<u>Hydrocarbon Technology Alternatives to Perchloroethylene for Dry Cleaning</u>

Prepared By:
Michael Morris and Katy Wolf
Institute for Research and Technical Assistance

Prepared for:
Cal/EPA's Department of Toxic Substances Control

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DISCLAIMER

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Perchloroethylene (PERC) is the most widely used dry cleaning agent in California. The chemical is a carcinogen, it is classified as a Hazardous Air Pollutant by U.S. EPA, it is classified as a Toxic Air Contaminant in California and it is a listed Resource Conservation and Recovery Act listed hazardous waste. The South Coast Air Quality Management District adopted a regulation to phase out the use of PERC in dry cleaning by 2020. PERC is a contaminant in the soil and groundwater at numerous dry cleaning sites and landlords are not allowing the use of PERC in lease renewals.

The California Air Resources Board recently surveyed the dry cleaning industry in California. Eighty-two percent of the cleaners in California use PERC. Because of the more stringent regulations and the position of landlords, dry cleaners are converting to alternatives. The major alternative adopted by cleaners to date and the alternative most likely to be adopted in the future is the hydrocarbon technology. More than 10 percent of the cleaners in California have already adopted the technology.

Cal/EPA's Department of Toxic Substances Control (DTSC) regulates hazardous waste in California. DTSC also supports pollution prevention which focuses on substituting less hazardous processes for hazardous processes used today. DTSC contracted with the Institute for Research and Technical Assistance (IRTA), a technical nonprofit organization, to evaluate and assess the characteristics of the hydrocarbon dry cleaning process. DTSC was interested in finding out more about the technology since many dry cleaners are likely to employ it in the future.

This document examines in more detail the characteristics of the hydrocarbon dry cleaning process. IRTA analyzed the performance and cost of seven dry cleaners using the hydrocarbon process. IRTA presents cost comparison data for PERC and hydrocarbon dry cleaning for five of the facilities. IRTA presents cost data for hydrocarbon dry cleaning for the remaining two facilities. The results of the cost analysis indicate that the cost of using hydrocarbon is comparable to the cost of using PERC.

Many of the dry cleaners that have adopted the hydrocarbon technology are using a blend of tonsil and diatomaceous earth which functions as an absorbent. The suppliers claim that use of the tonsil blend can minimize bacteria growth, prevent dye bleeding, make distillation unnecessary and make detergent use unnecessary. IRTA investigated these claims by conducting a series of tests.

The results of the tests indicate that the tonsil/diatomaceous earth blend absorbs water efficiently. It is the free water that causes bacteria growth in the hydrocarbon process. The test supports the claim that the tonsil blend minimizes bacteria growth. The test results also indicate that the tonsil blend is efficient in removing dyes. This suggests that dye bleeding can be prevented. The test results demonstrated that the tonsil blend does absorb Wesson oil. This lends credence to the claim that distillation is unnecessary for tonsil users.

IRTA used two methods for evaluating the cleaning ability of hydrocarbon with and without tonsil. First, IRTA interviewed several tonsil dry cleaners and they indicated that they were satisfied with the cleaning and, more important, their customers were also satisfied with the cleaning. Second, IRTA used the International Fabricare Institute Cleaning Performance Test, a standard industry test, to compare the cleaning capability of hydrocarbon with and without tonsil. IRTA ran four loads of clothing with tonsil and no distillation or detergent and compared the cleaning results with four loads of clothing without tonsil and with continuous distillation and detergent. The tonsil runs generally performed as well as or better than the non-tonsil runs for percent graying, yellowing and percent whitening. Both the tonsil and non-tonsil runs had poor water soluble soil removal, probably because the swatches used in the testing were not pre-spotted. The tonsil runs did not perform as well as the non-tonsil runs for rug soil removal.

IRTA compared the energy requirements for two dry cleaning facilities that provided utility costs based on utility bills. In both cases, the electricity and gas cost declined after the facilities converted from PERC to hydrocarbon with tonsil. IRTA conducted a test to measure the energy requirements with and without tonsil. Both the electricity and gas requirements for the two runs with tonsil were lower than the electricity and gas requirements for the two runs without tonsil.

DTSC had a special interest in whether or not the waste streams generated in the hydrocarbon process are classified as hazardous waste. IRTA sampled the waste streams from four tonsil hydrocarbon cleaners and four non-tonsil hydrocarbon cleaners. The DTSC Hazardous Materials Laboratory analyzed the samples. None of the waste streams analyzed for the eight cleaners were classified as hazardous waste based on the presence of metals or the characteristic of the flash point. The results revealed that separator water waste streams from all eight facilities did not exhibit aquatic toxicity. The results also revealed that the sludge waste streams from the four tonsil facilities did not exhibit aquatic toxicity whereas the sludge waste streams from the four non-tonsil facilities did exhibit aquatic toxicity. This may be a result of the fact that the non-tonsil facilities use detergent and the tonsil facilities do not. The results indicated that PERC and TCE, which are listed hazardous wastes, were present in six of the eight separator water waste streams and seven of the eight sludge waste streams. Other solvents were also found in both waste streams. Since PERC, TCE and other some of the other solvents in the waste streams are listed hazardous wastes, wastes containing them are classified as hazardous wastes. The likely source of these solvents is spotting compounds and IRTA has recently initiated a project sponsored by DTSC and U.S. EPA to identify, test and demonstrate alternative low-VOC, low toxicity alternative spotting agents.

Historically, it was dry cleaners' practice to pour the separator water generated in the dry cleaning process in the sewer. Because of contamination problems, another method of disposal was necessary. The industry began using evaporators to dispose of the PERC laden separator water. Several years ago, the Legislature added an exclusion to the Health and Safety Code to allow the evaporation of PERC containing separator water. The exclusion was very specific and only applies to PERC. Legislation is now required to allow the evaporation of hydrocarbon containing separator water. IRTA is seeking a sponsor for this legislation.

The Department of Health Services Hazard Evaluation System & Information Service (HESIS) is concerned with worker exposure to toxic chemicals. In this project, HESIS assisted IRTA by evaluating the toxicity of four hydrocarbon solvents used in California and the toxicity of Tonsil and diatomaceous earth based on the Material Safety Data Sheets. The findings indicate that the toxicity of all of the hydrocarbons is consistent with that of solvents in general. None of them pose risks of cancer and they are not selective reproductive or developmental toxicants. HESIS considers the hydrocarbons safer alternatives to PERC due to their lower toxicity. Both diatomaceous earth and Tonsil contain crystalline silica. Diatomaceous earth contains a much higher level of crystalline silica than does tonsil so it potentially poses more of a danger. Dry cleaners and suppliers should be concerned about exposure to the 50 percent/50 percent blend of tonsil and diatomaceous earth when it is dry and airborne. The largest supplier is providing the blend to cleaners in ziplock bags and the mixture is wet when it is disposed of as waste so potential exposure and health risks from inhalation in the dry cleaning industry should be minimal.

I. INTRODUCTION AND BACKGROUND

The California Air Resources Board (CARB) recently completed a survey of the dry cleaning industry in California. The survey indicates that there are about 5,040 dry cleaning facilities in the state and that 4,670 of them use perchloroethylene (PERC) as the solvent. More than 95 percent of the cleaning facilities have only one dry cleaning machine.

PERC is a carcinogen and it is classified as a Toxic Air Contaminant (TAC) in California. The chemical is also a Hazardous Air Pollutant (HAP) according to the U.S. Environmental Protection Agency (U.S. EPA). PERC is a listed hazardous waste under the Resource Conservation and Recovery Act (RCRA). The chemical is a contaminant in soil and groundwater in many locations in the U.S.

PERC has been used by the dry cleaning industry for many years. It is compatible with numerous textiles and it is a relatively aggressive cleaner for oil based soils. Before PERC was used, dry cleaners used low flash point petroleum solvents. The advantage of PERC over this cleaner is that it has no flash point and the use of PERC allowed cleaners to open shops in shopping centers and other heavily populated areas. PERC rapidly penetrated the dry cleaning market and, as the CARB survey figures show, 82 percent of the cleaning machines in California use the solvent. In earlier years, almost all cleaning machines used PERC.

Because of PERC's toxicity, there has been a significant movement away from the chemical over the last several years. In 1993, CARB adopted a statewide regulation on PERC dry cleaning. The regulation focused on requiring PERC dry cleaners to use certain types of equipment that minimized PERC emissions. It also included provisions for inspecting the equipment regularly and preventing and repairing leaks in a timely manner. The regulation also required every dry cleaning facility to have a certified operator who must attend a class describing various procedures for handling PERC every three years. CARB is currently in the process of amending the regulation.

In 1993, the U.S. EPA promulgated the National Emission Standards for Hazardous Air Pollutants (NESHAP) for PERC dry cleaning facilities. The standard is technology based and it applies to all cleaners in the U.S. that use PERC. EPA is currently assessing the risks PERC dry cleaners pose after implementing the NESHAP and may develop additional regulations to further reduce the risks from this sector.

In 2002, the South Coast Air Quality Management District (SCAQMD) substantially amended their PERC dry cleaning regulation, Rule 1421. The regulation requires cleaners to convert to more emission minimizing equipment by 2007 and it phases out the use of PERC dry cleaning by 2020.

PERC is commonly found as a contaminant in soil and ground water. One of the sources of PERC is the dry cleaning industry. Because of the cost of cleaning up the PERC contamination, landlords across the country are requiring cleaners to use alternative textile cleaning agents. Most cleaners lease their shops and generally the length of the lease is 10 years. As leases are renewed, landlords are not allowing the continued use of PERC.

The more stringent air regulations on PERC dry cleaning-- particularly the phaseout of PERC dry cleaning by the SCAQMD--and the landlord concerns are causing a dramatic transition to PERC alternatives in the dry cleaning industry. Over the last 15 years or so, alternative dry cleaning agents and technologies appropriate for the dry cleaning industry have been developed in response to the regulatory and market pressures. Many dry cleaners, particularly those in California, have begun to adopt alternatives. IRTA recently completed a project sponsored by CARB and U.S. EPA to evaluate the performance and cost of eight PERC dry cleaning alternatives. The alternatives that were investigated include:

- Hydrocarbon
- Pure Dry
- Green Earth
- Glycol Ether
- Traditional Wet Cleaning
- Icy Water
- Green Jet
- Carbon Dioxide

As mentioned earlier, CARB's survey results indicate that of the 5,040 dry cleaning facilities, 4,290 of them use PERC dry cleaning. There are 190 facilities that use PERC and one of the other alternatives. Of the 550 non-PERC facilities, 400 use the one of the alternative hydrocarbons called DF-2000, 90 use the Green Earth technology and the remaining 60 use one of the other hydrocarbons or one of the other alternatives.

This analysis suggests that most of the cleaners that have converted away from PERC are adopting the hydrocarbon technology. Because the hydrocarbon technology is likely to be much more widely used in the future, it is important to investigate its characteristics in much more detail. Cal/EPA's Department of Toxic Substances Control (DTSC), the California agency responsible for regulating hazardous waste, also has a strong interest in pollution prevention. DTSC contracted with the Institute for Research and Technical Assistance (IRTA) to perform an assessment of the hydrocarbon technology. IRTA is a technical nonprofit organization that identifies, tests and demonstrates alternatives to ozone depleting solvents, chlorinated solvents, toxic solvents and VOC solvents in a variety of different industries.

PERC Dry Cleaning Technology

PERC is an aggressive solvent for oil based contaminants. It has no flash point and it has a boiling point of 250 degrees F. In the dry cleaning process, PERC is combined with a small amount of water and detergent which functions as the cleaning agent. The process involves a wash step where the garments are washed, an extraction step where the PERC is extracted from the garments and a drying step at elevated temperature in which the garments are dried. A typical cycle for cleaning with PERC is 45 minutes.

In California, PERC is used in dry-to-dry closed loop machines. A picture of a PERC machine is shown in Figure 1-1. The garments are loaded into the wheel of the machine, the door is closed and the wash, extract and dry cycles are completed. At the end of the cycle, the door is opened and the garments are removed. The closed loop equipment includes a refrigerated condenser; the PERC is routed to the condenser where it is condensed and stored for reuse in the next cleaning cycle. Equipment with so-called secondary control also has a small carbon adsorber. Before the door is opened at the end of the cycle, the PERC in the wheel is routed to the carbon adsorber. It is desorbed from the carbon for reuse. Emissions of PERC generally occur from leaks in the machines and from the wheel of the machine when the door is opened at the end of the cycle.

Figure 1-1. PERC Dry Cleaning Machine

Equipment for use with PERC has filters that remove the insoluble material like dirt and hair. Some machines have cartridge filters and the newer equipment uses spin disk filters. The equipment also has a distillation unit that is used to separate the PERC from the higher boiling soluble materials like oils. The filters and still bottoms are disposed of as hazardous waste. Separator water is also generated in the PERC dry cleaning process. Water is introduced into the system in the PERC to clean water soluble contaminants, water is on the garments and water is generated when the refrigerated condenser operates. This water is put into a separator and the PERC, which is heavier than water, is physically separated from the water. The PERC is reused in the cleaning process and the water, which still contains some PERC, is evaporated or disposed of as hazardous waste.

In PERC dry cleaning, cleaners use spotting agents to remove the spots before they dry clean the garments in the machine. PERC is an aggressive solvent, it is easy to use and it is very forgiving. Even when a cleaner is not especially good at spotting, the PERC machine will remove many stains. After the cycle is completed, the garments, which are fully dry, are removed from the machine and finished with standard equipment.

Hydrocarbon Technology

As mentioned earlier, this technology is the most widely used alternative to PERC dry cleaning. Before PERC was adopted as the dry cleaning agent of choice, the industry relied on petroleum solvents for cleaning garments and other items. These petroleum solvents had flash points that were below 140 degrees F. When a cleaner wanted to locate in strip malls, the petroleum solvents could not be used because of fire regulations. The industry converted to PERC that does not have a flash point and could be used in strip malls.

The dry cleaning industry is experienced in using petroleum solvent cleaning and it was logical to pursue similar materials as an alternative to PERC. Exxon Mobil, Chevron and Shell have all developed hydrocarbon dry cleaning agents that have flash points above 140 degrees F. Because of their higher flash points, they can be used in strip malls. Material Safety Data Sheets (MSDSs) for DF-2000, the product offered by Exxon Mobil, Ecosolv Dry Cleaning Fluid, the product offered by Chevron, Shell Sol 140 HT, the product offered by Shell and Hydroclene Dry Cleaning Fluid, a product offered by a distributor called Caled, are shown in Appendix A.

The hydrocarbon process was the first chemical alternative to PERC to emerge and, at this stage, more than 400 cleaners in California are using it in place of PERC. The National Fire Protection Association (NFPA) classifies the hydrocarbon as a Class IIIA solvent and the equipment must be designed accordingly. The equipment for use with the new solvent is different from the equipment used with PERC. Because the hydrocarbon has a flash point, equipment sold for use with the new solvent either contains a vacuum or nitrogen which can be used to suppress the flammability in the machine in the event of ignition. Some hydrocarbon equipment, like PERC equipment, has a refrigerated condenser and other hydrocarbon equipment does not. Some hydrocarbon machines contain distillation units. Distillation of the hydrocarbon must be performed in a vacuum in all the equipment because the boiling point is higher than the boiling point of PERC. Hydrocarbon machines generally contain spin disk filters to remove the insoluble materials. A picture of a dry cleaning machine using hydrocarbon is shown in Figure 1-2.


Figure 1-2. Hydrocarbon Dry Cleaning Machine

Because hydrocarbon is a less aggressive solvent and because it does not evaporate as readily, the cycle time is longer. As discussed above, PERC machines have a cycle time of about 45 minutes and hydrocarbon machines have a cycle time ranging from 60 to 75 minutes. Some equipment manufacturers offer machines that have higher blower capacity which speeds up the drying time and shortens the cycle.

An issue with hydrocarbon solvents is that their use can support bacteria growth. Systems using hydrocarbon should remain free of water. Storage tanks should be bottom drained frequently and cleaners should distill the solvent frequently. Another method of controlling the water in hydrocarbon equipment is to use a material called tonsil which is discussed below.

Tonsil Hydrocarbon Cleaning

An MSDS for an absorbent called tonsil is shown in Appendix A. The material is made of natural calcium bentonite material that is acid activated. The cleaners using tonsil use it in a 50 percent tonsil/50 percent diatomaceous earth blend. An MSDS for diatomaceous earth, also an absorbent, is shown in Appendix A.

Tonsil suppliers claim that tonsil use has four advantages. First, it absorbs moisture in the hydrocarbon solvent and makes it much easier to control bacterial growth. Second, it makes distillation unnecessary. Because distillation is not necessary, the hydrocarbon equipment sold for use with tonsil does not include a distillation system. A picture of a hydrocarbon machine that uses tonsil is shown in Figure 1-3. Note that the footprint of the machine is much smaller than the footprint of the machine with a distillation system shown in Figure 1-2. Third, it makes use of detergent unnecessary. Fourth, it readily scavenges dyes that would cause bleeding and transfer of the dye to other garments.

Figure 1-3. Dry Cleaning Machine for Hydrocarbon with Tonsil

Project Focus

The purpose of this project was to evaluate the characteristics of the hydrocarbon cleaning process in detail. It is important to have as much information about the process as possible because it is likely to be adopted widely by dry cleaners over the next several years.

Section II of this document provides cost and performance information for seven dry cleaning facilities. Six of the facilities converted from PERC to hydrocarbon and one of the facilities began using hydrocarbon when the shop opened. Cost comparison data are provided for PERC and hydrocarbon for five of the facilities and cost data are presented for hydrocarbon for the remaining two facilities.

Section III of this document evaluates and compares certain characteristics of the hydrocarbon process with and without the use of tonsil. IRTA conducted laboratory tests to determine the behavior of tonsil and the results of these experiments are presented. IRTA conducted cleaning comparison tests for tonsil and non-tonsil hydrocarbon cleaners. IRTA also conducted tests designed to compare energy use for tonsil and non-tonsil hydrocarbon cleaning.

Section IV of this document examines the health and environmental characteristics of several hydrocarbon solvents, tonsil and diatomaceous earth. As part of this analysis, IRTA sampled waste streams from four hydrocarbon cleaners that use tonsil and four hydrocarbon cleaners that do not use tonsil. The DTSC Hazardous Materials Laboratory analyzed the samples and the results are presented here. IRTA also asked the Department of Health Services Hazard Evaluation System & Information Service (HESIS) to review the toxicity of the hydrocarbon solvents and the two absorbents. HESIS's evaluation is presented here.

Section V of this document summarizes the findings of the project.

II. CASE STUDIES OF HYDROCARBON CLEANING TECHNOLOGY

This section presents seven case studies of cleaners that are currently using the hydrocarbon technology. The facilities are listed in alphabetical order. Crown Drapery Cleaners, the first case study, and Sterling, the last case study, were presented in an earlier report prepared for the California Air Resources Board (CARB) and U.S. EPA that focused on a variety of alternative technologies to PERC dry cleaning. Both Crown and Sterling used PERC in the past and are now using hydrocarbon. Four other case studies describe facilities owned and operated by Flair Cleaners. The Santa Monica and Studio City Flair operations used PERC in the past and have converted to hydrocarbon. The Valencia Flair facility started up using hydrocarbon. The West L.A. Flair facility converted from PERC to hydrocarbon but data on the PERC use were not available. Porter Ranch Cleaners converted from PERC dry cleaning to hydrocarbon cleaning. Of the seven case studies presented here, five include the cost comparison of PERC and hydrocarbon dry cleaning and two include the cost of using hydrocarbon. Table 2-1 summarizes the information.

Table 2-1
Case Study Cleaners

Cleaning Facility	Technology	PERC Used Previously
Crown Drapery Cleaners	Hydrocarbon with Tonsil	Yes
Flair--Santa Monica	Hydrocarbon with Tonsil	Yes
Flair--Studio City	Hydrocarbon with Tonsil	Yes
Flair--West L.A.	Hydrocarbon--no Tonsil	Yes, but not presented
Flair--Valencia	Hydrocarbon with Tonsil	No
Porter Ranch	Hydrocarbon with Tonsil	Yes
Sterling	Hydrocarbon--no Tonsil	Yes

The information was collected from the cleaning facilities over the period from October 2003 through October 2005. The analysis represents each facility at a point in time and is a snapshot. In some cases, the facilities have made changes since the data were collected.

This section focuses on the case studies. It first discusses the assumptions that were made in the cost analysis and comparison. It then presents the analysis, cost or cost comparison for each of the case study facilities. It summarizes the results of the analysis based on the pounds of garments cleaned. Finally, it discusses and compares the costs of the hydrocarbon technology with and without tonsil.

COST ANALYSIS ASSUMPTIONS

The capital costs and operating costs for each facility are explicitly detailed in this section. The costs are all presented as annualized costs.

Capital Costs

Capital costs evaluated in the case studies included the cost of alternative cleaning equipment, the cost of installation and, in some cases, the cost of associated equipment. One cleaner purchased a chiller to facilitate use of the hydrocarbon technology.

The capital costs were annualized by amortizing the cost over a 15 year period under the assumption that the equipment would have a lifetime approximately that long. The cost of capital was assumed to be four percent based on the rate of interest between January 2004 through June 2004 reported in the Federal Register, Volume 68, Number 249, page 75317. Cleaners generally do not pay for their equipment in this way. They often use a leasing agency with a shorter payoff period and a higher interest rate. To achieve consistency throughout the case studies, however, IRTA adopted the approach outlined above.

Operating Costs

Operating costs for the cleaners participating in the project included:

- Solvent Cost
- Detergent Cost
- Electricity Cost
- Gas Cost
- Spotting Labor Cost
- Finishing Labor Cost
- Maintenance Labor Cost
- Maintenance Equipment Cost
- Compliance Cost
- Hazardous Waste Disposal Cost

IRTA initially decided to also include the cost of the spotting chemicals. After investigation, it was determined that cleaners purchase very small quantities of spotting agents and that this cost could be neglected. The operating costs that were included were those costs that might have differences when cleaners use PERC, hydrocarbon with tonsil and hydrocarbon without tonsil.

The solvent cost is the cost per gallon of the fluid used to perform cleaning. This cost does not include detergent.

Detergent cost is the cost of purchasing detergent which is added to the solvent to aid in soil removal.

The owners or operators of the facilities estimated their annual electricity and gas costs or based them on actual bills and this was the cost that was included in the case studies. Electricity and gas are used for other purposes than cleaning in a facility. Some of the facilities have air conditioning, all have lighting and most have multiple computers. Some of the facilities also provide laundry services which use gas and some electricity. It was not possible to separate the energy use for cleaning and for the other activities. IRTA collected the data primarily to compare the electricity and gas use with PERC and hydrocarbon. In Section III, a more detailed examination of the energy requirements was conducted to compare these requirements with and without tonsil use for the hydrocarbon technology.

Finishing and spotting labor were included in the analysis because they account for a very large portion of the total costs of operating a cleaning facility and IRTA wanted to examine differences in these costs based on the technology and the particular facility. In small cleaning facilities, owners and family members often perform some or all of the spotting and finishing for the business. In such cases, IRTA asked the owners to quantify their labor hours so the spotting and finishing costs could be included in the analysis. The owners and family members are not usually paid for their labor but they must devote their time to the activities and it is a real cost of the operation. Owners and family members in large cleaning facilities generally do not perform spotting or finishing; workers are hired to perform those tasks. The spotting labor cost is the cost of labor for spotting the garments. Similarly, the finishing cost is the cost of labor for finishing the garments.

The maintenance labor cost is the cost of labor to perform routine maintenance activities. For hydrocarbon facilities using tonsil, the cost of changing out the tonsil would be included in this category. This cost does not include maintenance labor for breakdowns or repairs. Maintenance equipment costs are the cost of equipment used in routine operation of equipment. Such costs include the cost of filters and the costs of the tonsil/diatomaceous earth blend.

The compliance cost is the labor cost for record keeping, reporting and routine machine inspection.

The hazardous waste disposal cost is the cost to the facility for disposing of hazardous waste. Hydrocarbon waste streams are generally treated as hazardous waste. As discussed later, some of the streams may not be classified as hazardous waste.

CASE STUDY ANALYSIS

The performance/cost analysis conducted for each of the seven participating facilities is presented below. As discussed above, five of the facilities are using tonsil whereas two are not. Six of the facilities converted from PERC to hydrocarbon dry cleaning. PERC costs are presented for five of these facilities which had a record of the PERC costs.

Crown Drapery Cleaners

Crown Drapery Cleaners is located in Huntington Beach California. The owner, Matt Borgerson, replaced two 55 pound PERC machines with two 35 pound hydrocarbon machines. The store cleans 168,000 pounds of clothing per year and is open six days per week.

The capital cost of the two 35 pound hydrocarbon machines was $90,000. Crown also purchased a chiller at a cost of $10,000. The chiller helps with efficiency in cooling the solvent more rapidly and shortens the cycle time. The cost of installing the two machines and the chiller was $5,000. The total capital cost amounted to $105,000. Assuming a life for the equipment of 15 years and a cost of capital of four percent, the annualized capital cost is $7,280.

The dry cleaning facility previously used 50 gallons of PERC per month or 600 gallons per year. At a cost of $8 per gallon for PERC, the annual cost of purchasing the solvent was $4,800. The facility now uses 55 gallons per month or 660 gallons per year of hydrocarbon solvent. At a cost of $5.37 per gallon, the solvent cost is now $3,544.

Crown purchased 220 gallons per year of detergent for use with PERC. At a cost of $26 per gallon, the annual cost of detergent was $5,720. The cleaner now uses a solid absorbent called Tonsil that makes it unnecessary to use detergent with the hydrocarbon solvent.

When Crown Cleaners used PERC, the electricity cost for the facility was $980 per month or $11,760 per year. After the facility converted to the hydrocarbon solvent, the electricity cost was lower, at $800 per month or $9,600 per year. In both cases, the electricity bills also include facility lighting and cooling. In addition to eliminating the need for detergent, use of the tonsil allows the cleaner to avoid distillation because the tonsil absorbs the oil.

When Crown Cleaners used PERC, the gas bill was $450 per month or $5,400 per year. After the conversion to the hydrocarbon, the gas bill is slightly lower, at $425 per month or $5,100 per year.

The cost of spotting labor is the same with the hydrocarbon solvent as it was with PERC. Spotting labor amounts to 60 hours per week or 3,120 hours per year. At Crown's labor rate of $10 per hour, the annual spotting cost is $31,200.

The cost of finishing labor is also the same with the hydrocarbon solvent as it was with PERC. The finishing labor with both solvents is 120 hours per week or 6,240 hours per year. At the labor rate of $10 per hour, the annual cost of the finishing labor is $62,400.

When the shop used PERC, the maintenance labor amounted to about 2.5 hours per week or 130 hours per year. At the labor rate of $10 per hour, the cost of maintenance labor was $1,300. With the hydrocarbon machine, the maintenance labor has been reduced to about one hour per week or 52 hours per year. At the labor rate of $10 per hour, the maintenance labor now amounts to $520 per year.

When Crown used PERC, the shop replaced six filters every two months. At a cost for each filter of $35, the annual cost of filter replacement was $1,260. With the hydrocarbon process, Crown purchases one 55-pound bag of tonsil every two months. At a cost of $117 per bag, the annual tonsil purchase amounts to $702. The tonsil is combined with diatomaceous earth; the facility purchases 50 pounds per month. At a cost of $30 per 50 pounds, the cost of the diatomaceous earth is $360 per year. The total cost of the tonsil and diatomaceous earth is $1,062 annually.

When the shop used PERC, compliance required five hours per week labor. At a labor cost of $10 per hour, the annual compliance cost was $2,600. Compliance costs with the hydrocarbon machines have been reduced to 15 minutes per day. The annual compliance costs are now $650 per year.

When PERC was used, the facility disposed of 110 gallons of hazardous waste every three months at a cost of $900. The annual disposal cost was $3,600. With the hydrocarbon, the facility disposes of two drums of hazardous waste every three months at a cost of $400. The annual cost of disposal is $1,600.

Table 2-2 shows the annualized cost comparison of using PERC and hydrocarbon for Crown Cleaners.

Table 2-2
Annualized Cost Comparison for Crown Drapery Cleaners

	PERC	Hydrocarbon
Annualized Capital Cost	-	$7,280
Solvent Cost	$4,800	$3,544
Detergent Cost	$5,720	-
Electricity Cost	$11,760	$9,600
Gas Cost	$5,400	$5,100
Spotting Labor Cost	$31,200	$31,200
Finishing Labor Cost	$62,400	$62,400
Maintenance Labor Cost	$1,300	$520
Maintenance Equipment Cost	$1,260	$1,062
Compliance Cost	$2,600	$650
Waste Disposal Cost	$3,600	$1,600
Total Cost	$130,040	$122,956

Flair Cleaners--Santa Monica

Flair Cleaners is located in Santa Monica, California. The store previously had two PERC machines. A few years ago, Flair replaced one of the PERC machines with a 70 pound hydrocarbon machine. The store now operates a 55 pound PERC machine and the new 70 pound hydrocarbon machine. Flair cleans 330,000 pounds of clothing per year.

The capital cost of the 75 pound hydrocarbon machine was $68,000. The installation cost amounted to $2,500. The total capital cost was $70,200. Assuming a cost of capital of four percent and a 15 year useful life for the machine, the annualized capital cost is $4,888.

When Flair had two PERC machines, the store used 720 gallons per year of the solvent. Assuming a cost for the solvent of $22.13 per gallon, the annual PERC cost was $15,934. Flair now uses 360 gallons of PERC per year. Assuming a cost for PERC of $22.13 per gallon, the annual cost of purchasing PERC is $7,967. Flair also uses 600 gallons per year of the hydrocarbon solvent. At a cost of $4.70 per gallon, the annual cost for the hydrocarbon is $2,820. The total annual cost of the PERC and hydrocarbon is now $10,787.

When Flair had two PERC machines, the facility purchased 100 gallons per year of detergent. At a cost for the detergent of $29.18 per gallon, the annual detergent cost amounted to $2,918. Flair uses tonsil so does not use detergent in the hydrocarbon machine currently. The facility uses 45 gallons of detergent in the PERC machine. The total annual detergent cost is now $1,313.

When the facility used PERC, the annual electricity cost was $21,000; there was no change in this cost when Flair converted one machine to hydrocarbon.

When the facility used PERC exclusively, the annual cost of gas amounted to $24,000. After Flair converted one machine to hydrocarbon, the annual cost of gas remained the same.

Flair estimates that 21 hours per week or 1,092 hours per year were used for spotting when the facility used PERC exclusively. At a spotting labor rate of $15 per hour, the annual cost of spotting was $16,380. Currently, the spotting labor is the same.

Flair estimates the labor used for finishing was 200 hours per week or 10,400 hours per year when PERC was used exclusively. At a finishing labor rate of $10 per hour, the annual finishing cost amounted to $104,000. Since converting one of the machines to hydrocarbon, the finishing labor cost has not changed.

When Flair used PERC exclusively, the maintenance labor was 12 hours per week or 624 hours per year. At a maintenance labor rate of $15 per hour, the annual cost of maintenance labor was $9,360. The maintenance labor has increased to 20 hours per week (six hours for the PERC machine and 14 for the hydrocarbon machine) or $1,040 per year. Again, assuming the labor rate of $15 per hour, the maintenance labor cost is now $15,600.

When Flair used PERC exclusively, there was no maintenance equipment cost since the PERC machines had no filters. Now, Flair purchases one and a half 55 pound bags of tonsil and one and a half 50 pound bags of diatomaceous earth each month. The cost of a 55 pound bag of tonsil is $130 and the cost of a 50 pound bag of diatomaceous earth is $20. On this basis, the annual cost of the materials is $2,700.

Flair estimates the compliance hours at two per week or 104 per year now and when PERC was used exclusively. Assuming a $15 per hour compliance labor rate, the annual compliance cost is $1,560.

When Flair used PERC exclusively, the annual hazardous waste disposal cost was $5,278. Now, the disposal cost amounts to $6,007.

Table 2-3 shows the annualized cost comparison of the two PERC machines and one PERC and one hydrocarbon machine for Flair Cleaners. The annualized cost of using PERC exclusively is four percent lower than the cost of using PERC and hydrocarbon.

Table 2-3
Annualized Cost Comparison for Flair Cleaners--Santa Monica

	PERC	Hydrocarbon/PERC
Annualized Capital Cost	-	$4,888
Solvent Cost	$15,934	$10,787
Detergent Cost	$2,918	$1,313
Electricity Cost	$21,000	$21,000
Gas Cost	$24,000	$24,000
Spotting Labor Cost	$16,380	$16,380
Finishing Labor Cost	$104,000	$104,000
Maintenance Labor Cost	$9,360	$15,600
Maintenance Equipment Cost	-	$2,700
Compliance Cost	$1,560	$1,560
Waste Disposal Cost	$5,278	$6,007
Total Cost	$200,430	$208,235

Flair Cleaners--Studio City

Flair Cleaners is located in Studio City, California. The store has two machines, one an older 50 pound PERC machine and the other, a 75 pound hydrocarbon machine that replaced a PERC machine. The store cleans 317,200 pounds of clothing per year.

The capital cost of the 75 pound hydrocarbon machine was $60,800. The installation cost amounted to $2,500. The total capital cost was $63,300. Assuming a cost of capital of four percent and a 15 year useful life for the machine, the annualized capital cost is $4,389.

When Flair had two PERC machines, the store used 460 gallons per year of the solvent.
Assuming a cost for the solvent of $22.13 per gallon, the annual PERC cost was $10,180. Flair now uses 228 gallons of PERC per year. Assuming a cost for PERC of $22.13 per gallon, the annual cost of purchasing PERC is $5,046. Flair also uses 605 gallons per year of the hydrocarbon solvent. At a cost of $4.70 per gallon, the annual cost for the hydrocarbon is $2,844. The total annual cost of the PERC and hydrocarbon is now $7,890.

When Flair had two PERC machines, the facility purchased 280 gallons per year of detergent. At a cost for the detergent of $23.84 per gallon, the annual detergent cost amounted to $6,675. Flair uses tonsil so does not use detergent in the hydrocarbon machine currently. The facility uses 140 gallons of detergent in the PERC machine. The total annual detergent cost is now $3,338.

When the facility used PERC, the annual electricity cost was $20,200; there was no change in this cost when Flair converted one machine to hydrocarbon.

When the facility used PERC exclusively, the annual cost of gas amounted to $27,360. After Flair converted one machine to hydrocarbon, the annual cost of gas was $28,800.

Flair estimates that 18 hours per week or 936 hours per year were used for spotting when the facility used PERC exclusively. At a spotting labor rate of $15 per hour, the annual cost of spotting was $14,040. Currently, the spotting labor has increased to 50 hours per week or 2,600 hours per year. Again, assuming the spotting labor rate of $15 per hour, the annual cost of spotting is now $39,000.

Flair estimates the labor used for finishing was 200 hours per week or 10,400 hours per year when PERC was used exclusively. At a finishing labor rate of $10 per hour, the annual finishing cost amounted to $104,000. Since converting one of the machines to hydrocarbon, the finishing labor cost has not changed.

When Flair used PERC exclusively, the maintenance labor was 12 hours per week or 624 hours per year. At a maintenance labor rate of $15 per hour, the annual cost of maintenance labor was $9,360. The maintenance labor has increased to 20 hours per week (six hours for the PERC machine and 14 for the hydrocarbon machine) or $1,040 per year. Again, assuming the labor rate of $15 per hour, the maintenance labor cost is now $15,600.

When Flair used PERC exclusively, there was no maintenance equipment cost since the PERC machines had no filters. Now, Flair purchases one and a half 55 pound bags of tonsil and one and a half 50 pound bags of diatomaceous earth each month. The cost of a 55 pound bag of tonsil is $130 and the cost of a 50 pound bag of diatomaceous earth is $20. On this basis, the annual cost of the materials is $2,700.

Flair estimates the compliance hours at two per week or 104 per year now and when PERC was used exclusively. Assuming a $15 per hour compliance labor rate, the annual compliance cost is $1,560.

When Flair used PERC exclusively, the annual hazardous waste disposal cost was $7,604. Now, the disposal cost amounts to $8,640.

Table 2-4 shows the annualized cost comparison of the two PERC machines and one PERC and one hydrocarbon machine for Flair Cleaners. The annualized cost of using PERC exclusively is 12 percent lower than the cost of using PERC and hydrocarbon.

Table 2-4
Annualized Cost Comparison for Flair Cleaners--Studio City

	PERC	Hydrocarbon/PERC

Annualized Capital Cost	-	$4,389
Solvent Cost	$10,180	$7,890
Detergent Cost	$6,675	$3,338
Electricity Cost	$20,200	$20,200
Gas Cost	$27,360	$28,800
Spotting Labor Cost	$14,040	$39,000
Finishing Labor Cost	$104,000	$104,000
Maintenance Labor Cost	$9,360	$15,600
Maintenance Equipment Cost	-	$2,700
Compliance Cost	$1,560	$1,560
Waste Disposal Cost	$7,604	$8,640
Total Cost	$200,979	$236,117

Flair Cleaners--West Los Angeles

Flair Cleaners is located in West Los Angeles, California. The store was converted from PERC to hydrocarbon several years ago and was one of the first cleaners in California to use the alternative solvent. Flair no longer has records for the PERC use and equipment so this analysis focuses only on the hydrocarbon use. Flair purchased two 88 pound machines. The store cleans 312,000 pounds of clothing per year.

The capital cost of each of the 88 pound machines was $68,000. Installation for each machine amounted to $2,500. The total capital cost was $141,000. Assuming a cost of capital of four percent and a 15 year useful life for the machines, the annualized capital cost is $9,776.

Flair uses 1,238 gallons per year of hydrocarbon solvent. The cost of the solvent is $4.70 per gallon. On this basis, the annual solvent cost amounts to $5,819.

Flair uses 277 gallons of detergent per year. This Flair facility does not use tonsil. The cost of the detergent is $27.27 per gallon. The annual detergent cost is $7,554.

The annual electricity cost for the facility is $20,400 and the annual gas cost is $26,400.

Flair estimates that 60 hours per week or 3,120 hours per year are devoted to spotting. At a spotting labor rate of $15 per hour, the annual cost of spotting is $46,800.

Flair estimates the labor used for finishing is 200 hours per week or 10,400 hours per year. At a finishing labor rate of $10 per hour, the annual finishing cost amounts to $104,000.

The maintenance labor is estimated at eight hours per week or 416 hours per year. At a maintenance labor rate of $15 per hour, the annual cost of maintenance labor is $6,240.

The facility does not use tonsil and the machines do not have filters so there is no maintenance equipment cost.

Flair estimates the compliance hours at two per week or 104 per year. Assuming a $15 per hour compliance labor rate, the annual compliance cost is $1,560.

The annual hazardous waste disposal cost for the facility is $4,368.

Table 2-5 shows the annualized cost of using the hydrocarbon solvent for Flair Cleaners.

Table 2-5
Annualized Cost for Flair Cleaners--West Los Angeles

	Hydrocarbon
Annualized Capital Cost	$9,776
Solvent Cost	$5,819
Detergent Cost	$7,554
Electricity Cost	$20,400
Gas Cost	$26,400
Spotting Labor Cost	$46,800
Finishing Labor Cost	$104,000
Maintenance Labor Cost	$6,240
Maintenance Equipment Cost	-
Compliance Cost	$1,560
Waste Disposal Cost	$4,368
Total Cost	$232,917

Flair Cleaners--Valencia

Flair Cleaners is located in Valencia, California. The store was opened a few years ago and the owners decided to use hydrocarbon. Flair purchased a 70 pound and a 35 pound machine. The store cleans 286,000 pounds of clothing per year.

The capital cost of the 70 pound machine was $68,000 and the capital cost of the 35 pound machine was $42,000. Flair also purchased a chiller for $1,000 and installation for each machine amounted to $2,500. The total capital cost was $116,000. Assuming a cost of capital of four percent and a 15 year useful life for the machines, the annualized capital cost is $8,043.

Flair uses 60 gallons per month or 660 gallons per year of hydrocarbon solvent. The cost of the solvent is $4.70 per gallon. On this basis, the annual solvent cost amounts to $3,102.

Flair does not use detergent; the facility uses tonsil as discussed below.

The annual electricity cost for the facility is $16,800 and the annual gas cost is $19,262.

Flair estimates that 43 hours per week or 2,236 hours per year are devoted to spotting. At a spotting labor rate of $15 per hour, the annual cost of spotting is $33,540.

Flair estimates the labor used for finishing is 160 hours per week or 8,320 hours per year. At a finishing labor rate of $10.50 per hour, the annual finishing cost amounts to $87,360.

The maintenance labor is estimated at 12 hours per week or 624 hours per year. At a maintenance labor rate of $15 per hour, the annual cost of maintenance labor is $9,360.

Flair purchases one 55 pound bag of tonsil and one 50 pound bag of diatomaceous earth each month. The cost of a 55 pound bag of tonsil is $130 and the cost of a 50 pound bag of diatomaceous earth is $20. On this basis, the annual cost of the materials is $1,800.

Flair estimates the compliance hours at two per week or 104 per year. Assuming a $15 per hour compliance labor rate, the annual compliance cost is $1,560.

The annual hazardous waste disposal cost for the facility is $3,600.

Table 2-6 shows the annualized cost of using the hydrocarbon solvent for Flair Cleaners.

Table 2-6
Annualized Cost for Flair Cleaners--Valencia

	Hydrocarbon
Annualized Capital Cost	$8,043
Solvent Cost	$3,102
Detergent Cost	-
Electricity Cost	$16,800
Gas Cost	$19,262
Spotting Labor Cost	$33,540
Finishing Labor Cost	$87,360
Maintenance Labor Cost	$9,360
Maintenance Equipment Cost	$1,800
Compliance Cost	$1,560
Waste Disposal Cost	$3,600
Total Cost	$184,427

Porter Ranch Cleaners

Porter Ranch Cleaners is located in Porter Ranch, California. The store has two 35 pound hydrocarbon machines which replaced two PERC machines. The store cleans 73,500 pounds of clothing per year.

The capital cost of the two 35 pound hydrocarbon machines was $67,000 including installation. Assuming a cost of capital of four percent and a 15 year useful life for the machine, the annualized capital cost is $4,645.

When Porter Ranch had two PERC machines, the store used 300 gallons per year of the solvent. Assuming a cost for the solvent of $19.50 per gallon, the annual PERC cost was $5,850. Porter Ranch now uses 150 gallons of hydrocarbon solvent per year. At a cost of $5.61 per gallon, the annual cost for the hydrocarbon is $842.

When Porter Ranch had two PERC machines, the facility purchased 60 gallons per year of detergent. At a cost for the detergent of $20 per gallon, the annual detergent cost amounted to $1,200. Porter Ranch uses tonsil so does not use detergent in the hydrocarbon machines currently.

When the facility used PERC, the annual electricity cost was $10,520; after the conversion to hydrocarbon, the annual electricity cost was $9,500.

When the facility used PERC, the annual cost of gas amounted to $10,300. After Porter Ranch converted to hydrocarbon, the annual cost of gas was $9,800.

Porter Ranch estimates that 12 hours per week or 624 hours per year were used for spotting when the facility used PERC. At a spotting labor rate of $13.13 per hour, the annual cost of spotting was $8,193. Currently, the spotting labor with hydrocarbon is the same.

Porter Ranch estimates the labor used for finishing was 126 hours per week or 6,552 hours per year when PERC was used. At a finishing labor rate of $10 per hour, the annual finishing cost amounted to $65,520. Since converting to hydrocarbon, the finishing labor cost has not changed.

When Porter Ranch used PERC, the maintenance labor was 1.5 hours per week or 78 hours per year. At a maintenance labor rate of $13.13 per hour, the annual cost of maintenance labor was $1,024. The maintenance labor has remained the same with the conversion to hydrocarbon.

When Porter Ranch used PERC, the facility replaced 75 filters per year. Assuming a cost of $75 for a box containing four filters, the annual maintenance equipment cost was $1,406. Now, Porter Ranch purchases one 55 pound bag of tonsil and one 50 pound bag of diatomaceous earth every six weeks. The cost of a 55 pound bag of tonsil is $130 and the cost of a 50 pound bag of diatomaceous earth is $20. On this basis, the annual cost of the materials is $1,300.

Porter Ranch estimates the compliance hours at four per year when PERC was used. Assuming a $13.13 per hour compliance labor rate, the annual compliance cost was $53. The facility now devotes one hour per year to compliance. Again, using the labor rate of $13.13 per hour, the compliance cost is now $13 per year.

When Porter Ranch used PERC, the facility disposed of 110 gallons of hazardous waste every six months or 220 gallons per year. Assuming a cost for disposal of 110 gallons of $750, the annual hazardous waste disposal cost was $1,500. Now, the facility disposes of two drums of hazardous waste annually for a total cost of $500.

Table 2-7 shows the annualized cost comparison of the two PERC machines and the two hydrocarbon machines for Porter Ranch Cleaners. The annualized cost of using hydrocarbon is four percent lower than the cost of using PERC.

Table 2-7
Annualized Cost Comparison for Porter Ranch Cleaners

	PERC	Hydrocarbon
Annualized Capital Cost	-	$4,645
Solvent Cost	$5,850	$842
Detergent Cost	$1,200	-
Electricity Cost	$10,520	$9,500
Gas Cost	$10,300	$9,800
Spotting Labor Cost	$8,193	$8,193
Finishing Labor Cost	$65,520	$65,520
Maintenance Labor Cost	$1,024	$1,024
Maintenance Equipment Cost	$1,406	$1,300
Compliance Cost	$53	$13
Waste Disposal Cost	$1,500	$500
Total Cost	$105,566	$101,337

Sterling Dry Cleaners

Sterling Dry Cleaners, located in Westwood, California, operated with two 45 pound PERC machines for several years. Almost three years ago, Sterling purchased two new hydrocarbon machines; one is a 60 pound machine and the other is a 90 pound machine. The store processes 254,800 pounds of clothing a year and operates seven days a week.

The capital cost of the two new hydrocarbon machines amounted to $100,000 and this includes installation. Assuming a 15 year machine life and a four percent cost of capital, the annualized capital cost is $6,933.

When Sterling used PERC, the facility purchased 825 gallons per year. Assuming a cost of $8 per gallon for PERC, the annual cost of solvent purchases amounted to $6,600. Sterling now purchases 330 gallons per year of the hydrocarbon solvent. At a cost of $6 per gallon, the solvent purchases are $1,980 per year.

Sterling uses the same amount of detergent with the hydrocarbon solvent as with PERC. About 200 gallons of detergent are used annually. At a cost of $25 per gallon, the annual detergent cost is $5,000.

When Sterling used PERC, the electricity cost for the shop was $21,100 and the gas cost was $19,100 per year. After Sterling converted to the hydrocarbon, the electricity cost increased to $26,600 and the gas cost increased slightly to $21,800.

When Sterling used PERC, the shop spent 80 hours per week or 4,160 hours per year spotting. Assuming Sterling's labor cost of $10.60 per hour, the annual spotting cost was $44,096. Spotting labor did not change when the shop converted to the hydrocarbon process.

With PERC, Sterling's finishing labor totaled 264 hours per week or 13,728 hours per year. Again assuming the labor rate of $10.60 per hour, the annual cost for finishing labor was $145,517. Finishing labor with the hydrocarbon process has not changed.

Maintenance labor at Sterling, at two hours per week or 104 hours per year, has not changed since the shop adopted the hydrocarbon process. Assuming Sterling's labor rate of $10.60 per hour, the annual maintenance labor cost amounts to $1,102.

When Sterling used PERC, the shop replaced 14 filters per year. Assuming a cost of $35 per filter, the annual maintenance equipment cost amounted to $490.

When Sterling used PERC, compliance with regulations required five hours per week or 260 hours per year. At a labor rate of $10.60 per hour, the annual compliance cost was $2,756. Compliance costs since the facility converted to the hydrocarbon process remain the same.

The cost of hazardous waste disposal for the facility has not changed. The cleaner disposes of 110 gallons of hazardous waste every two months at a cost of $600. The total annual cost is $3,600.

Table 2-8 shows the annualized cost comparison of PERC and hydrocarbon for Sterling.

Table 2-8
Annualized Cost Comparison for Sterling Dry Cleaners

	PERC	Hydrocarbon
Annualized Capital Cost	-	$6,933
Solvent Cost	$6,600	$1,980
Detergent Cost	$5,000	$5,000
Electricity Cost	$21,100	$26,600
Gas Cost	$19,100	$21,800
Spotting Cost	$44,096	$44,096
Finishing Cost	$145,517	$145,517
Maintenance Labor Cost	$1,102	$1,102
Maintenance Equipment Cost	$490	-
Compliance Cost	$2,756	$2,756
Waste Disposal Cost	$3,600	$3,600
Total Cost	$249,361	$259,384

RESULTS OF THE CASE STUDY ANALYSIS

Table 2-9 summarizes the results of the case study analysis for the seven facilities. The first column lists the cleaner's name. The second column indicates whether the facility uses PERC or hydrocarbon. In cases where the cleaner used PERC prior to converting to the hydrocarbon technology, there are two entries, one for PERC and one for hydrocarbon with or without tonsil. If the facility uses tonsil, the hydrocarbon entry has a T in parenthesis. The third column provides the pounds of clothing cleaned annually by each cleaner. The fourth column lists the annualized capital cost incurred by the cleaner in adopting the hydrocarbon technology. Note that there are no capital costs for the PERC process. Columns five through 14 show the annual cost figures for each of the operating cost items listed earlier. Column 15 shows the total cost including the contributions from both the capital and operating costs. Column 16 shows the total cost per pound of clothing cleaned. Finally, column 17 shows the total operating cost per pound of clothing cleaned. The values in column 17 exclude the capital cost numbers which were included only for the hydrocarbon technology and not for PERC dry cleaning.

Comparison of PERC and Hydrocarbon Technologies

Table 2-10 summarizes the total cost per pound and the operating cost per pound for all of the facilities that were evaluated. The total cost per pound figures include an equipment cost for hydrocarbon and do not include a similar cost for PERC.

Table 2-9

Annualized Cost Summary for Case Study Cleaners

Dry Cleaner	Cleaning Method	Pounds Per Year Cleaned	Costs: Annualized Capital	Solvent	Detergent	Electricity	Gas	Spotting Labor	Finishing Labor	Maintenance Labor	Maintenance Equipment	Compliance	Hazardous Waste Disposal	Total	Cost per pound cleaned	Cost per pound cleaned -- no machine
Crown	PERC	168,000	$0	$4,800	$5,720	$11,760	$5,400	$31,200	$62,400	$1,300	$1,260	$2,600	$3,600	$130,040	$0.77	$0.77
	Hydrocarbon (T)	168,000	$7,280	$3,544	$0	$9,600	$5,100	$31,200	$62,400	$520	$1,062	$650	$1,600	$122,956	$0.73	$0.69
Flair -- Santa Monica	PERC	330,000	$0	$15,934	$2,918	$21,000	$24,000	$16,380	$104,000	$9,360	$0	$1,560	$5,278	$200,430	$0.61	$0.61
	Hydrocarbon (T)/ PERC	330,000	$4,888	$10,787	$1,313	$21,000	$24,000	$16,380	$104,000	$15,600	$2,700	$1,560	$6,007	$208,235	$0.63	$0.62
Flair -- Studio City	PERC	317,200	$0	$10,180	$6,675	$20,200	$27,360	$14,040	$104,000	$9,360	$0	$1,560	$7,604	$200,979	$0.63	$0.63
	Hydrocarbon (T)/ PERC	317,200	$4,389	$7,890	$3,338	$20,200	$28,800	$39,000	$104,000	$15,600	$2,700	$1,560	$8,640	$236,117	$0.74	$0.73
Flair -- Valencia	Hydrocarbon (T)	286,000	$8,043	$3,102	$0	$16,800	$19,262	$33,540	$87,360	$9,360	$1,800	$1,560	$3,600	$184,427	$0.64	$0.62
Flair -- West LA	Hydrocarbon	312,000	$9,776	$5,819	$7,554	$20,400	$26,400	$46,800	$104,000	$6,240	$0	$1,560	$4,368	$232,917	$0.75	$0.72
Porter Ranch	PERC	73,500	$0	$5,850	$1,200	$10,520	$10,300	$8,193	$65,520	$1,024	$1,406	$53	$1,500	$105,566	$1.44	$1.44
	Hydrocarbon (T)	73,500	$4,645	$842	$0	$9,500	$9,800	$8,193	$65,520	$1,024	$1,300	$13	$500	$101,337	$1.38	$1.32
Sterling	PERC	254,800	$0	$6,600	$5,000	$21,100	$19,100	$44,096	$145,517	$1,102	$490	$2,756	$3,600	$249,361	$0.98	$0.98
	Hydrocarbon	254,800	$6,933	$1,980	$5,000	$26,600	$21,800	$44,096	$145,517	$1,102	$0	$2,756	$3,600	$259,384	$1.02	$0.99

Table 2-10
Annualized Total Cost Comparison for Cleaners

Facility	Technology	Pounds Per Year	Total Cost Per Pound	Operating Cost Per Pound
Crown	PERC	168,000	$0.77	$0.77
	Hydrocarbon (T)	168,000	$0.73	$0.69
Flair--Santa Monica	PERC	330,000	$0.61	$0.61
	Hydrocarbon (T)	330,000	$0.63	$0.62
Flair--Studio City	PERC	317,200	$0.63	$0.63
	Hydrocarbon (T)	317,200	$0.74	$0.73
Flair--Valencia	Hydrocarbon (T)	286,000	$0.64	$0.62
Flair--West L.A.	Hydrocarbon	312,000	$0.75	$0.72
Porter Ranch	PERC	73,500	$1.44	$1.44
	Hydrocarbon (T)	73,500	$1.38	$1.32
Sterling	PERC	254,800	$0.98	$0.98
	Hydrocarbon	254,800	$1.02	$0.99

The values in Table 2-10 allow a comparison of the operating costs of the PERC and hydrocarbon technologies. Two of the facilities, Crown and Porter Ranch, reduced their operating cost per pound when they converted from PERC to hydrocarbon. The other three facilities that converted from PERC to hydrocarbon, Flair--Santa Monica, Flair--Studio City and Sterling, experienced an increase in the operating cost per pound after the conversion to hydrocarbon. Flair--Santa Monica's cost increase was about two percent and Sterling's cost increase was about one percent. Flair--Studio City's cost increase was higher, about 16 percent. Flair--Valencia has the lowest operating cost per pound of any facility using hydrocarbon. Porter Ranch has the highest operating cost per pound of the facilities. In the earlier project IRTA conducted with CARB and U.S. EPA, the results indicated that facilities that clean less than 100,000 pounds of clothing annually are not as efficient as facilities that clean more than 100,000 pounds of clothing annually. Porter Ranch cleans 73,500 pounds of clothing annually which is 2.3 to 4.5 times less than all the other facilities. The higher operating cost per pound for this facility is therefore expected.

Comparison of Hydrocarbon With and Without Tonsil

The cleaner that has the lowest operating cost per pound, Flair--Valencia, uses tonsil. The cleaner that has the highest cost per pound, Porter Ranch, also uses tonsil. Of the large facilities (excluding Porter Ranch), Sterling, a facility that does not use tonsil, has the highest operating cost per pound. Of the large facilities, the four that use tonsil have an operating cost per pound of 70 cents or less. Of the large facilities, the two that don't use tonsil have an operating cost per pound higher than 72 cents per pound. This suggests that cleaners using tonsil may have a slight cost advantage but many more facilities would have to be evaluated to draw a definitive conclusion.

The facilities that use hydrocarbon with tonsil do not purchase detergent so they have no detergent cost. These facilities also do not distill their solvent. Crown, a facility using tonsil, experienced a decrease in electricity and gas costs upon conversion from PERC to hydrocarbon. Porter Ranch, a tonsil user, also experienced a cost decrease in these utilities upon conversion. Flair--Santa Monica, a cleaner using tonsil, had the same electricity and gas costs with PERC and hydrocarbon. Flair--Studio City, a cleaner using tonsil, had the same electricity cost but had a gas cost increase in converting from PERC to hydrocarbon. Sterling, a cleaner using tonsil, experienced cost increases in electricity and gas upon conversion from PERC to hydrocarbon. Conclusions as to whether the use of tonsil changes utility costs cannot be drawn from the few facilities evaluated here. A later section analyzes the change in utility costs with and without tonsil through direct measurement.

III. COMPARISON OF CERTAIN CHARACTERISTICS OF TONSIL AND NON-TONSIL HYDROCARBON PROCESSES

This section discusses and compares various parameters for hydrocarbon cleaners using tonsil and not using tonsil. It begins by describing tests designed by IRTA to investigate some of the claims made by tonsil suppliers. It then analyzes and compares the cleaning capability of tonsil and non-tonsil hydrocarbon processes based on a standard set of tests. Finally, it provides the results of direct testing of the utility requirements in a hydrocarbon machine with and without tonsil.

BACTERIA GROWTH

The tonsil suppliers claim that bacteria issues are minimized or eliminated when tonsil is used. Bacteria growth is often cited as a disadvantage of using hydrocarbon cleaning agents. Bacteria are brought in on soiled garments and introduced into the cleaning solvent. The metabolites from live bacteria and bacteria that die can cause odors in the process. Bacteria, like other forms of life, require water to survive. Odor can be eliminated by minimizing the accumulation of free water in the system.

Hydrocarbon cleaners that do not use tonsil must take certain measures routinely to prevent the free water from building up. Such measures include regular bottom draining of solvent storage tanks and frequent distillation. Cleaners who use tonsil generally do not perform distillation and they do not need to pay close attention to free water buildup.

To test the hypothesis that use of tonsil minimizes odor and does not allow the free water buildup, IRTA conducted a test. IRTA used the test apparatus shown in Figure 3-1. It is composed of three coffee filters positioned one above the other with an empty beaker at the bottom. Each of the filters contained three tablespoons of a mixture of 50 percent tonsil and 50 percent diatomaceous earth which is the mixture used by the industry. IRTA poured 100 milliliters of water in the top filter and waited 30 minutes. Figure 3-2 shows the apparatus as the water was passing through the filters. None of the water poured in the top filter passed through the three filters to exit in the beaker at the bottom.

This experiment demonstrates that the tonsil/diatomaceous earth mixture used by the industry effectively absorbs water. This lends credibility to the claim that bacteria is not as big an issue for cleaners using hydrocarbon with tonsil as it is for cleaners using hydrocarbon without tonsil. Even tonsil users, however, must be careful to change out the tonsil frequently enough that it does not become saturated.

DYE SCAVENGING

The suppliers of tonsil claim that dye bleeding is not an issue for cleaners that use tonsil. At times, cleaners put colored garments into a load and the dye, because it is not fast, bleeds into the solvent and is deposited on other garments. To test the hypothesis that

Figure 3-1. Test Apparatus

Figure 3-2. Water Passing Through Filters

tonsil prevents this deposition, IRTA used the same apparatus shown in Figure 3-1. In this case, IRTA poured 150 milliliters of DF-2000 combined with red dye through the three filters. A picture of the beaker containing the DF-2000 and the red dye is shown in

Figure 3-3. As indicated in the final figure, Figure 3-4, the red dye was effectively

Figure 3-3. Beaker Containing DF-2000 and Red Dye

Figure 3-4. Beaker Containing DF-2000 With Red Dye Removed

scavenged by the tonsil/diatomaceous earth blend during the 30 minute test sequence. No red dye was observed in the liquid in the beaker at the end of the test and 75 milliliters of clear DF-2000 was obtained in the beaker.

This experiment demonstrates that the tonsil blend appears to effectively absorb dyes that are released in the cleaning process. Again, users would need to exercise care to ensure that the tonsil is changed out often enough to prevent saturation.

<u>WESSON OIL ABSORPTION</u>

The suppliers of tonsil claim that distillation is not necessary when tonsil is used by hydrocarbon cleaners. Many cleaners have been operating hydrocarbon machines with tonsil and have not used distillation for several years. Distillation is used to remove high boiling non-volatile soils or undesirable solvent soluble soils from the solvent. Some components of the insoluble soils are high boiling body and food oils.

To test the hypothesis that distillation is not necessary, IRTA used the same apparatus described above to determine whether the tonsil/diatomaceous earth mixture would absorb a high boiling oil. In this case, IRTA poured 125 milliliters of Wesson Oil through the three filters containing the tonsil and diatomaceous earth. Figure 3-5 shows the 125 milliliters of Wesson Oil before it passed through the apparatus. Figure 3-6, taken after several hours, demonstrates that only 75 milliliters of the oil passed through all three filters.

Figure 3-5. Wesson Oil Before Passing Through Test Apparatus


Figure 3-6. Wesson Oil After Passing Through Test Apparatus

This experiment demonstrates that the tonsil/diatomaceous earth does appear capable of absorbing oil. In this case, the mixture absorbed 40 percent of the oil that was used in this experiment. This lends some credence to the claim that distillation is not necessary when the tonsil blend is used.

HYDROCARBON CONSUMPTION

In the experiment on dye bleeding described above, 150 milliliters of DF-2000 were poured in the top filter and 75 milliliters of the DF-2000 were obtained in the beaker at the end of the experiment. Figure 3-4 above shows the beaker containing about 75 milliliters of DF-2000. Half of the DF-2000 was absorbed by the tonsil/diatomaceous earth blend. This indicates that when the sludge is disposed of as waste in the hydrocarbon process, it contains a high concentration of DF-2000. This suggests that the consumption of hydrocarbon in hydrocarbon cleaners that use tonsil could be greater than the consumption of hydrocarbon in cleaners that do not use tonsil.

To investigate this issue further, IRTA calculated the consumption for the case study cleaning facilities discussed in Section II. In each case, consumption is defined as the annual pounds of garments cleaned divided by the annual gallons of hydrocarbon purchased. Table 3-1 summarizes the results of the calculations and specifies the tonsil users with a T in parentheses next to the plant name.

Table 3-1
Annual Consumption of Hydrocarbon for Case Study Facilities

Facility	Annual Hydrocarbon Usage (gallons)	Poundage Cleaned Per Year	Consumption (Pounds Per Gallon)
Crown (T)	600	168,000	280
Flair--Santa Monica (T)	600	165,000	275
Flair--Studio City (T)	605	158,600	262
Flair--Valencia (T)	660	286,000	433
Flair--West Los Angeles	1,238	312,000	252
Porter Ranch (T)	150	73,500	490
Sterling	330	254,800	772

The consumption figures are influenced by two factors. The first factor is the amount of hydrocarbon emitted and the second factor is the amount of hydrocarbon that remains in the waste. The higher the emissions and the higher the amount in the waste, the lower the consumption.

The five facilities that use tonsil have consumption figures that range from 262 to 490 pounds of garments per gallon of hydrocarbon used. One of the facilities that does not use tonsil is Flair--West Los Angeles and this facilities has a slightly lower consumption figure than the facilities that use tonsil. The Flair--West Los Angeles facility was one of the first facilities in Southern California to convert to hydrocarbon. The equipment used by the facility is not efficient and it may not be as conservative of emissions as the equipment in most of the other facilities. Sterling does not use tonsil and has a very high consumption figure of 772 pounds of garments per gallon of hydrocarbon used.

The major tonsil supplier has incorporated into dry cleaning machines a feature that may lead to better consumption for tonsil hydrocarbon cleaners. The feature involves compressing the tonsil sludge to obtain some of the hydrocarbon for reuse.

COMPARISON OF CLEANING CAPABILITY

IRTA used two methods to compare the cleaning capability of hydrocarbon processes using tonsil and not using tonsil. The first method of comparison is to examine the cleaning results of facilities that use tonsil and subjectively evaluate whether the cleaning is acceptable. Tonsil has been on the market for at least four years. Several cleaners have used tonsil regularly for a three year period. Others have used tonsil for a shorter period. Most of the cleaners that have converted from PERC to hydrocarbon or have started up new hydrocarbon facilities are very experienced dry cleaners. Most of the facilities using hydrocarbon are also using tonsil. In interviews with tonsil users, IRTA has determined that the cleaners are satisfied with the cleaning capability of hydrocarbon with tonsil process. Furthermore, these tonsil users indicate that their customers are satisfied with the cleaning capability of the process.

Description of Cleaning Test

The second method of comparing the cleaning capability of the tonsil and non-tonsil process is to use a traditional set of cleaning performance tests in the evaluation. IRTA relied on the Cleaning Performance Test (CPT) developed by the International Fabricare Institute (IFI) to test the cleaning capability of garments cleaned with tonsil and without tonsil. The IFI is a large national trade association of dry cleaners and allied industries businesses.

The IFI developed the CPT for their members so cleaners could assess the cleaning capability of their specific dry cleaning system. IFI indicates that one of the limitations of the CPT is that it measures the effect of the total cleaning process. They cannot be used under plant conditions to measure the contribution of individual component parts of the process. As an example, IFI states that the CPT cannot be used under plant conditions to evaluate a detergent only. Other factors like the solvent used or the characteristics of the equipment could also influence the results. With the limitations in mind, IRTA processed eight loads of garments under plant conditions to compare the CPT results for four loads of garments cleaned in hydrocarbon with tonsil and four loads of garments cleaned in hydrocarbon without tonsil.

The CPT involves cleaning five swatches stapled on a towel. The CPT towel is pinned in all four corners to a garment that goes through the cleaning process. Five different types of tests are conducted. First, two white swatches, a 65 percent polyester/35 percent cotton swatch and a 100 percent cotton swatch, are used for the graying test. This test measures soil redeposition. The percentage of graying is measured. Second, the percentage of yellowing is measured for the same polyester/cotton and 100 percent cotton swatches. Third, the percentage of whiteness is measured for the two swatches. Fourth, a white acetate swatch treated with table salt and a violet polyester swatch treated with food dye are used to measure the efficiency of water soluble soil removal. Fifth, a 100 percent cotton swatch containing rug soil is used to evaluate solid soil removal.

The IFI instructions indicate that the CPT towels should not be prespotted. IFI indicates that water soluble soil removal will be low in most cases and this is expected. As discussed below when the results are presented, this was the case for the eight IRTA runs.

IFI also recommends that the CPT towel be run in a light colored load. Dark fabrics usually carry much more soil than light fabrics; dark lint can have a strong effect on white swatches; and dark fabrics may have dyes which bleed. All eight of IRTA's runs were light loads.

IFI suggests that the CPT be run for a 20 minute wash cycle for the testing in a hydrocarbon system. Because most hydrocarbon dry cleaners use a shorter cycle of 10 minutes, IRTA decided that the cleaning test should be conducted to mimic what happens in a dry cleaning facility. The total cycle time, including wash, extract and dry was about one hour and five minutes.

The machine that was used for the testing was a Bergparma Force machine with a 40 pound capacity. Figure 3-7 shows a picture of this machine. Four loads of light colored garments were run without tonsil and with tonsil with the CPT towel. A picture of the CPT towel is shown in Figure 3-8. A picture of one of the loads in a basket before cleaning is shown in Figure 3-9 and a picture of the garments after cleaning is shown in Figure 3-10. In the case of the tonsil runs, no detergent was used. In the case of the runs without tonsil, the detergent that was used was Hydroclene Injection Detergent. A picture of the detergent is displayed in Figure 3-11. The amount of detergent used was based on the rule of one ounce of detergent per 10 pounds of clothing. The pounds of garments run was in the range of 30 pounds so about three ounces of detergent was used in the non-tonsil runs.

<u>Results of the Cleaning Test</u>

When each of the eight cleaning cycles was completed, IRTA removed the CPT towel from the garment and packaged it for mailing to IFI. IRTA also filled out the form that labels and describes each run but did not indicate to IFI that this was a test of tonsil.

Figure 3-7. Machine Used in Cleaning Performance Tests


Figure 3-8. CPT Towel Before Cleaning Runs

Figure 3-9. Load of Light Garments Processed in Cleaning Tests

Figure 3-10. Light Garments After Cleaning

Figure 3-11. Detergent Used in Cleaning Tests

The CPT test results are presented on a ranking scale. Table 3-2 shows this ranking scheme. The results are presented below the ranking scale and are given a numerical rating and a class rating (excellent, good, fair and poor).

Table 3-2
IFI Cleaning Performance Test Report

	% Graying		Yellowing		% Whiteness		Water Soluble Soil	Rug Soil
	Poly/C	C	Poly/C	C	Poly/C	C		
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-51	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73

The full results of the eight runs are presented in Appendix B. These results are summarized in Table 3-3.

Table 3-3
Results of the IRTA IFI CPT Tests for Tonsil and Non-Tonsil

	% Graying		Yellowing		% Whiteness		Water	Rug
	Poly/C	C	Poly/C	C	Poly/C	C	Soluble Soil	Soil
#1NT	E	G	E	G	E	G	P	G
#2NT	E	E	E	G	E	E	P	F
#3NT	E	P	F	G	G	F	P	P
#4NT	E	E	E	G	E	E	P	E
Average	2.5 E	3.75 E	0.75 E	1.0 G	95.3 G	91.8 G	0 P	79.3 F
#1T	E	E	G	E	E	E	P	P
#2T	G	E	E	G	E	E	P	P
#3T	G	E	E	G	E	E	P	F
#4T	E	G	G	G	E	G	P	P
Average	4.3 E	3.0 E	0.5 E	0.8 E	95.0 E	94.3 E	0 P	70.3 P

Note: NT is non-tonsil and T is tonsil.

In Table 3-3, the results are presented for the eight runs with a qualitative ranking. The average value listed for the set of four runs is an average of the quantitative values and a qualitative ranking of the average value.

The figures indicate that the tonsil and non-tonsil runs both resulted in an excellent rating on average for % Graying for both the polyester/cotton and the cotton swatches. The lower the value for % Graying, the better the cleaning. The tonsil runs gave a higher rating for the polyester/cotton swatch than the non-tonsil runs and a lower rating for the cotton swatch. This indicates that the tonsil runs performed better than the non-tonsil runs on the cotton swatch but did not perform as well as the non-tonsil for the polyester/cotton swatch.

In terms of yellowing, the lower the value, the better the performance. The non-tonsil and tonsil runs both had an excellent rating on average for the polyester/cotton swatch. The non-tonsil runs had a good rating for the cotton swatch whereas the tonsil runs had an excellent rating for the cotton swatch.

For % Whiteness, the higher the value, the better the performance. Both the tonsil and non-tonsil runs for the polyester cotton swatch resulted in an excellent rating on average. For the cotton swatch, the tonsil runs were rated excellent on average whereas the non-tonsil runs were rated as good on average.

Both the tonsil and non-tonsil runs had poor water soluble soil removal on average. As discussed above, this is to be expected because no pre-spotting was performed as recommended by IFI.

For rug soil removal, the higher the value, the better the performance. For the non-tonsil runs, the rug soil rating was fair on average whereas it was poor on average for the tonsil runs.

According to IFI, high yellowing and low whiteness can be a result of high non-volatile residue content in the solvent and the recommendation is to increase distillation. The other possible explanation is a possible excess dye in the solvent. Since the garments were all light loads, this second point would not apply. For yellowing and whiteness, the tonsil runs on average performed somewhat better than the non-tonsil runs. This indicates that distillation may not be necessary for cleaners using tonsil. The tonsil is also used as a bleaching agent so it may contribute to a higher whiteness of the garments.

The graying is a result of soil redeposition. IFI makes several suggestions for garments if the graying is too high. One of the suggestions is to increase distillation. On average, the tonsil runs showed a slightly better performance than the non-tonsil runs. Again, this indicates that distillation may not be necessary for tonsil cleaners.

The poor water soluble soil removal ratings for both the tonsil and non-tonsil runs likely indicates that pre-spotting is necessary to remove the water soluble stains from the garments.

Poor rug or solid soil removal can be a result of several factors, according to IFI. Two of these are low detergent content in the solvent and too short a wash time. The rating for the non-tonsil rug soil removal on average was fair and the rating for the tonsil rug soil removal on average was poor. Both these ratings are low which may be a result of too short a washing time. The rug soil removal was better with the non-tonsil, however, and this may be a result of the fact that no detergent was used in the tonsil runs.

COMPARISON OF ENERGY REQUIREMENTS

IRTA analyzed the energy requirements for hydrocarbon users in two ways. First, two of the facilities using hydrocarbon with tonsil provided utility usage figures for gas and electrical requirements directly from the utility bills. From this information, IRTA was able to compare the utility requirements when the facility used PERC and after the conversion to hydrocarbon with tonsil. Second, IRTA measured the electricity and gas usage directly for a hydrocarbon machine for two cycles where tonsil was used and two cycles where tonsil was not used.

Facility Utility Use

Crown and Porter Ranch provided IRTA with utility figures taken directly from utility bills. Both of these facilities used PERC before they converted to hydrocarbon cleaning. Crown's electricity cost declined from $11,760 per year when the facility used PERC to $9,600 per year after the conversion. Crown's gas cost declined from $5,400 per year with PERC to $5,100 after the conversion. For Porter Ranch, the electricity cost declined from $10,520 per year with PERC to $9,500 per year after the conversion and the gas cost declined from $10,300 to $9,800 annually. Both facilities use tonsil and both facilities experienced a lower cost for both gas and electricity after the conversion.

Sterling is the only facility that converted from PERC to hydrocarbon that does not use tonsil. Flair--West Los Angeles did make the conversion but the information on the costs with PERC was not available. Sterling estimated the cost of gas and electricity before and after the conversion but did not provide utility bills. Sterling's electricity cost increased from $21,100 with PERC to $26,600 with hydrocarbon. Sterling's gas cost increased from $19,100 with PERC to $21,800 with hydrocarbon.

The data suggest that utility costs are lower when tonsil is used with hydrocarbon than when tonsil is not used. This conclusion does not take into account fluctuations in gas and electricity costs and it is based on information from only three facilities. The conclusion is obviously suggestive rather than rigorous.

Utility Usage Tests

For the set of tests comparing the energy requirements for tonsil and non-tonsil cleaning runs, IRTA used the same Bergparma Force machine with a capacity of 40 pounds that was used in the cleaning tests. The machine did not have a refrigerated condenser and it included a distillation unit. Four sets of runs were conducted using the equipment. The same garments were processed for all four runs and 35 pounds of garments were used.

The cycle time for purposes of the testing began when the dry cleaning machine started processing the garments and ended when the machine stopped. The time allotted to loading and unloading the garments was not part of the cycle time.

The natural gas use was measured at the meter on the line entering the facility where the testing was conducted. A picture of the gas meter is shown in Figure 3-12. IRTA read the meter at the beginning and end of each cycle. Gas is used in the facility for the dry cleaning machine and a hot water heater. The hot water heater was operating during the testing and may have used a small amount of gas during a cycle. The hot water heater use was constant over all four cycles and the gas used for this purpose was likely to be minimal.

The electricity use was measured with a continuous monitor installed by Southern California Edison specifically for this testing; a picture of the monitor is shown in Figure 3-13. Figure 3-14 shows a plot of the electricity use in kilowatts (the y axis of the plot) over time (the x axis of the plot). The monitor gives a reading at 15 minute intervals. The reading at a particular 15 minute interval is the average reading for the previous 15 minute period. As an example, consider run #2 which began at 10:50 a.m. The 11:00 a.m. data point measured the five minutes before the cycle and the 10 minutes during the cycle. The 11:15, 11:30 and 11:45 a.m. data points were taken during the cycle and the 12:00 p.m. data point measured the electricity use for the last five minutes of the cycle.

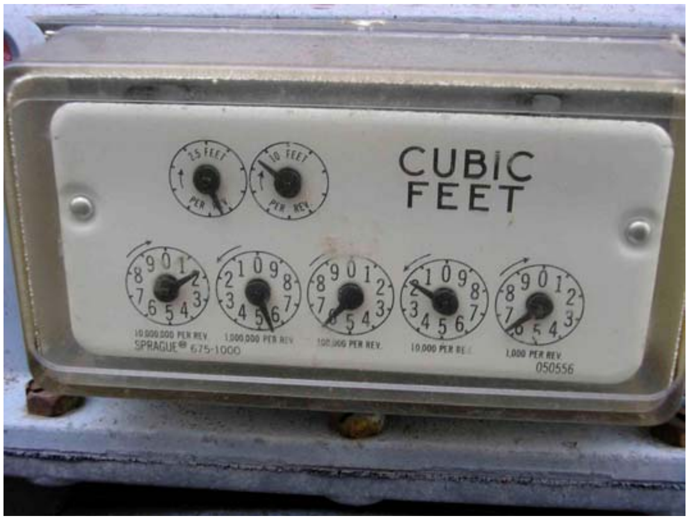


Figure 3-12. Gas Meter Used for the Gas Measurements

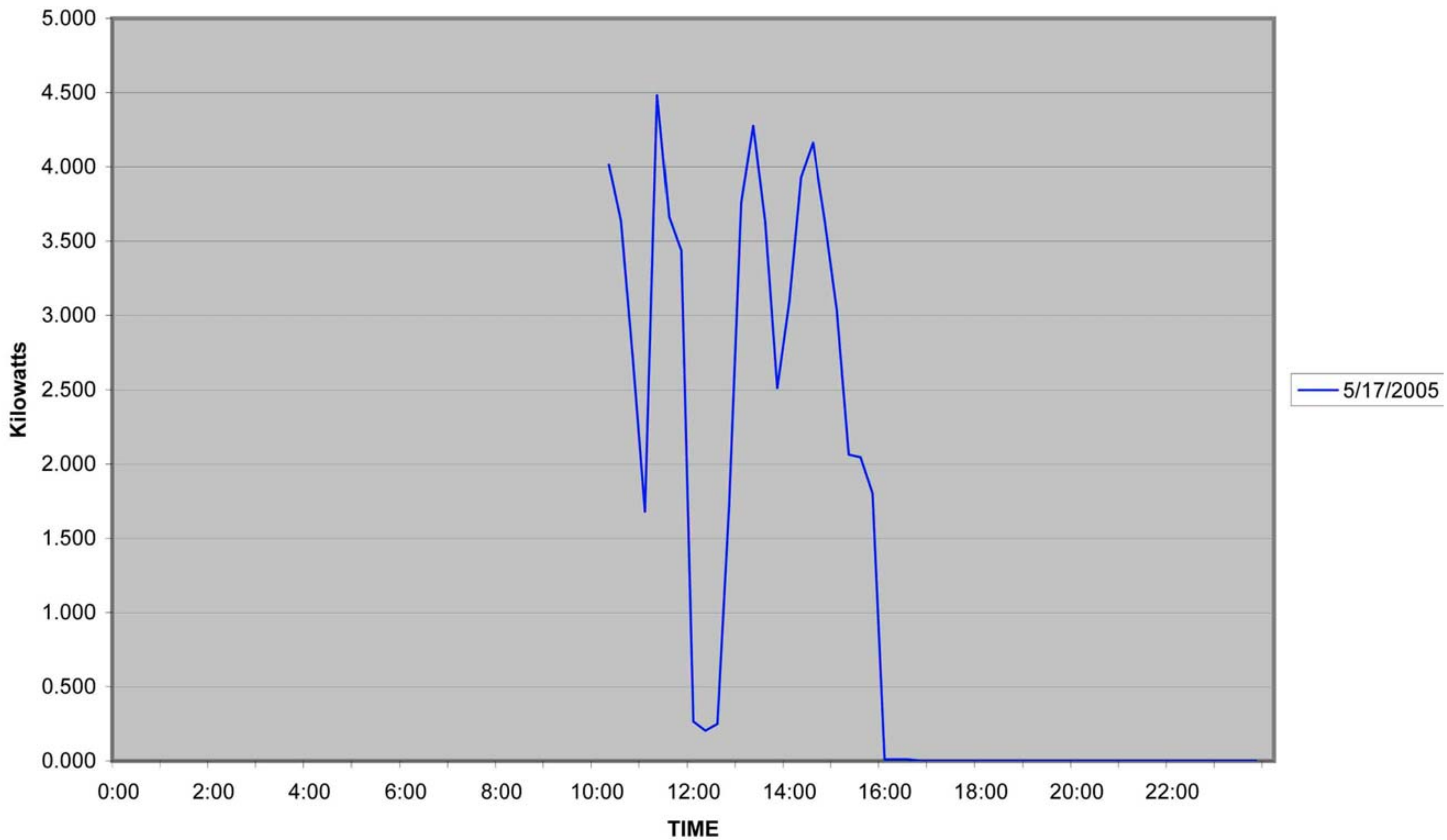

Figure 3-13. Monitor Used for the Electricity Measurements

Because the data points did not coincide with the beginning and end of a cycle, a correction was made. In this correction, IRTA used the average of the interval before the cycle started and the interval just after the cycle started to determine the electricity use for the first interval. At the end of the cycle, a similar correction was made.

The first run included no data for the first two intervals at 9:45 a.m. and 10:00 a.m. because the cleaning cycle started before the monitor was turned on. These first two intervals were assumed to have the same values as the second run.

Table 3-4 shows the results of the utility use for the four machine runs. All four runs included 35 pounds of garments. The first column of the table identifies the run. The first two loads were run with tonsil (indicated by the T in parentheses) and no distillation and the second two loads were run without tonsil and with continuous distillation. The second column shows the length of the cycle in minutes. The third and fourth columns

Figure 3-14
Electricity Monitor Measurements



show the gas meter readings in million cubic feet at the beginning and end of the cycle respectively. The fifth column shows the gas consumption for the run in million cubic feet. The sixth column shows the electricity consumption for each run in kilowatts.

Table 3-4
Utility Use With Tonsil and Without Tonsil

Run	Cycle Time (minutes)	Gas Reading Start (mcf)	Gas Reading End (mcf)	Gas Usage (mcf)	Electricity Usage (kW)
1 (T)	63	15617.6	15619.5	1.9	17.409
2 (T)	62	15619.5	15621.2	1.7	16.513
3	60	15622.3	15624.8	2.5	17.477
4	63	15625.0	15627.5	2.5	17.889

The figures of Table 3-4 illustrate that the gas usage and electricity usage for runs #1 and #2 are both lower than for runs #3 and #4. The first two loads were run with tonsil and the second two were not but the second two runs included continuous distillation. Taking the average of the first two runs and the second two runs, the gas usage for the tonsil runs is 28 percent lower than the gas usage for the non-tonsil runs. The electricity use for the tonsil runs is four percent lower than the electricity use for the non-tonsil runs.

The results of this analysis are limited because the data were taken for only four loads. They do suggest that utility requirements for tonsil users are likely to be lower than utility requirements for non-tonsil users. Distillation is not generally performed for facilities using tonsil. Distillation involves pulling a vacuum and heating the hydrocarbon to the boiling point; it primarily uses gas but it also uses some electricity. A tonsil user would be expected to use less gas and this is observed in the figures. A tonsil user might also be expected to use less electricity but the difference in electricity use should be smaller. This is also observed in the figures.

IV. HEALTH AND ENVIRONMENTAL CHARACTERISTICS OF THE HYDROCARBON PROCESS

This section presents the approach to and results of the waste analysis conducted by IRTA and the DTSC Hazardous Materials Laboratory (HML). It then focuses on a problem for hydrocarbon cleaners in evaporating their separator water. It describes certain characteristics of the hydrocarbon solvents. Finally, it presents an analysis of the toxicity and health effects of hydrocarbon solvents, tonsil and diatomaceous earth.

ANALYSIS OF WASTE STREAMS

In general, the facilities using hydrocarbon are currently disposing of their wastes as hazardous wastes. In the earlier project sponsored by CARB and U.S. EPA, some analysis of hydrocarbon waste streams was conducted. The results indicated that the hydrocarbon waste streams might not be classified as hazardous waste. During this project, IRTA and HML conducted a much more detailed investigation of the waste streams to determine whether they are classified as hazardous waste.

IRTA collected samples from eight dry cleaning facilities using the hydrocarbon process. Four of the samples were collected from machines that used tonsil and four were collected from machines that did not use tonsil. HML analyzed the waste streams. This subsection describes the waste streams that are generated, the protocol for the sampling and the results of the analysis.

Description of Waste Streams

The waste streams generated in the hydrocarbon dry cleaning process are of three types. For cleaners that do not use tonsil, the waste streams include distillation sludge, separator water and lint. For cleaners that do use tonsil, the waste streams include tonsil/diatomaceous earth sludge, separator water and lint. Nearly all new machines use permanent spin disc filters so filters no longer are a waste stream. Cleaners currently dispose of the sludge and lint with a hazardous waste transporter. They generally use an evaporator to dispose of the separator water.

Protocol for Sampling and Analysis Program

The hydrocarbons used in the dry cleaning process are various types of mineral spirits. The solvent is not a listed hazardous waste under the Resource Conservation and Recovery Act (RCRA). Thus wastes containing the hydrocarbon are not automatically considered to be hazardous wastes.

After the cleaning process, the wastes could contain metals at high enough concentrations that the stream would be classified as hazardous waste. Title 22 of the California Health and Safety Code of Regulations defines Soluble Threshold Limit Concentration (STLC) for various metals. Wastes with STLCs above the specified level are classified as hazardous waste. IRTA and HML decided to analyze the waste streams for metals.

If the flash point of a waste is lower than 140 degrees F, the waste would be classified as a hazardous waste because of its flammability characteristic. IRTA and HML decided to analyze the waste streams for flash point.

The wastes from the cleaning process were also tested for Volatile Organic Compounds (VOCs). In the hazardous waste regulations, chemicals are not on the VOC list based on their atmospheric reactivity. The term VOC, in this case, is more general and refers to volatile materials. In some cases, the VOC compound could be a RCRA listed hazardous waste. In other cases, the VOC compound might not be a RCRA listed hazardous waste. IRTA and HML decided to analyze the waste streams for VOCs.

California has additional criteria for waste streams. If the waste exhibits the toxicity characteristic by being aquatically toxic, it is classified as hazardous waste. To determine if a waste is aquatically toxic, fathead minnows are exposed for 96 hours to a sample of the waste and the LC-50 is calculated. The LC-50 is the concentration of the waste at which 50 percent of the fish die. A waste exhibits the characteristic of toxicity due to its aquatic toxicity if it has an acute 96-hour LC-50 less than 500 milligrams per liter. The smaller the LC-50 value, the more toxic to fish is the waste. IRTA and HML decided to analyze the waste streams for aquatic toxicity.

IRTA sampled the distillation sludge and separator water from four hydrocarbon cleaners that do not use tonsil. IRTA also sampled the tonsil/diatomaceous earth sludge and separator water from four hydrocarbon cleaners that do use tonsil. The sludge and separator water samples were analyzed for metals, flash point, VOCs and aquatic toxicity. IRTA sampled lint in all eight facilities and the lint was analyzed for metals for seven of the facilities. To preserve confidentiality, the name of the cleaner where sampling was conducted is not revealed. The cleaners are described as Hydrocarbon Cleaner number 1 through 4 (HC-1, HC-2, HC-3 and HC-4) or Tonsil Hydrocarbon Cleaner number 1 through 4 (THC-1, THC-2, THC-3 and THC-4). The Hydrocarbon Cleaners do not use tonsil and the Tonsil Hydrocarbon Cleaners do use tonsil.

Metals Analysis Results

The metals analysis results indicate that none of the sludge, separator water or lint samples contained any metals above their respective STLC levels. This result was not unexpected because the dry cleaning process involves cleaning garments which would not commonly contain metals. The analysis demonstrated that none of the samples was classified as hazardous waste based on the presence of metals.

Flash Point Analysis Results

The flash point analysis results indicated that none of the sludge or separator water samples had a flash point greater than 140 degrees F. The analysis demonstrated that none of the samples was classified as hazardous waste based on the characteristic of flash point.

Aquatic Toxicity Analysis Results

As discussed earlier, if the LC-50 of the sample is greater than 500 milligrams per liter in the aquatic toxicity test, the sample is classified as hazardous waste in California. Table 4-1 summarizes the results of the aquatic toxicity tests for the sludge and separator water for the eight dry cleaners. A "no" entry in the table indicates that the LC-50 of the sample was greater than 500 milligrams per liter and a "yes" entry indicates that the LC-50 of the sample was less than 500 milligrams per liter.

Table 4-1
Results of Aquatic Toxicity Testing

Cleaner	Separator Water	Sludge
HC-1	No	Yes
HC-2	No	Yes
HC-3	No	Yes
HC-4	No	Yes
THC-1	No	No
THC-2	No	No
THC-3	No	No
THC-4	No	No

The values of Table 4-1 show that the separator water from all eight dry cleaning facilities did not exhibit aquatic toxicity. The values also show that the sludge samples from the four dry cleaning facilities that do not use tonsil do exhibit aquatic toxicity and the sludge samples from the four dry cleaning facilities that do use tonsil do not exhibit aquatic toxicity.

One possible explanation for this definitive result is that the facilities that use tonsil do not use detergent whereas the facilities that do not use tonsil do use detergent. In some cases, surfactants that are present in detergents may exhibit aquatic toxicity. In earlier work with the auto repair industry, IRTA found that certain water-based cleaners containing surfactants exhibited aquatic toxicity; some exhibited aquatic toxicity before they were used and some exhibited aquatic toxicity after they were used. Surfactants are designed to lower surface tension and this makes it easier for the surfactant to penetrate the fish gill and kill the fish. In the case of hydrocarbon cleaning the detergent might also facilitate hydrocarbon penetration of the fish gill with the same result. No matter what the mechanism, it is clear from the results presented here that the waste streams from cleaners that use tonsil do not exhibit aquatic toxicity.

VOC Analysis Results

The method used to test for VOCs in the waste streams is EPA Method 8260B "volatile organic compounds by GC/MS. Table 4-2 summarizes the results of the analysis of the separator water and the sludge for the eight facilities that were sampled. The table includes the analysis results for only two VOCs, PERC and trichloroethylene (TCE), another chlorinated solvent. As discussed below, other VOCs were also found in several of the waste streams.

Table 4-2
VOCs Found in Analysis of Separator Water and Sludge

Facility	VOC	Separator Water Concentration (micrograms per liter)	VOC	Sludge Concentration (milligrams per kilogram)
THC-1	PERC	30,000	PERC	19
	TCE	9,000	TCE	6
THC-2	PERC	230	PERC	1,900
	TCE	2,400	TCE	400
THC-3	PERC	ND	PERC	3
	TCE	ND	TCE	ND
THC-4	PERC	6	PERC	30
	TCE	ND	TCE	ND
HC-1	PERC	71	PERC	ND
	TCE	ND	TCE	ND
HC-2	PERC	ND	PERC	130
	TCE	ND	TCE	ND
HC-3	PERC	17	PERC	2
	TCE	2	TCE	ND
HC-4	PERC	16,000	PERC	12
	TCE	ND	TCE	ND

The figures in Table 4-2 show that PERC was found in the separator water at six of the eight cleaners. PERC was found in the sludge at seven of the eight cleaners. TCE was found in the separator water at three of the eight cleaners and it was found in the sludge at two of the cleaners. Although the source of the PERC is not known with certainty, it might have two origins. First, PERC is used in spotting chemicals that are used to pre-spot garments. Second, a PERC residual could remain in garments previously cleaned in a PERC machine. The source of the TCE is likely to be spotting chemicals, some of which contain the chemical.

Other VOCs were found when the separator water and sludge was analyzed. Acetone, for example, was found in the separator water at all eight cleaners and it ranged in concentration from 800 to 49,000 micrograms per liter. Acetone was not found in the sludge at any of the cleaners.

Other VOCs that were found at seven of the facilities in either the separator water or the sludge included:

- 2-hexanone
- methyl ethyl ketone (MEK)
- methyl isobutyl ketone (MIBK)
- xylene
- isopropyl benzene
- n-propyl benzene
- 1,3,5-trimethylbenzene
- 1,2,4-trimethylbenzene
- sec-butylbenzene
- naphthalene
- CFC-12
- chloromethane

At one of the cleaners, the separator water was heavily contaminated with organic solvent when it was sampled. The separator water contained some of the components identified at the other seven facilities. In addition, other VOCs that were found included bromochloromethane and toluene.

The origin of the acetone and other common solvent cleaners like MEK, MIBK, toluene and xylene is likely to be spotting chemicals. Some of the other components like naphthalene and the benzene derivatives could be present in trace quantities in the spotting chemicals or in the hydrocarbon used for dry cleaning. CFC-12 may still be used by some cleaners in refrigerated condensers in the dry cleaning equipment.

All of the cleaners that were sampled were found to have PERC or TCE in either the separator water, the sludge or both. The presence of the PERC and TCE in the waste makes the waste hazardous because both chemicals are listed hazardous wastes under RCRA. The wastes are called F001 or F001 listed wastes. F001 includes the two chemicals as spent halogenated solvents used in degreasing. F002 includes the two chemicals as spent halogenated solvents. The categories include "all spent solvent mixtures or blends containing, before use, a total of ten percent or more (by volume) of one or more of the above halogenated solvents....." PERC and TCE are used in certain spotting chemicals called Paint, Oil and Grease (POG) removers and their concentration is well above ten percent by volume. Acetone is classified as an F003 listed hazardous waste. Some of the other solvents that were found, including xylene, MIBK, toluene and MEK, are also classified as listed hazardous wastes under the F003 and F005 categories.

Summary of Waste Analysis Results

The detailed laboratory analysis results are presented in Appendix C, an appendix that is separate from this report. For the VOC analysis, the tonsil facilities in the appendix are designated as TPDC #1 through TPDC #4 and the non-tonsil facilities are designated as PDC #1 through PDC #4. Interested parties can obtain this appendix from DTSC.

The results of the analysis indicate that separator water and sludge from the hydrocarbon cleaning process where tonsil is used are not, by themselves, classified as hazardous waste. The separator water from the hydrocarbon cleaning process where tonsil is not used is not, by itself, classified as hazardous waste. The sludge from the hydrocarbon cleaning process where tonsil is not used is classified as hazardous waste. The separator water and sludge from the eight hydrocarbon cleaners that use tonsil and that do not use tonsil are classified as hazardous waste because of the presence of PERC, TCE, acetone or other VOCs.

The likely origin of the PERC, TCE and acetone is spotting chemicals. If hydrocarbon cleaners using tonsil did not use spotting chemicals containing listed hazardous wastes, the results indicate that the wastes generated in the process would not be classified as hazardous wastes. IRTA has recently initiated a project sponsored by DTSC and U.S. EPA Region IX that focuses on finding low toxicity, low-VOC alternative spotting chemicals.

Evaporation of Separator Water

One of the waste streams generated in the hydrocarbon cleaning process is separator water which was discussed earlier. Water enters the dry cleaning equipment on the garments and a small amount may be added to clean water soluble contaminants. The water that exits the process is passed into a separator where most of the hydrocarbon is physically separated from the water. The hydrocarbon is lighter than water so it can be bled from the top of the separator for reuse. The remaining water still contains a small amount of hydrocarbon and it may also contain small quantities of other solvents that are used in spotting chemicals, as described earlier.

Many years ago, when virtually all dry cleaners used PERC, the practice for many years was to pour the separator water, in this case contaminated with PERC, into the sewer. Because of problems from soil and ground water contamination from PERC, dry cleaners began using evaporators to treat the PERC separator water. Because PERC is a RCRA listed hazardous waste, the separator water is classified as a hazardous waste. DTSC requires a hazardous waste treatment permit for a generator to evaporate PERC containing separator water. Because there are so many dry cleaners in California and because nearly all of them would need to use evaporators to treat separator water, DTSC granted an exclusion for the separator water to be treated with an evaporator without the need for a treatment permit if certain conditions were met. The section of the California

Health and Safety Code that provides this exclusion for PERC dry cleaners is presented in Appendix D.

The exclusion pertains only to dry cleaners who are evaporating separator water containing PERC; it does not apply to dry cleaners who are evaporating separator water containing hydrocarbon. Local hazardous waste inspectors are telling dry cleaners that using evaporators to treat hydrocarbon laden separator water without a treatment permit is not currently allowed by the statute. This is causing some confusion in the dry cleaning industry.

The Bay Area Air Quality Management District wrote a letter dated June 8, 2005 to DTSC asking for clarification on the issue of evaporating non-PERC containing separator water. The Korean Drycleaners & Laundry Association of Southern California also wrote a similar letter dated July 15, 2005 to DTSC on the same issue. DTSC responded to both letters by indicating that under current law, evaporation of non-PERC containing separator water without a treatment permit, is not allowed. All four of these letters are included in Appendix D.

The results of the analysis conducted during this project indicate that separator water generated in the hydrocarbon dry cleaning process that does not contain listed hazardous wastes like PERC and TCE is not classified as hazardous waste. Such non-hazardous wastes would not require a DTSC treatment permit to be evaporated. Because so many hydrocarbon dry cleaners are likely to be using spotting chemicals containing PERC, TCE and other listed hazardous wastes, however, it would be prudent to change the statute to allow the evaporation of hydrocarbon separator water. Section 25201.8 (6) specifies that "The effluent is a hazardous waste solely due to its PCE (perchloroethylene) content." This section would need to be changed to read "due to its PCE (perchloroethylene) and hydrocarbon content" to allow hydrocarbon dry cleaners to use evaporators to treat their separator water without the need for a treatment permit. DTSC is supportive of changing the statute but cannot make the change internally. A bill that specifies the change would have to be introduced and passed by the legislature and signed by the Governor. IRTA is searching for a sponsor for such a bill.

CHARACTERISTICS OF HYDROCARBON SOLVENTS

Several different hydrocarbon solvents are used in the dry cleaning industry today. DF-2000, a product from Exxon Mobil, is the most widely used hydrocarbon in dry cleaning. Other hydrocarbons used for dry cleaning include: Ecosolv, offered by Chevron Phillips; Shell Sol 140 HT, offered by Shell Oil Company; and Hydroclene, offered by Caled Chemical. All of the hydrocarbons have flash points. Table 4-3 lists the flash points for each of the hydrocarbons.

Table 4-3
Hydrocarbon Flash Points

Product	Flash Point (degrees F)
DF-2000	147
Ecosolv	142
Shell Sol 140 HT	143
Hydroclene	145

The flash points of the hydrocarbons used in dry cleaning are higher than 140 degrees F. This allows the materials to be used in shopping centers.

Under the air regulations, VOCs are chemicals that are more reactive then ethane. Unless solvents are specifically exempted by U.S. EPA, they are considered to be VOCs which contribute to photochemical smog. PERC has been deemed exempt from VOC regulations and it is not classified as a VOC. All of the hydrocarbons used in the dry cleaning industry are classified as VOCs.

The CARB survey indicates that typical DF-2000 dry cleaning machines emit about 36 gallons or 230 pounds of hydrocarbon annually. CARB estimates that, if all dry cleaning facilities in California converted to hydrocarbon, the VOC emissions from dry cleaning would amount to about two tons per day.

Toxicity of Hydrocarbon Solvents

MSDSs for four of the hydrocarbon solvents used in California are shown in Appendix A. The Department of Health Services Hazard Evaluation System and Information Service (HESIS) reviewed the MSDSs to evaluate the potential toxicity of the hydrocarbon solvents. This subsection is based on the HESIS assessment.

The DF-2000 hydrocarbon is listed as “Synthetic Aliphatic Hydrocarbon, Hydrotreated.” Based on the CAS number provided on the MSDS, this chemical is “Naphtha (Petroleum) Hydrotreated Heavy.” According to the American Chemistry Council (ACC), this material consists of complex hydrocarbon reaction products that are predominantly C5 (five carbon atoms) through C12 (12 carbon atoms). The category is in a production stream with a reported typical analysis that includes 23 percent toluene, 32 percent C8 aromatics and one percent naphthalene, with the balance primarily other aromatics and lesser amounts of paraffins.

EPA has established a program called the High Production Volume (HPV) challenge. This is a voluntary industry testing program designed to obtain health and environmental data on nearly 2,800 chemicals that are produced or imported in quantities greater than one million pounds annually. About 400 American chemical companies have volunteered to sponsor testing for approximately 2,300 chemicals on the list. The ACC is sponsoring the Naphtha (Petroleum) Hydrotreated Heavy category. The ACC concluded that this category is of low acute toxicity, is unlikely to induce genetic damage in vivo and is unlikely to induce reproductive or developmental toxicity. They further concluded that existing data adequately characterized this category. There is no indication on the EPA website that EPA disagrees with this conclusion.

The MSDS for DF-2000 indicates health hazards that are consistent with other organic solvents. Inhalation exposure to this hydrocarbon can depress the central nervous system and cause symptoms similar to those caused by drinking alcohol. Vapors can irritate the eyes, nose, throat and lungs. Frequent or prolonged skin contact can cause irritation and dermatitis.

The category Naphtha (Petroleum) Hydrotreated Heavy is not regulated by the California Occupational Safety and Health Administration (Cal/OSHA). Exxon Mobil recommends a Time Weighted Average (TWA) of 1200 milligrams per meter cubed or 171 ppm for the hydrocarbon.

The MSDS for Ecosolv Dry Cleaning Fluid lists C10 to C13 isoalkanes as more than 99 percent of the product. HESIS found no toxicity information on this category of chemical. The category is an HPV chemical but the EPA HVP website had no reference to a test plan or robust summary. In a toxicity study performed on isoparaffins (J. Appl. Toxicol., 1990, 10(2), p 135), the authors report that isoparaffins have a very low order of acute toxicity, are not dermal irritants and did not produce symptoms in human volunteers exposed to 100 ppm for six hours.

Information on the MSDS for Ecosolv Dry Cleaning Fluid also supports the indication of low toxicity. Like DF-2000, risk and safety phrases on the MSDS are consistent with solvent toxicity.

C10 to C13 isoalkanes are not regulated by Cal OSHA. Chevron Phillips recommends an exposure level of 1200 milligrams per meter cubed, the same level recommended by Exxon Mobil for DF-2000.

The MSDS for Shell Sol 140 HT and the MSDS for Hydroclene list the same CAS number for their hydrocarbon. The hydrocarbon, according to the Shell MSDS, is a complex combination of predominantly C9 to C12 hydrocarbons. The CAS number is described as "Solvent Naphtha (Petroleum), Medium Aliphatic."

Little toxicity information for the chemical was found by HESIS. One website, sponsored by Environmental Defense (http://www.scorecard.org/chemical-profiles/summary.tcl?edf_substance_id-64742-88-7) lists Solvent Naphtha (Petroleum), Medium Aliphatic as less hazardous than most chemicals in three ranking systems for human health, ecological health and combined human and ecological health.

This category is being sponsored by the ACC under the EPA HPV Challenge program. HESIS could find no information on development of a test plan or robust summary on the EPA HPV website.

Petroleum Distillates or Naphtha is not on Cal/OSHA's List of Permissible Exposure Limits (PELs). Since Cal/OSHA standards have to be at least as protective as Federal OSHA standards, the Cal/OSHA PEL should be consistent with the OSHA PEL of 2000 milligrams per meter cubed or 500 ppm. The Hydroclene MSDS does not recommend a TWA for their hydrocarbon. The Shell MSDS lists an OSHA PEL as 100 ppm. This PEL is inconsistent with information from the OSHA website and with the National Institute for Occupational Safety and Health (NIOSH) Occupation Health Guideline which lists it as 500 ppm. The MSDS also lists the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) as 100 ppm. However, there is no ACGIH TLV for Solvent Naphtha (Petroleum), Medium Aliphatic in the 2005 TLV booklet.

Based on the available information, the toxicity of all of the hydrocarbons is consistent with that of solvents in general. None of them pose risks of cancer and they are not selective reproductive or developmental toxicants. As mentioned in the introduction section, PERC is a carcinogen and a toxic air contaminant. HESIS has calculated the risk posed by PERC at the Cal/OSHA PEL of 25 ppm to a worker; this risk, at 13 percent or 130 in 1,000, is very high. HESIS considers the hydrocarbons safer alternatives to PERC due to their lower toxicity.

Toxicity of Tonsil and Diatomaceous Earth

HESIS also evaluated the MSDSs for and the toxicity of Tonsil and diatomaceous earth. This subsection summarizes the HESIS evaluation.

The MSDS for Tonsil lists the ingredients as 94 to 99 percent Bentonite Acid Leached and one to six percent Crystalline Silica (quartz). Bentonite is a naturally occurring clay material that is presumably non-toxic since it is contained in some nutritional products and is marketed as a component of diet products. The CAS number that corresponds to bentonite is on the EPA "List of Other (Inert) Pesticide Ingredients List 4--Inerts of Minimal Concern" and is identified as "Clay." HESIS did not find any information on toxicity data in standard toxicology databases.

Crystalline silica is listed as a carcinogen on the Proposition 65 List in California. On December 10, 2005, the Office of Environmental Health Hazard Assessment (OEHHA) adopted a Chronic Reference Exposure Level (REL) for silica of three micrograms per meter cubed (respirable) to prevent lung damage from silicosis. The CAS number for silica for which the REL was developed is 7631-86-9. This CAS number is identified by EPA and NIOSH as low toxicity, "Amorphous, Hydrated Silica." It is not clear why OEHHA used this CAS number instead of 14808-60-7, the CAS number for crystalline silica listed on the Tonsil MSDS.

The chronic inhalation health hazards of crystalline silica are addressed on the MSDS. The Cal/OSHA PEL for crystalline silica is 0.1 milligrams per meter cubed (respirable dust). A Cal/OSHA Advisory Committee recently proposed lowering the PEL to 0.01 milligrams per meter cubed and this proposal is under consideration.

The MSDS for diatomaceous earth lists the ingredient as “Kieselguhr, Soda Ash Flux-calcined” as 100 percent. It also indicates that the product may contain up to 75 percent crystalline silica in the form of cristobalite at less than 70 percent and quartz at less than five percent. Both cristobalite and quartz are crystalline silica.

The health hazards of crystalline silica are described on the MSDS. For inhalation, the MSDS indicates that crystalline silica causes dryness and irritation to the respiratory tract. It also indicates that excessive inhalation may cause decreased pulmonary function, lung damage and silicosis. Acute silicosis is manifested by dyspnea, fever, cough and weight loss. Severe respiratory symptoms may lead to death. For chronic exposure, the MSDS indicates that prolonged inhalation exposure may produce silicosis. Progressive respiratory and cardiopulmonary impairment may be fatal. Chronic inhalation of crystalline silica is a lung cancer hazard. Other health hazard information is discussed above under Tonsil.

Diatomaceous earth is an absorbent that is used extensively. It is used as a filter aid for beer, wine, fruit juices and vegetable oils, in the paint, varnish, lacquer and polish industries, as a pest control agent and as a filtering agent in swimming pools. Crystalline silica is dangerous when it is an airborne dust. When it is wet, it does not pose a danger. Diatomaceous earth has been used widely in the dry cleaning industry as an absorbent for 50 years.

Diatomaceous earth contains a much higher level of crystalline silica than does tonsil so it potentially poses more of a danger. Dry cleaners and suppliers should be concerned about exposure to the 50 percent/50 percent blend of tonsil and diatomaceous earth when it is dry and airborne. As discussed earlier, the blend is supplied to cleaners in ziplock bags and the mixture is wet when it is disposed of as waste so potential exposure and health risks from inhalation should be minimal.

V. SUMMARY AND CONCLUSIONS

Eighty-two percent of the dry cleaning machines in California use PERC. The chemical is a carcinogen that poses a significant risk to workers and community members. The major alternative to PERC in dry cleaning is hydrocarbon which is currently used by more than 10 percent of dry cleaners.

The SCAQMD has adopted a regulation that will phase out PERC use in dry cleaning in 2020. CARB is developing more stringent standards for PERC dry cleaning users. Most cleaners lease their facilities and landlords are requiring cleaners to stop using PERC when their leases are renewed. Over the next 10 or 15 years, there is likely to be substantial conversion to alternatives in dry cleaning and a significant fraction of dry cleaners will convert to hydrocarbon.

This document examines in more detail the characteristics of the hydrocarbon dry cleaning process. IRTA analyzed the performance and cost of seven dry cleaners using the hydrocarbon process. IRTA presents cost comparison data for PERC and hydrocarbon dry cleaning for five of the facilities. IRTA presents cost data for hydrocarbon dry cleaning for the remaining two facilities. The results of the cost analysis indicate that the cost of using hydrocarbon is comparable to the cost of using PERC.

Many of the dry cleaners that have adopted the hydrocarbon technology are using a blend of tonsil and diatomaceous earth as an absorbent. The suppliers claim that use of the tonsil blend can minimize bacteria growth, prevent dye bleeding, make distillation unnecessary and make detergent use unnecessary. IRTA investigated these claims by conducting a series of tests.

The results of the tests indicate that the tonsil/diatomaceous earth blend absorbs water efficiently. It is the free water that causes bacteria growth in the hydrocarbon process. The test supports the claim that the tonsil blend minimizes bacteria growth. The test results also indicate that the tonsil blend is efficient in removing dyes. This suggests that dye bleeding can be prevented. The test results demonstrated that the tonsil blend can absorb Wesson oil. This lends credence to the claim that distillation is unnecessary for tonsil users.

IRTA used two methods for evaluating the cleaning ability of hydrocarbon with and without tonsil. First, IRTA interviewed several tonsil dry cleaners and they indicated that they were satisfied with the cleaning and, more important, their customers were also satisfied with the cleaning. Second, IRTA used the IFI CPT, a standard industry test, to compare the cleaning capability of hydrocarbon with and without tonsil. IRTA ran four loads of clothing with tonsil and no distillation or detergent and compared the cleaning results with four loads of clothing without tonsil and with continuous distillation and detergent. The tonsil runs generally performed as well as or better than the non-tonsil runs for percent graying, yellowing and percent whitening. Both the tonsil and non-tonsil runs had poor water soluble soil removal, probably because the CPT swatches were not pre-spotted. The tonsil runs did not perform as well as the non-tonsil runs for rug soil removal.

IRTA compared the energy requirements for two facilities that provided utility costs based on utility bills. In both cases, the electricity and gas cost declined after the facilities converted from PERC to hydrocarbon with tonsil. IRTA conducted a test to measure the energy requirements with and without tonsil. Both the electricity and gas requirements for the two runs with tonsil were lower than the electricity and gas requirements for the two runs without tonsil.

DTSC had a special interest in whether or not the waste streams generated in the hydrocarbon process are classified as hazardous waste. IRTA sampled the waste streams from four tonsil hydrocarbon users and four non-tonsil hydrocarbon users. The DTSC Hazardous Materials Laboratory analyzed the samples. None of the waste streams analyzed for the eight cleaners were classified as hazardous waste based on the presence of metals or the characteristic of the flash point. The results indicated that separator water waste streams from all eight facilities did not exhibit aquatic toxicity. The results also indicated that the sludge waste streams from the four tonsil facilities did not exhibit aquatic toxicity whereas the sludge waste streams from the four non-tonsil facilities did exhibit aquatic toxicity. This may be a result of the fact that the non-tonsil facilities use detergent and the tonsil facilities do not. The results indicated that PERC and TCE, which are listed hazardous wastes, were present in six of the eight separator water waste streams and seven of the eight sludge waste streams. Other solvents were also found in both waste streams. The likely source of these solvents is spotting compounds. Since PERC, TCE and certain other solvents in the waste streams are listed hazardous wastes, wastes containing these solvents would be classified as hazardous wastes.

Several years ago, the Legislature added an exclusion to the Heath and Safety Code to allow, in most circumstances, the evaporation of PERC containing separator water. The exclusion was specific to PERC. Legislation is required to allow the evaporation of hydrocarbon containing separator water. IRTA is seeking a sponsor for this legislation.

HESIS, which is part of DHS, assisted IRTA in this project by evaluating the toxicity of four hydrocarbon solvents used in California and for Tonsil and diatomaceous earth based on the MSDSs. The findings indicate that the toxicity of all of the hydrocarbons is consistent with that of solvents in general. None of them pose risks of cancer and they are not selective reproductive or developmental toxicants. HESIS considers the hydrocarbons safer alternatives to PERC due to their lower toxicity.

Both diatomaceous earth and Tonsil contain crystalline silica. Diatomaceous earth contains a much higher level of crystalline silica than does tonsil so it potentially poses more of a danger. Dry cleaners and suppliers should be concerned about exposure to the 50 percent/50 percent blend of tonsil and diatomaceous earth when it is dry and airborne. The largest supplier is providing the blend to cleaners in ziplock bags and the mixture is wet when it is disposed of as waste so potential exposure and health risks from inhalation in the dry cleaning industry should be minimal.