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FINAL REPORT
CONTRACT NO. 96-324

For

THE ASSESSMENT OF THE EFFECTIVENESS OF ROOM ENCLOSURES WITH VENTILATION SYSTEMS IN REDUCING RISK AT DRY CLEANING FACILITIES USING PERCHLOROETHYLENE

Prepared for

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Disclaimer

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ABSTRACT

In October 1991, the California Air Resources Board (ARB) identified PERC as a toxic air contaminant and discovered that PERC is a human carcinogen. Exposure to PERC also causes acute and chronic health effects such as irritation of the respiratory tract, skin and eyes, dizziness, diminished cognitive abilities, and kidney and liver damage. The dry cleaning industry is the largest user of PERC solvent in California and it is used by a majority of dry cleaners. In October 1993, the ARB adopted an airborne toxics control measure to reduce PERC emissions from dry cleaning operations based on their assessment of the dry cleaning industry.

Dry cleaners usually have either natural or general ventilation systems installed at their facilities. A natural ventilation system consists of open doors, windows, and vents in a dry cleaning facility in conjunction with the wind and convective forces including temperature and PERC concentration profiles. Many facilities also have general ventilation such as air conditioning units or large fans on top of their building. Emissions from these systems are released at ground level or on rooftops. The public, particularly those living downwind, can be exposed to relatively high levels of PERC from these facilities.

No data existed on the effectiveness of room enclosures with ventilation systems in reducing risk to the public at dry cleaning facilities that use perchloroethylene. The first objective of this project was to obtain emission data for estimating perchloroethylene capture efficiencies for the types of room enclosures currently in use. Then the source testing data is used as an input parameter to the industry-wide risk assessment model, which is employed to estimate the health risk posed by these facilities.

The second objective was to develop guidelines for dry cleaning industry in terms of specifications, methods of installation, kinds of control systems, costs of operation, estimates of the capture efficiencies of these systems and their risk reduction potential. The control measures on the nine facilities varied from full vapor barrier room enclosures (three facilities), partial vapor barrier room enclosures (three facilities), to local ventilation system (three facilities).

Risk created by a dry cleaner is dependent on the amount of emissions, the proximity to receptors, and how the emissions are released and dispersed. Various ventilation system's perchloroethylene emission rates were measured and were entered into the ISCST3 model to calculate the dispersion of the system, and determine the risk using dispersion and risk assessment parameters. It is very difficult to evaluate the Cancer Risk related to different types of vapor collection systems associated with the cleaning equipment inside the building. There are many variables not related to the vapor collection system that directly affect the dispersion model results. The modeling results suggested that height of the stack, exit velocity of the stack, and location of the stack on the building roof (downwash) are the most critical parameters in risk reduction.

After analysis of the data, it was concluded that cancer risks were found to be generally highest for facilities equipped with natural ventilation and lowest for facilities with full vapor barrier rooms.

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EXECUTIVE SUMMARY

Perchloroethylene, a dry cleaning detergent, is believed harmful to human health. There may be a risk of cancer when people are exposed to a certain level of perchloroethylene. Ventilation is commonly used to exhaust air/vapor produced in cleaning processes. However, there are no reports about perchloroethylene emissions associated with different ventilation systems during dry cleaning processes.

Dry cleaners usually have either natural or general ventilation systems installed at their facilities. A natural ventilation system consists of open doors, windows, and vents in a dry cleaning facility in conjunction with the wind and convective forces including temperature and PERC concentration profiles. Many facilities also have general ventilation such as air conditioning units or large fans on top of their building. Emissions from these systems are released at ground level or on rooftops. The public, particularly those living downwind, can be exposed to relatively high levels of PERC from these facilities.

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AVES and ERMI (subcontractor) selected nine test facilities in this project, with the help of Bay Area AQMD Staff. The control measures on the nine facilities varied from ventilated room enclosures, partial ventilated room enclosures, to local ventilation system. To determine the health risk (potential cancer cases per million) by dry cleaning processes, capture efficiencies of perchloroethylene by the three ventilation systems are investigated. Samples were collected at each facility from ventilation systems, waste streams, fabrics, lint and indoor air inside the facilities.

Using facilities' purchase records for perc consumption rates produced a problem in mass balances. It was not clear how much of the purchased perc was used within the year, and the amount used on any one day can vary. Collecting data over one day could lead to some of the problems in the mass balance approach and the "lost" perc. The mass balance on one day might be different on another. The total mass balance approach will be useful only when accurate perchloroethylene daily consumption at each facility is available. Since most facilities have incomplete perchloroethylene purchase record (no existing perchloroethylene inventory before adding new perchloroethylene), it is difficult to establish daily consumption from yearly purchase record. AVES estimated perchloroethylene daily consumption by using an emission factor of perchloroethylene multiplied by the weight of clothes cleaned during that time period (poundage). The accountability of perchloroethylene from source testing data showed a range of 91.98% to 125.51% (except for facility 8) of perchloroethylene emissions based on clothes poundage. This is an indication that poundage is a reasonable estimate for perchloroethylene emissions at most facilities.

Based on the source testing results of nine dry-cleaning facilities using perchloroethylene, the majority of the perc emissions were associated with the waste streams (wastewater, sludge and lint). The residual perc in the waste stream accounts for 47% to 95% of the total perc used. The mean waste percentages for dry cleaning machines with and without secondary controls were 88.9% and 41.4%, respectively. Therefore, the use of secondary controls is associated with a higher percentage of perc in the waste stream than when no secondary controls are used.

Risk created by a dry cleaner is dependent on the amount of emissions, the proximity to receptors, and how the emissions are released and dispersed. Various ventilation system's perchloroethylene emission rates were measured by source testing and were entered into the ISCST3 model to calculate the dispersion of the system, and determine the risk using dispersion and risk assessment parameters. It is very difficult to evaluate the cancer risk related to different types of vapor collection systems associated with the cleaning equipment inside the building. There are many variables not related to the vapor collection system that directly affect the dispersion model results. The modeling results suggested that height of the stack, exit velocity of the stack, and location of the stack on the building roof (downwash) are the most critical parameters in risk reduction.

AVES then developed guidelines for dry cleaners to use when considering room enclosures with ventilation systems. Also identified were the costs associated with purchasing, installing, and operating the different types of enclosure/ventilation systems. In addition, cancer risks were found to be generally highest for facilities equipped with natural ventilation and lowest for facilities with Partial Vapor Rooms or Vapor Barrier Rooms.

The percent cancer risk reduction and cost effectiveness between use of different ventilation types were summarized below.

- Conversion from LOC to PVR resulted in an 86.0% reduction in cancer risk at 20 meters.
- Conversion from the PVR to the VB resulted in an additional 75.7% reduction in cancer risk at 20 meters.
- Conversion from the LOC directly to VB resulted in a 96.6% reduction in cancer risk at 20 meters.
- Conversion from LOC to PVR: 30.4% equipment cost increase ($1,050) - 86.0% reduction in cancer risk at 20 meters.
- Conversion from the PVR to the VB: 44.4% equipment cost increase ($2,000) – 75.7% reduction in cancer risk at 20 meters.
- Conversion from LOC directly to VB: 88.4% equipment cost increase ($3,050) –96.6% reduction in cancer risk at 20 meters.

Realizing the difficulties of using mass balance methodology to calculate capture efficiency, a temporary total enclosure (TTE) approach can be used. In addition, it is recommended that ambient air testing within the facility be conducted before-and-after the enclosure installation to estimate the effectiveness of these systems in reducing occupational exposures. Conducting additional testing using the temporary total enclosure and before-and-after the enclosure installation approaches would give a more complete assessment and further validate the effectiveness of these systems.

1.0 INTRODUCTION

The objective of this study was to assist the State of California, Air Resources Board (ARB) by conducting an assessment of the effectiveness of room enclosures with ventilation systems in reducing risk at dry cleaning facilities using perchloroethylene.

Since no data existed on the effectiveness of room enclosures with ventilation systems in reducing risk to the public at dry cleaning facilities that use perchloroethylene, the first objective of this project was to obtain emissions data for estimating perchloroethylene capture efficiencies for the types of room enclosures currently in use. Then the source testing data could be used as an input parameter to the industry-wide risk assessment model, which is used to estimate the health risk posed by these facilities.

The second objective of this project was the development of guidelines to provide the dry cleaning industry with specifications, methods of installation, kinds of control systems, costs of operation, estimates of the capture efficiencies of these systems and their risk reduction potential. The specifications include fan capacity, exhaust velocity, exhaust stack dimensions, stack location, intake location within the facility, and the types of materials used in the construction of enclosures.

Nine test sites were selected that used ventilated room enclosures, partial ventilated room enclosures or local ventilation systems, which are described detailed in Section 2. A testing plan was then prepared describing the sampling and analytical methods to be used to analyze for perchloroethylene in waste streams, ventilation systems, clothing, lint and ambient air inside the facilities, as detailed in Section 3. After the field portion of the project was completed, AVES then calculated the total emissions including the perchloroethylene emissions that were captured by the enclosure/ventilation system and measured, and fugitive perchloroethylene emissions, which were not measured. These results are shown in Section 4. Based on the findings presented in Section 4, AVES used the ISCST3 model to estimate the perchloroethylene emission impacts from these dry cleaners. To determine the risk (potential cancer cases per million) of a ventilation system, AVES entered the various ventilation systems perchloroethylene capture efficiency and facility emission rate into the dispersion model to calculate the dispersion of the system, and determine the risk using dispersion and risk assessment parameters. Please refer to Section 5 for the results of the risk assessment. As shown in Section 6, guidelines were developed for dry cleaners to use when considering room enclosures with ventilation systems. Also identified were the costs associated with purchasing, installing, and operating the different types of enclosure/ventilation systems. Conclusions and Recommendations are summarized in Section 7 of this report.

2.0 SITE SELECTION

AVES and Bay Area AQMD Staff visited some potential facilities. These sites were presented to ARB as potential testing sites for approval. A total of nine facilities were approved by ARB for testing. They are divided into three groups, e.g. local ventilation system (LOC), partial vapor barrier rooms (PVR) and full vapor barrier rooms (VBR). Within each group, there are minor differences between facilities by using secondary control, or fugitive control, or without additional control. Numbers were used to identify facilities as shown below in Table 2-1.

Table 2-1 Selected Facilities

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

First generation dry cleaning machine technology required that washing and drying be performed in separate machines, and that clothing be manually transferred from the washing unit to the drying unit. After the clothes were washed, they were transferred to a drying unit where most of the remaining perchloroethylene was evaporated, recovered in a condenser and reused. However, significant perchloroethylene loss occurred when clothes were transferred from the washing unit to the drying unit.

Second generation technology[1] eliminated the need for manual transfer of clothing because washing, extraction, and drying were all performed in the same machine. Fresh air was introduced into the drum in the last step of the drying cycle and exhausted to the outdoor atmosphere, either directly or through a control device. Typical control devices consisted of a carbon adsorber or azeotropic control device plus a small carbon adsorber. The elimination of garment transfer in dry-to-dry vented machines substantially reduced perchloroethylene fugitive emissions.

[1] AQMD Rule 1421 prohibits the operation of any vented machine within AQMD jurisdiction as of 10/1/98.

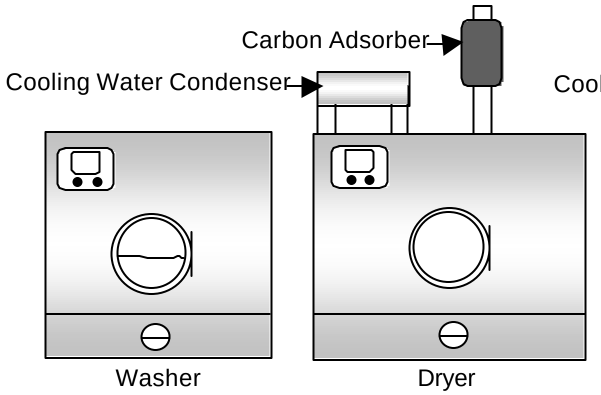


Figure 2-1 First Generation Transfer Machine

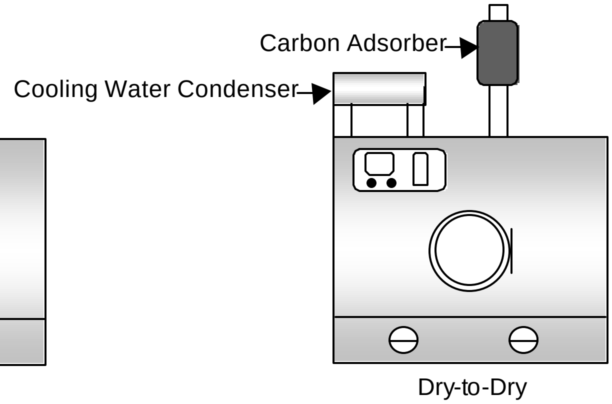


Figure 2-2 Second Generation Vented Machine

Third generation equipment consists of a closed-loop dry-to-dry cleaning machine equipped with a refrigerated condenser or other equivalent primary control system that mechanically condenses perchloroethylene vapors. A “converted machine” is a vented machine (second generation) that has been modified to be a closed-loop machine by eliminating the aeration step, installing a primary control system, and providing for recirculation of the perchloroethylene-laden vapor with no exhaust to the atmosphere or workroom during the drying cycle. A converted machine allows venting to the ambient air through a fugitive control system after the drying cycle is complete and only while the machine door is open. Fugitive emissions are the source of 100% of total emissions from facilities using closed-loop machines. See Figure 2-3 for an example of a Third Generation Closed-Loop Machine.

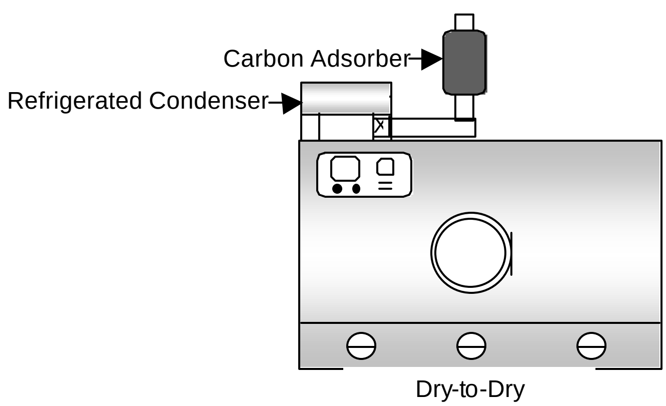


Figure 2-3 Third Generation Closed-Loop Machine

Fourth Generation dry cleaning equipment is a closed-loop refrigerated dry cleaning machine that has a "secondary control system" (e.g., closed-loop refrigerated condenser with a drying sensor and an integral carbon adsorber). The secondary control system reduces the concentration of perchloroethylene in the recirculating air at the end of the drying cycle below the level achievable with a refrigerated condenser alone. Secondary control systems are designed and offered as an integral part of a production package by the original equipment manufacturer. See Figure 2-4 for example of Fourth Generation Secondary Control Machine.

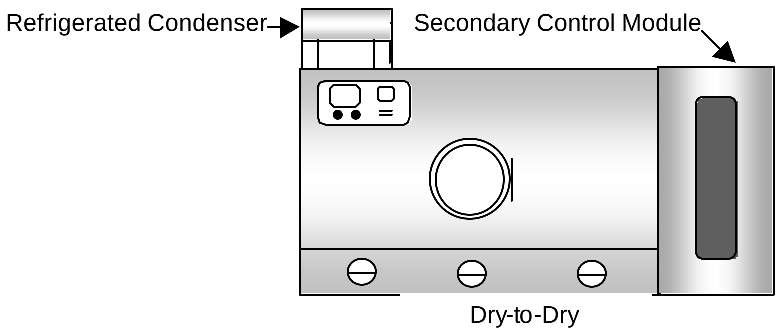


Figure 2-4 Fourth Generation Secondary Control Machine

2.1 Local Ventilation Systems

In LOC, hoods and shrouds are used to capture fugitive emissions at points of release. They are also necessary for some non-residential facilities to minimize exposure of perchloroethylene to nearby residents or commercial/industrial receptors. Fume hoods usually have plastic curtains on each side (or a combination of walls and curtains) to minimize cross-flow draft problems and provide better capture effect. See Figure 2-5 for LOC.

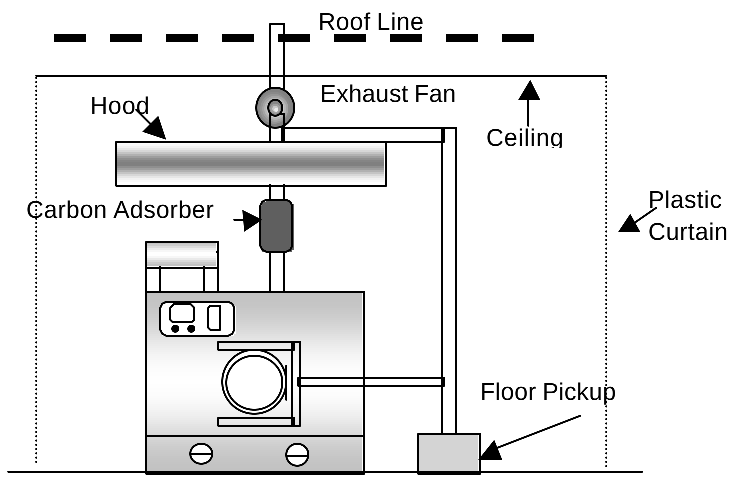


Figure 2-5 Local Ventilation System

2.2 Partial Vapor Room

PVR is constructed of material resistant to diffusion of solvent vapors, such as metal foil with a layer of insulation sheeting or heavy plastic sheeting sandwiched between dry wall sheets with offset seams. Seams and gaps are sealed with aluminized tape (not standard duct tape). Plexiglas could be used as windows to allow light in and to facilitate operation. The PVR surrounds 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 door(s) are normally closed (self-closing or alarmed). See Figure 2-6 for example of a PVR.

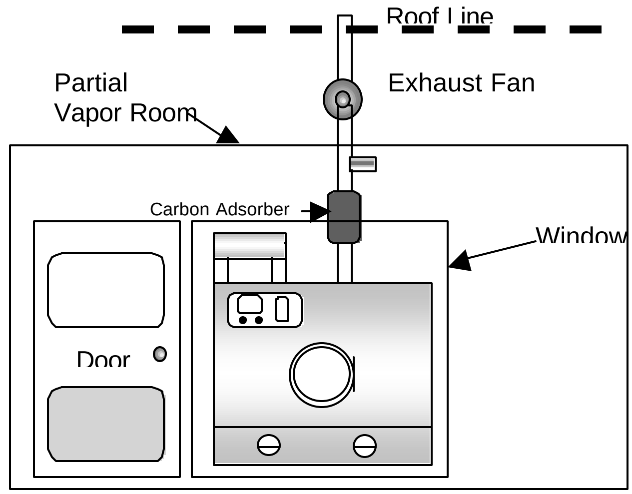


Figure 2-6 Partial Vapor Room

2.3 Vapor Barrier Room

VBR is 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; large gaps are caulked with silicon sealant prior to taping. See Figure 2-7 for VBR.

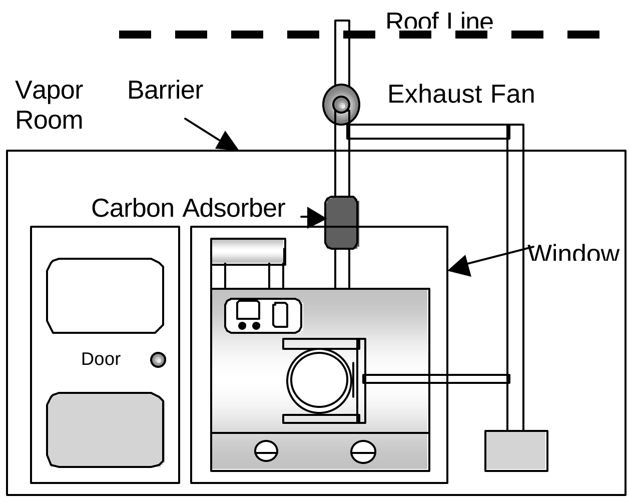


Figure 2-7 Vapor Barrier Room

The door(s) to the VBR are normally closed (self-closing devices are used); it may be a Swinging" design that opens both ways and/or a sliding door. Windows may be installed in doors or walls to allow in light, for safety reasons, or for make-up air. Plexiglas or tempered glass is most often used.

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 also 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. Warm air rises transporting solvent vapors effectively. Fan are used to produce air flow to maintain a capture velocity greater than 100 feet per minute at any intentional gap or opening or about 50 FPM at entry door when (temporarily) open.

An exhaust fan may be installed inside the VBR (near ceiling at back of machine or VBR) or outside the facility on a wall or on the roof. The fan is run continually (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.

2.4 Natural Ventilation

Many facilities do not have active ventilation systems and Perc is emitted from doors, windows, passive roof vents, and other smaller openings. Natural ventilation depends on wind and convective forces to move air through natural openings. This is not very effective, dispersion is usually very poor, and nearby receptors, particularly those within the same building, may be exposed to a high risk. Natural ventilation is usually adequate only for a stand-alone facility with a reasonable buffer zone.

2.5 General Ventilation

General ventilation systems typically have one or more large capacity fans on the roof and either have rain caps or exhaust horizontally. Capture efficiency depends on the air change rate inside the shop. Because most of the emissions are released at roof level, the wind has an opportunity to disperse the emissions and the impact at ground level is reduced somewhat. However, the effects of building downwash can trap all or part of the emissions plume into the lee of the building (cavity zone) increasing exposure to nearby receptors.

Based on the input received from ARB and Bay Area AQMD, AVES and Environmental and Risk Management, Inc. (ERMI) prepared a testing plan for the field test program. This test plan described the methods to be used to sample and analyze the perchloroethylene in the waste streams, ventilation systems, clothing, lint and ambient air inside the facilities. The fieldwork is described below:

3.1 Number of Samples to Be Collected

The following matrix summarizes the sampling location and the number of samples collected.

Table 3-1 Matrix of Samples for Dry Cleaning Facilities without Carbon Adsorbers

Sources	Samples per Facility	No. of Facilities	Total Samples	
			Planned	Collected
Stack Air	4	9	36	34[1]
Indoor Ambient	3	9	27	36[2]
Wastewater	2	9	18	18[3]
Sludge	3	9	27	18[3]
Cartridge Filter [4]	3	9	27	0
Fabrics	3	9	27	27
Lint	2	9	18	14[5]
Total	20	9	180	149

[1]. "Stack" sample refers only to the effluent air sample to be collected from the vapor barrier ventilation stack. Three runs were conducted at each facility except facility 8, plus two blank per trip (4 trips total).

[2]. 27 post-construction samples collected and 9 pre-construction samples.

[3] 18 composite samples (2 vials per facilities) collected.

[4]. For facilities that the filter cartridge data were not available, we used empirical data from BAAQMD.

[5] Since some facilities did not generate enough lint for each run, composite samples were collected at facility 1, 3, 4, 5, 6, 8, 9.

3.2 Sampling and Analysis Methods

The methods for sampling and analysis of perchloroethylene are presented in Table 3-2.

Table 3-2 Reference Test Methods

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

[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]. The samples are taken inside of the facility, but outside of the enclosures.

3.2.1 Emission Sampling from Stacks

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

The specific sampling location within the stack was determined after the velocity of the exhaust stack; and 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.

Since the make-up of the air stream is primarily ambient room air, ERMI used a molecular weight of 29.0 to calculate the molecular weight of the effluent air stream as permitted in CARB Reference Test Method 2.

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

3.3 Stack Testing and Analysis Procedures

1. AVES contract laboratory shipped overnight three SUMMA canisters to each site. The SUMMA canisters were pre-cleaned by the Applied P&Ch Laboratory (Chino, CA) and delivered under chain-of-custody protocol to ERMI. Upon receipt, ERMI personnel checked each canister to verify that there is a vacuum of at least 29.5 inches of mercury. The results were recorded in the field logbook.

2. Each stack had two sampling ports installed within the range of 2 - 8 times of duct diameter from the exit specified in CARB Method 1 to ensure that there are no obstructions to the airflow at the sampling point. The sampling ports were 2-1/2 inch diameter holes located 90 degrees apart and on the same plane.

3. The diameter of each exhaust stack dictated how many sampling points the velocity test would measure, as well as their specific location along each sample traverse point. CARB Test Method 1 was used for determining the sampling port locations as well as the individual sample traverse points for each of the facilities to be tested.

4. The velocity of the effluent gas stream was measured in accordance with the procedures specified in CARB Test method 2. ERMI used an appropriately sized standard Pitot tube and inclined water manometer to determine the differential in pressure (Δp) of the effluent gas stream at each specified point along both sample port traverses. The temperature of the effluent air stream was also measured with a type K thermocouple connected to a digital temperature indicator (DTI).

5. The stack gas stream was checked for cyclonic flow following the procedures specified in CARB Test Method 1.

6. Once the profile of the exhaust stack gas stream was identified, ERMI personnel selected a single representative sampling location that best represents an average velocity or degree of cyclonic flow from one of the traverse points.

7. The sample collection probes were constructed of 1/8-inch diameter-stainless steel tubing, approximately 5 feet in length. Since particulate matter is not a concern, there was not be a particulate filter installed on the tip of the sample probe. The end of the sample probe/sample line (one contiguous piece) was connected to the inlet of the sample collection valve which was connected to the SUMMA canister. The sample control valve was pre calibrated to collect a one-hour sample with the SUMMA canister. This sampling valve has been used in numerous compliance testing programs for various Air Districts throughout California as well as the EPA under the auspices of the Superfund Innovative Technology Evaluation (SITE) program, which ERMI was a contractor. A vacuum gauge was installed between the sampling valve and the SUMMA canister(see Figure 3-1), and isolated with a Stainless Steel Swagelok® on-off valve. Once the sampling apparatus has been assembled, ERMI personnel placed a /-inch Stainless Steel Swagelok® cap on the end of the sample probe. The SUMMA canister sample valve was then opened and the vacuum gauge on-off valve opened. The integrity of the sampling system was determined by monitoring any change in the vacuum gauge.

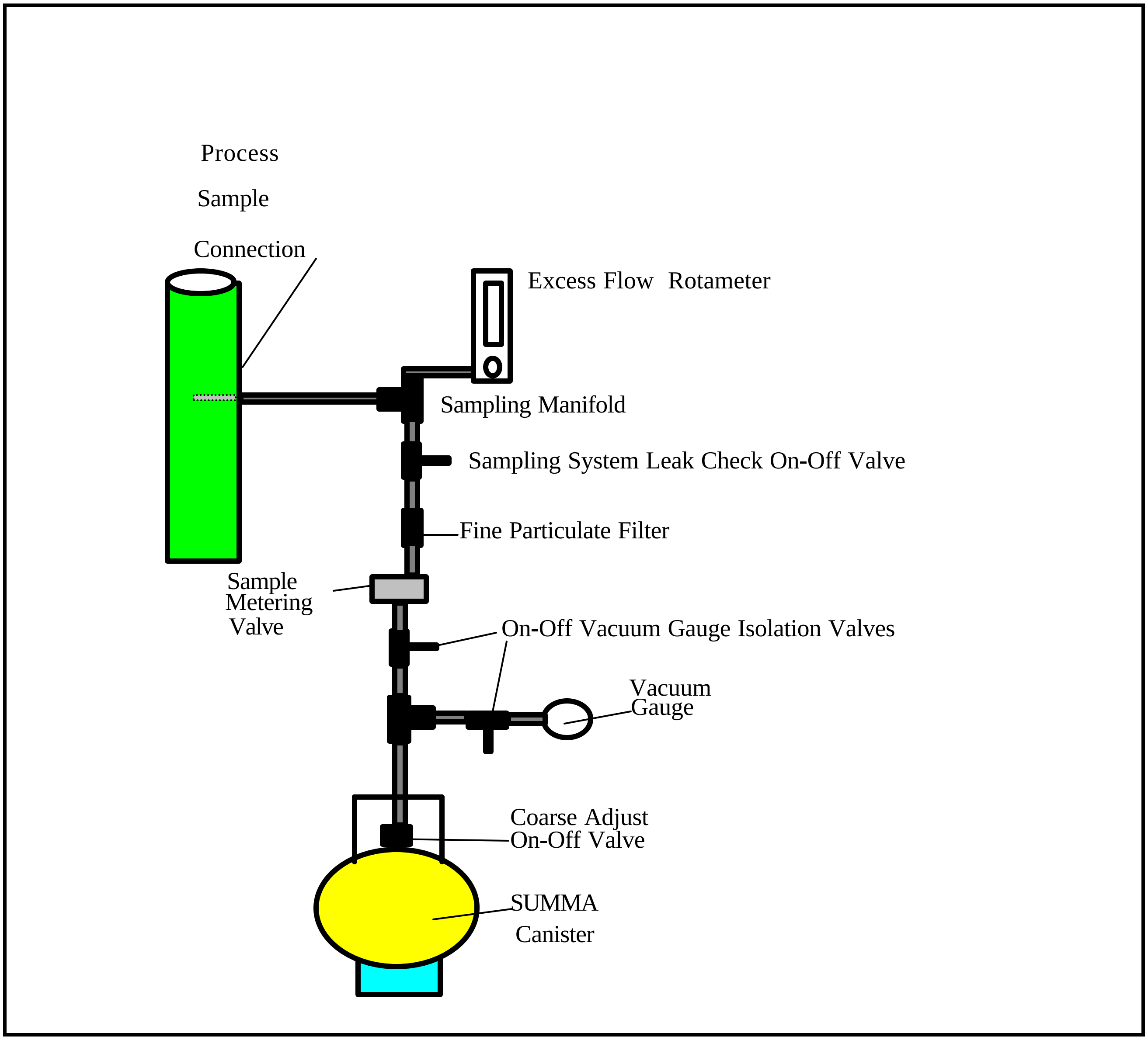


Figure 3-1 SUMMA Canister Sampling System

8. Once the integrity of the sampling system was determined, the Swagelok® cap was removed from the tip of the sample probe and the sample probe was inserted into the pre-determined sampling location. The SUMMA canister-sampling valve was opened and an initial vacuum reading taken. Once the vacuum reading had been taken, the on-off valve was closed and the test runs commenced. ERMI personnel monitored the SUMMA canister vacuum every ten minutes throughout the duration of the machine cycle (from the beginning of the wash cycle to the end of unloading clothes).

9. After the sampling period (consistent with the dry cleaning cycle), ERMI personnel closed the SUMMA canister-sampling valve and removed the sample probe from the sampling port. The sampling valve assembly was removed and the residual vacuum of the SUMMA canister was measured and recorded in the field logbook. The canister was properly labeled and a chain-of-custody form filled out.

10. Two additional samples were then collected after the first sample in the same manner as described above.

11. The samples were sent overnight to AVES contract laboratory under chain-of-custody protocol. The analytical laboratory completed the chain-of-custody form and log in the samples. The samples were analyzed within 72. The samples were analyzed for perchloroethylene following the analytical procedures specified in CARB Method 422. CARB 422 specifies the direct injection of the air sample from the SUMMA canister to a gas chromatograph equipped with an electron capture detector (GC/ECD). The contract laboratory adhered to all analytical QA/QC requirements.

12. The volumetric-flow rate was calculated in accordance to the procedures specified in CARB Test Method 2. As mentioned previously, ERMI used a value of 29.0 for the stack dry molecular weight. The volumetric flow rate was calculated as dry standard cubic feet per minute.

13. The mass emissions of perchloroethylene was calculated using the following formula:

$$Emissionrate(lb/hr) = \frac{(ppmvPerc) \times PercMol.Wt(165.8)}{379 \times 10^{6}} \times DSCFM^{[1]} \times 60$$

[1] Dry Standard Cubic Feet per Minute (See ARB Method 2)

3.3.1 Wastewater, Sludge, Cartridge Filter, Fabrics and Lint

Wastewater, sludge, and filters generated from the dry cleaning facilities were collected following the ARB approved Final Test Protocol as the guideline (see Appendix D). All the samples collected were stored in a cold box and shipped back to lab within 7 days. The samples were analyzed within 7 days. A completed chain-of-custody form was included with each set of samples.

Wastewater

Wastewater was collected from the machine wastewater separator during the sampling period each day. If there is not enough sample volume for each run, composite samples may be used from the combination of several runs. The wastewater reservoir was emptied before testing began. The wastewater was placed in a clean container. The wastewater was gently mixed by swirling in a container and measured by a measuring cup to determine volume for each test run. A glass thief was used to transfer liquid from container to volatile organic analysis (VOA) vials. When collecting the samples, liquids were introduced into the vials gently to reduce the potential for agitation that could drive off volatile compounds. In general, liquid samples were poured into a vial without introducing any air bubbles within the vial as it was being filled. The vials were completely filled to the top at the time of sampling, so that when the septum cap is fitted and sealed, and the vial inverted, no headspace was visible. The sample was hermetically sealed in the vial at the time of sampling, and was not opened prior to analysis to preserve their integrity. The samples were refrigerated during shipping and storage and transported under chain-of-custody protocol to the analytical laboratory. Two wastewater samples were collected at each site. To monitor possible contamination, a trip blank was prepared from organic-free reagent water and 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 mixed by swirling in a container and measured using a measuring cup to determine volume. Vials samples with solid or semi-solid matrices (e.g., sludge) were completely filled as best possible. The vials were tapped slightly as they were filled to try and eliminate as much free air space as possible. Three vials were filled per sample location. If an insufficient quantity of waste was generated each load at some facilities, composite samples for all three runs were collected from the same sludge container. When collecting the samples, liquids and solids were introduced into the vials gently to reduce agitation that could drive off volatile compounds. In general the sludge was placed into the vials without introducing any air bubbles within the vial as it was being filled. All vials were immediately labeled at the point at which the sample was collected. The vials were sealed in separate plastic bags to prevent cross contamination between samples, particularly the waste samples containing high levels of volatile organic compounds. The samples were stored in a cold box with blue ice during shipping and storage and transported under chain-of-custody protocol to the analytical laboratory.

Cartridge Filter

Since it is impossible to weigh the cartridge filters onsite, disposal record and empirical data were collected from the Bay Area AQMD.

Fabrics

Residual perchloroethylene content for several fabrics was quantified as fugitive emissions for this project. Three fabric types were selected: wool blends, rayon and silk. The fabrics were weighed before testing. These fabrics were added into the load as test coupons. At the end of the cleaning cycle, the test coupons were removed, and immediately sealed in double bag and sent to the analytical laboratory for analysis. At the laboratory, 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 in the perchloroethylene line. The samples collected from the entire sampling period were placed and sealed in double bags. The samples were double-bagged to prevent possible damage during the shipping. At the laboratory, the test coupons were extracted using methanol and analyzed using NIOSH Method 1003. The total amount of lint generated during the sampling period was weighed and recorded.

Other Data

Perchloroethylene usage and the weight of dry cleaned clothes or number of garments of items were recorded during the sampling period. When available, the dry cleaning equipment costs, ventilation system costs, equipment and fan capacity, building dimensions, receptor information, and other available specific site information were also recorded for future reference and for running computer models to estimate exposure concentrations and risks to the public around the dry cleaning facility.

3.4 Ambient Air Sampling inside the Dry Cleaning Facility

The main purpose of performing ambient air monitoring inside the facilities was to provide a base line for dry Cleaner worker exposure. It is believed that personal monitoring systems were more appropriate for indoor air quality measurement and much more cost effective to determine worker exposure. Based on the approval of ARB staff, personal monitoring pumps with absorbent tubes for sampling and analysis were used to measure indoor ambient perchloroethylene concentrations.

Calibrated personal sampling pumps were either attached to an employee or attached to the wall at locations closest to the potential emission sources (i.e., dry cleaning machines and recently cleaned clothes) for the predominant amount of time over the course of a work day. The calibrated personnel sampling pumps will draw air through charcoal absorbent tubes that were analyzed at a laboratory to determine average employee exposure concentrations during the sampling period. NIOSH Method 1003 was used to analyze the collected samples within 14 days to meet EPA's shelf life requirements.

All samples were analyzed in the Applied P & Ch Laboratory in Chino, California. Details of the PERC usage, perc concentrations, sample volumes and weights are attached in Appendix A.

4.0 FIELD TESTING AND MEASUREMENT OF CAPTURE EFFICIENCIES

In dry cleaning operations, the majority of perchloroethylene is lost either through emissions to the atmosphere or losses in the waste products. A small amount of perchloroethylene is also retained in clothes, but that amount is insignificant relative to the total perchloroethylene emitted from dry cleaning operations. The perchloroethylene capture efficiency of a ventilation system in this project is defined as the percentage of the stack emissions divided by the total amount of stack air emission and indoor air emission. The amount of perchloroethylene captured by ventilation system is equal to the amount of stack emissions, which can be obtained through stack sampling. Due to leakage, door opening and other operating processes, a small amount of perchloroethylene can not be captured by the ventilation system in the facility enclosure. This amount of perchloroethylene is determined by indoor air sampling.

Residual perchloroethylene content from clothes was considered as fugitive emissions for this project. A portion of the perchloroethylene emissions from clothes was captured by the indoor air emission monitoring. However, part of the perchloroethylene remained in clothes. Perchloroethylene emissions from clothes are not considered in the calculation of capture efficiency since part of the off-gasing amount was captured by the indoor air emission monitoring already. In addition, some perchloroethylene is discharged through other media, e.g. adsorption by cartridge filters, discharge through sludge and wastewater, which are also measured by taking samples. They are not considered in the calculation of capture efficiency since they are not removed by ventilation system.

An alternative to determine capture efficiency is to use a temporary total enclosure (TTE) around a perchloroethylene dry cleaning machine (EPA-450/4-91-020a). A temporary enclosure can be constructed in a way that access to the machine by shop personnel is allowed for equipment maintenance. Air to the TTE will be supplied at a known rate with temporary ductwork and a blower. Exhaust air, which contained fugitive perc from the dry cleaning machine, will be routed to a single exhaust. While the machine is operating, it is necessary to continuously monitor perc emissions with a flame ionization analyzer (FIA), and measure vapor leak concentrations with a hand-held photoionization detector (PID). However, it would be difficult to implement on a perchloroethylene dry cleaning machine with partial vapor barrier room or a full vapor barrier room.

An approach to determine the effectiveness of ventilation enclosure in reducing occupational exposures is to conduct testing before-and-after the ventilation enclosures had been installed. This approach was attempted by AVES for three facilities (one local ventilation system, one partial vapor barrier room, and one full vapor barrier room) during the project period. Pre-construction testing was performed on two facilities right before the ventilation enclosures had been installed and a couple months in advance on one facility. Due to the different operation conditions (facilities generally had less dry cleaning activities before the completion of new ventilation enclosures), all in-door ambient air samples showed less perchloroethylene concentrations than those collected after the completion of new ventilation enclosures. Therefore, pre-construction ambient indoor air data were not used in this study.

AVES determined the amount of perchloroethylene consumed by the machine(s) at the nine selected facilities during the test period and subtracted the amount of perchloroethylene in the waste streams (including perchloroethylene-contaminated water, sludge from still residues and filter muck, lint, and filters associated with the dry cleaning machine).

4.1 Source Test Data

The following is a summary of the data from the testing. Details of the PERC usage, rate of emissions, and weight of samples are attached in Appendix A.

Facility 1 (VBR)		Units	Test Conducted on 5/12/1998, Started at 8:00 AM				
			Method	PQL[1]	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	1.5	0.9	0.9
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.2	0.2
Wastewater[2]		mg/l	EPA 8260 (GC/MS)	5			30.8
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1			15
	Silk	mg/kg	NIOSH1003 (ECD)	0.1			43
	Wool	mg/kg	NIOSH1003 (ECD)	0.1			280
Lint[3]		mg/kg	NIOSH1003 (ECD)	0.1		560	290
Sludge Samples[4]		mg/kg	EPA 8260 (GC/MS)	5			501000

[1] PQL- Practical Quantification Limit
[2] 2 composite samples from machine overflow into waste container; the machine only produced a couple of drops of wastewater per load.
[3] The first lint sample was generated from 3-4 loads, the second sample was from one load.
[4] Composite sample from the dry cleaning machine sludge container. The machine produced not enough to obtain sample. About 120 ml of sludge produced in three days.

Facility 2 (VBR)		Units	Test Conducted on 5/14/1998, Started at 9:30 AM				
			Method	PQL	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	5.3	0.8	3.1
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.4	0.2
Wastewater [1]		mg/l	EPA 8260 (GC/MS)	5		180	
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1			10
	Silk	mg/kg	NIOSH1003 (ECD)	0.1			120
	Wool	mg/kg	NIOSH1003 (ECD)	0.1			460
Lint		mg/kg	NIOSH1003 (ECD)	0.1	1000	680	1600
Sludge Samples[2]		mg/kg	EPA 8260 (GC/MS)	5			633000

[1] 2 vials of wastewater were collected at the end of the 2nd load (300 ml from 1st load, 300 ml from the second load).
[2] Accumulated from 04/30 to the test date 05/14, 3 vials of composite samples were collected.
[3] Strong air current noted in the room.

Facility 3 (VBR)		Units	Test Conducted on 5/14/1999, Started at 9:50 AM				
			Method	PQL	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	6.3	4.3	9.7
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.1	0.8
Wastewater[1]		mg/l	EPA 8260 (GC/MS)	5			129
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1			5.1
	Silk	mg/kg	NIOSH1003 (ECD)	0.1			2.6
	Wool	mg/kg	NIOSH1003 (ECD)	0.1			90.3
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1			463
Sludge Samples[3]		mg/kg	EPA 8260 (GC/MS)	5			107000

[1] Composite sampling, 2 vials.
[2] Composite sampling.
[3] Samples were collected from sludge storage tank.

Facility 4 (PBR)		Units	Test Conducted on 5/13/1998, Started at 8:00 AM				
			Method	PQL	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	14.3	27.3	16.6
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	1.5	4.4	2.5
Wastewater[1]		mg/l	EPA 8260 (GC/MS)	5	290		
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1	14.9		
	Silk	mg/kg	NIOSH1003 (ECD)	0.1	110		
	Wool	mg/kg	NIOSH1003 (ECD)	0.1	310		
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1			
Sludge Samples[3]		mg/kg	EPA 8260 (GC/MS)	5	64000		

[1] Composite samples from Columbia machine waste bucket (1 ml generated per load).
[2] Unable to obtain lint from dry cleaning machine. Main fabrics cleaned are leather.
[3] Composite samples from two machines units from waste storage drum (about 200 gallons generated per year, however, no records available to verify the number).

Facility 5 (PBR)		Units	Test Conducted on 5/14/1998, Started at 9:30 AM				
			Method	PQL	#1	#2	#3
Stack Samples[1]		ppmV	EPA 8260 (GC/MS)	0.2	0.2	9.1	0.2
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	2.1	2.3	3.1
Wastewater[2]		mg/l	EPA 8260 (GC/MS)	5			190
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1			11
	Silk	mg/kg	NIOSH1003 (ECD)	0.1			23
	Wool	mg/kg	NIOSH1003 (ECD)	0.1			160
Lint[3]		mg/kg	NIOSH1003 (ECD)	0.1			220
Sludge Samples		mg/kg	EPA 8260 (GC/MS)	5			20000

[1] The second stack sample was collected using a sorbent tube instead of a SUMMA canister due to vacuum failure.
[2] Composite samples 1200 ml from 1st load, 340 ml from second load, and 0 ml from 3rd load.
[3] Very little lint produced after one load. A composite sample was collected from the three loads.

Facility 6 (PVR)		Units	Test Conducted on 5/12/1999, Started at 2:00 AM				
			Method	**PQL**	**#1**	**#2**	**#3**
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	1.5	14.3	9.7
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.2	0.1	0.2
Wastewater[1]		mg/l	EPA 8260 (GC/MS)	5			457
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1	22		
	Silk	mg/kg	NIOSH1003 (ECD)	0.1	2.3		
	Wool	mg/kg	NIOSH1003 (ECD)	0.1	163		
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1	333	306	230
Sludge Samples[3]		mg/kg	EPA 8260 (GC/MS)	5			202000

[1], [2], [3] Composite sample.

Facility 7 (LOC)		Units	Test Conducted on 1/21/1999, Started at 5:00 AM				
			Method	**PQL**	**#1**	**#2**	**#3**
Stack Samples		ppmV	EPA 8260	0.2	12.8	26.4	20.2
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.6	1.2
Water Samples[1]		mg/l	EPA 8260	5	108		100
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1		23	
	Silk	mg/kg	NIOSH1003 (ECD)	0.1		0.4	
	Wool	mg/kg	NIOSH1003 (ECD)	0.1		340	
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1	470	750	
Sludge Samples[3]		mg/kg	EPA 8260	5			510000

[1] Wastewater was collected at the end of the 1st and 3rd loads (2000 ml from 1st load, 1100 ml from the 2nd and 3rd load), 2 vials.
[2] Lint was collected after the 1st load and the 2nd load.
[3] No sludge sampled from the drum.

Facility 8 (LOC)		Units	Test Conducted on 1/22/1999, Started at 9:00 AM				
			Method	PQL	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2		10.8	4.1
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.1	0.3
Wastewater[1]		mg/l	EPA 8260 (GC/MS)	5			93
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1		9.8	
	Silk	mg/kg	NIOSH1003 (ECD)	0.1		1.9	
	Wool	mg/kg	NIOSH1003 (ECD)	0.1		130	
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1			500
Sludge Samples[3]		mg/kg	EPA 8260 (GC/MS)	5			490000

[1] Most wastewater was generated during the 3rd load.
[2] Composite sample from loads #1, #2, and #3.
[3] No sludge was sampled from the drum.

Facility 9 (LOC)		Units	Test Conducted on 5/12/1999, Started at 10:08 AM				
			Method	PQL	#1	#2	#3
Stack Samples		ppmV	EPA 8260 (GC/MS)	0.2	14.7	16.2	17.4
Ambient Air Sample		ppmV	NIOSH1003 (ECD)	0.005	0.1	0.0	0.1
Water Samples[1]		mg/l	EPA 8260 (GC/MS)	5			819
Fabrics	Rayon	mg/kg	NIOSH1003 (ECD)	0.1	121		
	Silk	mg/kg	NIOSH1003 (ECD)	0.1	2.2		
	Wool	mg/kg	NIOSH1003 (ECD)	0.1	207		
Lint[2]		mg/kg	NIOSH1003 (ECD)	0.1			177
Sludge Samples[3]		mg/kg	EPA 8260 (GC/MS)	5			3000

[1] Composite result
[2] Composite sample
[3] Collected from waste barrel.

4.2 Field Observation

Facility 1 (Full Room Enclosure): During the test, AVES staff noticed that the dry cleaning machine only produced a couple of drops of wastewater per load and composite sample from machine overflowed to a waste container. The machine did not produce enough sludge each load, only one sample was obtained from sludge produced in 3 days (<120 ml). This facility was extremely airtight with limited air intake into the enclosure. Ventilation fan capacity for this facility was underrated (148 SCFM was measured during source testing).

Facility 2 (Full Room Enclosure): A strong air current was noticed in the room on the day of the test. Since there is not enough sludge volume for each load, composite sludge samples were collected from material in the waste drum. This facility was well maintained with no leaks observed.

Facility 3 (Full Room Enclosure): The facility is very clean. Lint sample was from 3 loads. AVES staff was not able to collect a sludge sample during the test, thus the sample was collected from waste storage which had not been emptied for 23 months. The sludge container (55 gallon drum) was sealed by a lid with a pot hole (about 2 inches diameter). With the help of BAAQMD, the 1997-1998 data submitted to BAAQMD was used in the calculations.

Facility 4 (Partial Vapor Room): There are two machines in this facility: Columbia and Union. The facility had been used for cleaning leather coats specially. Due to the use of oil required when cleaning leather jackets, it was unable to collect lint from the two machines. Wastewater was collected from composite sample taken from Columbia machine waste bucket. The records from last year showed that approximately 1700 pounds of clothes washed per month for Union machine. AVES staff noticed that a wet solvent laden leather jacket was hung outside the PVR during testing. This facility was poorly maintained with lots of leaks observed.

Facility 5 (Partial Vapor Room): Upon facility owner's request, AVES staff tested the facility at midnight. Very little lint generated from one load; thus the sample collected was after 3 loads. The facility's records were out of date and AVES staff was not able to verify the records.

Facility 6 (Partial Vapor Room): Dusty conditions were prevalent at this facility. A composite sample of water was collected from the wastewater separator. The sludge would not be cleaned out until the weekend, thus the vials was left at the facility to collect sludge. AVES staff returned to this facility on next Monday. Three sludge samples were collected by the facility owner over the weekend. The owner did not provide the detail information regarding the perchloroethylene usage and manifest. With the help of BAAQMD, the 1997 data was used in our calculations.

Facility 7 (Local Ventilation): One wastewater sample was collected from the first run and one composite wastewater sample was collected from the 2nd and 3rd runs. The sludge samples were also composite samples from all three runs (collected from the sludge bin located right behind the dry cleaning machine with a pipe through a cover for the bin). Lint samples were collected for the 1st and 2nd runs. After the 2nd load, the operator left for the day. Thus no lint sample was collected for 3rd run.

Facility 8 (Local Ventilation): The lint sample was composite from loads 1, 2 and 3. Sludge samples were collected from the sludge bin located right behind the dry cleaning machine with a pipe through a cover for the bin. Material in the sludge bin was about one day old according to the facility owner. The wastewater sample was collected after the 3rd load.

Facility 9 (Local Ventilation): AVES was unable to collect sludge samples between runs. Therefore, the sludge sample was collected from the waste barrel. The sludge container was covered by a lid with a pot hole (about 2 inches diameter). The lint sample was collected from the combination of all 3 loads. The facility owner provided a copy of the 1997 data submitted to BAAQMD.

Since there is no heating/ventilation/air conditioning system (HVAC) in any of the facilities tested, the main driving force of the indoor air change is from the ventilation of dry cleaning machines. Smoke tests using Drager air current tubes were designed to determine air currents in workroom. When air was pumped into the tube by means of a rubber bulb, aerosol emerges in the form of white smoke. Smoke tests using Drager air current tubes were conducted at three facilities. The speed of white smoke being sucked into the gap or opening of the room enclosures varied in every facility. However, all three facilities operated the room enclosure under negative pressure. Smoke test method is a popular field technique, however, it is a qualitative approach not a quantitative approach.

Smoke testing at these facilities proved that the ventilation systems of the dry cleaning machines was much stronger than the natural draft from doors and windows. AVES estimated the air changes rates (ACR) by dividing indoor air volume (enclosure and outside enclosure) by the fan capacities (volumetric flow rates). The air change rates for nine facilities are used in indoor perc emissions calculation and are listed in Appendix A. If the ventilation system is operated properly, all indoor air emissions will go through the stack given enough time. This may create a minor double counting for point source emissions and volume source emissions. Therefore, the estimated risk assessment from modeling is a very conservative worst case scenario.

4.3 Mass Balance

The concept of mass balance is defined as the perchloroethylene input being equal to the perchloroethylene output of the dry cleaning machines. The input is the mass consumption by the cleaning machine, and the output is the sum of perchloroethylene discharging through different media, e.g. air emission, wastewater, sludge, cartridge filters, residual in fabrics, and lint. The input data of mass consumption can be obtained from facility records since each dry cleaning facility in the BAAQMD is required to keep the logs and records showing site-specific data. As for the output data of perchloroethylene discharging, field sampling should be collected from each possible media of perchloroethylene discharging.

AVES staff met with Robert Grant (RD), Greg Harris (SSD), Tony Servin (PTSD), and Todd Wong (SSD) on September 21, 1999 for quarterly review. Preliminary results for nine facilities were presented and discussed. The test results suggest that most of the ventilation systems are doing their job, but perc is lost through sloppy handling at some facilities. In general, there is a discrepancy between the Perc usage and summing the waste stream, ventilation, clothing output flows. There are a lot of variables in the operation of a dry cleaning facility. People at the same facility operate the machines differently. The clothing throughput can vary significantly from day to day within one facility.

Some of the facilities had poor record keeping. For those dry cleaning facilities with poor record, perchloroethylene daily consumption and Perc content in the waste streams were back calculated by using the consumption of perchloroethylene in a certain period of time divided by the number of operational days during that time period. Perchloroethylene daily emissions were also back calculated by using the emission factors of perchloroethylene multiplied by the weight of clothes cleaned during that time period (poundage).

Using facilities' purchase records for perc produced a problem in mass balances. It was not clear how much of the purchased perc was used within the year, and the amount used on any one day can vary. Collecting data over one day could lead to some of the problems in the mass balance approach and the "lost" perc. The mass balance on one day might be different on another. Using generic emission factors for different generation machines instead of perc usage, AVES was able to get better accountability of perc emissions from source testing data. For a secondary control machine, the typical emission is 10 pounds of Perc per 1000 pounds of clothes (Perc Dry Cleaner Industry-wide Risk Assessment Guidelines, CAPCOA, May 18, 1999). Thus, an emission factor of 0.01 Ibs of perc emission per lb. of clothes was used to estimate the perc emissions for a secondary control machine. For a closed-loop dry-to-dry machine, the typical emission is 18 pounds of Perc per 1000 pounds of clothes (Dry Cleaning Industry Wide Risk Assessment, CAPCOA, August 18, 1995). Thus, an emission factor of 0.018 Ibs of perc emission per lb. of clothes was used to estimate the perc emissions for the closed-loop machine.

As shown below perchloroethylene delivery receipts were also compared with perchloroethylene emissions for each facility:

- Facility 1 (Full Room Enclosure): Average 0.0638 gallons of perchloroethylene usage per day based on purchase record versus 0.0490 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 2 (Full Room Enclosure): Average 0.2132 gallons of perchloroethylene usage per day based on purchase record versus 0.1389 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 3 (Full Room Enclosure): Average 0.2800 gallons of perchloroethylene usage per day based on purchase record versus 0.0444 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 4 (Partial Room Enclosure): Average 0.4845 gallons of perchloroethylene usage per. day based on purchase records versus 0.1968 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 5 (Partial Room Enclosure): Average 0.2367 gallons of perchloroethylene usage per day based on purchase record versus 0.2059 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 6 (Partial Room Enclosure): Average 0.7267 gallons of perchloroethylene usage per day based on purchase record versus 0.3487 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 7 (Local Ventilation): Average 0.1144 gallons of perchloroethylene usage per day based on purchase record versus 0.2952 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 8 (Local Ventilation): Average 0.3333 gallons of perchloroethylene usage per day based on purchase record versus 0.3100 gallons of perchloroethylene emissions per day based on clothes poundage.

- Facility 9 (Local Ventilation): Average 0.5600 gallons of perchloroethylene usage per day based on purchase record versus 0.2173 gallons of perchloroethylene emissions per day based on clothes poundage.

Based on incomplete yearly purchase records (no existing perchloroethylene inventory before adding new perchloroethylene and not all newly purchased perchloroethylene were consumed within one year), most facilities may show more perchloroethylene emissions than the actual amount. AVES estimated perchloroethylene daily emissions by using the emission factors of perchloroethylene multiplied by the weight of clothes cleaned during that time period (poundage). In Table 4-1, the accountability of perchloroethylene emissions from source testing data showed a range of 91.98% to 125.51% (except for facility 8) of perchloroethylene emissions based on clothes poundage. This is an indication that poundage is a reasonable estimate for perchloroethylene emissions at most facilities.

Table 4-1. Mass Balance Summary

Facility No.	Emissions Based on Poundage (g/day)	Emissions based on Source Test (g/day)	Accountable (%)
1	301.59	368.88	122.31
2	854.20	844.12	98.82
3	273.14	336.26	123.11
4	1210.67	1370.48	113.2
6	2145.17	1973.04	91.98
7	1816.00	2279.21	125.51
8	1906.80	1109.24	58.17
9	1336.91	1371.16	102.56

Note: Due to unreliable testing data from Facility 5, no accountability was estimated.

Test data of all facilities participating in the testing are summarized below. A comprehensive mass balance calculation is included in Appendix A.

Table 4-2 Facility Mass Balance Based on Source Testing Data (g/Day)

Facility	Non-air emission of Perc						Air emission of perc			Total
	Fabrics	Lint	Sludge	Waste water	Cartridge Filter	Subtotal	Stack	Indoor Air	Subtotal	
1	4.12	0.00	318.58	0.00	30.76	353.46	15.26	0.16	15.42	368.88
2	16.07	0.00	634.98	0.11	61.52	712.68	129.58	1.86	131.44	844.12
3	1.25	0.00	125.58	0.08	61.52	188.43	147.01	0.83	147.84	336.26
4	16.46	0.00	2.66	0.00	164.05	183.17	1154.99	32.32	1187.31	1370.48
5	4.41	0.00	23.85	0.07	123.03	151.36	12.07	0.65	12.72	164.07
6	11.11	0.00	928.02	0.62	0.00	939.75	1032.18	1.10	1033.28	1973.04
7	19.25	0.00	1059.96	0.53	574.16	1653.9	616.23	9.09	625.32	2279.21
8	6.43	0.00	63.33	0.24	0.00	70.00	1038.42	0.81	1039.23	1109.24
9	10.39	0.00	13.39	1.67	820.23	845.68	524.95	0.53	525.48	1371.16

Table 4-3 Facility Total Emissions Through Ventilation (g/day)

Facility	Ventilation	Machine Type	Stack	Indoor Air	Total Emissions Through Ventilation	Source Test Total
1	VBR	Secondary Control	15.26	0.16	15.42	368.88
2	VBR	Secondary Control	129.58	1.86	131.44	844.12
3	VBR	Closed Loop	147.01	0.83	147.84	336.26
4	PVR	Secondary Control	1154.99	32.32	1187.31	1370.48
5	PVR	Secondary Control	12.07	0.65	12.72	164.07
6	PVR	Fugitive Control	1032.18	1.10	1033.28	1973.04
7	LOC	Secondary Control	616.23	9.09	625.32	2279.21
8	LOC	Closed Loop	1038.42	0.81	1039.23	1109.24
9	LOC	Closed Loop	524.95	0.53	525.48	1371.16

4.4 Capture Efficiency

The perchloroethylene capture efficiency of a ventilation system is defined as the percentage of the stack emissions divided by the total amount of stack air emission and indoor air emission. Capture efficiency of each facility was calculated based upon the actual source test data collected on site. Indoor air perchloroethylene emissions were determined by indoor air concentrations multiplied by the air change rates. A portion of the perchloroethylene amount from clothes was captured by the indoor air emission monitoring and a portion of the perchloroethylene remained in clothes. Perchloroethylene emissions from clothes are not considered in the calculation of capture efficiency since part of the off-gasing amount was captured by the indoor air emission monitoring already.

Table 4-4. Capture Efficiency

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

As shown in Table 4-4, the results indicate that the capture efficiencies of all facilities are over 95 percent except for facility 5. The capture efficiency of facility 5 was surprisingly low. AVES staff requested to revisit the facility to observe their operation, the owner refused our request. Several possibilities that might cause this low capture efficiency. For example, if the operator did not follow the operation requirement or if there was spill, the facility's fugitive emission can increase dramatically. Due to the unusual testing time (the facility owner only allowed testing from 12:30 AM to 3:30 AM), it was hard to determine what exactly caused this low capture efficiency.

The highest indoor concentration was obtained at facility 4. The reason could be well explained by what happened during sampling period at the field. When sampling the indoor air quality at facility 4, it accidentally happened that a leather jacket was being cleaned. After cleaning, it was hung up in the area where the sampling instrument was placed. Since leather has porous surface, it intends to absorb more perchloroethylene vapor in cleaning processes. Therefore, it also releases more perchloroethylene after cleaning, which leads to a higher indoor sampling concentration.

4.5 Statistical Data Analysis

Data collected for this test program included perchloroethylene concentrations in indoor air, stack air, fabrics and waste streams. Site-specific data such as perchloroethylene 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.

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 perchloroethylene in waste products than occurs without secondary controls. Table 4-5 shows the amounts of perchloroethylene that accumulated in three types of dry-cleaner waste materials (sludge, lint, and filters) at six of the facilities[2]. Table 4-5 also shows the waste as a percentage of the total perchloroethylene accounted for.

Table 4-5 Mass Balance Summary: Bay Area Dry Cleaner Study

Facility No.	Secondary Control	Ventilation Type			Perchloroethylene Used (lbs/yr		
		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	N0			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).

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

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 4-6 below for detailed results). We conclude, therefore, that the use of secondary controls is associated with a higher percentage of perchloroethylene in the waste stream than when no secondary controls are used.

Table 4-6 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	6.12	26.86	
Standard Error	3.53	13.43	
Coefficient of	6.88	64.93	
Mean	88.91	41.37	Difference = 47.54
Variance	37.43	721.36	Ratio = 0.052

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

Based on the results of the mass balance calculations of perchloroethylene dry-cleaning facilities in the Bay Area Air Basin, the majority of the perchloroethylene emissions were associated with the waste streams (wastewater, sludge and lint). The residual perchloroethylene in the waste stream accounts for 47% to 95% of the total perchloroethylene used.

5.0 DISPERSION MODELING AND RISK REDUCTION

The US EPA ISCST3 dispersion model was used to estimate the perchloroethylene emission impacts from the dry cleaners. The ISCST3 dispersion model can calculate concentrations for each hour of meteorological data and also average these values for longer periods such as a year.

To determine the risk (potential cancer cases per million) of a ventilation system, AVES entered the various ventilation system's perchloroethylene capture efficiency and facility emission rate into the ISCST3 model to calculate the dispersion of the system, and determine the risk using dispersion and risk assessment parameters.

Initially, each test facility’s risk was calculated for both natural and general ventilation to determine the baseline risk for those scenarios. Each facility's risk was then calculated with the installed enclosure or local system. The risk reduction potential of a facility with an enclosure or a local system is also calculated as the percent reduction in risk, as compared with the risk of the same facility using either natural or general ventilation.

An exposure assessment was used to estimate extent of public exposure and determine the maximum exposed individual residential receptor and the maximum exposed individual worker. To determine the maximum exposed individual receptor, the following procedures were followed:

a) Emissions quantification. For this project, source testing data and site-specific data were used to estimate the perchloroethylene emissions.

b) ISCST3 modeling to estimate concentrations for a particular pollutant at a site. The concentrations were estimated by using quantity of the emissions, pollutant release parameters, and representative meteorological data.

c) Duration of exposure. Lifetime residential exposure is assumed to be 24 hours/day, 365 days/year for 70 years. Offsite worker exposure is assumed to be 8-hours/work day, 240 days/year and a 46-year working lifetime. For this project, only lifetime residential exposure was estimated, since all the dry cleaner test sites were located in the residential areas.

5.1 Modeling Work

The ISCST3 dispersion model was used to estimate the perchloroethylene emission impacts from the dry cleaners. ISCST3 model (version 99155, dated 06/99) was used to calculate perchloroethylene concentrations for each hour of meteorological data and also to average these values for a year. Emission scalars were used to model the emissions during the day (8:00 AM to 4:00 PM).

As was mentioned in Section 2, a total of nine facilities were tested in this study. After evaluation of the test results, ARB concluded that only eight facilities would be modeled. Site-specific parameters, including release parameters and facility layouts were used to model each of the tested dry cleaning facilities. As a baseline for determining risk reduction potential of enhanced ventilation system, each of the tested facilities were modeled assuming both natural and general ventilation in addition to the enclosure/ventilation system. The enhanced ventilation scenario was modeled using a point source to represent emissions captured by the enhanced ventilation system in addition to volume sources to represent a facility's air emissions (i.e., fugitive emissions). The total fugitive emissions should be considered equal to the combined emissions from clothes, stack, and air. Emissions associated with clothes may be double counted as indoor air emissions, however, this is the worst case scenario. The modeling parameters for eight facilities were listed in Table 5-1.

Table 5-1. Modeling Input Parameters

Facility No.	Point Source				Volume Source		
	Stack Height (m)	Stack Diameters (m)	Velocity (m/s)	Modeling Temp. (Deg. K)	Release Height (m)	Sigma y0 (m)	Sigma z0 (m)
1	5.8	0.203	2.2	330	2.3	2.1	2.1
2	24.0	0.203	16.0	330	11.4	20.2	10.6
3	13.1	0.191	16.5	330	4.6	3.2	1.5
4	9.4	0.203	14.9	330	3.8	1.1	2.7
6	8.8	0.254	9.8	330	3.0	7.1	2.8
7	8.6	0.203	9.8	330	3.8	7.1	3.5
8	7.8	0.254	17.0	330	3.1	10.6	2.8
9	8.0	0.356	3.7	330	3.2	4.3	2.1

The receptor fields for all modeling runs were identical to ensure comparability between all modeling scenarios for each facility as well as between facilities. The polar grid receptor network was used in the modeling. The receptor network consists of 396 receptor points on eleven concentric distance rings centered on the stack location. The receptor locations are placed along 36 direction radials, beginning with 10 degrees and incrementing by 10 degrees in a clockwise fashion. Site-specific meteorological data were used for modeling runs. Meteorological data were provided by the Bay Area Air Quality Management District. The details of the specific data were listed in Table 5-2.

Table 5-2. Met Site

Facility No.	Met Site		Facility Coordinates	
	Site Name	Site Location	Longitude (km)	Latitude (km)
1	POT	Potrero Hill	549.30	4181.0
2	POT	Potrero Hill	549.56	4181.0
3	POT	Potrero Hill	549.19	4183.5
4	FST	San Francisco STP	551.18	4179.1
6	BUR	San Jose Burbank	594.74	4128.4
7	CHV	Chevron-Richmond Refinery	556.79	4201.8
8	SAN	San Francisco Sanitary Fill	551.96	4167.5
9	BUR	San Jose Burbank	597.25	4129.8

Building downwash may increase risk in some situations. Building downwash occurs when wind blowing over and around a building creates zones of turbulence that cause the pollutants emitted from a roof vent or short stack to be entrained into turbulent zones and become mixed. These pollutants are moved rapidly toward the ground resulting in higher ground-level pollutant concentrations near the building. Building downwash was considered when running ISCST3 dispersion model. Although dry cleaners generally work 5 days a week, all days of the week were modeled for this study. An average operational of eight hours was used in the model input. The annual average emissions were multiplied by a factor for the actual emissions (Table 5-3). The details of the model input parameters and output results are presented in Appendix C.

Table 5-3. Maximum Concentration Adjustment Factors

Facility No.	Modeling Time (hour)	No. of Loads (load/ day)	Cleaning Time (min)	Actual Time (hour)	Maximum Annual Concentration Hourly Adjustment Factor	Modeling (days)	Actual Operation (days)	Maximum Annual Concentration Daily Adjustment Factor
	(a)*	(b)	©	(d)=(b)* ©/60**	=(d)/(a)	(e)	(f)	=(f)/(e)
1	8	3.5	41	2.4	0.3	7.0	5.0	0.7
2	8	4	70	4.7	0.6	7.0	5.0	0.7
3	8	3	38	1.9	0.2	7.0	5.0	0.7
4	8	6	53	5.3	0.7	7.0	5.0	0.7
6	8	14	50	11.7	1.5	7.0	5.0	0.7
7	8	5	48	4.0	0.5	7.0	5.0	0.7
8	8	9	52	7.8	1.0	7.0	5.0	0.7
9	8	6	35	3.5	0.4	7.0	5.0	0.7

* It was modeled eight hours of emissions, from 8:00 AM - 4:00 PM
** This is the actual emission release time for the facility.

The ISCST3 dispersion model was run using four scenarios:

1) The source test data collected for each facility;

2) the facility's perchloroethylene emissions based on its clothes poundage;

3) the total perchloroethylene emissions from source test data collected for the facility as a volume source (natural ventilation), and;

4) 80% of the captured perc emissions from source test data as a point source and the remaining 20% as a volume source (general ventilation).

Scenario 1: The perc emissions were estimated based on source test results. Perc emissions include fugitive air emissions, stack emissions and emissions from clothes. Emissions captured by stack were modeled as a point source; the air and clothes emissions were modeled as a volume source.

Scenario 2: The perc emissions were estimated based on clothes poundage. Perc emissions include fugitive air emissions, stack emissions and emissions from clothes. For a secondary control machine, the typical emission is 10 pounds of Perc per 1000 pounds of clothes (Perc Dry Cleaner Industry-wide Risk Assessment Guidelines, CAPCOA, May 18, 1999). Thus, an emission factor of 0.01 lbs of perc emission per lb. of clothes was used to estimate the perc emissions for the second scenario. For a closed-loop dry-to-dry machine, the typical emission is 18 pounds of Perc per 1000 pounds of clothes (Dry Cleaning Industry Wide Risk Assessment, CAPCOA, August 18, 1995). Thus, an emission factor of 0.018 lbs of perc emission per lb. of clothes was used to estimate the perc emissions for the closed-loop machine. The stack and volume source emission ratio was the same as the scenario 1.

Scenario 3: This is a simulation of facility with natural ventilation. The perc emissions were estimated based on source test results. Perc emissions include fugitive air emissions, stack emissions and emissions from clothes. It was assumed that the perc was emitted as a volume source.

Scenario 4: This is a simulation of facility with general ventilation. The perc emissions were estimated based on source test results. Perc emissions include fugitive air emissions, stack emissions and emissions from clothes. It is assumed that 20 percent of perc was emitted as a volume source; and 80 percent of perc was emitted as a point source.

The first two scenarios were the comparisons of the source test data with the facility's perc emissions calculated based on clothes poundage. As was mentioned in Section 2, Perc is emitted from doors, windows, passive roof vents and smaller opening from facilities with natural ventilation; Perc is emitted at roof level from facilities with general ventilation system. Scenario 3 and 4 were run to compare the effect of the natural and general ventilation systems for the same facility.

5.2 Risk Characterization

An exposure assessment was used to estimate the extent of public exposure and determine the maximum exposed individual residential receptor and the maximum exposed individual worker.

Exposure to perc varies greatly and is generally dependent on the following factors:

a) The amount of emissions from the facility;
b) The proximity of receptors to the dry cleaner, and;
c) The dispersion of emissions including ventilation, building configurations, and meteorology.

Cancer risks were calculated at the point of maximum concentration for a residence in this assessment.

Cancer Risk = (annual average concentration)(Unit Risk Value)(years of exposure)/70 years.

The Unit Risk Value (URV) is the upper-bound estimate of the probability that a person would contract cancer as a result of constant exposure to an ambient air concentration of 1 ug/m3 over a 70-year lifetime. OEHHA has determined the URV for perc to be 5.9E-6 ((µg/m^3) . For a residence, years of exposure are 70. Multiplying a factor of 1,000,000 converts the risk unit to "in one million"

Table 5-4 presents the maximum cancer risk estimated for eight facilities based on the source test data collected in this project. The source testing data of facility 5 was considered unreliable due to the unusual testing time (the facility owner only allowed testing from 12:30 AM to 3:30 AM). In the Quarterly Review Meeting September 1999, ARB staff agreed to exclude Facility 5 from modeling. Tables 5-5 to Table 5-12 present the facilities' risk and their baseline risks. The following is an example of the analysis:

Facility 7
Local Meteorological Data: Chevron-Richmond Refinery (CHV)
Rural dispersion coefficients
Air Emissions based on total emission of 2279 g/day (see Appendix A) from source test was = 645 grams per day (stack emission + indoor air emission + fabrics)
(645 g/day * 1/(5 loads * 48 min. * 60 sec./min) = 0.0448 g/s)
Air Emissions based on total emission of 1816 g/day (see Appendix A) from poundage estimation = 514 grams per day (stack emission + indoor air emission + fabrics)
(514 g/day * 1/(5 loads * 48 min. * 60 sec./min) = 0.0357 g/s)
Building Dimension: 15 m x 30 m x 7.6 m

Stack Source:
Stack Height: 8.6 m
Stack Gas Exit Velocity = 9.8 m/s
Gas Exit Temperature = 330 Deg. K
Stack Diameters = 0.203 m

Volume Source:
Sigma y0 = 7.1 m
Sigma Z0 = 3.5 m
Release Height = 3.8 m

Polar Grid Receptor networks: receptors are placed along 36 direction radials, beginning with 10 degrees and incrementing by 10 on several concentric distance rings. There are 396 receptors in this modeling run.
Loads: 5 loads per day, 48 minutes per load.

Ventilation: Local Ventilation
Stack Emissions = 0.0428 g/s (source test data)
Fugitive Emissions = 0.00197 g/s (source test data)
Maximum Concentrations: 1.86 µg/m^3 * 0.5 * 0.71 (hourly and daily adjustment factor in Table 5-3) = 0.66 µg/m^3
Maximum Cancer Risk: 0.66 * 5.9E-6 * 10E6 =4 in one million (See Table 5-10, at 40 meters distance)

Ventilation: Natural Ventilation

Fugitive Emissions = 0.0448 g/s (source test data)
Maximum Concentrations: 6.64 $\mu g/m^3$ * 0.5 * 0.71 (hourly and daily adjustment factor in Table 5-3) = 2.36 $\mu g/m^3$
Maximum Cancer Risk: 2.36 * 5.9E-6 * 10E6 = 14 in one million (See Table 5-10, at 40 meters distance)

Ventilation: General Ventilation
Stack Emissions = 0.0358 g/s (80% of the total emission based on source test data)
Fugitive Emissions = 0.00895 g/s (20% of the total emission based on source test data)
Maximum Concentrations: 2.62 $\mu g/m^3$ * 0.5 * 0.71 (hourly and daily adjustment factor in Table 5-3) = .93 $\mu g/m^3$
Maximum Cancer Risk: .93 * 5.9E-6 * 10E6 = 6 in one million (See Table 5-10, at 40 meters distance)

Ventilation: Local Ventilation
Stack Emissions = 0.0341 g/s (based on poundage data)
Fugitive Emissions = 0.00157 g/s (based on poundage data)
Maximum Concentrations: 1.48 $\mu g/m^3$ * 0.5 * 0.71 (hourly and daily adjustment factor in Table 5-3) = 0.53 $\mu g/m^3$
Maximum Cancer Risk: 0.53 * 5.9E-6 * 10E6 =3 in one million (See Table 5-10, at 40 meters distance)

Risks are generally highest for natural ventilation and lowest for the enhanced ventilation system (see Table 5-4 to 5-13). It was assumed that 80% of the perchloroethylene emissions emits to the stack and 20% of the emissions emits to the air as a volume source for general ventilation systems. If the source test data from the stack was less than 80% of the total emissions, the cancer risks from facilities with enhanced ventilation would be higher than risks from facilities with general ventilation according to the assumptions made in this analysis. Due to the difference in locations and facility specific parameters, it is hard to do the detail comparisons among the facilities. It is worth noting that the facilities with vapor barrier rooms tested in this study have maximum cancer risks smaller than significant risk levels. For most of the facilities, the risks estimated from source test data and the risks estimated from facilities clothes poundage data are very close. Plots of risks estimated from facilities verses distances are included in Appendix B. Complete modeling input and output files are attached in Appendix C.

Table 5-4. Maximum Cancer Risk, in One Million

Facility No.	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
1	VBR	5.E-01	3.E-01	2.E-01	2.E-01	1.E-01	7.E-02	4.E-02	3.E-02	9.E-03	4.E-03	3.E-03
2	VBR	5.E-02	4.E-02	3.E-02	2.E-01	1.E-01	1.E-01	1.E-01	8.E-02	4.E-02	2.E-02	1.E-02
3	VBR	5.E-02	1.E-01	2.E-01	3.E-01	3.E-01	3.E-01	2.E-01	2.E-01	6.E-02	3.E-02	2.E-02
4	PVR	2.E+00	8.E+00	7.E+00	7.E+00	6.E+00	4.E+00	3.E+00	2.E+00	6.E-01	3.E-01	2.E-01
6	PVR	1.E+00	8.E+00	9.E+00	7.E+00	6.E+00	3.E+00	2.E+00	1.E+00	4.E-01	2.E-01	9.E-02
7	LOC	4.E-01	4.E+00	3.E+00	2.E+00	2.E+00	1.E+00	8.E-01	6.E-01	2.E-01	1.E-01	6.E-02
8	LOC	4.E+00	6.E+00	6.E+00	6.E+00	5.E+00	3.E+00	2.E+00	2.E+00	5.E-01	3.E-01	2.E-01
9	LOC	5.E+00	7.E+00	6.E+00	5.E+00	3.E+00	2.E+00	1.E+00	8.E-01	2.E-01	8.E-02	5.E-02

Note: Based on exposure to an annual average perc concentration in a residential setting.

Table 5-5. Maximum Cancer Risk for Facility 1 (Vapor Barrier Room), in One Million

PERC. Emission 19.5 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	VBR	5.E-01	3.E-01	2.E-01	2.E-01	1.E-01	7.E-02	4.E-02	3.E-02	9.E-03	4.E-03	3.E-03
Poundage	VBR	4.E-01	3.E-01	2.E-01	1.E-01	1.E-01	6.E-02	4.E-02	3.E-02	8.E-03	4.E-03	2.E-03
General		5.E-01	3.E-01	2.E-01	2.E-01	1.E-01	7.E-02	4.E-02	3.E-02	9.E-03	4.E-03	3.E-03
Natural		1.E+00	5.E-01	3.E-01	2.E-01	1.E-01	7.E-02	5.E-02	3.E-02	9.E-03	4.E-03	3.E-03

Table 5-6. Maximum Cancer Risk for Facility 2 (Vapor Barrier Room), in One Million

PERC. Emission 148 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	VBR	5.E-02	4.E-02	3.E-02	2.E-01	1.E-01	1.E-01	1.E-01	8.E-02	4.E-02	2.E-02	1.E-02
Poundage	VBR	5.E-02	4.E-02	3.E-02	2.E-01	2.E-01	1.E-01	1.E-01	8.E-02	4.E-02	2.E-02	1.E-02
General		7.E-02	7.E-02	5.E-02	2.E-01	2.E-01	1.E-01	1.E-01	9.E-02	4.E-02	2.E-02	1.E-02
Natural		4.E-01	3.E-01	3.E-01	5.E-01	4.E-01	2.E-01	2.E-01	1.E-01	5.E-02	3.E-02	2.E-02

Table 5-7. Maximum Cancer Risk for Facility 3 (Vapor Barrier Room), in One Million

PERC. Emission 149 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	VBR	5.E-02	1.E-01	2.E-01	3.E-01	3.E-01	3.E-01	2.E-01	2.E-01	6.E-02	3.E-02	2.E-02
Poundage	VBR	4.E-02	1.E-01	2.E-01	2.E-01	2.E-01	2.E-01	2.E-01	1.E-01	5.E-02	3.E-02	2.E-02
General		7.E-01	6.E-01	5.E-01	5.E-01	4.E-01	3.E-01	2.E-01	2.E-01	6.E-02	3.E-02	2.E-02
Natural		4.E+00	3.E+00	2.E+00	1.E+00	1.E+00	5.E-01	3.E-01	2.E-01	7.E-02	3.E-02	2.E-02

Table 5-8. Maximum Cancer Risk for Facility 4 (Partial Vapor Room), in One Million

PERC. Emission 1204 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	PVR	2.E+00	8.E+00	7.E+00	7.E+00	6.E+00	4.E+00	3.E+00	2.E+00	6.E-01	3.E-01	2.E-01
Poundage	PVR	2.E+00	7.E+00	6.E+00	6.E+00	5.E+00	3.E+00	2.E+00	2.E+00	5.E-01	3.E-01	2.E-01
General		1.E+01	1.E+01	9.E+00	8.E+00	6.E+00	4.E+00	3.E+00	2.E+00	6.E-01	3.E-01	2.E-01
Natural		6.E+01	3.E+01	2.E+01	1.E+01	9.E+00	5.E+00	3.E+00	2.E+00	6.E-01	3.E-01	2.E-01

Table 5-9. Maximum Cancer Risk for Facility 6 (Partial Vapor Room) , in One Million

PERC. Emission 1044 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	PVR	1.E+00	8.E+00	9.E+00	7.E+00	6.E+00	3.E+00	2.E+00	1.E+00	4.E-01	2.E-01	9.E-02
Poundage	PVR	1.E+00	8.E+00	1.E+01	8.E+00	7.E+00	4.E+00	2.E+00	2.E+00	4.E-01	2.E-01	1.E-01
General		7.E+00	1.E+01	9.E+00	8.E+00	6.E+00	3.E+00	2.E+00	1.E+00	4.E-01	2.E-01	9.E-02
Natural		4.E+01	2.E+01	1.E+01	8.E+00	6.E+00	3.E+00	2.E+00	1.E+00	3.E-01	2.E-01	9.E-02

Table 5-10. Maximum Cancer Risk for Facility 7 (Local Ventilation), in One Million

PERC. Emission 645 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	LVS	4.E-01	4.E+00	3.E+00	2.E+00	2.E+00	1.E+00	8.E-01	6.E-01	2.E-01	1.E-01	6.E-02
Poundage	LVS	3.E-01	3.E+00	2.E+00	2.E+00	2.E+00	1.E+00	6.E-01	5.E-01	2.E-01	8.E-02	5.E-02
General		2.E+00	6.E+00	4.E+00	3.E+00	2.E+00	1.E+00	9.E-01	6.E-01	2.E-01	1.E-01	6.E-02
Natural		9.E+00	1.E+01	8.E+00	5.E+00	3.E+00	2.E+00	1.E+00	7.E-01	2.E-01	1.E-01	6.E-02

Table 5-11. Maximum Cancer Risk for Facility 8 (Local Ventilation), in One Million

PERC. Emission 1046 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	LVS	4.E+00	6.E+00	6.E+00	6.E+00	5.E+00	3.E+00	2.E+00	2.E+00	5.E-01	3.E-01	2.E-01
Poundage	LVS	7.E+00	1.E+01	1.E+01	9.E+00	8.E+00	5.E+00	4.E+00	3.E+00	9.E-01	5.E-01	3.E-01
General		3.E+00	8.E+00	7.E+00	6.E+00	5.E+00	3.E+00	2.E+00	2.E+00	5.E-01	3.E-01	2.E-01
Natural		0.E+00	2.E+01	1.E+01	8.E+00	6.E+00	4.E+00	2.E+00	2.E+00	6.E-01	3.E-01	2.E-01

Table 5-12. Maximum Cancer Risk for Facility 9 (Local Ventilation), in One Million

PERC. Emission 536 g/day	Vent Type	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
Source test	LVS	5.E+00	7.E+00	6.E+00	5.E+00	3.E+00	2.E+00	1.E+00	8.E-01	2.E-01	8.E-02	5.E-02
Poundage	LVS	5.E+00	6.E+00	6.E+00	4.E+00	3.E+00	2.E+00	1.E+00	8.E-01	2.E-01	8.E-02	4.E-02
General		1.E+01	8.E+00	6.E+00	5.E+00	4.E+00	2.E+00	1.E+00	8.E-01	2.E-01	8.E-02	5.E-02
Natural		3.E+01	2.E+01	9.E+00	6.E+00	4.E+00	2.E+00	1.E+00	8.E-01	2.E-01	8.E-02	5.E-02

Table 5-13 Percentage of Risk Reduction by Converting Natural and General Systems to Different Ventilation System

No. [1]	System Conversion	Distance from stack (meter)										
		20	40	60	80	100	150	200	250	500	750	1000
1	Natural to VBR	56.9	35.4	21.4	14.4	10.4	5.5	3.3	2.2	0.4	0.3	0.0
	General to VBR	0	0	0	0	0	0	0	0	0	0	0
2	Natural to VBR	87.8	87.8	87.8	65.8	62.0	51.4	44.5	40.3	29.5	24.3	21.4
	General to VBR	39.4	39.4	39.3	13.9	12.1	8.7	6.8	5.7	3.7	2.8	2.5
3	Natural to VBR	98.6	95.2	88.6	79.8	68.7	48.0	35.7	27.9	13.3	9.1	7.0
	General to VBR	93.0	78.8	59.6	42.8	29.3	14.9	9.5	6.8	2.8	1.9	1.4
4	Natural to PVR	95.9	74.4	59.9	46.7	37.4	23.9	17.0	12.8	5.4	3.2	2.0
	General to PVR	79.7	32.6	20.0	12.8	9.1	5.0	3.3	2.4	1.0	0.6	0.4
6	Natural to PVR	96.7	58.9	24.4	6.1	0	0	0	0	0	0	0
	General to PVR	84.0	20.7	5.8	1.2	0	0	0	0	0	0	0
7	Natural to LOC	95.6	71.9	59.1	48.7	42.1	31.6	25.3	21.0	11.6	7.9	5.6
	General to LOC	78.0	28.6	18.9	13.3	10.5	7.0	5.2	4.1	2.1	1.4	0.9
8	Natural to LOC	N/A	65.6	43.6	29.8	22.2	12.0	7.4	5.1	2.1	1.1	0.7
	General to LOC	N/A	24.6	13.1	7.6	5.3	2.6	1.5	1.0	0.4	0.2	0.1
9	Natural to LOC	86.0	56.3	31.2	17.2	9.5	1.8	0	0	0	0	0
	General to LOC	52.7	19.1	7.7	3.7	1.9	0.3	0	0	0	0	0

Note: The value zero is used when there is no risk reduction.

The stack exit velocity in reducing cancer risk is very critical. All facilities tested have no caps or rain hoods on ventilation exhausts. The stack exit velocities at Facilities 2, 3, and 8 are higher. As a result, the cancer risk reduction percentages for those three facilities are good. On the other hand, Facility 1 has an under-powered motor with a low stack exit velocity, the cancer risk reduction percentage for facility 1 is the worst. It was assumed that 80% of the perchloroethylene emissions emits to the stack and 20% of the emissions emits to the air as a volume source for general ventilation systems. If the source test data from the stack was less than 80% of the total emissions, the cancer risks from facilities with enhanced ventilation would be higher than risks from facilities with general ventilation according to the assumptions made in this analysis. AVES noticed that Facility 6 and Facility 9 showed less risk reduction potential at longer distance. Since Facility 6 and Facility 9 used the same meteorological data from the same meteorological station to model, AVES believes that the lower average wind speed of the meteorological data used in modeling may contribute to the adverse dispersion for these two facilities. Facility 8 is a very large building, modeling results at 20 meters from the stack are not meaningful (it is still inside the building).

6.0 GUIDELINES FOR THE INSTALLATION OF ROOM ENCLOSURES

AVES developed guidelines for dry cleaners to use in considering room enclosures with ventilation systems. We identified the costs associated with purchasing, installing, and operating the different types of enclosure/ventilation systems and included system specifications. AVES also included a summary of the capture efficiencies, risk reduction potentials, and reduction in occupational exposures for each ventilation/enclosure system.

6.1 Construction, Installation, and Enclosure/Ventilation Specifications

Full Vapor Barrier Rooms (VBRs) and Partial Vapor Barrier Rooms (PVRs) should be constructed of material resistant to diffusion of solvent vapors such as metal foil faced insulation sheets (minimum 22 mil) or heavy plastic sheeting sandwiched between dry wall (gypsum) sheets. Seams should be offset for multiple layers of material and sealed with aluminized tape at each layer. It is also recommended to caulk with silicon sealant for large gaps prior to taping. Some vapor barrier materials may need to be covered with gypsum board to meet fire and building code requirements.

Local Ventilation System: Local Ventilation Systems (LOCs) should have hoods and shrouds to capture fugitive emissions at point of release and are necessary for some nonresidential facilities to minimize exposure of perc to nearby residents or commercial/industrial receptors. Fume hoods should have plastic curtains on the sides (or a combination of walls and curtains) to minimize cross-flow drafts and provide better capture velocity.

6.1.1 Stack Design

Full Vapor Barrier Room [Total Room Enclosure]: The stack should extend at least 5 feet (up to 15 feet) above the roofline or any adjacent roof and at least 30 feet from any air intake or window. The diameter of the stacks should generally be between 8 and 14 inches with an air flowrate of 1000 to 2500 CFM to provide good dispersion. This will provide an exhaust velocity of between 10 to 20 meters per second. Partial Vapor Room [Partial Room Enclosure]: The stack should extend at least 5 feet (up to 15 feet) above the roofline or any adjacent roof and at least 30 feet from any air intake or window. The diameter of the stacks should generally be between 8 and 14 inches with an air flowrate of 1000 to 2500 CFM to provide good dispersion. Local Ventilation System: The stack should extend at least 5 feet (up to 15 feet) above the roofline or any adjacent roof and at least 30 feet from any air intake or window. The diameter of the stacks should generally be between 8 and 14 inches with an air flowrate of 1000 to 2500 CFM to provide good dispersion.

Proper stack design eliminates rain intrusion with offset legs, drains, and internal deflectors. External holes may also have drain holes. Stacks should not have rain caps to allow emissions to be exhausted vertically.

6.1.2 Air Change Rate

Air Change Rate is defined as the number of displacements of a volume of air, equal to the volume of a restricted working region of a facility where solvent emissions occur, in a specific time period. For example, a 5,000 cubic feet per minute fan would cause one air change every five minutes (or 12 air changes per hour) for a working region with a volume of 25,000 cubic feet. Generally, an air change rate of at least once every 10 minutes is considered adequate in a stand-alone building. A greater air change rate is recommended for mixed-use buildings. The air change rate should be greater than once every five minutes for a co-residential facility and once every ten minutes for a non-residential facility.

Partial Vapor Rooms or Vapor Barrier Rooms are more effective than local or general ventilation systems for capturing emissions. They are highly recommended for co-located situations such as multi-story commercial buildings and shopping malls that do not have good separation between buildings.

6.1.3 Ventilation System/ Fans

Full Vapor Barrier Rooms (VBR): A vapor barrier room restricts diffusion and transport of solvent vapors that escape from a dry cleaning machine because a ventilation fan collects virtually all the vapors and exhausts them through a stack above the building. Fresh make-up air may be supplied from the shop through gaps around the entry door(s) or additional sliding windows and adjustable louvers if necessary. Make-up air should be introduced at the front of the machine and at the same height as the loading door. The ventilation duct or fan intake should be placed near the ceiling directly above the back of the machine or at the rear of the VBR. Warm air rises transporting solvent vapors towards the ceiling. Placing the fan near the ceiling will remove the warm air and vapors effectively. The fan should produce an adequate air flow (minimum 1000 CFM) to maintain a capture velocity greater than 100 feet per minute at any intentional gap or opening or about 50 FPM at the entry door when temporarily open.

Partial Vapor Rooms and Local Ventilation Systems: If a closed-loop dry cleaning machine is not totally enclosed (by walls for PVR or plastic curtains for LOC), an inductive door fan, a fugitive control system or a fugitive capture shroud should be required to assure that most of the emissions from the loading door are captured by the ventilation fan. There should be adequate airflow (minimum 1000 CFM but likely much higher: 2,500-10,000 CFM) to maintain a capture velocity greater than 100 feet per minute at any fugitive capture structure (such as a shroud at the loading door and the fume hood). An air change rate of at least once every 10 minutes should be adequate in a stand alone building, but greater air change is recommended for mixed-use buildings. The exhaust fan(s) may be installed inside the PVR/LOC or outside the facility on a wall or on the roof; and should be a high pressure (1-3 " H_{20}) design with a minimum capacity of 1000 CFM and should be run whenever the dry cleaning machine is operating. The ventilation duct or fan intake should be placed near the ceiling directly above the back of the machine or at the rear of the PVR or LOC.

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. Pollutant emissions are normally reduced due to the installation of a relatively small carbon adsorption system. A secondary emission control system has a small carbon adsorber that collects residual solvent vapors from recirculating air at the end of the drying cycle. Fugitive and secondary emission control systems must be regularly inspected to maintain effectiveness.

6.1.4 Doors and Windows

Full Vapor Barrier Rooms [Total Room Enclosure]s: The door(s) to VBR's should normally be closed with a self-closing device. Design features may vary, but are normally a "swinging" design that opens both ways or a sliding door. It is recommended that windows be constructed of Plexiglas or tempered glass.

Partial Vapor Barrier Rooms [Partial Room Enclosures]: Maintenance entry door(s)should normally be closed with a self-closing device or alarm. Plexiglas may be used for windows to allow fight to enter the facilities and for safety reasons.

Local Ventilation Systems: This type of system has the front loading door and no windows. The door should contain either a fugitive capture shroud or an inductive door fan.

6.1.5 Electrical Circuits

Circuits for dry cleaning machines start with the Electric Circuit Breaker Panel. The machine is hooked up to the panel via an AC outlet. A fan control switch may be installed on the panel to power the motor for the fan. Interlock switches should be available on a control panel on the face of the machine.

Ventilation system interlocks that operate whenever the dry cleaning machine is operating are required for non-residential facilities and continuously for co-residential facilities. Therefore it is necessary to install a control interlock or a contactor relay, that will interrupt the power to the control system of the dry cleaning machine when power to the fan is switched off. This way, a facility operator may operate the ventilation fan during shutdown and maintenance of the dry cleaning machine.

6.2 Costs, Cost Effectiveness and Risk Reduction

The capital costs between the three different types of dry cleaning systems vary on the size of the machine and how the machine is constructed and installed. Some rooms may need to be custom built to fit in a corner of a room or as a stand-alone structure. Costs may include the construction of walls or the installation of a blower, exhaust system, foil, or fan. Since each facility's ventilation room requires different specifications according to the dry cleaner operator's needs and the regulating air quality management board, the costs of each must vary. The cost estimates that follow are estimates for a typical dry cleaning system. Costs include the construction, purchase and installation of the system.

6.2.1 Capital Costs

AVES contacted several construction companies and found that to construct a Full Vapor Barrier Room would cost between $5,000-$8,000. A Partial Vapor Barrier Room could be constructed for about $4,500, and the Local Ventilation System would be about $2,900-$4,000.

6.2.2 Operational Costs

The operation of a typical dry cleaning system requires electricity, natural gas, filters, fans, and detergents varies from machine to machine based on the capacity and design of each. On average each of these systems uses less than one hundred gallons of perchloroethylene in a year. The Full Vapor Barrier Room uses an average of sixty gallons of perchloroethylene per year with an operational range of plus/minus 50 gallons for different facilities. The Partial Vapor Barrier Room and the Local Ventilation System are estimated to use 100 gallons of perchloroethylene per year with an operational range of plus/minus 80 gallons for different facilities. Perchloroethylene costs an average of $7.50 a gallon.

An example of operational costs, in the form of electrical costs, for a dry cleaning operation with one Full Vapor Barrier Room is approximately $900. This total includes the total electrical cost incurred by the shop per month. It is assumed that the machine utilizes approximately $450 worth of electrical costs. Typically there are one, two or three cleaning machines in a local dry cleaning operation and there is usually one vapor fan per machine. Thus the vapor barrier fan electrical costs alone could vary by a factor of three depending on the number of dry cleaning machines. In the example above, in which it is assumed the cost for operation of one machine is $450 per month. A similar shop with three dry cleaning machines would incur electrical costs of $1350 per month for the machines and perhaps a 30 percentage increase for the remaining shop operations, totaling approximately $1,935 per month. Another factor that could vary the total shop electrical costs is the type of air conditioning it uses, e.g. refrigeration, wet sump or circulating fans. These “other factors” made it very difficult to isolate the electrical cost per vapor fan from the total electrical invoice for the shop, which results in a wide range of potential average operational cost between similar vapor barrier types which compounds the variability between three vapor extraction systems.

The ventilation fans for the exhaust of PERC from dry cleaners are typically driven by electric motors ranging from ½ to 1 ½ hp. The Bay Area AQMD experience has shown this range of horsepower is not directly related to the type of vapor capture system, i.e. LOC, PVB, and VB. The exhaust stack design and construction requirements are the primary factors that dictate the required motor size (Scott Lutz, personal communication). The Bay Area AQMD requirement is for a minimum of 1000 cfm airflow. The engineering design to achieve the minimum 1000 cfm flow, along with construction limitations for each building site controls the exhaust motor power requirement. The design defines the stack height and diameter to achieve an exit velocity for a given flow rate. In addition each building site dictates potential back pressure in the stack through building height, number of bends, and degree of bend. In summary, it is the design and construction factors that dictate the motor horsepower required to meet the minimum flow of 1000 cfm.

Table 6-1 Operating Costs

Annual Electrical Cost for Ventilation Exhaust Motor

No.	Volts	Amperes	Watts	kW	Elec. Rate	Residential Area	Commercial Area
					$0.12/kw-hr.	24 hr/day 300 days/yr.	10 hrs/day 280 days/yr.
I.	**1/2 Horse power**					**VB and PVR**	**PVR and LOC**
1	115	9.0	1035	1.035	$0.12	$894.24	$347.76
2	115	9.6	1104	1.104	$0.12	$953.86	$370.94
3	115	10.4	1196	1.196	$0.12	$1,033.34	$401.86
Average		**9.7**			**$0.12**	**$960.48**	**$373.52**
II	**1 Horse power**						
4	115	13.3	1530	1.530	$0.12	$1,321.49	$513.91
5	115	13.8	1587	1.587	$0.12	$1,371.17	$533.23
6	115	14.4	1656	1.656	$0.12	$1,430.78	$556.42
Average		**13.8**			**$0.12**	**$1,374.48**	**$534.52**
	1 1/2 Horse power						
7	115	16.4	1886	1.886	$0.12	$1,629.50	$633.70
8	115	16.8	1932	1.932	$0.12	$1,669.25	$649.15
9	115	18.2	2093	2.093	$0.12	$1,808.35	$703.25
Average		**17.1**			**$0.12**	**$1,702.37**	**$662.03**

Note: Theoretically, 1 kW-hr is equivalent to 1.34 HP. However, electrical motors are not able to meet the theoretical conversion due to thermal loss.

The cost for operation of typical exhaust fans with ½, 1, and 1 ½ hp motors is provided in Table 6-1. The amperage draw for an electric motor varies based on the motor design and efficiency. Three typical amperage drawn, watts used, are provided for the three different horsepower motors. The cost calculation is also based on a cost of $0.12 per kilowatt-hour and this cost may vary depending on location and time of day.

The costs are provided for dry cleaner operation in residential areas and in commercial areas. The operating cost calculation for residential areas is based on the exhaust fans operating 24 hours a day for 300 days a year. The operating cost calculation for commercial areas is based on fan operating duration of 10 hours a day for 280 days a year. The calculations show that annual exhaust fan operation cost may vary by a factor of 2, depending on the design and motor power requirement to drive the fan.

The three types of rooms being discussed vary in energy costs and maintenance costs. There is not enough history in dry cleaning with these three types of systems to clearly state maintenance costs. Some dry cleaning businesses perform their own maintenance while others hire or have contract maintenance personnel to work on their machines. Maintenance costs therefore vary greatly between contract/hire repairs and owner repairs. In addition, the range of maintenance costs fluctuates between the three systems and within each one depending on the size of each and the types of repairs being performed.

6.2.3 Cost Effectiveness and Risk Reduction

Cost effectiveness in terms of capture efficiency of each room and the amount of perc still needs to be analyzed. Different machines release different amounts of perc emissions. Each of the ventilation systems helps to disperse any fugitive or ambient air, and any perc released from the machine.

Summary:

1. The perc concentrations calculated by the model are for outside the building and are not associated with the dry cleaner operations inside the building. Thus the risks are determined for receptors "on-the-street" at various distances from the exhaust stack as shown in Table 6-2.

2. It is very difficult to evaluate the Cancer Risk related to different types of vapor collection systems associated with the cleaning equipment inside the building. There are many variables not related to the vapor collection system that directly affect the dispersion model results. For example, they are:
   - Concentration of perc in the equipment drum, when opened,
   - With or without a secondary vapor collection system on the equipment,
   - Height of the Stack ,
   - Exit velocity of the stack air/gas
   - Building size and shape
   - Location of the stack on the building roof (downwash)
   - Building ventilation system (positive, negative, or recirculation) and,
   - Ventilation collection type around the equipment (LOC, PVR, and VBR).

   Comparisons of the risk results between Facility 2 and 3 can provide a good example of the influence by these factors. The daily perc emissions were very close (148 vs. 149 g/day). Yet the cancer risk was an average of twice as high for facility 3 as it was for facility 2 from 60 to 1000 meters form the source.

3. In discussion with the equipment manufactures, and installers it was found that the potential emissions from the dry cleaning equipment vary orders of magnitude. This variation is due to the equipment itself (i.e. age, maintenance, type, Generation", etc). Thus the vapor collection system for the equipment can be exposed to a wide range of perc concentrations to collect and exhaust.

4. The eight facilities tested had daily perc emissions ranging from 19.5 to 1204 g/day. In an attempt to compare the cancer risk between facilities, the cancer risk was normalized (refer to Table 6-3 below). For example, Facility 4 estimated cancer risk at 20 meters was converted from 2.48 to .206 by dividing 12.04 (per 100g/day perc emitted).

5. Three facilities with similar parameters were selected to compare the cancer risk between ventilation types (refer to Table 6-4 below).

6. The percent cancer risk reduction between use of different ventilation types was determined. Results are shown below in Table 6-5.
Conversion from LOC to PVR resulted in an 86.0% reduction in cancer risk at 20 meters.
Conversion from the PVR to the VBR resulted in an additional 75.7% reduction in cancer risk at 20 meters.
Conversion from the LOC directly to VBR resulted in a 96.6% reduction in cancer risk at 20 meters.

7. The cost effectiveness or cost (% and dollars) for each reduction in cancer risk was calculated for each ventilation type (refer to Table 6-6 below).

- Conversion from LOC to PVR: 30.4% equipment cost increase ($1,050) – 86.0% reduction in cancer risk at 20 meters.

- Conversion from the PVR to the VBR: 44.4% equipment cost increase ($2,000) – 75.7% reduction in cancer risk at 20 meters.

- Conversion from LOC directly to VBR: 88.4% equipment cost increase ($3,050) – 96.6% reduction in cancer risk at 20 meters.

8. There is good correlation for reduction in cancer risk due to the conversion of the more efficient ventilation (vapor collection) systems for distances out to 1000 meters from the source (stack). There appears to be an anomaly for conversion from LOC to PVR at distances greater then 100 meters from the source. However, maximum cancer risks are in the same order of magnitude. This may be an artifact of the dispersion modeling with it's many variables as shown in Tables 5-1, 5-2 and 5-3.

Table 6-2 Maximum Cancer Risk Per Million

No	Emission 100g/day	Vent Type	Distance from stack (meter)								
			20	40	60	80	100	150	200	250	500
1	0.20	VBR	0.49	0.34	0.24	0.17	0.13	0.07	0.04	0.03	0.01
2	1.48	VBR	0.05	0.04	0.03	0.16	0.15	0.12	0.10	0.08	0.04
3	1.49	VBR	0.05	0.13	0.21	0.26	0.31	0.28	0.22	0.17	0.06
4	12.04	PVR	2.48	7.71	7.35	6.63	5.64	3.68	2.52	1.82	0.59
6	10.44	PVR	1.19	7.71	8.74	7.47	6.00	3.46	2.18	1.48	0.38
7	6.45	LOC	0.41	3.94	3.12	2.47	1.96	1.20	0.81	0.59	0.20
8	10.46	LOC	3.84	5.70	6.00	5.51	4.71	3.14	2.18	1.59	0.54
9	5.36	LOC	4.81	6.65	5.94	4.60	3.50	1.89	1.16	0.78	0.20

Table 6-3 Normalized Maximum Cancer Risk Per Million

No [1]	Emission 100g/day	Vent Type	Distance from stack (meter)								
			20	40	60	80	100	150	200	250	500
1	0.20	VBR	3.0E+00	1.9E+00	1.4E+00	9.9E-01	7.3E-01	3.9E-01	2.4E-01	1.7E-01	4.8E-02
2	1.48	VBR	3.0E-02	2.5E-02	8.0E-02	7.1E-02	1.1E-01	8.5E-02	6.9E-02	5.7E-02	2.5E-02
3	1.49	VBR	3.4E-02	7.4E-02	1.3E-01	1.7E-01	2.1E-01	2.0E-01	1.6E-01	1.2E-01	4.2E-02
4	12.04	PVR	1.4E-01	2.0E-01	5.5E-01	5.3E-01	5.9E-01	3.6E-01	2.6E-01	1.9E-01	5.3E-02
6	10.44	PVR	6.1E-02	5.2E-01	8.6E-01	7.7E-01	6.2E-01	3.5E-01	2.2E-01	1.5E-01	3.8E-02
7	6.45	LOC	4.2E-01	6.3E-01	5.2E-01	4.0E-01	3.1E-01	2.0E-01	1.3E-01	9.6E-02	3.1E-02
8	10.46	LOC	3.7E-01	5.5E-01	5.7E-01	5.3E-01	4.5E-01	3.0E-01	2.1E-01	1.5E-01	5.2E-02
9	5.36	LOC	1.0E+00	1.2E+00	1.0E+0	7.6E-01	5.8E-01	3.2E-01	2.0E-01	1.4E-01	3.6E-02

Table 6-4 Risk by Ventilation System Type Per Million

No [1]	Emission 100g/day	Vent Type	Distance from stack (meter)								
			20	40	60	80	100	150	200	250	500
3	1.49	VBR	3.4E-02	7.4E-02	1.3E-01	1.7E-01	2.1E-01	2.0E-01	1.6E-01	1.2E-01	4.2E-02
4	12.04	PVR	1.4E-01	2.0E-01	5.5E-01	5.3E-01	5.9E-01	3.6E-01	2.6E-01	1.9E-01	5.3E-02
9	5.36	LOC	1.0E+00	1.2E+00	1.0E+0	7.6E-01	5.8E-01	3.2E-01	2.0E-01	1.4E-01	3.6E-02

[1] Facility number

Table 6-5 Percent Risk Reduction Between Ventilation Types (UNIT: %)

No	Type Change	Distance from stack (meter)								
		20	40	60	80	100	150	200	250	500
A	VBR/PVR	75.7	63.0	76.4	67.9	64.4	44.4	38.5	36.8	20.8
B	PVR/LOC	86.0	83.3	45.0	30.3	-1.7	-12.5	-30.0	-35.7	-47.2
C	VBR/LOC	96.6	93.8	87.0	77.6	63.8	37.5	20.0	14.3	-16.7

Table 6-6 Cost Effectiveness Percent Risk Reduction By Cost of Ventilation Type

Type	Equipment/ Ave. Cost[1] ($ K)	Ave. Cost[1] Increase ($ K)	Distance from stack (meter)								
			20	40	60	80	100	150	200	250	500
[2]VBR	5.0-8.0/6.5	2.0	75.7	63.0	76.4	67.9	64.4	44.4	38.5	36.8	20.8
PVR	4.5/4.5										
[3]PVR	4.5/4.5	1.05	86.0	83.3	45.0	30.3	-1.7	-12.5	-30.0	-35.7	-47.2
LOC	2.9-4.0/3.45										
[4]VBR	5.0-8.0/6.5	3.05	96.6	93.8	87.0	77.6	63.8	37.5	20.0	14.3	-16.7
LOC	2.9-4.0/3.45										

[1] Cost includes equipment purchase and installation.
[2] Ventilation system converts from PVR to VBR.
[3] Ventilation system converts from LOC to PVR.
[4] Ventilation system converts from LOC to VBR.

7.0 CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Using facilities' purchase records for perc produced a problem in mass balances. It was not clear how much of the purchased perc was used within the year, and the amount used on any one day can vary. Collecting data over one day could lead to some of the problems in the mass balance approach and the "lost" perc. The mass balance on one day might be different on another. The total mass balance approach will be useful only when accurate perchloroethylene daily consumption at each facility is available. Since most facilities have incomplete perchloroethylene purchase record (no existing perchloroethylene inventory before adding new perchloroethylene), it is difficult to establish daily consumption from yearly purchase record. AVES estimated perchloroethylene daily consumption by using the emission factor of perchloroethylene multiplied by the weight of clothes cleaned during that time period (poundage). The accountability of perchloroethylene from source testing data showed a range of 91.98% to 125.51% (except for facility 8) of perchloroethylene emissions based on clothes poundage. This is an indication that poundage is a reasonable estimate for perchloroethylene emissions at most facilities.

Based on the results of the mass balance calculations of nine dry-cleaning facilities using perchloroethylene, the majority of the perc emissions were associated with the waste streams (wastewater, sludge and lint). The residual perc in the waste stream accounts for 47% to 95% of the total perc used. 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. Therefore, the use of secondary controls is associated with a higher percentage of perc in the waste stream than when no secondary controls are used.

To determine the risk (potential cancer cases per million) of a ventilation system, various ventilation system's perc capture efficiency and facility emission rate were measured, which were also entered into the ISCST3 model to calculate the dispersion of the system, and determine the risk using dispersion and risk assessment parameters.

It is very difficult to evaluate the Cancer Risk related to different types of vapor collection systems associated with the cleaning equipment inside the building. There are many variables not related to the vapor collection system that directly affect the dispersion model results. The modeling results suggested that height of the stack, exit velocity of the stack, and location of the stack on the building roof (downwash) are the most critical parameters in risk reduction.

The percent cancer risk reduction and cost effectiveness between use of different ventilation types were summarized below.

- Conversion from LOC to PVR resulted in an 86.0% reduction in cancer risk at 20 meters.
- Conversion from the PVR to the VB resulted in an additional 75.7% reduction in cancer risk at 20 meters.
- Conversion from the LOC directly to VB resulted in a 96.6% reduction in cancer risk at 20 meters.
- Conversion from LOC to PVR: 30.4% equipment cost increase ($1,050) - 86.0% reduction in cancer risk at 20 meters.
- Conversion from the PVR to the VB: 44.4% equipment cost increase ($2,000) – 75.7% reduction in cancer risk at 20 meters.
- Conversion from LOC directly to VB: 88.4% equipment cost increase ($3,050) –96.6% reduction in cancer risk at 20 meters.

RECOMMENDATIONS

Alternative Approaches

Realizing the difficulties of using mass balance methodology to calculate capture efficiency, a temporary total enclosure (TTE) approach can be used (EPA-450/4-91-020a). A temporary enclosure can be constructed around a perchloroethylene dry cleaning machine, allowing access to the machine by shop personnel and for equipment maintenance. Air to the TTE will be supplied at a known rate with temporary ductwork and a blower. Exhaust air, which contained fugitive perc from the dry cleaning machine, will be routed to a single exhaust. While the machine is operating, it is necessary to continuously monitor perc emissions with a flame ionization analyzer (FIA), and measure vapor leak concentrations with a hand-held photoionization detector (PID). However, it would be difficult to implement on a perchloroethylene dry cleaning machine with partial vapor barrier room or a full vapor barrier room.

In addition, it is recommended that ambient air testing within the facility be conducted before-and-after the enclosure installation to estimate the effectiveness of these systems in reducing occupational exposures. This approach was attempted by AVES during the project period. However, due to the different operation conditions (facilities had scheduled less dry cleaning activities before the completion of new ventilation enclosures), all in-door ambient air samples showed less perchloroethylene concentrations than those collected after the completion of new ventilation enclosures. Unless pre-construction testing can be scheduled with the same loads of clothes and tested at the same period of time (such as load 2 to load 4), the test results may not represent the same operation conditions. Before and after testing also could be conducted in adjacent residences to determine how ventilation enclosures reduce exposure to receptors located in adjacent residential or commercial buildings.

Because of problems associated with the mass balance approach, we recommend that additional research be conducted to quantify the effectiveness of dry cleaning room enclosures with ventilation systems. Conducting additional testing using the above recommended approaches would give a more complete assessment and further validate the effectiveness of these systems.

<u>Better Housekeeping, Operation And Maintenance Practices</u>

Housekeeping, operation and maintenance are the biggest factors in reducing fugitive emissions. The following practices are recommended for every dry cleaner to reduce fugitive emissions:

- 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.

- Spills and leaks also contribute to fugitive emissions and environmental liability. Dry cleaner operators should establish a program of inspections and maintenance. This program should include: Inspecting containers and equipment weekly to be sure they are not leaking, performing regular and preventive maintenance including replacement of gaskets, seals, and other machine components, closing the separator and button trap covers before operating the dry cleaning machine. Exercising caution when filling machines, changing filters, during distillation or any solvent handling procedure, filter housings should be completely drained before servicing or changing filters.

- After emptying the dry-cleaner at the end of the day, place next day's first load into drum. This eliminated one opening and closing of the door per day.

- Clean stills in the morning when they are cool, line pan with plastic so that no perc residue remains on the pan.

- Operators should personally supervise each solvent delivery to reduce overfills, leaking equipment, and other possible discharges, have the solvent supplied directly from the truck into the storage tank of the dry cleaning machine, use spigots and pumps to dispense the perc into the machine solvent tank. If possible, use a direct coupling device for transferring solvent.

- Operators should ensure that solvents are not transferred or stored in open or leaking Containers, funnels should be used when transferring wastes to storage containers. Operators should train personnel in the hazards of spills and how to minimize the potential for spills will reduce a facilities environmental liability potential.

APPENDIX –A

MASS BALANCE CALCULATIONS

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. Where site-specific data were not available, empirical data were used to conduct mass balance calculations.

Collecting data over one day could lead to some of the problems in the mass balance approach and the "lost" perc. The mass balance on one day might be different on another. The total mass balance approach will be useful only when accurate perchloroethylene daily consumption at each facility is available. Since most facilities have incomplete perchloroethylene purchase record (no existing perchloroethylene inventory before adding new perchloroethylene), it is difficult to establish daily consumption from yearly purchase record. AVES estimated perchloroethylene daily consumption by using the emission factor of perchloroethylene multiplied by the weight of clothes cleaned during that time period (poundage). The accountability of perchloroethylene from source testing data showed a range of 91.98% to 125.51% (except for facility 8) of perchloroethylene emissions based on clothes poundage. This is an indication that poundage is a reasonable estimate for perchloroethylene emissions at most facilities.

Test data for the nine facilities are summarized below in the following tables.

Facility 1 (VBR)	**Union 353 U2000, 35# Sec.**					
Perc Usage	0.0490	gal/day		301.59	g/day	
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	
Fabrics	112.6	mg/kg	36.5	kg/day	4.12	g/day
Lint	C1	mg/kg	10.1	g/day	0.00	g/day
Sludge	501000	mg/kg	504.7	ml/day	318.58	g/day
Wastewater	30.8	mg/l	157.7	ml/day	0.00	g/day
Stack	7.0	µg/l	2180397	l/day	15.26	g/day
Air	678.1	µg/m3	238.3	m3/day	0.16	g/day
Cartridge Filter	3075.9	g/cart	3	cart/yr	30.76	g/day
Total					368.88	g/day
Accountable					122.31%	
Capture Efficiency					98.95%	

C1: two samples (560 and 290 mg/kg)

Facility 2 (VBR)	Columbia MEC 350, 50# Sec.				
Perc Usage	0.1389	gal/day	854.2		g/day
Sources	Perc Conc.		Amount		Perc Emissions	

Sources	Perc Conc.		Amount		Perc Emissions	
Fabrics	196.7	mg/kg	81.7	kg/day	16.07	g/day
Lint	C2	mg/kg	4.8	g/day	0.00	g/day
Sludge	633000	mg/kg	946.4	ml/day	634.98	g/day
Wastewater	180.0	mg/l	600.0	ml/day	0.11	g/day
Stack	20.8	µg/l	6229706	l/day	129.58	g/day
Air	1559.7	µg/m3	1191.65	m3/day	1.86	g/day
Cartridge Filter	6151.7	g/cart	3	cart/yr	61.52	g/day
Total					844.12	g/day
Accountable					98.82%	
Capture Efficiency					98.59%	

C2: three samples (1000,680 and 1600 mg/kg)

Facility 3 (VBR)	Clean line Closed-loop, 25 #					
Perc Usage	0.0444	gal/day	273.14		g/day	
Sources	Perc Conc.		Amount		Perc Emissions	
Fabrics	33.0	mg/kg	38.1	kg/day	1.25	g/day
Lint	C3	mg/kg	2.4	g/day	0.00	g/day
Sludge	107000	mg/kg	918.0	ml/day	125.58	g/day
Wastewater	129.0	mg/l	590.0	ml/day	0.08	g/day
Stack	46.0	µg/l	319583	l/day	147.01	g/day
Air	2170.2	µg/m3	383.0	m3/day	0.83	g/day
Cartridge Filter	3075.9	g/cart	6	cart/yr	61.52	g/day
Total					336.26	g/day
Accountable					123.11%	
Capture Efficiency (Accountable)					99.44%	

C3: composite sample (463 mg/kg)

Facility 4 (PVR)	Columbia Turbo-dry 840, 35 lbs (older), Union-					
Perc Usage	0.1968	gal/day		1210.7	g/day	
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	
Fabrics	145.0	mg/kg	113.5	kg/day	16.46	g/day
Lint	C4	mg/kg	0	g/day	0.00	g/day
Sludge	2092.1	mg/kg	1324.8	ml/day	2.66	g/day
Wastewater	290.0	mg/l	3.0	ml/day	0.00	g/day
Stack	132.0	µg/l	8749906	l/day	1154.99	g/day
Air	13562	µg/m3	2383.3	m3/day	32.32	g/day
Cartridge Filter	6151.7	g/cart	8	cart/yr	164.05	g/day
Total					1370.48	g/day
Accountable					113.20%	
Capture Efficiency					97.28%	

C4: no lint due to leather jacket operation

Facility 5 (PVR)	Columbia MEC 50 lb.					
Perc Usage	0.2059	gal/day		1266.5	g/day	
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	
Fabrics	64.7	mg/kg	68.1	kg/day	4.41	g/day
Lint	C5	mg/kg	1.0	g/day	0.00	g/day
Sludge	20000	mg/kg	1135.5	ml/day	23.85	g/day
Wastewater	30.8	mg/l	2310.0	ml/day	0.07	g/day
Stack	1.4	µg/l	8919807	l/day	12.07	g/day
Air	1356.2	µg/m3	476.66	m3/day	0.65	g/day
Cartridge Filter	6151.7	g/cart	6	cart/yr	123.03	g/day
Total					164.07	g/day
Accountable					N/A	
Capture Efficiency					94.92%	

C5: composite sample (220 mg/kg)
Due to unreliable testing data from Facility 5, no accountability was estimated.

Facility 6 (PVR)	Columbia CLOS, 40 lbs				
Perc Usage	0.3487	gal/day	2145.2	g/day	
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	
Fabrics	62.0	mg/kg	178.0	kg/day	11.11	g/day
Lint	C6	mg/kg	11.0	g/day	0.00	g/day
Sludge	202000	mg/kg	4642.9	ml/day	928.02	g/day
Wastewater	457.0	mg/l	1353.3	ml/day	0.62	g/day
Stack	57.7	µg/l	17899079	l/day	1032.18	g/day
Air	1078.0	µg/m3	1021.42	m3/day	1.10	g/day
Cartridge Filter	0.0	g/cart	0	cart/yr	0.00	g/day
Total					1973.04	g/day
Accountable					91.98%	
Capture Efficiency					99.89%	

C6: three samples (333, 306 and 230 mg/kg)

Facility 7 (LOC)	Columbia Turbodry W/Sec. 80 lbs					
Perc Usage	0.2952	gal/day	1816.0	g/day		
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	
Fabrics	121.0	mg/kg	158.9	kg/day	19.25	g/day
Lint	C7	mg/kg	17.9	g/day	0.00	g/day
Sludge	510000	mg/kg	1823.1	ml/day	1059.96	g/day
Wastewater	103.0	mg/l	5166.7	ml/day	0.53	g/day
Stack	134.3	µg/l	4587329	l/day	616.23	g/day
Air	4272.2	µg/m3	2127.95	m3/day	9.09	g/day
Cartridge Filter	3075.9	g/cart	56	cart/yr	574.16	g/day
Total					2279.21	g/day
Accountable					125.51%	
Capture Efficiency					98.55%	

C7: two samples (470 and 750 mg/kg)

Facility 8 (LOC)	Flomatic CLOS, 37 lb				
Perc Usage	0.31	gal/day	1906.8	g/day	
Sources	**Perc Conc.**		**Amount**		**Perc Emissions**	

Sources	Perc Conc.		Amount		Perc Emissions	
Fabrics	47.0	mg/kg	136.2	kg/day	6.43	g/day
Lint	C8	mg/kg	11.6	g/day	0.00	g/day
Sludge	490000	mg/kg	99.5	ml/day	63.33	g/day
Wastewater	93.0	mg/l	2550	ml/day	0.24	g/day
Stack	131.3	µg/l	7906771	l/day	1038.42	g/day
Air	1132.5	µg/m3	714.99	m3/day	0.81	g/day
Cartridge Filter	0.0	g/cart	6	cart/yr	0.00	g/day
Total					1109.24	g/day
Accountable					58.17%	
Capture Efficiency					99.92%	

C8: composite sample (500 mg/kg)

Facility 9 (LOC)	Permac M40			
Perc Usage	0.2173	gal/day	1336.9	g/day

Sources	Perc Conc.		Amount		Perc Emissions	
Fabrics	110	mg/kg	94.4	kg/day	10.39	g/day
Lint	C9	mg/kg	3.20	g/day	0.00	g/day
Sludge	3000	mg/kg	4433.2	ml/day	13.39	g/day
Wastewater	819	mg/l	2036	ml/day	1.67	g/day
Stack	109.3	ug/l	4801404.5	l/day	524.95	g/day
Air	519.4	ug/m3	1021.415	m3/day	0.53	g/day
Cartridge Filter	3075.9	g/cart	88	Cart/yr	820.23	g/day
Total					1371.16	g/day
Accountable					102.56%	
Capture Efficiency					99.90%	

C9: composite sample (177 mg/kg)

APPENDIX - B

PLOTS OF RISK ANALYSIS VERSUS DISTANCES FOR DRY CLEANING FACILITIES

Figure 1. Maximum Cancer Risk for Facility 1 (Vapor Barrier Room, Perc Emission 19.5 Gram/Day, Rural)

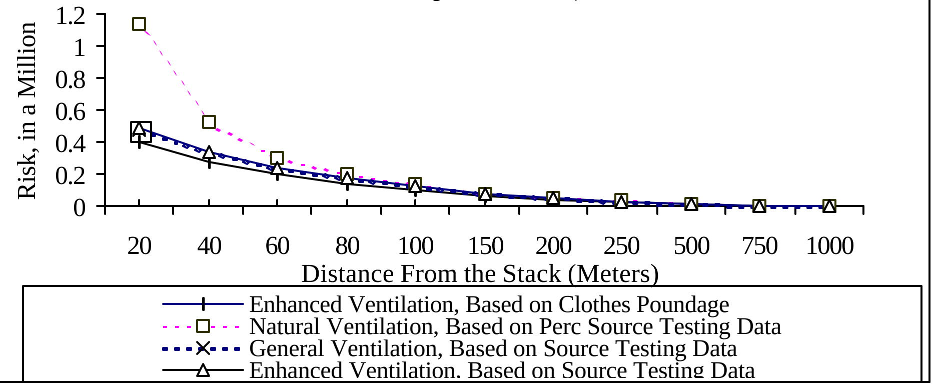


Figure 2. Maximum Cancer Risk for Facility 2 (Vapor Barrier Room, Perc Emission 148 Gram/Day, Rural)

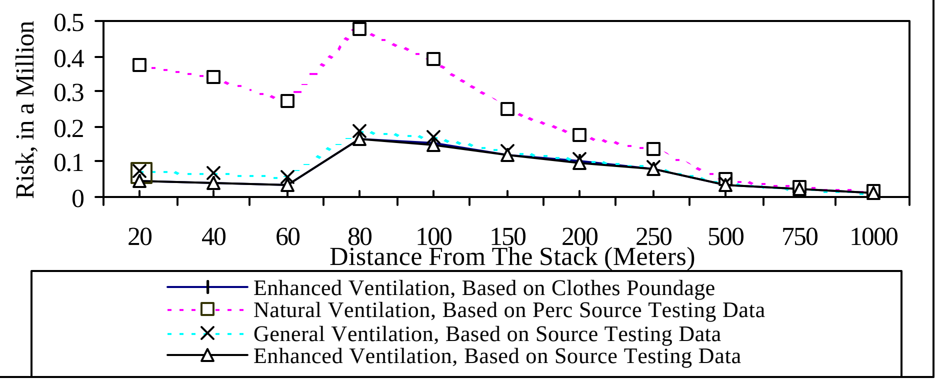


Figure 3. Maximum Cancer Risk for Facility 3 (Vapor Barrier Room, Perc Emission 149 Gram/Day, Rural)

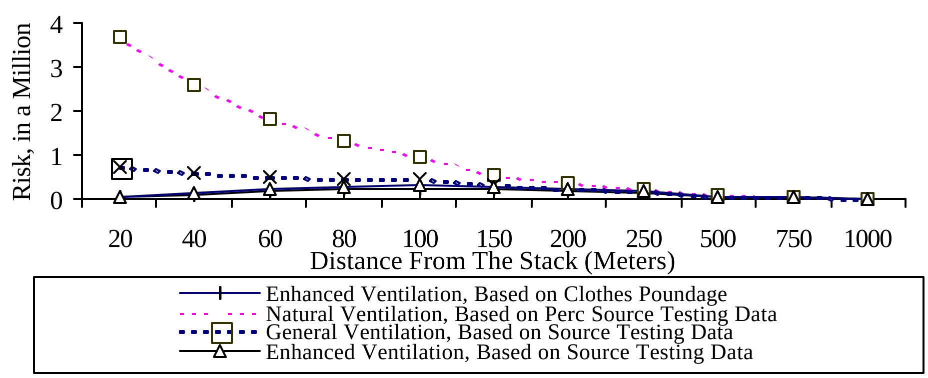


Figure 4. Maximum Cancer Risk for Facility 4 (Partial Vapor Barrier Room, Perc Emission 1203.8 Gram/Day, Rural)

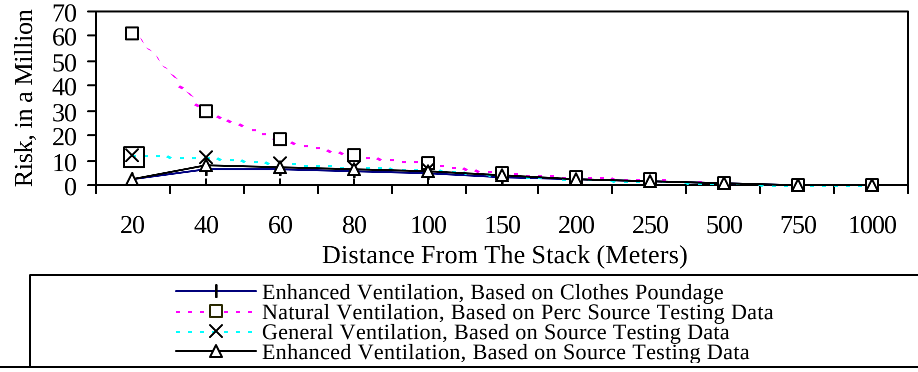


Figure 5. Maximum Cancer Risk for Facility 6 (Partial Vapor Barrier Room, Perc Emission 1044.4 Gram/Day, Rural)

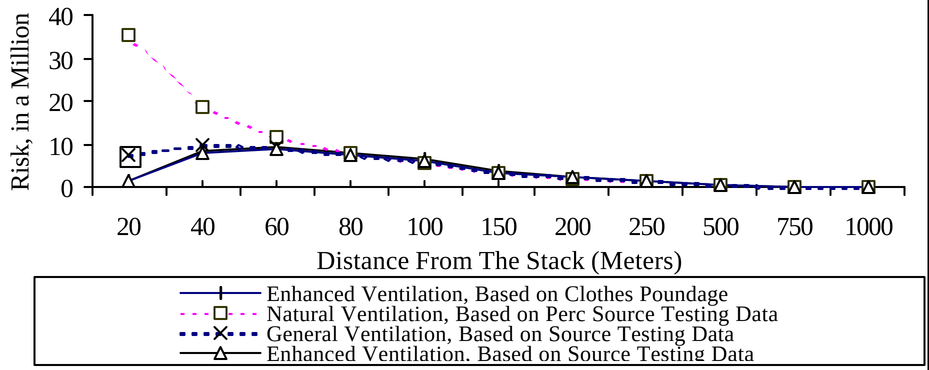


Figure 6. Maximum Cancer Risk Using (Local Ventilation Facility 7, Perc Emission 645 Gram/Day, Rural)

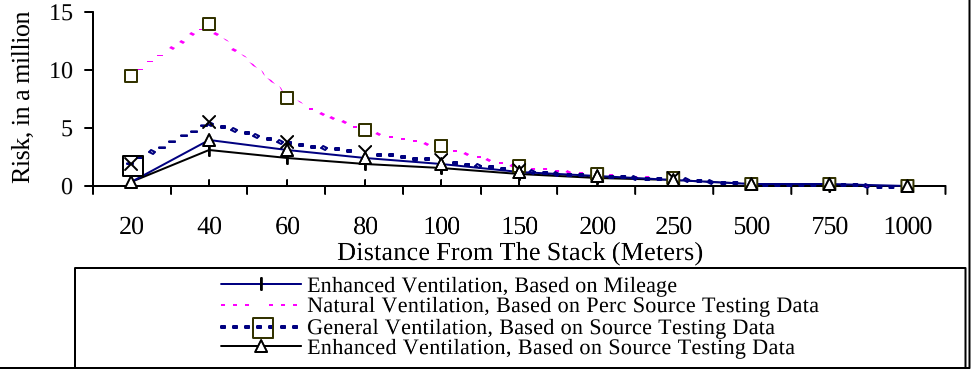
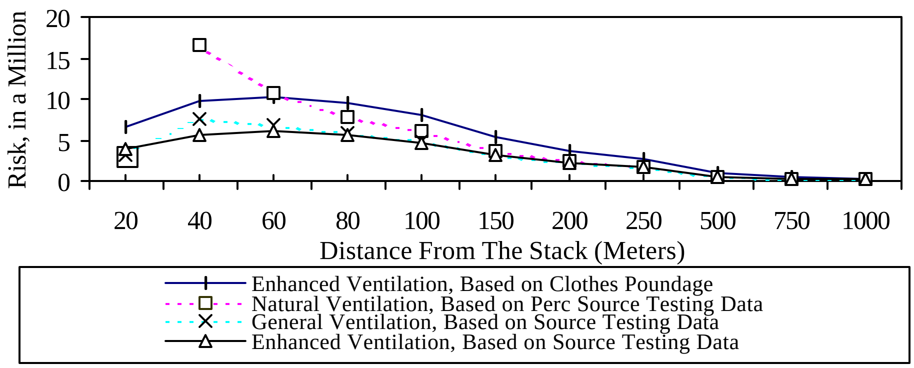


Figure 7. Maximum Cancer Risk for Facility 8 (Local Ventilation, Perc Emission 1046 Gram/Day, Rural)



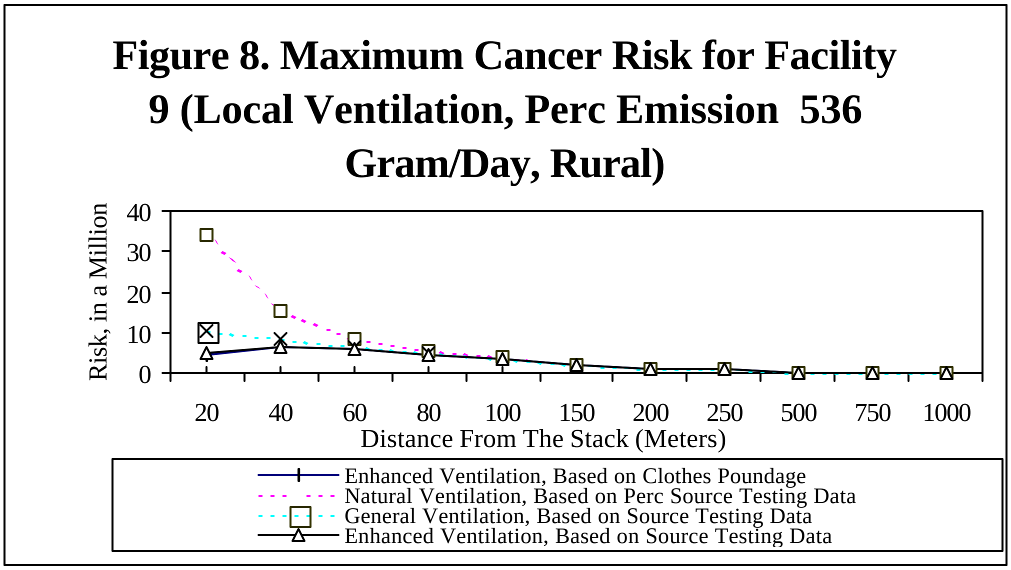


Figure 8. Maximum Cancer Risk for Facility 9 (Local Ventilation, Perc Emission 536 Gram/Day, Rural)
Risk, in a Million
40
30
20
10
0
20
40
60
80
100
150
200
250
500
750
1000
Distance From The Stack (Meters)
Enhanced Ventilation, Based on Clothes Poundage
Natural Ventilation, Based on Perc Source Testing Data
General Ventilation, Based on Source Testing Data
Enhanced Ventilation, Based on Source Testing Data

APPENDIX – C

MODELING INPUT AND OUTPUT
(Hardcopy Available Upon Request)

Files are too big to be included. Electronic files are available upon request.

APPENDIX – D

FINAL TEST PROTOCOL

R-96-01-214

AN ASSESSMENT OF THE EFFECTIVENESS OF ROOM ENCLOSURES WITH VENTILATION SYSTEMS IN REDUCING RISK AT DRY CLEANING FACILITIES USING PERCHLOROETHYLENE

Final Test Protocol

for

California Air Resources Board

May 15, 1998

Contract No. 96-324

Prepared By:

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TEST PROTOCOL

Based on the input received from ARB staff and Bay Area AQMD staff, AVES and Environmental and Risk Management, Inc. revised this testing plan for the field test program. This test protocol describes the methods to sample and analyze Perchloroethylene in waste streams, ventilation systems, clothing, lint and ambient air inside the facilities.

1. POTENTIAL TESTING SITES

With the help of Bay Area AQMD Staff Scott Lutz, AVES and ERMI staff visited nine facilities. These sites are presented here to ARB as potential testing sites. Three types of facilities will be tested: Local Ventilation, Partial Vapor Room and Vapor Barrier Rooms. Local Ventilation is a ventilation system with physical structures (fume hoods, flexible walls, and shrouds) designed to capture fugitive emissions near the machine. Partial Vapor Rooms encloses 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 are completely surrounds a dry cleaning machine and is constructed of material resistant to diffusion of solvent vapors with seams and gaps sealed with metalized tape to eliminate transport.

2. NUMBER OF SAMPLES TO BE COLLECTED

The following matrix summarizes the sampling location and the number of samples to be collected.

TABLEL 1. UPDATED MATRIX OF SAMPLES AND ANALYSES FOR DRY CLEANING FACILITIES WITHOUT CARBON ADSORBERS[1]

Sources	Pre-Construction Facilities			Post-Construction Facilities			
	Samples per Facility	No. of Facilities	Total Samples	Samples per Facility	No. of Facilities	Total Samples	**Total**
Stack[2]	--	--	--	4	9	36	36
Indoor Ambient	2	3	6	2	9	18	24
Wastewater	--	--	--	2	9	18	18
Sludge	--	--	--	3	9	27	27
Filter Cartridge[3]	--	--	--	3	9	27	27
Fabric	--	--	--	3	9	27	27
Lint	--	--	--	2	9	18	18
Total	**2**	**3**	**6**	**19**	**9**	**171**	**177**

Remarks:
1. Per ARB's request on 9/18/97.
2. "Stack" sample refers only to the effluent air sample to be collected from the vapor barrier ventilation stack. Three runs plus one blank per stack test.
3. If the filter catridge is not available, we'll use empirical data from BAAQMD.

3. SAMPLING AND ANALYSIS METHODS

The proposed methods for sampling and analysis for Perchlorethylene is presented in Table 3. The team will follow the procedures outlined in each of the referenced test with the exceptions where noted.

Table 2 - Reference Test Methods

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

1. Sampling method will follow EPA TO-14 (using Summa Canister instead of Tedlar Bag to prevent sample loss during shipping). Analytical method will follow ARB Method 422.
2. Sampling method will follow NIOSH Method 1003 and analyzed by ECD instead of FID.
3. Inside the facility

3.1 Emission Sampling from the Stacks

The team will determine the mass emissions of the Perchloroethylene from the exhaust stacks. Three test runs will be performed on the exhaust stack during dry cleaning cycles (one stack sample per dry cleaning cycle). The team will collect the exhaust stack PERC emissions through a stainless steel sample probe directly into an evacuated SUMMA canister in accordance to procedures described later in this section.

The specific sampling location within the stack will be determined after the velocity of the exhaust stack; effluent gas stream has been profiled. The velocity of the gas stream from the ventilation stack will be measured in accordance to the procedures specified in CARB Reference Methods 1, and 2. The stack diameter and sampling location is different for each of the proposed test sites. During the site visits, ERMI personnel determined that the stacks which, were connected to the particular ventilation device, were accessible and that they would meet the criteria for sampling in accordance to the referenced test methods (CARB Method 1,2). During the initial site visits, it was premature to ask the owners of the selected sites to bring in a ladder/scaffolding to access the stacks, drill two holes in their stack, and measure the velocity of the gas stream. This procedure will be conducted when the test program is commenced. Since the make-up of the air stream is primarily ambient room air (or potentially air conditioned air), ERMI will use ambient levels of O_2, CO_2, and moisture content to calculate the molecular weight of the effluent air stream as permitted in CARB Reference Test Methods 2. The molecular weight of 29.0 along with the velocity measurements will be 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 Perchloroethylene will be determined for the ventilation stack at each facility after the profile of the gas stream has been determined. The basis for sample point selection will require that it be a "representative" point along a traverse with respect to the velocity or any potential cyclonic nature of the effluent gas stream.

Proposed Testing and Analytical Procedures

1. The contract laboratory will ship via overnight delivery three SUMMA canisters to each site. The SUMMA canisters will be pre-cleaned and delivered under chain-of-custody. Upon receipt, ERMI personnel will check each canister to verify that there is a vacuum of at least 29.5 inches of mercury. The results will be recorded in the field log book.

2. The stack will have two sampling ports installed within the eight and two duct diameter requirements specified in CARB Method 1 to ensure that there are no obstructions to the airflow at the sampling point. The sampling ports will consist of two ½ inch diameter holes located 90 degrees apart and on the same plane.

3. The diameter of the exhaust stack will dictate as to how many sampling point the velocity test will measure, as well as to their specific location along each sample traverse point. CARB Test Method 1 will be adhered to for determining the sampling port locations as well as the individual sample traverse points for each of the facilities to be tested.
4. The velocity of the effluent gas stream will be measured in accordance with the procedures specified in CARB Test method 2. ERMI will utilize an appropriately sized standard pitot tube and inclined water manometer to determine the differential in pressure (Δp) of the effluent gas stream at each specified point along both sample port traverses. The temperature of the effluent air stream will also be measured with a type K thermocouple connected to a digital temperature indicator (DTI).

5. The stack gas stream will be checked for cyclonic flow following the procedures specified in CARB Test Method 1.

6. Once the profile of the exhaust stack gas stream has been identified, ERMI personnel will select a single representative sampling location from one of the traverse points. The sample point will represent an average velocity or degree of cyclonic flow.

7. The sample collection probe will be constructed of $^{1}/_{8}$ inch diameter stainless steel tubing, approximately 5 feet in length. Since particulate matter is not a concern there will not be a particulate filter installed on the tip of the sample probe. The end of the sample probe/sample line (one contiguous piece) will be connected to the inlet of the sample collection valve which, is connected to the SUMMA canister. The sample control valve is pre calibrated to collect a one-hour sample with the SUMMA canister. This sampling valve has been used on numerous compliance testing programs for various Air Districts throughout California as well as the EPA under the auspices of the Superfund Innovative Technology Evaluation (SITE) program, which ERMI is a contractor. A vacuum gauge is installed between the sampling valve and the SUMMA canister, and it is isolated with a Stainless Steel Swaggelok on-off valve. Once the sampling apparatus has been assembled, ERMI personnel will place a $^{1}/_{8}$ Stainless Steel Swaggelok cap on the end of the sample probe. The SUMMA canister sample

valve will be opened and the vacuum gauge on-off valve will be opened. The integrity of the sampling system will be determined by monitoring any change in the vacuum gauge.

8. Once the integrity of the sampling system has been determined the Swagelok cap will be removed from the tip of the sample probe and the sample probe will be inserted to the pre-determined sampling location. The SUMMA canister-sampling valve will be opened and an initial vacuum reading will be taken. Once the vacuum reading has been taken the on-off valve will be closed and the test runs will commence. ERMI personnel will monitor the SUMMA canister vacuum every ten minutes throughout the duration of the testing period (approximately one hour).

9. After the sampling period (consistent with the dry cleaning cycle), ERMI personnel will close the SUMMA canister-sampling valve and remove the sample probe from the sampling port. The sampling valve assembly will be removed and the residual vacuum of the SUMMA canister will be measured and recorded in the field logbook. The canister will be properly labeled and the chain-of-custody will be initiated.

10. Two additional samples will then be collected in the same manner as described above.

11. The samples will be sent via overnight delivery to the contracted laboratory under chain-of-custody procedures. The analytical laboratory will complete the chain-of-custody and log in the samples. The samples will be analyzed within 72 hours from receiving the samples. The samples will be analyzed for Perchloroethylene following the analytical procedures specified in CARB Method 422. CARB 422 specifies the direct injection of the air sample from the SUMMA canister to a gas chromatograph equipped with an electron capture detector (GC/ECD). The contract laboratory will adhere to all analytical QA/QC requirements. All raw data will be included in the analytical report.
12. The volumetric flow rate will be calculated in accordance to the procedures specified in CARB Test Method 2. As mentioned previously, ERMI will utilize a value of 29.0 for the stack dry molecular weight. The volumetric flow rate will be calculated as dry standard cubic feet per minute.
13. The mass emissions of Perchloroethylene will be calculated using the following formula:

$$Emissionrate(lb/hr) = \frac{(ppmvPerc) \times PercMol.Wt(165.8)}{379 \times 10^{6}} \times DSCFM^{[1]} \times 60$$

[1] Dry Standard Cubic Feet per Minute (See ARB Method 2)

3.2 Waste Water, Sludge, and Fabrics and Lint

Waste water, sludge, and filters generated from the dry cleaning facilities will be collected using EPA/SW-846-ED-3 as the guideline. All the samples collected will be stored in a cold box and shipped back to lab within 7 days. The samples will be analyzed within 7 days. Therefore, all the samples are analyzed within 14 days to meet EPA's requirement. We will include a chain-of-custody form with each set of samples.

WasteWater

WasteWater will collected from the machine separator during the sampling period on each day. WasteWater will be placed in a clean container. The wastewater will be gently swirled to be mixed in the container and measured by a measuring cup for its volume. A glass thief will be used to transfer liquid from container to vials. When collecting the samples, liquids should be introduced into the vials gently to reduce agitation which might drive off volatile compounds. In general liquid samples should be poured into the vial without introducing any air bubbles within the vial as it is being filled. Should bubbling occur as a result of violent pouring, the samples must be poured out and the vial refilled. The vials should be completely filled at the time of sampling, so that when the septum cap is fitted and sealed, and the vial inverted, no headspace is visible. The sample should be hermetically sealed in the vial at the time of sampling, and must not be opened prior to analysis to preserve their integrity. The samples will be refrigerated during shipping and storage. Two wastewater samples will be collected for each site.

To monitor possible contamination, a trip blank prepared from organic-free reagent water will be carried throughout the sampling, storage, and shipping process.

Sludge

Sludge from still bottoms will be collected using a clean container at the end of each sampling period. One sludge sample will be collected for every dry cleaning cycle. The sludge will be gently swirled to be mixed in the container and measured by a measuring cup for its volume. Vials samples with solid or semi-solid matrices (e.g., sludge) will be completely filled as best as possible. The vials should be tapped slightly as they are filled to try and eliminate as much free air space as possible. Three vials will be filled per sample location. When collecting the samples, liquids and solids should be introduced into the vials gently to reduce agitation which might drive off volatile compounds. In general liquid samples should be poured into the vial without introducing any air bubbles within the vial as it is being filled. Should bubbling occur as a result of violent pouring, the sample must be poured out and the vial refilled. There should be no visible headspace.

All vials will be labeled immediately at the point at which the sample is collected. The three vials from each sampling location will then be sealed in separate plastic bags to prevent cross-contamination between samples, particularly if the sampled waste is suspected of containing high levels of volatile organic. The samples will be refrigerated during shipping and storage.

Fabrics

Residual PERC content for several fabrics will be quantified as part of this project. Three fabrics types will be selected: wool blends, rayon and silk. Fabrics will be weighted before testing. These fabrics will be added into the load as test coupons. At the end of the cleaning cycle, the test coupons will be removed, and immediately sealed in double bag and then, sent to the Lab for analysis. The samples are double-bagged to prevent possible damage during the shipping. At the lab, the test coupons will be extracted using methanol and analyzed using NIOSH Method 1003.

Lint

At the end of the cleaning cycle, lint samples will be collected from the lint filter in the PERC line. The samples collected from the entire sampling period will be placed and sealed in double bags. The samples are double-bagged for possible damage during the shipping. Analysis will be performed at the lab using NIOSH Method 1003. The total amount of lint generated during the sampling period will be weighted and recorded.

Other Data

PERC usage and the weight of dry cleaning clothes or number of clothes need to be recorded during the sampling period. The types of dry cleaning equipment, equipment cost, installation cost, cost associated with ventilation installation, fan capacity, building dimension, receptor information, and other site available site specific information will also be recorded for future reference and for running computer model to estimate exposure concentrations and risks to the public around the dry cleaning facility.

3.3 Ambient Air Sampling inside the Dry Cleaning Facilities

The main purpose to perform ambient air monitoring inside the facilities at various locations is to provide a base line for worker exposure. It is believed that personal monitoring system is more appropriate for indoor air quality measurement and much more cost effective to determine worker exposure. Based on the approval of ARB staff, personal monitoring pumps with absorbent tubes for sampling and analysis will be used to measure the indoor ambient PERC concentration on a work day.

We will determine occupational exposures to workers at the facilities using personal monitoring techniques. Calibrated personal sampling pump will be either attached to a employee or attached to the wall at locations closest to the emission sources (i.e., dry cleaning machines and recently cleaned clothes) the predominant amount of time over the course of a work day. The calibrated personnel sampling pump will draw air through a charcoal sorbent tube which will be analyzed at a laboratory to determine average employee exposure concentrations during the sampling period. NIOSH Method 1003 will be followed. All the sample will be analyzed within 14 days to meet EPA’s shelf life requirements.

3.4 QA/QC Plan

Quality control procedures will be used by the team to assure quality data. The proposed procedures are listed and described below.

- <u>Laboratory Blank</u> -- A blank sample will be analyzed by the laboratory operating the instrument as described in the methods. The frequency of blank sample analysis is one per batch. Blank levels will be use to establish the system baseline.

- <u>Replicate Analysis</u> -- The frequency of replicate sample analysis is one per batch. The criteria for acceptable laboratory precision is $\pm$30% relative percent difference (RPD).

- Blank Sample -- A blank sample will be obtained by collecting the SUMMA canister sample directly from a Tedlar bag filled with UHP grade air The frequency of blank samples is a minimum of 5% or one per trip. A blank sample will be collected at the onset of testing (i.e., pre-use blank test). Blank levels will be use to establish the SUMMA canister sampling baseline.

- Specific Method Performance -- Specific method (e.g. EPA Method 8260) quality control is conducted as per method. Typically this includes laboratory blanks, species recovery, and adherence to other method performance objectives such as calibration and retention time identifications.

- Sample Management -- Sample management is defined by the specific sampling method used to satisfy the program objectives.