a year.

The mean waste percentages for dry cleaning machines with and without secondary controls were 88.9% and 41.4%, respectively. A two-tailed Student's t test showed that these means were reliably different ($t_{df=3} = 3.4238$, $p \leq 0.0417$; see Table 5-7 below for detailed results). Based on this finding, AVES/PES concluded that the use of secondary controls is associated with a higher percentage of perc in the waste stream than when no secondary controls are used.

[3] Two facilities were excluded because each had one machine with secondary controls and one without, and their wastes were combined.

Table 5-7 t-Test Analysis Results

	Secondary Control	No Secondary Control	
Sample Size	3	4	
Missing Data	0	0	
Minimum	82.51	1.99	
Maximum	94.7	60.8	
Range	12.19	58.81	
Standard Deviation	6.1179	26.8582	
Standard Error	3.5321	13.4291	
Coefficient of Variation	6.8809	64.9259	
Mean	88.9100	41.3675	Difference = 47.5425
Variance	37.4281	721.3637	Ratio = 0.0519

Results of the mass balance calculations of perc dry cleaning facilities in the Bay Area Air Basin showed that the majority of the perc emissions were associated with the waste streams (wastewater, sludge and lint). The residual perc in the waste streams accounted for 47% to 95% of the total perc used. AVES/PES expects the same perc mass balance distribution would apply to perc dry cleaning facilities in the South Coast Air Basin.

5.3 FUGITIVE EMISSIONS CONTROLS

Fugitive emissions are the major source of total emissions from facilities using closed-loop machines. Perc emissions can also result when opening the front loading door, adding solvent to the machine, or cleaning traps and filters. AVES/PES worked with several equipment manufacturers to evaluate factory-engineered primary and secondary fugitive emission control systems and practices.

5.3.1 Primary Control Devices

- Refrigerated Condensers

  Refrigerated condensers are used as primary controls on all types of dry cleaning machines. They are efficient at removing perc vapor from an air stream and are relatively easy to maintain. Vented machines with one-pass refrigerated condensers may achieve up to 70 percent collection efficiency, while closed-loop machines are capable of achieving greater than 95 percent collection efficiency. The use of refrigerated condensers can reduce the perc vapor concentration in the drum to 8,600 parts per million volume (ppmv) or less.

- Vapor Adsorbers

  Vapor adsorbers are control devices that use activated carbon, synthetic polymer adsorbent, or other substances to trap perc vapors and allow the solvent to be recovered later. The two most common types of vapor adsorbers are discussed below:

  1. Carbon Adsorbers

     A carbon adsorber is the most common vapor adsorber used as a primary control device on both transfer and vented dry-to-dry machines. During the drying cycle for these machines, the perc and moisture-laden air is passed through water-cooled coils to condense the perc and water vapors from the air stream. The perc-water mixture is sent to a water separator where the perc is recovered and returned to the solvent tank. Carbon adsorbers can effectively reduce a perc-laden air stream to 300 ppmv or less.

  2. Polymeric Vapor Adsorber

     Dow Chemical has a system called Temporary Vapor Storage, or TVS. This involves a new adsorption technology using a synthetic polymeric adsorbent bed. The main advantage of this technology is that it does not use steam to desorb the polymeric adsorbent bed, so it does not generate wastewater containing perc.

5.3.2 Secondary Control Devices

Opening the loading door of closed-loop machines to remove dry cleaned materials at the end of the drying cycle is a substantial source of perc emissions. The concentration of perc in the drum at the end of the drying cycle can be as high as 8500 to 8600 ppmv (ARB, 1993). The use of secondary control devices to route perc vapors from the drum, button and lint traps through a vapor adsorber can reduce perc concentrations in the drum to 300 ppmv or less. Secondary control devices generally consist of a carbon adsorber that operates in series with the refrigerated condenser on a closed-loop machine to strip the perc vapors from the air. Most secondary devices use electrically- or steam-heated air or heating coils to strip the perc from the vapor adsorber.

5.3.3 Ventilation Systems

Dry cleaning facilities typically use either natural ventilation (through doors and windows) or general ventilation (building exhaust and make-up air through fans and coolers). AVES/PES found several more efficient ventilation systems to control fugitive emissions.

Vapor barrier rooms (VBR) are usually constructed of material resistant to solvent vapors such as metal foil-faced insulation sheets or heavy plastic sheeting sandwiched between dry wall (gypsum) sheets. The seams and gaps are sealed with aluminized tape, and large gaps are caulked with silicon sealant prior to taping. See Figure 5.1 for VBR.

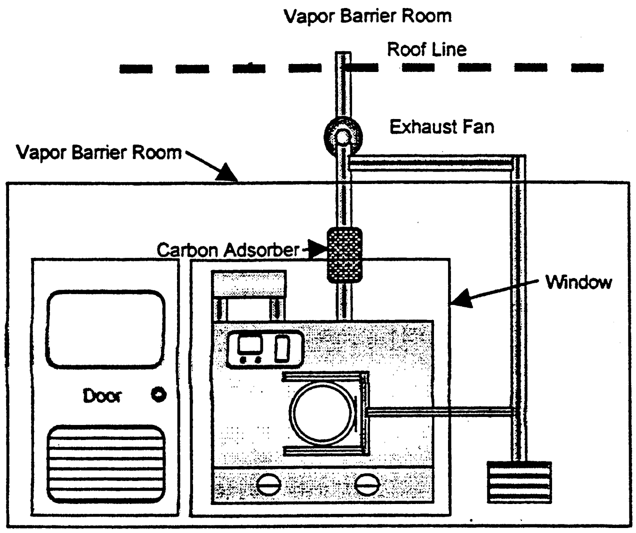


Figure 5.1 Vapor Barrier Room

The door(s) to the VBR are normally closed. Self-closing devices are used; examples include a “swinging” design that opens both ways, or a sliding door. Windows may be installed in doors or walls to allow light, for safety reasons, or for make-up air. Plexiglas or tempered glass is usually used.

Fresh make-up air may be supplied from the shop through gaps around the entry door(s) or, if necessary, with sliding windows or adjustable louvers. Make-up air may be introduced at the front of the machine and at the same height as the loading door. The ventilation duct or fan intake is usually placed near the ceiling directly above the back of the machine or at the rear of the VBR. A fan produces air flow to maintain a capture velocity greater than 100 feet per minute at any intentional gap or opening or about 50 feet per minute at the entry door when (temporarily) open.

The exhaust fan may be installed inside the VBR or outside the facility on a wall or on the roof. The fan is run continuously (24 hours a day, 365 days a year) in a co-residential facility and whenever the dry cleaning machine is operating or being maintained in a non-residential facility.

Partial Vapor Room and Local Ventilation Systems

Partial Vapor Rooms (PVRs) are also constructed of material resistant to diffusion of solvent vapors such as metal foil-faced insulation sheeting or heavy plastic sheeting sandwiched between dry wall sheets (offset seams). Seams and gaps are sealed with aluminized tape, rather than standard duct tape. Plexiglas may be used as windows to allow light and for safety. The PVR should surround the back of the machine with the face of the machine and loading door accessible to the operator from the outside of the room. Maintenance entry doors are normally closed (self-closing or alarmed). See Figure 5.2 for example of a PVR.

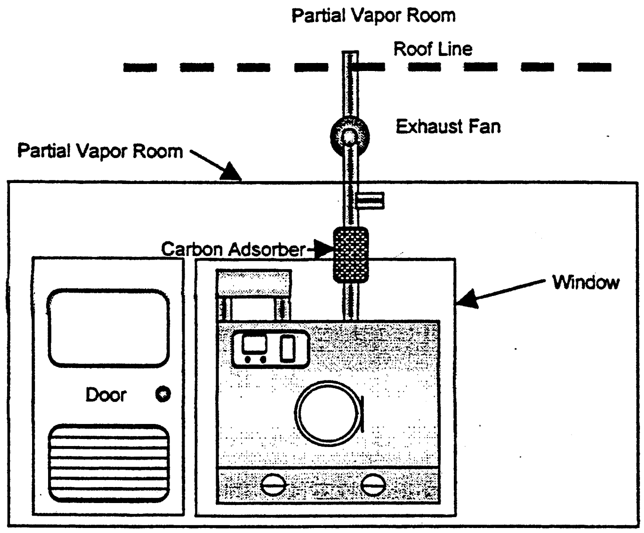


Figure 5.2 Partial Vapor Room

In local ventilation systems (LVS), hoods and shrouds are used to capture fugitive emissions at the point of release and are necessary for some non-residential facilities to minimize exposure of perc to nearby residents or commercial/industrial receptors. Fume hoods usually have plastic curtains on the sides (or a combination of walls and curtains) to minimize cross-flow draft problems and provide better capture velocity. An example of a typical LVS appears in Figure 5.3.

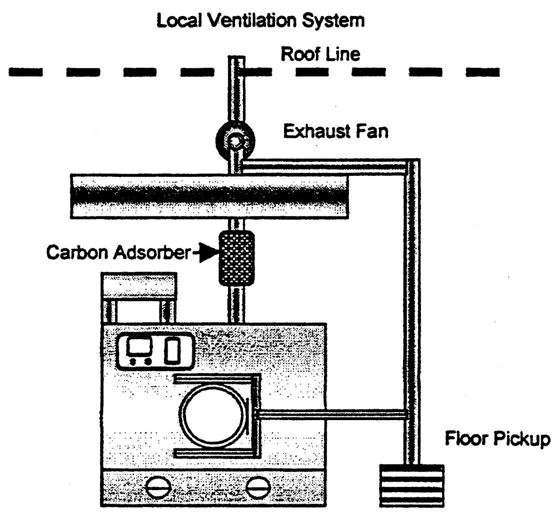


Figure 5.3 Local Ventilation System

If a closed-loop dry cleaning machine is not totally enclosed (by walls for PVR or plastic curtains for LVS), an inductive door fan, a fugitive control system, or a fugitive capture shroud is recommended to assure that most of the emissions from the loading door are captured by the ventilation fan.

There should be adequate airflow (about 1000 cubic feet per minute but likely much higher: 2,500-10,000 cubic feet per minute) to maintain a capture velocity greater than 100 feet per minute. An air change rate of at least once every 10 minutes is generally adequate in a stand-alone building, but more frequent air changes are usually recommended for mixed-use buildings.

Exhaust fans should be a high-pressure (1-3" H_2O) design with a minimum capacity of 1000 cubic feet per minute (CFM). The fan(s) may be installed inside the PVR/LVS or outside the facility, on a wall or on the roof, and should be run whenever the dry cleaning machine is operating or being maintained. The ventilation duct or fan intake is usually placed near the ceiling directly above the back of the machine or at the rear of the PVR or LVS. The stack should extend at least 5 feet above the roofline of the building or on any adjacent roof and at least 30 feet from any air intake or window. Emissions must be exhausted vertically (no rain caps). Proper stack design eliminates rain intrusion with offset legs, drains, and internal ridges. The diameter of the stack is related to the total air flowrate and desired exhaust velocity for good dispersion: generally a diameter of 8 to 14 inches and a flowrate of 1000 to 2500 CFM will provide adequate exhaust velocity (10-20 meters per second).

Partial Vapor Rooms or Vapor Barrier Rooms are more effective than local or general ventilation for capturing emissions and are highly recommended for co-located situations such as multi-story commercial buildings and shopping malls that do not provide good separation between units. A fugitive control system or a secondary control system is also recommended to reduce emissions and associated risk. A fugitive control system has an inductive door fan that draws air from drum and through the loading door prior to and/or when the loading door is opened; exhaust is normally abated with a carbon adsorption system. A secondary control system has a small carbon adsorber that collects residual solvent vapors from recalculating air at the end of the drying cycle. Fugitive and secondary control systems must be regularly regenerated to be effective.

5.3.4 LVS Enclosing a Dry Cleaning Machine

Combinations of solid walls and plastic curtains may create an effective capture area. Walls or plastic curtains should extend at least 3 feet in front and back of the machine for operation and maintenance. The exhaust fan should be mounted above or behind the machine near the ceiling. Exhaust points should be at least 5 feet above the building or adjacent building and 30 feet from any window or air intake. To minimize fugitive emissions, an LVS with a Loading Door Shroud (or partial vapor room) that does not enclose the loading door of a standard closed-loop machine must include:

1) A capture shroud at the loading door;

2) An inductive door fan; or

3) A fugitive control system to minimize fugitive emissions.

Effective capture systems should have a capture velocity greater than 100 feet per minute.

5.3.5 Capture Efficiencies

To calculate the capture efficiency of each ventilation system, the amount of perc emitted through the room enclosure ventilation stack was divided by the total emissions of the machine in the enclosure. A mass balance of perc usage was used to estimate total emissions at the test facilities. AVES/PES determined the amount of perc consumed and subtracted the amount of perc in the waste stream and the estimated amount of perc retained in the fabrics. Th.. difference was the total perc emis..ons from the dry cleaning facility. Capture efficiency of each facility was calculated based upon the source test data collected on site (see Table 5-8).

Table 5-8 Capture Efficiencies

Facility	Type	Machine Type	Stack Emission	Indoor Air Emission	Capture Efficiency Stack/(Stack + Indoor Air)
Facility 1	VBR	Secondary Control	15.26	0.16	98.7%
Facility 2	VBR	Secondary Control	129.58	1.86	98.9%
Facility 3	VBR	Closed Loop with Fugitive Control	147.01	0.83	99.0%
Facility 4	PVR	Closed Loop and Secondary Control	1154.99	32.32	97.0%
Facility 5	PVR	Secondary Control	12.07	0.65	94.6%
Facility 6	PVR	Closed Loop with Fugitive Control	1032.18	1.1	100.0%
Facility 7	LVS	Closed Loop and Secondary Control	616.23	9.09	99.0%
Facility 8	LVS	Closed Loop	1038.42	0.81	100.0%
Facility 9	LVS	Closed Loop	524.95	0.53	100.0%

As shown in Table 5-8, the capture efficiencies of all facilities tested were over 95 percent except for Facility 5. Because further attempts to investigate this anomaly were rejected by the facility owner/operator. AVES/PES staff could only speculate as to the cause(s) of low capture efficiency at that facility. For example, failure to follow operating requirements or the presence of a spill could have increased the facility's fugitive emissions dramatically.

5.4 PERCHLOROETHYLENE DRY CLEANING EQUIPMENT CARE

Properly maintained to manufacturer specifications, perc dry cleaning equipment runs more efficiently, maintains the highest solvent mileage possible, and releases fewer emissions into the atmosphere.

AVES/PES reviewed operational, service, and maintenance specifications for dry cleaning machine care from the following manufacturers:

- Lindus
- Frigosec
- Columbia
- Union
- Multimatic

Service specifications were based on either a calendar or cyclic approach. Calendar service was recommended on a daily, weekly, monthly, quarterly, biannual and/or annual basis. Cyclic service was recommended after completion of 4, 8, 50, 200, 300, 1800 and/or 3000 operating cycles.

Based on contacts with dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel, AVES/PES compiled user-friendly, cost-effective operational, service, and maintenance recommendations which will improve the ability of dry cleaners to detect equipment leaks and reduce fugitive perc emissions by reducing the frequency/probability of leaks and spills. AVES/PES further developed housekeeping practices based on dry cleaner owners' and operators' recommendations for the reduction of fugitive emissions. These recommendations are described in greater detail below.

Operations

Manufacturers' recommendations for this area included activities to minimize fugitive emissions from dry cleaning machines that could be accomplished by equipment operators while performing their regular duties.

Service

Service recommendations identify ways that equipment service personnel can minimize spills, fugitive emissions, and maintain peak performance from the machine.

Maintenance

Dry cleaner operators should always consult operating manuals from equipment manufacturing and service companies for specific recommendations about maintaining the machines and control devices they operate.

Housekeeping

General housekeeping practices include steps that all shop personnel can take to enhance the overall efficiency of the dry cleaning operation and reduce fugitive emissions.

5.4.1 Summary of Manufacturers' Recommended Operating Practices

The perc dry cleaning operator weighs and transfers clothes, maintains records, and operates the machine. The operator is the individual most likely to detect fugitive emissions at the five components most likely to leak (front loading door, still, lint trap, button trap, and water separator) during their normal activities.

Table 5-9 lists several equipment manufacturers' recommended operating practices for maintaining equipment performance.

Table 5-9 Summary of Manufacturers' Recommended Operating Practices

Manufacturer / Frequency	Manufacturers' Recommended Operating Practices: Forenta, Model D-345	Wyatt-Bennett Equipment Co.	ILSA (Columbia), MEC 200-360
Every 4th Load, or every 3 cycles	Clean button trap		
Daily	Drain compressed air filter Check filter pressure	Check lint trap and button trap after each load and clean	Clean air and lint filter Clean the gaskets
Weekly	Clean lint filter housing Clean interior lint screen Check air pressure	Remove any lint that may have collected in the air duct between basket and recovery sections	Drain separator water

5.4.2 Summary of Manufacturers' Recommended Service Practices

Table 5-10 lists several equipment manufacturers' recommended service practices.

5.4.3 Summary of Manufacturers' Recommended Maintenance Practices

Perc dry cleaning manufacturers' recommendations for maintenance are shown in Table 5-11. Most manufacturers do not recommend replacement of gaskets on the front loading door, still, lint trap, button trap, and water separator at a specific moment in time, advising instead that these gaskets be replaced only when required as part of routine service or upon discovery of a leak.

5.4.4 Recommended Housekeeping Practices

Most dry cleaner operators know that good housekeeping is one of the easiest and least expensive ways to reduce waste. Poor housekeeping results in spills and overflows that contribute to a facility's total fugitive emissions and increase the expense of perc disposal and replacement. Recommended housekeeping practices are shown in Table 5-12, and recommended equipment upgrades are shown in Table 5-13.

Table 5-10 Summary of Manufacturers' Recommended Service Practices

Manufacturer / Frequency	Manufacturers' Recommended Service Practices: Forenta, Model D-345	Wyatt-Bennett Equipment Co.	ILSA (Columbia), MEC 200-360
Daily	Drain compressed air filter Empty water separator Skim water container Check filter pressure Drain still residue	Check heat sensor probe for linting located under lint trap in air outlet Check still for cleanliness Turn grease cups one-half turn daily on bearing housing	Drain condensation from the compressed air maintenance unit Drain wastewater from the water tank Remove distillation sludge from the still and fill neutralizing additive Clean the drying control device Clean the gaskets Check doping container Check the machine to verify the presence of gas leaks using a leak finder Check nitrogen
Weekly	Clean still residues	Remove any lint that may have collected in the air duct between basket and recovery sections Check still for cleanliness They must be checked and cleaned if the steam traps are equipped with strainers	Drain separator water
Monthly	Check hoses and gaskets Remove reclaiming housing hand hole cover		Clean the water separator Clean the water tank
Every 3 Months	Clean the water separator		
Every 6 Months		Remove and clean lint from air heater and air cooler Clean lint from all air drying passage Drain water separator Clean and refill it with clean solvent Check and clean steam trap strainers (if present)	

Table 5-11 Summary of Manufacturers' Recommended Maintenance Practices

Manufacturer / Frequency	Manufacturers' Recommended Maintenance Practices: Forenta, Model D-345	Wyatt-Bennett Equipment Co.	ILSA (Columbia), MEC 200-360
Every 12 Months	Annual preventive checks	Clean solvent tanks	Annual check by an ILSA-authorized engineer

Table 5-12 Summary of Recommended Housekeeping Practices

Recommended Housekeeping Practices		Estimated Cost
1	Store all perc and wastes in sealed containers that do not leak.	0
2	Keep all perc and waste containers closed during storage except when waste is being added or removed.	0
3	Inspect and document perc and waste containers weekly for evidence of leaks or deterioration.	0
4	Provide some type of secondary containment that will hold up to 110% of the largest container stored in the area.	$2,800
5	Use spigots and pumps when dispensing new materials and funnels when transferring wastes to storage containers to reduce the possibilities of spills.	0
6	Keep shop floors clean and dry and use dry or damp clean-up techniques to minimize cost.	0
7	Mark the purchase date on containers and adopt a "first in, first out" policy in order to use up old materials before new ones are bought.	0
8	Do not mix hazardous chemicals with non-hazardous chemicals.	0
9	Keep storage and work areas clean and well-organized by keeping all containers closed and properly labeled.	0

Table 5-13 Summary of Recommended Equipment Upgrades

Recommended Equipment Upgrades		Estimated Cost
1	Install carbon adsorbers for secondary control[1].	$7,500-8,500
2	Install Local Ventilation System (LVS).	$2,900-4,000
3	Install Partial Vapor Barrier Room (PVBR).	$4,500-5,5000
4	Install Full Vapor Barrier Room (FBVR).	$5,000-8,000
5	Replace cartridge filters with spin disk filters.	$3,800-4,800
6	Install emissions control devices to capture fugitive emissions.	$1,200-1,400
7	Replace current machine "at the end of its life" with dry-to-dry Fourth Generation Machine.	$35,000-50,000
8	Install secondary containment devices such as floor sealants, troughs and metal drip pans under solvent-containing drums and waste containers.	$2,800-3,200
9	Purchase an extra set of gaskets for the loading doors, stills, lint traps, button traps, and water separators for emergencies.	$150-200

[1] These costs may vary. AVES/PES received estimates of $7,000 for equipment and $1,100 for labor.

6.0 RECOMMENDED CHANGES TO THE STATE ATCM

Task 6 of this project focused on:

- Proposing reasonable, justifiable, cost-effective and achievable leak limits, monitoring requirements, and maintenance and operational practices, based on observations and findings, and
- Recommending how these changes can be incorporated into the State Airborne Toxic Control Measure (ATCM) and implemented throughout the State of California.

The State Airborne Toxic Control Measure (ATCM) requires each facility to test for perc leaks on a weekly basis, and to use a portable halogenated hydrocarbon detector, a portable gas analyzer, or an alternative method approved by its local air district to locate vapor leaks at concentrations exceeding 50 ppm. AVES/PES worked closely with various groups within the dry cleaning industry and related industries to identify a number of monitoring equipment manufacturers and vendors that could provide the necessary technical support to meet the needs of this task.

AVES/PES conducted a health risk assessment using the United States Environmental Protection Agency's (EPA's) SCREEN3 model to predict hourly average perc concentrations at various distances from a dry cleaning plant. The screening model predicted that, with a composite vapor leak concentration of 100 ppm as perc, the individual cancer risk would be less than 10 in 1 million beyond approximately 50 meters from the modeled perc dry cleaning facility and less than 1 in 1 million at 250 meters from the facility. Based on the results from this risk assessment, the CAPCOA Enforcement Managers' ATCM Dry Cleaner Subcommittee may wish to consider a vapor leak concentration limit of 100 ppm as perc.

AVES/PES found that the currently available vapor leak detection equipment is either impractical, or prohibitively expensive for the typical dry cleaner to use in verifying its emissions fall below the ATCM's limit of 25 ppm expressed as perc. Direct-reading devices for quantifying perc concentrations near 25 ppm expressed as perc cost about $3500, which many small dry cleaner operators cannot afford.

6.1 MONITORING, REPAIR, RECORD KEEPING AND REPORTING

The current ATCM requires the following:

6.1.1 Monitoring (ATCM § A 2.)

According to the ATCM a vapor leak is an emission of perc vapor from unintended openings in a dry cleaning system. A vapor leak is defined as a rapid audible or visual signal from a halogenated hydrocarbon detector, or a concentration of perc exceeding 25 ppm expressed as perc as indicated by a portable analyzer. A liquid leak is defined as one drop of liquid solvent from any one component in three minutes. Where liquid and vapor leaks cannot be repaired immediately upon detection, the ATCM also requires that repairs be made within 24 hours of detection.

6.1.2 Record of Equipment Leaks and Repairs (ATCM § A 2.)

To avoid citation for leak violations, the Dry Cleaner Owner/Manager is required to record the date, duration, and nature of any malfunction, spill, incident, or emergency response at the facility along with any corrective action taken. This record is to be kept on site for review during annual inspection by the local air district.

6.1.3 Service and Repair Log (ATCM § f.1.a.)

When a leak is found, the date and type of repair are to be entered on a service and repair log. The service and repair log is used to keep track of repairs and parts ordered in accordance with the timeframe specified in the Dry Cleaning ATCM.

6.1.4 Reporting (ATCM § e.)

All perc dry cleaning facility operators should maintain records of perc dry cleaning equipment operation, maintenance, leak testing, solvent usage, and solvent and hazardous waste disposal. Photocopies of required records should be submitted to the local air district as required.

Below are items not specifically addressed by the current ATCM:

6.1.5 Perchloroethylene Leaks

Problem: Liquid leaks can be a significant source of fugitive emissions and have greater potential to contaminate the soil and groundwater than vapor leaks.

Reason: A liquid perc leak on an untreated concrete floor will migrate through the floor and into the soil within a short time.

Recommendation: Any dry cleaning facility with a liquid perc leak that cannot be repaired within one working day after detection should be required to shut down the machine and not operate the dry cleaning equipment until the leak is repaired.

6.1.6 Monitoring Equipment

Problem: The most common low-cost leak detectors used by the dry cleaning industry are too sensitive. They do not allow the dry cleaner operator to pinpoint the leak source, and do not produce the quantitative data necessary to determine which leaks need repair.

Reason: The current generation of low-cost halogen leak detectors is designed for refrigerant leak detection and is not calibrated for perc.

Recommendation: Halogen leak detectors used with a soap solution can help to pinpoint a leak source. However, the use of a halogen leak detector with a soap solution only indicates the presence/absence of a leak. Quantifiable emission concentration data requires the use of a portable direct reading photo ionization detector (PID). However, the high cost of a direct-reading PID such as MiniRAE (estimated at about $3,495) creates a substantial economic burden for small business dry cleaners. RAE Systems, the manufacturer of MiniRAE, also manufactures a lower cost real-time reading PID (ToxiRAE) at about $1300.

6.1.7 Hoses and Tubing

Problem: Liquid and vapor leaks through hoses and tubing on perc dry cleaner connections.

Reason: Hoses and tubing not impervious to perc will allow perc to pass into the atmosphere.

Recommendation: Rigid piping and approved flex joints should be used whenever possible.

6.1.8 Spare Parts

Problem: Without spare parts, dry cleaner cannot perform repairs for minor liquid and vapor leaks in a timely manner.

Reason: Dry cleaner operators usually do not stock parts.

Recommendation: Dry Cleaner Owners/Managers should maintain sufficient spare gaskets and seals on the premises to repair leaks at the front loading door, still, lint trap, button trap, and water separator for each dry cleaning machine.

6.2 PERCHLOROETHYLENE LEAK LIMIT EVALUATION

As discussed in Task 4, current perc vapor leak detection equipment is too impractical or expensive for the typical dry cleaner to use in verifying that the ATCM limit of 25 ppm expressed as perc is not exceeded. Direct-reading devices for quantifying perc concentrations near 25 ppm expressed as perc cost about $3500, which many small dry cleaner operators cannot afford. Less expensive halogenated hydrocarbon leak detectors sound an alarm when a pre-set concentration threshold is exceeded, but do not display concentrations. These alarm devices were originally designed to detect fluorocarbon refrigerant leaks, and have thresholds so low that alarms are sounded even at leak concentrations well below the limit. However, the alarm devices can be redesigned with higher leak concentration thresholds. The question is: At what detection threshold should they be set?

AVES/PES conducted a screening risk assessment, using measurement data from the source test at Douglas Square Cleaners to obtain a preliminary estimate of how high the vapor leak limit could be set. In one of the test runs, the average perc concentration in the temporary total enclosure (TTE) exhaust was 125 ppm. It was assumed that this value was the sum of the concentrations resulting from all machine leaks. The corresponding net mass emission of perc was 0.226 lb for the load (this rate integrates a variety of instantaneous emission rates, which vary throughout the dry cleaning cycle). The facility averages 5.5 loads per day, 5 days per week, 52 weeks per year, or 1,430 loads per year. Based on this test run, annual perc emissions would be (0.226 lb/load)(1430 loads/yr) = 323.18 lb/yr. The corresponding annual average emission rate is 0.00465 grams per second (g/s).

AVES/PES used the U.S. Environmental Protection Agency's SCREEN3 model to predict hourly average perc concentrations at various distances from a dry cleaning plant. Because SCREEN3 generally provides more conservative values (i.e., higher concentrations, all other things being equal) than a model which uses actual hourly meteorological data, the risk values reported here are probably higher than they would be if a model such as the Industrial Source Complex Short Term (ISCST) model had been used.

In the SCREEN3 model, the predicted concentration at a given distance, all other things being equal, is directly proportional to the emission rate. The emission rate is proportional to the TTE (or leak) concentration. We therefore scaled the emission rate to various leak concentrations, and determined the individual cancer risk at 10-meter intervals from 10-300 meters (m) from the plant. In addition, for each leak concentration we determined the distances to the points where the individual cancer risk equals 1 in 1 million, 10 in 1 million and 25 in 1 million.

Figure 6.1 shows risk isopleths (in units of 10^{-6} risk) for various combinations of leak concentration and distance from the source. For a residence 50m from a dry cleaning facility at a vapor leak of 25 ppm expressed as perc, the risk is about 2.5 in 1 million. Because the predicted ambient perc concentration is directly proportional to the leak concentration, if the limit were raised to 50 ppm expressed as perc, the risk would double to 5 in 1 million.

The figure can also be used to estimate the distance within which the risk equals or exceeds a given value, given the leak concentration. For example, at a distance of 10 meters, no leak concentration below 33 ppm results in a risk of 10 in 1 million. At 50 meters, no leak concentration below 101 ppm results in that level of risk.

Figure 6.2 shows the distance within which the risk equals or exceeds 1 in 1 million, 10 in 1 million, or 25 in 1 million, as a function of leak concentration. At the vapor leak limit of 23 ppm expressed as perc, the unit cancer risk exceeds 1 in 1 million at distances out to about 162 meters from the facility, and it exceeds 10 in 1 million out to about 23 meters from the facility. Nowhere would the unit cancer risk exceed 25 in 1 million. If the limit were raised to 100 ppm expressed as perc, the unit cancer risk would exceed 1 in 1 million out to 252 meters from the facility. The radii of the 10 in 1 million and 25 in 1 million isopleths would be 50 meters and 16 meters, respectively.

These findings suggest that the vapor leak limit may be increased without seriously increasing risk to the general population. However, to confirm the assumption that a leak concentration of 125 ppm expressed as perc corresponds to an emission rate of 0.226 lb per load, and to ensure that associated risk levels fall below the limits specified in recently amended AQMD Rule 1402, AVES/PES recommends that additional tests be conducted for at least three additional perc dry cleaners in the South Coast Air Basin. One of the dry cleaning machines should be a converted transfer machine, while the other machines could be newer closed-loop machines. More detailed modeling, including a variety of meteorological conditions, would also help provide a more realistic estimate of the impacts of changing the leak limit on risk to the public.

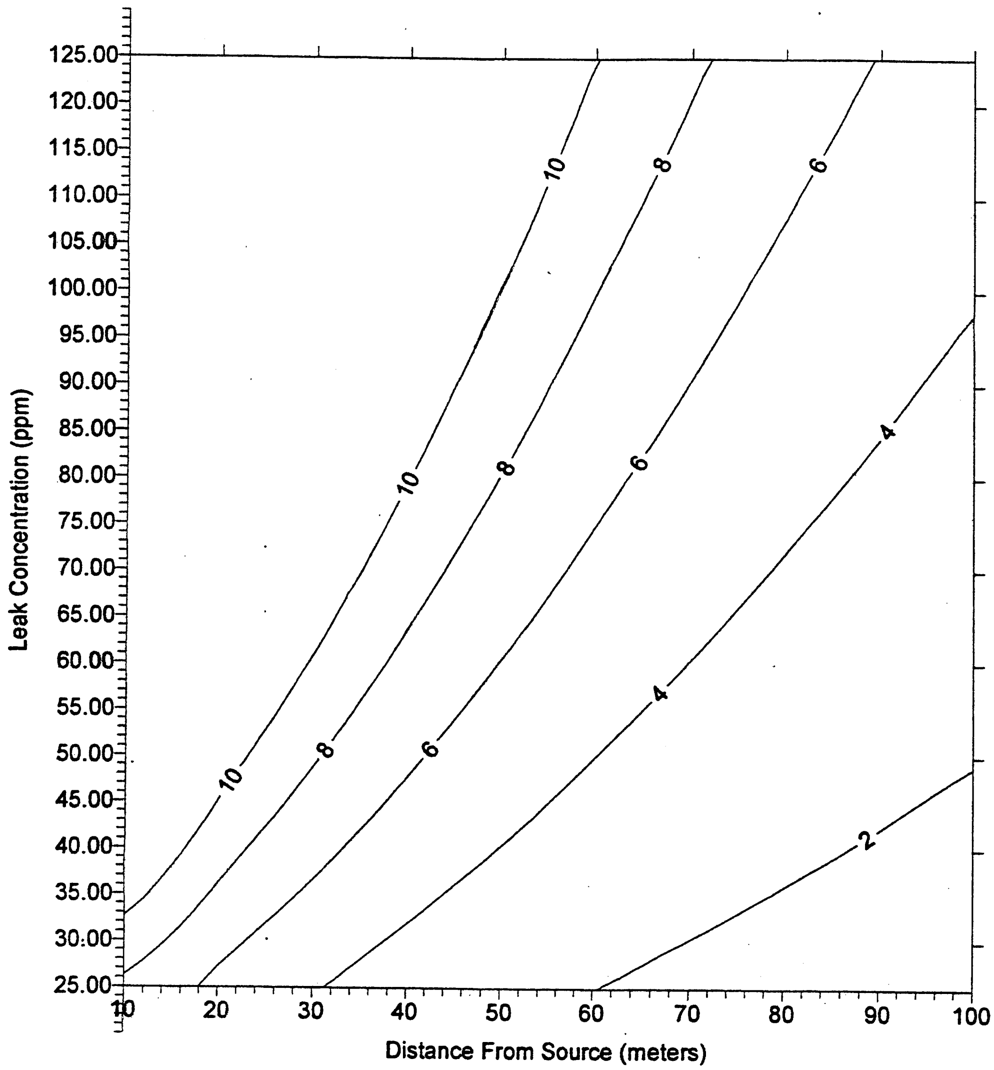


Figure 6.1. Unit Cancer Risk as a Function of Leak Concentration and Distance from Facility.

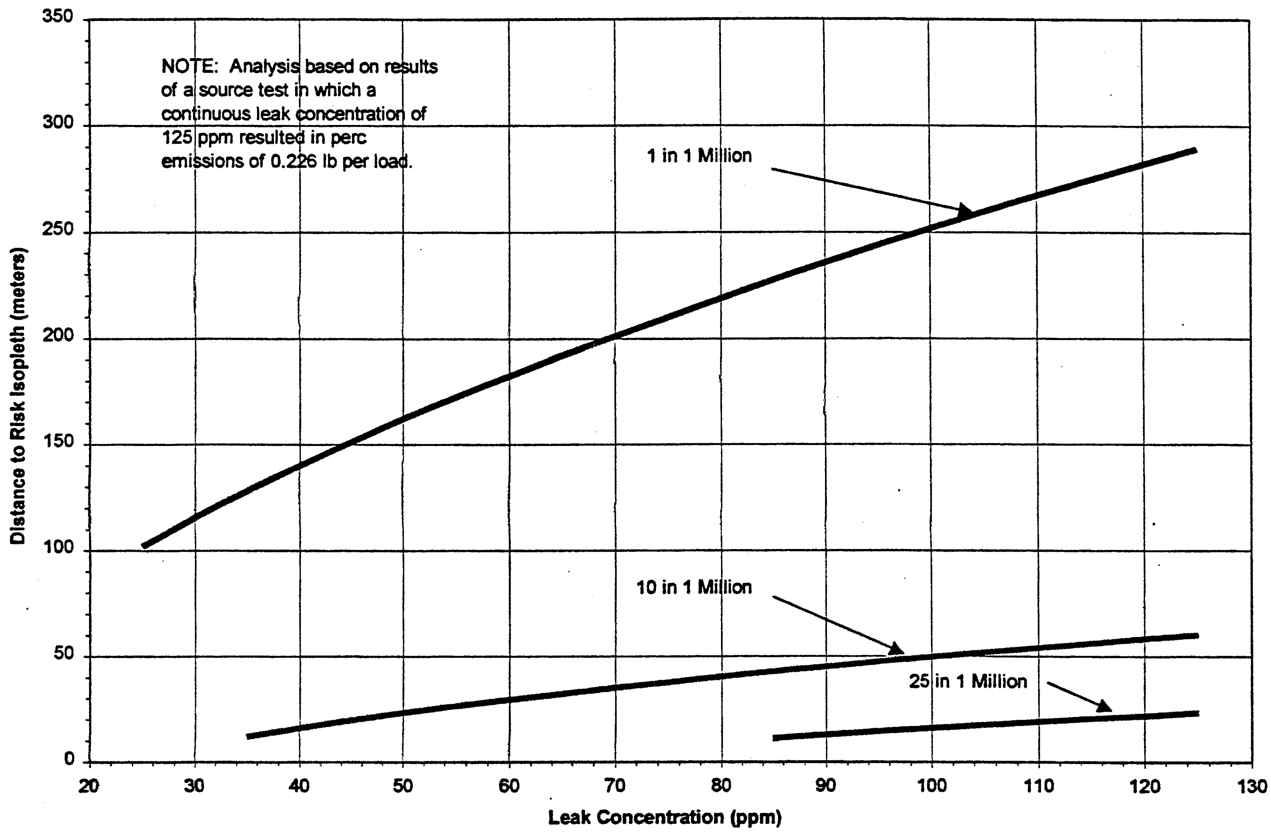


Figure 6.2. Distance to Selected Individual Cancer Risk Levels as a Function of Leak Concentration.

6.3 EFFECTIVE OPERATING AND MAINTENANCE PRACTICES

The current ATCM does not include effective operating and maintenance practices

Properly maintained to manufacturer specifications, perc dry cleaning equipment runs more efficiently, maintains the highest solvent mileage possible, and releases fewer emissions into the atmosphere.

AVES/PES reviewed operational, service, and maintenance specifications for dry cleaning machine care from the following manufacturers:

- Lindus
- Frigosec
- Columbia
- Union
- Multimatic

Service specifications were based on either a calendar or cyclic approach. Calendar service was recommended on a daily, weekly, monthly, quarterly, biannual and/or annual basis. Cyclic service was recommended after completion of 4, 8, 50, 200, 300, 1800 and/or 3000 operating cycles.

Based on contacts with dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel, AVES/PES compiled user-friendly, cost-effective operational, service, and maintenance recommendations which will improve the ability of dry cleaners to detect and reduce fugitive perc emissions by reducing the frequency/probability of leaks and spills (in Task 5). Furthermore, AVES/PES developed additional operational, service, and maintenance practices for the reduction of fugitive emissions. These recommendations are described in more detail below.

Operations

Manufacturers' recommendations included activities that could be accomplished by equipment operators while performing their regular duties to minimize fugitive emissions from dry cleaning machines.

Service

Service recommendations identify ways that equipment service personnel can minimize spills, fugitive emissions, and maintain peak performance from the machine.

Maintenance

Dry cleaner operators should always consult operating manuals from equipment manufacturing and service companies for specific recommendations about maintaining the machines and control devices they operate.

Housekeeping

General housekeeping practices include steps that all shop personnel can take to enhance the overall efficiency of the dry cleaning operation and reduce fugitive emissions.

6.3.1 Additional Recommended Operating Practices

Based on contacts with dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel, AVES/PES identified additional user-friendly, cost-effective practices to reduce fugitive emissions and increase perc mileage. The recommended practices are shown in the Table 6-1.

Table 6-1 Summary of Additional Recommended Operating Practices

	Additional Recommended Operating Practices	Cost
1	Check the water/solvent separator while the machine is operating to make sure that no solvent is drained off with the water.	0
2	Close machine loading doors immediately after transferring articles to or from the machines and open button traps and lint baskets only long enough to clean.	0
3	Continuously monitor for strong solvent odors.	0
4	Make frequent visual observation for pools or droplets of perc and feel for leaks from gaskets by passing dry tissues over equipment surface.	0
5	Do not overload the equipment.	0
6	If possible, do not underload the equipment since underloading the machine decreases solvent mileage.	0
7	Check dampers to make sure that they open and close properly during the aeration cycle and wipe face with a damp terry cloth towel daily.	0
8	Inspect loading door gasket and machine face for materials that could cause leakage from door.	0
9	Clean button trap after every load of drapery as UV rays cause the fabric to deteriorate and drapery fabrics trap a large amount of dirt which settles out.	0
10	Purchase spare lint filter and alternate lint filters to minimize downtime and door open time.	$25-100 per unit

6.3.2 Additional Recommended Service Practices

Dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel provided additional user-friendly, cost-effective steps which could easily be incorporated into the equipment maintenance schedule to reduce fugitive emissions and increase mileage. These recommended practices are shown in Table 6-2.

Table 6-2 Summary of Additional Service Practices

	Additional Recommended Service Practices	Cost
1	Use filter cookers to extract more solvent from the filters.	$100-200 per unit
2	Use spigots and pumps when dispensing new materials and funnels when transferring wastes to storage containers to reduce the possibilities of spills.	0
3	Add water to still bottoms following final boil down to recover additional solvent and to reduce solvent content in the still bottoms.	0
4	Clean still daily in the morning when it is cool.	0
5	Clean still bottom residues down to ¼ inch or less to keep the thicker residue from reducing the still's efficiency.	0
6	Weekly leakage inspection of hoses, pipes, couplings, valves, gaskets, seals, pumps, solvent tanks, water separators, muck cookers, stills, and filter housings.	0
7	Weekly leak inspection of all secondary containment such as berms or metal trays.	0
8	Clean lint buildup from condenser coils for refrigeration systems weekly.	0
9	Clean lint screens to avoid clogging fans and condensers weekly.	0
10	Clean lint buildup from filters that precede the carbon filters weekly.	0
11	Check the temperatures on the refrigerated condenser daily to ensure they register at about 7.2 degrees C or 45 degrees F.	0
12	Clean drying sensors weekly.	0

6.3.3 Additional Recommended Maintenance Practices

Dry cleaner operators, dry cleaner manufacturers' representatives, and service personnel recommended additional user-friendly, cost-effective steps which could easily be incorporated into the equipment maintenance schedule to reduce equipment downtime and fugitive emissions. These recommended additions are shown below in Table 6-3.

Table 6-3 Summary of Additional Maintenance Practices

	Additional Recommended Maintenance Practices	Cost
1	Replace front loading door, still, lint trap, button trap, and water separator gaskets annually.	$100-200 per set
2	Test all components of the dry cleaning machine for leaks with a PID.	$1300-3500 (one time)

6.4 RECOMMENDED CH. .IGES TO THE STATE ATCM

Recommended modifications to the State ATCM with respect to leak limits, maintenance and operational practices, and monitoring requirements are summarized in the following:

Table 6-4 Recommended Changes to State ATCM

Requirement	Problem	Recommendation (s)	Reason
A (2). The State ATCM requires that perc dry cleaning equipment be tested for leaks using a portable halogenated hydrocarbon detector, a portable gas analyzer, or an alternative method approved by the district to locate vapor leaks at concentrations exceeding 25 ppm expressed as perc.	Leak detectors with digital or analog displays that allow the operator to accurately measure the leak rate cost $1300 or more. The relatively high cost prevents this technology from being considered as an improved cost-effective, user-friendly monitoring option. Less expensive leak detectors utilize heated diode sensors to detect halogen based gases. These halogen detectors were mainly designed for refrigerant leak detection and are not calibrated for perc. These detectors indicate the presence of a vapor leak by emitting a rapid audible signal and a visual signal (red light). When used with a soap solution, halogenated hydrocarbon detectors can detect smaller perc vapor leaks. However, this method still does not yield the quantitative data necessary to determine which leaks require repair.	If the leak limit concentration were increased from 25 ppm expressed as perc to 100 ppm expressed as perc[4], the alarm threshold of simple sensing instruments (such as the TIF) could be modified to help keep dry cleaners in compliance. Depending on demand, the cost of such a modification is not expected to exceed $50 per unit. <u>Implementation method</u>: Create an incentive for producing leak detectors calibrated for perc by requiring all dry cleaners to purchase and use the detectors on a daily basis to test for leaks. If a dry cleaner operator sends a photocopy of a receipt demonstrating "proof of purchase" of a new direct-reading leak detector with the facility's annual report, a one time credit of $100 could be issued to the facility's permit account. Other strategies to maximize dry cleaners' access to cost-effective, user-friendly perc monitoring options (such as ToxiRAE monitors or recalibrated halogenated hydrocarbon detectors) are: (1) working with dry cleaner trade associations, (2) offering small business loan at a subsidized rate, and (3) renting out PID monitors at a minimal fee.	AVES/PES conducted a screening risk assessment, using measurement data from the source test at Douglas Square Cleaners. The screening model predicted that the individual cancer risk would be less than 10 in 1 million beyond about 50 meters from the modeled perc dry cleaning facility and less than 1 in 1 million at 250 meters from the facility. Based on the results from this risk assessment, AQMD may wish to consider establishing a leak concentration limit of 100 ppm expressed as perc.

[4] Based on screening risk assessment performed by AVES/PES (see Section 3.11 of this report). Although the screening risk assessment suggests that increasing the vapor leak limit will not seriously increase the risk to the public, AVES/PES recommends further testing at a minimum of three additional perc dry cleaning facilities to confirm this result. Risk levels should not exceed limits specified in recently amended AQMD Rule 1402.

Requirement	Problem	Recommendation (s)	Reason
D. The State ATCM requires that perc dry cleaning equipment be tested for leaks on a weekly basis. The ATCM also requires that liquid and vapor leaks be repaired within 24 hours of detection.	Vapor and liquid leaks contribute significantly to perc emissions released to the atmosphere. Leaks can occur wherever parts are mechanically connected, and these connections can be loosened by wear, normal expansion and contraction created by variations in temperature and vibration of equipment. There seems to be a conflict between the desire to test for leaks on a weekly basis and the repair of a detected leak within 24 hours.	Increase the frequency of leak monitoring from once a week to at least 2-3 times a week. **Implementation method:** AQMD Inspectors should ask to see copies of the Daily Leak Check Logs and Service and Repair Logs when they visit a facility. If the logs are not available, or leaks have not been repaired within the required timeframe, the Inspector should take appropriate enforcement action. Copies of these and other logs should by sent to AQMD with the facility's annual report. Other strategies to encourage dry cleaners' access to conduct daily monitoring are: (1) offering small business loan at a subsidized rate from local APCDs, (2) renting out PID monitors from dry cleaner trade associations, and (3) developing creative penalties to help bring dry cleaners back into compliance.	Leaks occurring between weekly leak tests could go undetected for up to a full week.

Requirement	Problem	Recommendation (s)	Reason
D (3). The State ATCM requires perc dry cleaning facilities to have one or more trained operators. A trained operator may be an owner, operator, or other full-time employee of the facility who shall have successfully completed the initial course of an environmental training program. Each trained operator shall also successfully complete the refresher course of an environmental training program at least once every three years. The original record of completion is evidence of meeting these requirements.	No training requirements for operation, servicing and repair of perc dry cleaning equipment are included in the State ATCM.	Based on reviews of perc dry cleaner manufacturers operation and maintenance manuals, surveys, and visits to dry cleaner facilities it is recommended that AQMD establish two distinct dry cleaner personnel classifications (Owner/Manager and Dry Cleaner Equipment Operator) and two training requirements (Environmental and Equipment). To meet Environmental and Equipment requirements, the Owner/Manager and Dry Cleaner Equipment Operator should receive environmental training from certifying agencies/schools, or individuals. Owner/Manager's and Dry Cleaner Equipment Operators should be required to attend a training course conducted by their equipment manufacturer or manufacturer's representative, covering the operation, maintenance and service of their specific equipment. Training courses should be subject to random audit by AQMD Inspectors. **<u>Implementation method</u>:** When AQMD Inspectors visit a dry cleaning facility, they should ask to see copies of the Owner/Manager's and Dry Cleaner Equipment Operator's certificates of successful completion of the required courses. If the certificates of successful completion are not available, then the Inspector should take appropriate enforcement action.	Operating, servicing, and repairing dry cleaning equipment according to manufacturers' specifications would result in fewer perc leaks.

Requirement	Problem	Recommendation (s)	Reason
NONE The State ATCM requires that, after 1994, perc dry cleaning facilities maintain copies of the equipment operation and service manuals on site.	Most small dry cleaner operators rely on one service company that "knows" their equipment. Service companies themselves are often very small operations.	The State ATCM should be changed to require that, in addition to operation and service manuals, perc dry cleaning facilities maintain copies of equipment maintenance and service manuals on the premises. **Implementation method:** AQMD Inspectors should ask to see the copies of equipment maintenance and service manuals when they visit a facility. If the facility does not have copies of these maintenance and service manuals, the Inspector should take appropriate enforcement action.	The State ATCM requires that liquid and vapor leaks be repaired within 24 hours of detection. Dry cleaner facilities do not keep stocks of spare parts, and rely on their service company to be able to provide them with parts and or service within the 24-hour period. By keeping up-to-date maintenance and service manuals on the premises, shop personnel could correctly describe equipment models, and spare parts requirements to available service companies for faster service. AQMD Inspectors could also use the manuals to compare equipment specifications and conduct discussions with dry cleaner personnel.
D. Any liquid leak or vapor leak shall be repaired within 24 hours of detection. 1. If repair parts are not available at the facility, the parts shall be ordered within two days of detecting such a leak. Such repair parts shall be installed within five working days after receipt. A facility with a leak that has not been repaired by the end of the 15th working day after detection shall not operate the dry cleaning equipment without a leak-repair extension from AQMD, until the leak has been repaired.	Small dry cleaner facilities do not maintain a stock of spare parts, relying instead on their service companies to stock parts. Depending on the availability of service personnel, there may be a substantial delay in obtaining the necessary parts and performing required repairs.	Dry cleaning facilities should maintain replacement gaskets on the premises for the front loading door, still, lint trap, button trap, and water separator. **Implementation method:** AQMD Inspectors should ask to see spare gaskets when they visit a facility. If the facility does not have spare gaskets, the Inspector may take appropriate enforcement action.	Allowing perc leaks to continue for up to 15 days seems excessive.

Requirement	Problem	Recommendation (s)	Reason
NONE The State ATCM does not require annual replacement of gaskets on dry cleaning equipment.	Most fugitive emissions were traced to the front loading door, still, lint trap, button trap, and water separator.	The State ATCM should be changed to require annual replacement of gaskets on the front loading door, still, lint trap, button trap, and water separator on an annual basis. **Implementation method:** Encourage dry cleaner operators to replace gaskets on an annual basis by requiring them to send AQMD proof of purchase of their new gaskets. Upon receipt, AQMD could issue a $100 credit to the facility's permit account.	Small dry cleaning facilities do not perform maintenance on a regular basis.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Task 1: Compiling Available Leak Data from Local APCDs

Based on available data from local APCDs, dry cleaning equipment leaks appeared to fall into three groups according to the frequency of their occurrence. The most frequently reported leak points were located in the still and the loading doors, which together accounted for about one-third the reported fugitive emissions. The second group was comprised of the button trap, lint trap, water separator, refrigerated condenser and filter, which accounted for approximately 43 percent of the leaks. The third group included the remaining eight major components (solvent tank, condenser, hazardous waste container, solvent recirculating pump, drum, wastewater container, dip tank, and pump). These eight components accounted for the remaining 22 percent of the fugitive emissions reported.

Task 2: Surveying Manufacturers on Design Criteria and Recommended Maintenance Practices

Survey results from 110 facilities confirmed APCD leak data with respect to dry cleaning equipment components found most likely to leak. Dry cleaners reported that the front loading door (55%), still (33%), lint trap (25%), button trap (14%), and water separator (12%) were more likely to leak than any other components.

Survey results indicated that newer dry cleaning machines appear to have a lower potential to release fugitive emissions. Higher quality gaskets and improved maintenance on newer dry cleaning machines may be responsible for this difference. Older dry cleaning machines have a greater potential to release fugitive emissions due to normal wear, vibration and lack of necessary maintenance. Dry cleaning machine operators can be effective in reducing these fugitive emissions by changing gaskets annually. Some manufacturers recommend upgrading gaskets to Viton, but this recommendation is limited to gaskets around the sight glass and all areas requiring rigid seals, and is not suitable for use on front loading doors.

Task 3: Conducting Temporary Total Enclosure Testing

The temporary total enclosure (TTE) approach is a practical, effective means to measure fugitive emissions from the operation of a perc dry cleaning machine. The two machines tested may be considered to represent devices at opposite ends of a spectrum of "poor" to "excellent" maintenance practices and emission controls (most perc dry cleaning operations can be assumed to fall well within these extremes). The Douglas Square Cleaners machine had fugitive emissions of about 0.23 lb of perc per cleaning cycle, and approximately 5.6 lb of perc per 1,000 lb of clothes cleaned. The Gordon Ranch Cleaners machine had fugitive emissions of about 0.023 lb of perc per cleaning cycle, and about 0.57 lb of perc per 1,000 lb of clothes cleaned. Thus, the emission rate from this machine was only 10 percent of that of the Douglas Square Cleaners machine.

AVES/PES prepared risk isopleths for various combinations of leak concentrations and distances from the source. A screening risk analysis provided approximate lower and upper thresholds for individual cancer risk in areas surrounding a "best" and "worst" case facility, respectively. For the "best" case, the individual cancer risk does not exceed 10 in 1 million at any point outside the facility, and the risk does not exceed 1 in 1 million risk beyond approximately 51 meters (167 feet). For the "worst" case, the individual cancer risk exceeds 10 in 1 million out to a distance of 65 meters (213 feet) from the facility, and exceeds a 1 in 1 million risk out to 305 meters (1,000 feet).

Results from these two case studies indicate that good operating and maintenance practices can effectively reduce fugitive emissions. The owner of the Gordon Ranch Cleaners changed gaskets for the front loading door, still, lint trap, button trap, and water separator annually. This practice is a very effective way to reduce fugitive emissions.

Task 4: Surveying Monitoring Equipment

Halogenated hydrocarbon detectors were developed for the refrigeration and air conditioning industry and are calibrated to provide a visual or audible signal for refrigerant leaks exceeding ¼ ounce per year. When used with a soap solution, halogenated hydrocarbon detectors can detect, but not quantify, perc vapor leaks. Although direct-reading PIDs can produce the quantitative data necessary to determine which leaks require repair, the cost of even the least expensive direct-reading PID ($1300) may be financially burdensome for most dry cleaner operators.

If the State ATCM leak limit concentration were increased from 25 ppm expressed as perc to 100 ppm expressed as perc, simple sensing instruments such as halogenated hydrocarbon detectors could be modified to detect leaks exceeding 100 ppm. This change would provide dry cleaner operators with a low-cost option to maintain compliance with State ATCM requirements. By requiring all dry cleaner operators to purchase and use these detectors on a daily basis to test for leaks, fugitive emissions would be reduced. Manufacturers would be encouraged to produce leak detectors calibrated for perc once the monitoring requirement is tightened.

Strategies to maximize dry cleaners' access to cost-effective, user-friendly perc monitoring options (such as a direct-reading PID) include encouraging dry cleaner trade associations to purchase and share the devices with their members, offering small business loans at a subsidized rate, and renting PID monitors for a minimal fee.

Task 5: Performing Engineering Analysis and Developing Housekeeping Methods

AVES/PES selected nine perc dry cleaning facilities in the Bay Area Air Basin to conduct an engineering analysis. In addition to determining mass emissions of perc from exhaust stacks and indoor air, AVES/PES collected wastewater, sludge, lint, and filters using EPA/SW-846-ED-3 to complete a mass balance for each facility.

Mass balance calculations showed that perc emissions were primarily associated with waste streams (wastewater, sludge and lint), where residual perc accounted for 47% to 95% of the total perc used. Test results also showed a higher percentage of perc in the waste stream when secondary controls were used than when they were not. AVES/PES expects the same perc emission distribution would apply to perc dry cleaning facilities in the South Coast Air Basin.

Operation and Maintenance

In general, new and tighter machine designs also significantly reduce fugitive emissions. Perc recovery is increased with the new spin-filter design or disc filtration. This new design results in less waste, lower perc emissions from waste removal, reduced operator exposure to perc, lower overall perc loss, and a possible decrease in disposal cost. New machines are equipped with a perc-drying sensor that runs through the microprocessor and monitors perc concentrations in the clothes. The sensor monitors perc returning from the condenser during drying. When properly programmed, the sensor prevents operators from short-cycling loads resulting in a loss of perc to the atmosphere, and the exposure of operators to excess vapors.

Many older machines can be retrofitted in the field with after-market primary and secondary emissions control devices and filtration equipment to reduce fugitive emissions. Such retrofits have to be evaluated for cost and potential effectiveness on a case-by-case basis due to variations in equipment design, perc usage, equipment usage patterns, operating conditions and operating controls. However, dry cleaning machines that use card technology rather than microprocessor controls are not as easily retrofitted with secondary emissions control devices.

Dry cleaner machine operators should be instructed to observe their equipment for leaks during normal equipment operation. Particular attention should be paid to system components, including loading doors, stills, lint traps, button traps, water separators, condensers, wastewater containers, discharge vents, solvent pumps, filters, lint filter doors, and solvent tanks.

Dry cleaning machines should be tested daily by the dry cleaning machine operator using a halogen leak detector and soap solution to detect perc leaks. Any perc leaks found should be repaired immediately. Additionally, dry cleaner operators should replace the gaskets for the loading doors, stills, lint traps, button traps, and water separators of their equipment on an annual basis.

After emptying the dry cleaning machine at the end of the day, dry cleaning machine operators should place the next day's first load into the drum to eliminate one opening and closing of the door per day.

Dry cleaning machine operators should clean muck cookers in the morning when they are cool, and line the muck pan with plastic so that no perc residue remains on the pan.

Dry cleaning machine operators should personally supervise each solvent delivery to reduce overfills, leaking equipment, and other possible discharges. Solvent should be supplied directly from the truck into the storage tank of the dry cleaning machine, and spigots and pumps should be used to dispense the perc into the machine solvent tank. If possible, a direct coupling device should be used to transfer the solvent.

Dry cleaning machine operators should ensure that solvents are not transferred or stored in open or leaking containers, and that funnels are used when transferring wastes to storage containers. Operators should train personnel about the hazards of spills and how minimizing the potential for spills will reduce a facility's potential for environmental liability.

Housekeeping

Dry cleaning machine operators should improve housekeeping practices. Improving housekeeping practices is often the easiest, quickest, and least expensive way to reduce fugitive emissions and waste. Good housekeeping includes effective inventory control and efficient operating procedures; proper labeling all perc and waste containers; and using spigots, pumps and funnels when transferring perc and waste materials.

Spills and leaks contribute to fugitive emissions and environmental liability. Dry cleaner operators should establish a weekly program of inspections and maintenance.

This program should include:

- ✓ Inspecting containers and equipment weekly to be sure they are not leaking.
- ✓ Performing regular, preventive maintenance including replacement of gaskets, seals, and other machine components, and closing the separator and button trap covers before operating the dry cleaning machine.
- ✓ Exercising caution during any solvent-handling procedures, including filling machines, changing filters, and distillation. All filter housings should be completely drained before servicing or changing filters.

Task 6: Changes to the State ATCM

Based on observations and findings from Tasks 1-5, changes to the State ATCM with respect to leak limits, operating and maintenance practices, monitoring, report, recordkeeping, and reporting requirements are recommended.

In general, study results suggest that the State ATCM and AQMD Rule 1421 should de-emphasize vapor leak concentrations as an indicator of compliance, relying instead on the adoption and enforcement of detailed maintenance standards and associated recordkeeping practices to reduce fugitive perc emissions from leaks. Key to this effort is assuring that dry cleaners are properly trained to operate their equipment more effectively. Enforcing correct procedures and good practices with dry cleaner operators can substantially minimize the potential for leaks. Other findings and recommendations include:

- **Leak Limits**
  The screening model predicted that the individual cancer risk would be:
  ✓ Less than 10 in 1 million beyond about 50 meters and
  ✓ Less than 1 in 1 million at 250 meters
  from the modeled perc dry cleaning facility with a composite vapor leak concentration of 100 ppm expressed as perc. Based on the results from this risk assessment, the CAPCOA Enforcement Managers' ATCM Dry Cleaner Subcommittee may wish to consider a vapor leak concentration limit of 100 ppm expressed as perc. By increasing the leak limit concentration from 25 to 100 ppm expressed as perc[5], the alarm threshold of simple sensing instruments such as the TIF now used for leak detection could be modified accordingly to help keep dry cleaners in compliance.

- **Leak Testing Equipment**
  The relatively high cost of halogenated hydrocarbon detectors capable of quantifying perc emissions may be unduly burdensome for small dry cleaners. The use of a soap solution with a TIF unit can provide owners/operators with a visual indication of the relative size of existing leaks. AQMD may wish to consider combining this practice with annual requirements for a more precise quantitative evaluation of the shop as a modification to existing regulatory requirements.

- **Training**
  Based on reviews of perc dry cleaner manufacturers' operation and maintenance manuals, surveys, and visits to dry cleaner facilities, two distinct dry cleaner personnel classifications (Dry Cleaner Owner/Manager and Dry Cleaner Equipment Operator) and two distinct training requirements (Environmental and Equipment) should be established. Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should receive environmental training from certifying agencies/schools/individuals. Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should be required to complete an annual refresher course, as described below.

  ✓ Environmental

  Within one month of purchasing perc dry cleaning equipment or becoming employed at a perc dry cleaning shop, Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should attend an Environmental Training Program approved by AQMD (unless they have completed similar training within the past year). The program should be developed to provide Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators with a good understanding of the benefits and requirements of complying with the ATCM.

[5] Assuming, for AQMD purposes, that associated risk levels do not exceed those specified in recently amended AQMD Rule 1402.

✓ Equipment

Within two months of purchasing perc dry cleaning equipment or becoming employed at a perc dry cleaning shop, Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators attend an equipment training course conducted by the manufacturer or manufacturer's representative (unless they have completed similar training within the past year). The course should cover the operation, maintenance and service of the particular equipment used at their facility.

- **Certificates of Training**

  Current training certificates should be posted on the premises in a conspicuous place.

- **Operations and Design Specifications**
  Dry Cleaner Owners/Managers should be required to maintain copies of manufacturers' operation and design specification manuals on the premises. Perc dry cleaning equipment properly maintained to manufacturers' specifications runs more efficiently, maintains the highest solvent mileage possible, and releases fewer emissions into the atmosphere.

- **Liquid Leaks**
  A dry cleaning facility without secondary containment that has a liquid perc leak not repaired by the end of the 1st working day after detection (or 5th working day after detection for facilities equipped with secondary containment) should not operate the dry cleaning equipment until the leak is repaired.

- **Vapor Leaks**
  A dry cleaning facility with a vapor perc leak not repaired by the end of the 5th working day after detection should not operate the dry cleaning equipment until the leak is repaired.

- **Spare Parts**
  For each dry cleaning machine, Dry Cleaner Owners/Managers and Dry Cleaner Equipment Operators should maintain sufficient spare gaskets and seals on the premises to repair leaks at the front loading door, still, lint trap, button trap, and water separator.

- **Hoses and Tubing**
  Some hoses and tubing are not impervious to perc. To reduce the potential of releasing perc into the environment, rigid piping and approved flex joints should be used.

- **Service and Repair Logs**
  If a leak is found, the date and type of repair should be listed on a service and repair log. The service and repair log is used to keep track of repairs and is a record of parts to be ordered in accordance with the timeframe specified in the Dry Cleaning ATCM. This log must be available to an AQMD inspector upon request.

If a leak cannot be repaired immediately, the leaking component should be tagged and the date noted on a service and repair log. Parts should be ordered within two working days of the date when the leak was detected, and the order date should be recorded on the service and repair log.

Once the part is received, it should be installed within five working days after receipt. If not repaired by the end of the 5th working day, a leaking piece of equipment should not be operated without a leak repair extension from AQMD. The dates on which parts are received and installed and repairs are completed must be included on the service and repair log.

Standardized logs and checklists should be developed and implemented by perc dry cleaner operators. These logs and checklists should be available for review by AQMD inspectors, and copies should be submitted to AQMD with each facility's annual emissions report.

- **Additional recommendations to reduce emissions from older or inefficient equipment**
  Older, 3rd generation, and converted machines are very leaky, inefficient, and difficult to maintain. AQMD may wish to:

  - Sunset the use of all 3rd generation machines.
  - Create incentives for adopting new 5th generation machines by reducing or eliminating some recordkeeping, mandatory maintenance and testing requirements for the first five years of use.
  - Require secondary controls on <u>all</u> machines.
  - Require more testing and mandatory maintenance for older or inefficient equipment (with records).
  - Require partial or total enclosure with ventilation and roof venting for older or inefficient equipment.

7.2 RECOMMENDED ADDITIONAL FUGITIVE EMISSIONS TESTING

Obtaining a useful correlation between measured vapor leak concentrations and mass fugitive emission rates will require further fugitive emission testing. AVES/PES recommends that such testing be conducted at a minimum of three more perc dry cleaners in the South Coast Air Basin. One of the dry cleaning machines should be a converted transfer machine, while the other machines could be newer pieces of equipment. Additionally, total enclosure tests should be conducted to verify the benefits of replacing all high leakage point gaskets on an annual basis. These tests should be conducted before and after gasket replacement.

The following elements should be incorporated in the field study design:

- Tests should measure emission rates with a temporary total enclosure (TTE) in place, and vapor leak concentrations without the TTE.

- The machines tested should represent a variety of control options and levels of maintenance; they should be neither as "clean" as the Gordon Ranch Cleaners equipment, nor as "dirty" as the Lincoln Square Cleaners unit.

- On at least three separate days before the emissions test day, vapor leak concentrations should be measured at each prospective test site, and no repairs or other alterations to the equipment should be allowed. Vapor leaks should also be measured during the last normal load before the TTE is constructed. If these values depart significantly from the pre-test values, then the emissions test should not proceed.

- If evidence indicates that a liquid leak has occurred within a week of the test day, the emissions test should not be performed.

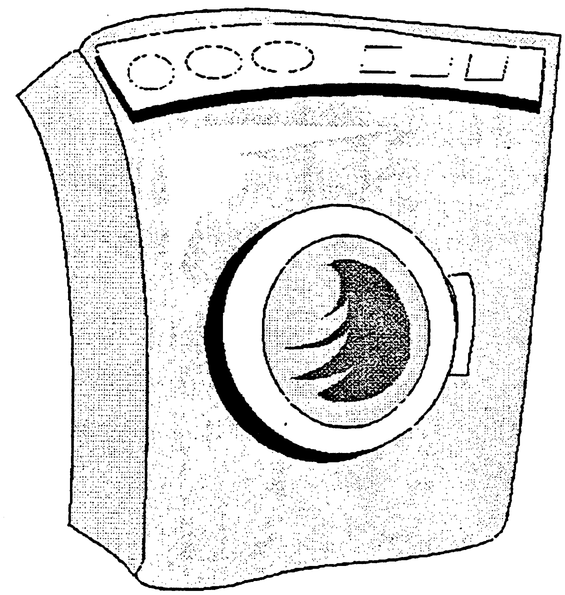
Appendix A

DRY CLEANER'S GUIDE to CLEAN AIR Self-Inspection Booklet

DRY CLEANER'S GUIDE
to
CLEAN AIR

Self-Inspection Booklet

INTRODUCTION



Air pollution is a serious problem in Southern California. Every day, tons of pollutants are released to the air from thousands of sources throughout our region, including **dry cleaners** that use **perchloroethylene ("perc")**.

Perc is a liquid chemical solvent used to clean fabrics without risk of shrinkage, fading of dyes, or otherwise harming sensitive natural or synthetic fabrics. Like many liquid chemical solvents, perc evaporates quickly when exposed to air.

Because perc is **toxic**, exposure to liquid perc or perc vapors can be harmful to human health. **Perc use and disposal are regulated by various federal, state, and local regulatory agencies** (including local air districts and sanitation districts) to help reduce potential risks to public health. For example, used perc cannot be dumped down the drain when it becomes dirty, but must be recycled through filtration and/or distillation and disposed of as hazardous waste.

How can <u>dry cleaners like you</u> help reduce perc emissions to the air?

With the proper control equipment, an effective maintenance program, and good operating and "housekeeping" procedures, you can improve air quality, reduce exposure of workers and customers to toxic solvent vapors, reduce your solvent purchases, and avoid possible fines.

(1) Know your equipment

- ✓ Be sure your dry cleaning machine is permitted and in compliance with AQMD Rule 1421.
- ✓ Keep a copy of your operating, service and maintenance manuals on hand at your shop, and be sure to follow the manufacturer's suggested operating, service and maintenance recommendations.
- ✓ Attend environmental training classes as required by this rule and the California ATCM, and refer to your training materials for additional information.

(2) Once a week, check perc leaks

Vapor and liquid leaks contribute significantly to perc emissions to the atmosphere. Leaks can occur any time during operation, service and maintenance. They can occur anywhere that parts are mechanically connected. Connections can be loosened by wear, normal expansion and contraction created by variations in temperature, and vibration of equipment.

Leaks are most frequently found in the gaskets of the loading door or service access openings and are usually obvious by sight, smell, or touch. Sometimes drops of perc are visible on the outside of a machine; or perc and air vapor can be felt coming from the dry cleaner components.

To reduce fugitive perc emissions, AQMD requires you to test your dry cleaning equipment weekly for liquid and vapor leaks. You must use a halogenated leak detector, portable gas analyzer, or an alternative AQMD-approved method to perform your weekly test.

If any leaks are found, they must be repaired within one day if the parts are on site and can be repaired by the trained equipment operator or service company. If needed, parts must be ordered within two days and installed within five days after they are received. Results of weekly leak checks must be submitted to AQMD with each facility's annual report.

(3) **Practice good housekeeping**

Good housekeeping practices can reduce your shop's waste and save money. Ask your employees, vendors and your AQMD Inspector for tips to reduce fugitive emissions and reduce pollution. Many pollution prevention practices are low-cost and low-risk money-saving alternatives. Here are some examples:

✓ After removing the last load for the day from the dry cleaning machine, place the next day's first load into the drum to eliminate one drum door opening and closing each day.

✓ Keep all perc and waste containers closed during storage except when waste is being added or removed.

✓ Inspect and document perc and waste containers weekly for evidence of leaks or deterioration.

✓ Drain all filters in a sealed container overnight to remove perc.

✓ Use spigots and pumps when dispensing new materials and funnels when transferring wastes to storage containers to reduce the risk of spills.

✓ First thing every morning, clean muck cookers and stills before operating the machine while it is still cool.

- ✓ Practice gooa inventory control by marking the purchase date on containers and adopt a "FIFO" (first in, first out) policy to use old materials first before new ones are bought and used.
- ✓ Do not mix hazardous chemicals with non-hazardous chemicals.
- ✓ Keep storage and work areas clean and well-organized by keeping all containers closed and properly labeled.

(4) Keep records up-to-date

AQMD requires all perc dry cleaning facility operators to maintain records of perc dry cleaning equipment operation, maintenance, leak testing, solvent usage, and solvent and hazardous waste disposal.

All perc dry cleaner operators must submit self-inspection checklists and records of operation, maintenance, service, solvent mileage, and a copy of the trained operator's certificate on an annual basis.

Dry cleaner operators are required to maintain photocopies of these reports and checklists on site for five years. Additionally, copies of all equipment operation and maintenance manuals must be kept on site and made available for inspection by AQMD personnel upon request.

Copies of the dry cleaning weekly, monthly and annual reports, leak checklist and service and repair logs are included in the following pages of this booklet.

DRY CL ANING FACILITY MONTHLY EPORT

Pounds of Clothes Per Load

Year: ______ **Month:** ______ **Facility Name** ____________ **Machine ID:** ______

Example: 2000 Example: January Example: Acme Dry Cleaners Example: DC-1

Use One Sheet For Each Dry Cleaning Machine

LOAD NUMBER

DATE	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
1													
2													
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												TOTAL THIS MONTH	

DRY CLEANING FACILITY ANNUAL REPORT

Submit One Report Per Dry Cleaning Machine

Facility Name: ______________________ Operator Name: ______________

Street Address: ______________________ Telephone No. ______________

City: ______________________ State: ______ Zip Code: ______________

Dry Cleaning Machine ID: ______________

Reporting Period: ______________________ To: ______________________

Pounds of Clothes Cleaned Per Month		Gallons of Perc Added Per Month	
Month	**Column "A"**	**Date**	**Column "B"**
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
TOTAL "A"		**TOTAL "B"**	

TOTAL "A" ______________ =

TOTAL "B" ______________

Mileage = A/B **Mileage**

Prepared By: ______________________________

Printed Name

Signature: ______________________________

Note: Attach Copies of Certifications for all Dry Cleaning Machine Operators and Owner/Managers and Submit to Air Quality Management District.