

Evaluation of New and Emerging Technologies for Textile Cleaning

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ABSTRACT

This project was conducted by the Institute for Research and Technical Assistance (IRTA) and was sponsored by the California Air Resources Board and U.S. EPA. It involved conducting a technology assessment of the alternative processes to perchloroethylene (PERC) dry cleaning. PERC is classified as a suspect carcinogen and it is being increasingly regulated in California. The alternatives that were evaluated in the project include hydrocarbon, Pure Dry, Green Earth, glycol ether, traditional wet cleaning, icy water, Green Jet and carbon dioxide. IRTA focused on 14 case studies of cleaners that had adopted the alternative technologies. Nine of these plants converted from PERC to the alternative and five started up using the alternative. IRTA analyzed the performance and cost of the alternatives and compared them to the plants' costs prior to conversion. IRTA developed stand alone case studies for each of the 14 facilities. IRTA performed a model plant analysis that extended the results of the case studies to the industry as a whole. This analysis included a small model plant cleaning 40,000 pounds of clothing annually and a large model plant cleaning 100,000 pounds of clothing annually. Several of the technologies were found to be lower, comparable or slightly higher in cost than PERC dry cleaning. All of the case study cleaners were satisfied with the alternative technologies they had adopted.

EXECUTIVE SUMMARY

Perchloroethylene (PERC) is the most widely used dry cleaning agent. The chemical is a potential carcinogen, it is classified as a Hazardous Air Pollutant by EPA and a Toxic Air Contaminant in California. PERC is a contaminant at numerous dry cleaning sites and landlords are increasingly reluctant to allow cleaners to use the technology. For this reason and because regulations are becoming more stringent in California, cleaners have begun converting to alternatives.

Under the sponsorship of the California Air Resources Board (CARB) and U.S. EPA, the Institute for Research and Technical Assistance (IRTA), a technical nonprofit organization, conducted this project to evaluate and assess the alternative technologies to PERC dry cleaning and to compare their performance and cost. CARB is evaluating whether or not to strengthen the state PERC dry cleaning regulation and EPA is interested in pollution prevention and alternatives analysis.

During the project, IRTA evaluated eight different alternatives to PERC including hydrocarbon, Pure Dry, Green Earth, glycol ether, traditional wet cleaning, icy water, Green Jet and carbon dioxide. IRTA worked with 14 cleaners that had adopted the alternative technologies. Nine of these case study plants converted from PERC dry cleaning to one of the alternatives and five of them adopted the new alternative upon startup. IRTA evaluated the performance and cost of the alternative technologies for all 14 case study facilities and compared the performance and cost of the alternative technologies to PERC dry cleaning for nine of the facilities. IRTA prepared stand alone case studies for all of the facilities. The findings indicate that all of the cleaners that adopted the alternatives were satisfied with the new technologies, even those cleaners that increased their costs through the conversion.

IRTA also generalized the results of the case study facilities to the industry as a whole by performing a model plant analysis. A small model plant cleaning 40,000 pounds of clothing annually and a large model plant cleaning 100,000 pounds of clothing annually were evaluated. The effects of the increasing price of PERC because of a fee and the grants provided by the South Coast Air Quality Management District and CARB were incorporated into the analysis. In general, the results of the model plant analysis indicate that the cost of some of the alternative technologies are lower than, comparable to or slightly higher than the costs of PERC dry cleaning. These include hydrocarbon, Green Earth, Green Jet, icy water and traditional wet cleaning. The glycol ether and carbon dioxide technologies had higher costs than PERC dry cleaning.

Table E-1 summarizes and compares the performance and cost of PERC dry cleaning and the alternative technologies based on the results of the case studies and the model plant analysis. The eight technologies evaluated during the project are included in the table. One additional technology—hydrocarbon with tonsil—was also evaluated. Tonsil is an absorbent material used by some cleaners that employ the hydrocarbon technology. The table indicates whether the cleaning capability of each technology is aggressive, gentle or

**Table E-1
Performance and Cost Comparison of PERC and Alternative Technologies**

Cleaning Method	Cleaning Capability	Cost			Advantages	Other Issues	Disadvantages
		Spotting Labor	Finishing Labor	Capital			
PERC	aggressive	medium	medium	medium	process easy to use		not good for delicates
Hydrocarbon	gentle	medium	medium	medium	can clean delicates, good hand, in-kind technology		can have bacteria growth, longer cycle time
Hydrocarbon with Tonsil	gentle	medium	medium	medium	can clean delicates, good hand, no distillation or detergent, in-kind technology		longer cycle time
Pure Dry	gentle	medium	medium	medium	can clean delicates, good hand, in-kind technology		can have bacteria growth, longer cycle time, possible change in composition
Green Earth	gentle	high	low	medium	can clean delicates, very good hand, in-kind technology		longer cycle time
Glycol Ether	aggressive	low	medium	medium	cleans water soluble and oil-based soils, in-kind technology		longer cycle time, water separation difficult, distillation boil over
Traditional Wet Cleaning	aggressive	medium	high	low	can clean delicates		finishing more difficult, not-in-kind technology
Icy Water	aggressive	medium	medium	medium	can clean delicates, may not need tensioning equipment		longer drying cycle, not-in-kind technology
Green Jet	very gentle	high	low	low	can clean delicates, less finishing		doesn't clean well, not-in-kind technology
Carbon Dioxide	gentle	high	medium	high	good hand		detergent issues, problems with acetate, expensive equipment, not-in-kind technology

very gentle. It also ranks three cost elements of each technology as low, medium or high. Two of the cost elements that were analyzed, spotting and finishing labor costs, were determined to account for the majority of total facility costs. Table E-1 also presents the advantages and disadvantages of each of the technologies.

IRTA partnered with the Los Angeles County Sanitation Districts (LACSD) to sample and analyze certain waste and discharge streams that arise from use of the alternative technologies. The sampling was performed at a limited number of facilities so the results should be judiciously extended to the industry as a whole. In California, wastes are classified as hazardous if they exhibit aquatic toxicity. The findings indicated that the still bottom generated from distillation of the glycol ether, Green Earth and carbon dioxide exhibited aquatic toxicity whereas it did not for the hydrocarbon. Another waste stream, separator water from the glycol ether, Green Earth and hydrocarbon processes, did not exhibit aquatic toxicity. Four wash and rinse effluent samples from wet cleaning facilities were also analyzed. Although they did not exhibit aquatic toxicity, some of the streams contained PERC and/or trichloroethylene (TCE), another toxic chlorinated solvent. If wet cleaning effluent streams contain PERC and TCE above a certain threshold level, they would be classified as hazardous waste and they could not be discharged. The likely origin of the PERC and TCE is spotting chemicals. Work on alternative spotting chemicals is required to address this issue.

IRTA did only limited analysis of the toxicity of the alternatives in this project and the information is presented in Chapter IV.. The Office of Environmental Health Hazard Assessment in California is evaluating the toxicity of the chemical alternatives to PERC dry cleaning at the request of CARB and the results were not available at the time of publication of this document.

The project findings indicate that many cleaners have successfully converted from PERC dry cleaning to alternative technologies. The cleaners are satisfied with the performance of the alternatives even in cases where the technology is more expensive to use. Many of the technologies have costs that are lower, comparable to or only slightly higher than the cost of using PERC dry cleaning.

I. INTRODUCTION AND BACKGROUND

There may be as many as 5,040 dry cleaning facilities in California and most of them perform cleaning on the premises. The California Air Resources Board (CARB) recently completed a survey of the industry. The survey results indicate that more than 92 percent of the cleaners have one dry cleaning machine and 85 percent of them use perchloroethylene (PERC) exclusively. About four percent of the cleaners use both PERC and another alternative.

PERC is a potential 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 (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. The advantage of PERC over low flash point petroleum solvents that were used before PERC became the dry cleaning solvent of choice is that PERC has no flash point. The use of PERC allowed cleaners to open shops in minimalls and other heavily populated areas where facilities need to be fortified in various ways if solvents with low flash points are used. PERC rapidly penetrated the dry cleaning market and it is used by the vast majority of dry cleaning facilities today.

In 1993, CARB adopted a 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.

In 1993, the U.S. EPA promulgated the National Emission Standards for Hazardous Air Pollutants (NESHAP) for PERC dry cleaning facilities. The so-called Maximum Achievable Control Technology (MACT) 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. The SCAQMD also established a financial assistance program to provide grants to cleaners to assist them in adopting alternative technologies.

In 2002, CARB initiated an effort to examine whether or not to strengthen the 1993 regulation on PERC dry cleaning. In that light, CARB developed and conducted a survey of the dry cleaning industry to obtain information on the industry's current status. CARB also assembled a working group composed of dry cleaners, equipment manufacturers, alternative technology representatives and government agency representatives. CARB has held several working group meetings and has solicited input from the working group members on related issues.

CARB is also responsible for implementing Assembly Bill (AB) 998, "Non-Toxic Dry Cleaning Incentive Program" which was signed by the Governor in 2003. AB998 requires CARB to develop and administer a fee-funded grant and demonstration program. The fee on PERC for the dry cleaning industry is \$3 per gallon the first year and it is to increase by \$1 per gallon each year thereafter through 2013. CARB began assessing the fee on the manufacturers and importers of PERC in August 2004. CARB will use the funds to provide \$10,000 grants to assist dry cleaners in switching to non-toxic and non-smog forming alternative cleaning technologies. CARB will also use some funds to establish a demonstration program to showcase these alternative technologies.

As part of their regulatory evaluation, CARB contracted with the Institute for Research and Technical Assistance (IRTA) to perform an assessment of the alternative cleaning technologies to PERC in dry cleaning. The project is funded by CARB and U.S. EPA. IRTA is a technical nonprofit organization that identifies, tests and demonstrates alternatives to ozone depleting solvents, chlorinated solvents and VOC solvents in a variety of different industries. IRTA also sought and received additional funding for a project with U.S. EPA to further evaluate the alternative cleaning technologies.

Over the last 15 years, alternative dry cleaning agents and technologies appropriate for the dry cleaning industry have been developed. Faced with increasingly stringent air and toxics regulations, soil contamination cleanup costs and the reluctance of landlords to renew leases of PERC cleaning shops, some dry cleaners, particularly in California have begun to adopt the alternatives. A number of the technologies are fairly mature at this stage and others are still emerging. Eight different alternative technologies were examined during IRTA's CARB and EPA project.

IRTA's work for EPA involved developing six case studies of cleaners using the alternative technologies. IRTA was to compare the performance and cost of PERC dry cleaning and the alternatives used by the six cleaners. After an initial investigation, IRTA determined that 14 case studies would be required to adequately define the alternatives available to the industry. IRTA developed the additional case studies under the CARB project. The CARB project also involved designing two model plants, a large and a small dry cleaner using PERC. The costs to the small and large representative dry cleaners in converting to the alternatives were assessed. Finally, the CARB project also included a limited investigation of the waste and discharge streams of the alternative technologies. IRTA was assisted in this effort by the Los Angeles County Sanitation Districts (LACSD); the LACSD lab analyzed the samples collected by IRTA.

This document combines the results of IRTA's EPA and CARB project. The project is enhanced by integrating the results of the two efforts. Section II of the document provides more detailed information on the alternative technologies. Section III presents the case study analysis for the 14 cleaners that participated in the project. Section IV provides details on the results of the waste and discharge stream analysis and discusses the grant programs that have been established to assist cleaners in converting to alternative technologies. Section V focuses on the model plant analysis and discusses the results. Finally, Section VI summarizes the results and findings of the project.

II. ALTERNATIVE CLEANING PROCESSES

There are several alternative cleaning processes available today to the dry cleaning industry. Some of the new technologies have been adopted by many cleaners and others are still emerging and do not yet have widespread use. Eight technologies were evaluated in this project. They include the following processes:

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

The technologies that were selected for evaluation are technologies that cleaners are using in place of PERC dry cleaning. These technologies are considered viable based on the fact that cleaners are using them and their customer base appears to accept them. It's worth noting that all technologies, including PERC dry cleaning, have advantages and disadvantages and no technology is ideal. Cleaners can select the best technology based on their particular needs and requirements.

In the course of the project, IRTA staff visited 32 cleaning facilities that used one or more of the alternative processes. The cleaners included:

- Nine Hydrocarbon facilities
- One Pure Dry facility
- Seven Green Earth facilities
- One Glycol Ether facility
- Eight Traditional Wet Cleaning facilities
- One Icy Water facility
- Two Green Jet facilities
- Three carbon dioxide facilities

IRTA collected information for the technology assessment from all of these facilities. IRTA collected much more detailed information from 14 of the facilities to conduct a cost analysis of particular alternative technologies. IRTA selected facilities for the more detailed analysis based on whether they had cost information and were willing to make it available for the project. IRTA wanted to focus on all technologies that were used in California in 2003. In some cases, the cleaner had used PERC and the information could be used to perform a comparative cost analysis; in other cases, the cleaners had started up their facility with the new technology so no comparative cost analysis was possible.

ALTERNATIVE CLEANING AGENTS AND METHODS

This section presents information on the PERC dry cleaning process as a baseline for reference and then discusses the alternative technologies evaluated during the project.

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 2-1. 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 controls 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 2-1. 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 which is used to separate the PERC

from the higher boiling material 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

This technology is the most widely used alternative to PERC dry cleaning. CARB estimates that there may be 400 cleaners in California using the hydrocarbon process. In the SCAQMD grant program, about 80 percent of the cleaners who have received grants have adopted the hydrocarbon process.

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 which 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-Mobile, Chevron and Shell have 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. The new cleaning materials are isoparaffins, synthetic hydrotreated aliphatic hydrocarbons without an odor. The solvent is hydrotreated to remove trace quantities of aromatic components which are more toxic than aliphatic hydrocarbons and they give off an odor. A material safety data sheet (MSDS) for the Exxon Mobil product, called DF-2000, is 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 now 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, most equipment sold for use with the new solvent contains nitrogen which can be used to suppress the flammability in the machine in the event of ignition. Some equipment, like PERC equipment, has a refrigerated condenser and other equipment does not. Distillation of the hydrocarbon must be performed in a vacuum in

all the equipment because the boiling point is much higher than the boiling point of PERC. A picture of a dry cleaning machine using hydrocarbon is shown in Figure 2-2.



Figure 2-2. Hydrocarbon Dry Cleaning Machine

The machines sold for use with the hydrocarbon process originally had a longer cycle time than PERC machines. Because the hydrocarbon is a less aggressive solvent and because it does not evaporate as readily, the cycle time was longer. As discussed above, PERC machines have a cycle time of about 45 minutes and hydrocarbon machines have a cycle time ranging from one hour to 75 minutes. Some equipment manufacturers now provide hydrocarbon machines that have the same cycle time as a PERC machine. This has been achieved by increasing the blower capacity which speeds up the drying cycle.

The hydrocarbon solvent is not as aggressive as PERC for grease and oil contaminants. This has advantages and disadvantages. The disadvantage is that it is not as aggressive a cleaner as PERC for very dirty garments with oil based stains. More pre- or post-spotting of such garments is likely to be necessary. The advantage is that the hydrocarbon solvent can be used to clean delicate garments like silks, wedding gowns, drapes, suedes and leathers and beaded garments whereas PERC cannot. It can also be used with garments with fugitive dyes that might bleed with PERC. Cleaners using the hydrocarbon report that the “hand” or the feel of the garments cleaned with hydrocarbon is better than the hand of garments cleaned with PERC. This can affect the finishing of the garments.

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

A number of hydrocarbon cleaners are using tonsil. Cleaners using other technologies have recently started to use the material. Tonsil is an absorbent made of natural calcium bentonite material that is acid activated. An MSDS for the material is shown in

Appendix A. The cleaners using tonsil use it in a 50 percent tonsil/ 50 percent diatomaceous earth blend. The suppliers claim the blend has four major advantages. First, it apparently absorbs moisture in the hydrocarbon solvent and makes it much easier to control bacterial growth. Second, it makes distillation unnecessary, apparently because it selectively absorbs the soluble contaminants that would be removed through distillation. Because distillation is not necessary, the equipment for use with tonsil is smaller; a picture is shown in Figure 2-3. Third, it makes the use of detergent unnecessary. Fourth, it readily scavenges dyes that would cause bleeding. IRTA included two hydrocarbon cleaners, one using tonsil and one not using tonsil, in the case study analysis to examine the effects of tonsil. IRTA has also recently initiated a project sponsored by Cal/EPA's Department of Toxic Substances Control, to further investigate the effects of tonsil use in hydrocarbon processes.



Figure 2-3. Dry Cleaning Machine for Hydrocarbon with Tonsil

Pure Dry Technology

This process is a variation of the hydrocarbon process. It uses a solvent similar to the solvent used in the hydrocarbon process but it contains two additional materials in small quantities. One of these materials is a hydrofluoroether (HFE) which is apparently added to accelerate drying and the other is a perfluorocarbon (PFC) which is apparently added to suppress the flash point of the hydrocarbon. An MSDS for the Pure Dry solvent is shown in Appendix A. Only a few cleaners in California have adopted this process.

Equipment similar to the hydrocarbon equipment described above has been designed for use with this solvent. It is not clear that the solvent maintains its composition over time. The HFE and PFC are much more volatile than the hydrocarbon and may evaporate from the mixture during use and particularly during distillation. Some cleaners and vendors have reported that the flash point of the material, listed as 350 degrees F in the MSDS, declines to the 140 degree range during use. Unless the HFE and PFC form an azeotrope

with the hydrocarbon at their particular concentration in the blend, they would simply evaporate and not be retained in the mixture. An azeotrope is a blend of two materials that has the same composition in the liquid as in the vapor. The MSDS for the Pure Dry material indicates that the vacuum distillation temperature must remain below 80 degrees F or the flashpoint will change to the 140 to 200 degrees F range. This indicates that the material is not an azeotrope and the HFE and PFC are likely to be lost from the mixture.

The characteristics of the Pure Dry process are similar to the characteristics of the hydrocarbon process. The Pure Dry process can be used to clean delicate items and the so-called hand of the garments cleaned with the process is very good. The Pure Dry solvent, like plain hydrocarbon, is not as aggressive for oil based contaminants as PERC. The suppliers of the process claim that the cycle time for the process is shorter than for hydrocarbon and this would be so only if the PFC is retained in the mixture and aids in drying.

The price of the plain hydrocarbon solvent is between \$5 and \$6 per gallon. The price of the Pure Dry solvent is much higher, at about \$15 per gallon, presumably because the HFE and PFC, although present in small quantities, are very expensive.

Green Earth Technology

This technology relies on a volatile methyl siloxane called decamethylcyclopentasiloxane or D5 as the cleaning solvent. An MSDS for the material is shown in Appendix A. The flash point of the D5 solvent is higher than the flash point of the hydrocarbon solvent, at 171 degrees F. Like the hydrocarbon solvent, D5 is classified as a combustible liquid. It should be used in equipment designed to handle combustible solvents like the hydrocarbon equipment described earlier.

Several cleaners have converted from PERC to D5 over the last several years. The cleaner, like hydrocarbon, is less aggressive for oil based contaminants than is PERC. As for the hydrocarbon, this leads to advantages and disadvantages. Delicate items can be cleaned in the solvent but more spotting is likely to be required. According to cleaners, the D5 gives a very good hand which refers to the feel of the garment; the hand is reportedly even better than hydrocarbon, and it makes finishing garments much easier.

The vapor pressure of D5 is lower than the vapor pressure of PERC and the hydrocarbon. Because of this, the cycle time is longer than the cycle time for PERC machines. As mentioned above, new equipment has been designed with larger blowers that can shorten the cycle time. Even when these blowers are used, however, the cycle time when D5 is used is somewhat longer than the cycle time of the hydrocarbon.

The Green Earth solvent and water have similar specific gravity. This means that separation of the solvent and water is more difficult. Separators for use with the technology have been designed to accommodate this feature.

One equipment supplier is offering the option of converting PERC equipment so it can be used with D5. In the case study analysis, IRTA included two cleaners using D5, one using a converted PERC machine and the other using a new machine designed for combustible solvents.

Glycol Ether Technology

This cleaning technology is based on use of a mixture of substituted aliphatic glycol ethers. The trade name for one of the glycol ether technologies is Rynex. It is not clear what glycol ethers make up the cleaner. A complicating factor is that the supplier of Rynex has changed from one mixture to another in the past. An MSDS for the material is shown in Appendix A. There is only one facility in California using the technology presently.

In principal, a glycol ether technology would be the best dry cleaning technology from a cleaning perspective. Glycol ethers are aggressive solvents for oil based contaminants. Glycol ethers are infinitely miscible in water so they can remove water soluble soils very effectively as well. As discussed later, the one dry cleaner using Rynex in California does not require detergent because the glycol ethers carry water and the combination can remove oil based and water soluble soils. The chemicals have a flash point so they should be used in equipment designed to handle combustible solvents.

The fact that the Rynex mixture is miscible in water poses problems for the water separation process. The specific gravity of water and glycol ethers is similar so physical separation is slow. The California cleaner using Rynex has had problems in the distillation process because equipment that can handle combustible solvents has not been designed specifically to handle the Rynex solvent. During distillation, the solvent/water combination boils over instantly. The boiling point of water is 212 degrees F so, in a vacuum system, the water will come over very quickly. The Rynex, which has a much higher boiling point will not come over until the higher temperature is reached. The traditional combustible solvent equipment must be modified to route the water to one chamber and the glycol ether to another based on their boiling point differences. Until suitable equipment is designed, cleaners using Rynex will not be able to separate the water from the solvent and will experience boil over during distillation. The distributor for Rynex recently reported that the equipment problem has been solved.

The Rynex process has been available for many years but it has been adopted by very few dry cleaners. The vapor pressure of Rynex is low so the cycle time for the solvent is longer than for PERC. Because there is an issue of water separation, finishing of the garments which may contain high concentrations of water could be more difficult.

Traditional Wet Cleaning

Traditional wet cleaning, often referred to as professional wet cleaning, has been available as an alternative to PERC for more than a decade. It relies on water, conditioners, degreasers and detergent for cleaning the garments. Wet cleaning is an

aggressive cleaning method and it is effective on both oil based and water soluble soils. Although wet cleaning has been adopted fairly widely as a supplementary technology to PERC dry cleaning, only a few cleaners have implemented the technology as an exclusive cleaning method. Almost all of the cleaners that have adopted wet cleaning exclusively are relatively small facilities.

There are several equipment manufacturers that make equipment designed for wet cleaning. A typical set of wet cleaning equipment is shown in Figure 2-4. The process generally consists of a computer controlled washer and dryer and specialized finishing units called tensioning equipment. In order to prevent dimensional change and to make finishing easier, many garments are dried with a residual of moisture. Garments that are dried completely may shrink and are difficult to finish. The dryers include moisture sensors and can be shut off at a particular moisture level. After they are removed from the machine, the still wet garments are hung and later finished using tensioning equipment. The tensioning equipment helps to form garments and restore constructed garments during finishing and helps to prevent them from shrinking. The wet cleaning equipment can also be used for processing garments that are laundered.



Figure 2-4. Wet Cleaning Equipment

Advantages of wet cleaning, are that it is an aggressive cleaning method, it eliminates most health and environmental problems (see Section IV), delicate items like wedding gowns and suede and leather garments can be cleaned effectively with the technology and the equipment is generally less costly than the equipment used for alternative solvents. Disadvantages of wet cleaning are that cleaners must learn entirely new processing methods, the garments with residual moisture must be hung and this requires space and the finishing is more difficult and time consuming with certain garments like structured jackets.

Icy Water Technology

This technology is similar to traditional wet cleaning but incorporates other features. Like traditional wet cleaning, the icy water technology relies on water, detergent, conditioners and degreasers to accomplish cleaning. The company supplying the technology has two types of equipment. One of these is a wash unit and a separate dryer; the other is a combined unit that washes and dries the garments. One facility in California is currently using this technology.

Some of the features of the icy water technology have been designed to minimize or eliminate garment shrinkage. Garments shrink if they are not conditioned, if the process involves heat and if they are agitated. The icy water technology equipment has been designed to minimize temperature and agitation. Garments that are commonly dry cleaned are processed in icy water (water at a temperature of 38 degrees F) and are dried in cold air. The washer is fitted with a refrigerated condenser so it can operate with the water at lower temperature. In the dryer, the garments are partially dried in heated air and cold air, generated with a compressor, can be used to eliminate the residual moisture. The washer has three settings; it can use hot water or tap water for garments that will not shrink and icy water for garments that are commonly dry cleaned. The garments are agitated with only one revolution per minute in the washer and only 60 revolutions per minute in the dryer. The facility using this technology in California purchased tensioning equipment but does not need to use it for finishing the garments with the icy water technology.

The dryer also includes a feature that allows so-called chemical cleaning. This is the same as the Green Jet technology described below. In chemical cleaning, garments that are not very dirty can be processed using a mist of water and detergent in the icy water technology dryer. An MSDS for the detergent used in this type of cleaning is provided in Appendix A. The cleaner using the icy water equipment processes half of the garments received in the dryer using the chemical cleaning method. The remaining 50 percent of the garments are processed with the immersion methods in the icy water technology washer.

This technology has the same advantages as the traditional wet cleaning technology. In addition, it is more forgiving than traditional wet cleaning. Finishing with the icy water technology is easier than with traditional wet cleaning and the garments that are not very dirty can be chemical cleaned in the dryer. The garments can be fully dried in the dryer and they do not have to be hung with residual moisture. When the garments are fully dried, however, the drying cycle is quite long.

Green Jet Technology

The Green Jet Technology involves the use of chemical cleaning and drying in one machine. A picture of a Green Jet machine is shown in Figure 2-5. As described above, the process involves using a mist of water and detergent to clean the garments; they are not immersed in liquid. This process is appropriate only for processing garments that are

lightly soiled. The machine cycle is shorter than the cycle for PERC. This process uses the same detergent as the chemical cleaning described above in the icy water technology.



Figure 2-5. Green Jet Equipment

Advantages of the technology are that the equipment is less expensive than the equipment for other technologies and the finishing is much easier than for other technologies. The disadvantage is that spotting is more difficult because the cleaning process--a mist--is not aggressive.

Carbon Dioxide Technology

This technology relies on liquid carbon dioxide under a pressure of 700 pounds per square inch to clean garments. Many oil based contaminants are soluble in carbon dioxide. The equipment for use with the carbon dioxide process is pressurized prior to the cleaning cycle and depressurized after the cleaning cycle. The contaminants are separated from the carbon dioxide, which is now a gas. The cycle time for carbon dioxide is about the same as the cycle time with PERC dry cleaning. Because the equipment is pressurized, the equipment for use with carbon dioxide is expensive; it is made of stainless steel and must be capable of holding pressure. The equipment includes filters for removing particulate contaminants and a distillation unit for separating the soluble contaminants.

The technology does not involve heat so the carbon dioxide is a gentle cleaner. The detergent used in the carbon dioxide process is relatively expensive and is reported by some cleaners using the technology as not aggressive enough. More spotting is required with carbon dioxide than with PERC. Because the carbon dioxide is a gentle cleaner, it can be used for cleaning delicate items with a proviso. Some materials, like vinyl, rubber

or beads, swell during the cleaning process. Once the pressure is released at the end of the cycle, some of these materials do not revert to their original shape. Some acetate materials cannot be cleaned with carbon dioxide and some garments have acetate linings; this material will undergo dimensional change in carbon dioxide. Triacetate materials can experience a color change with carbon dioxide. Finishing requirements for the carbon dioxide process are similar to finishing requirements with PERC dry cleaning.

The carbon dioxide for use in the process can be stored in a bulk storage tank by the cleaner or the cleaner can use a service which regularly changes out the empty tanks when more carbon dioxide is needed. Some of the equipment requires a large amount of space but one machine is about the same size as a PERC dry cleaning machine. A picture of the smaller carbon dioxide machine is shown in Figure 2-6.



Figure 2-6. Carbon Dioxide Equipment

The carbon dioxide technology is still emerging and the equipment representatives report that changes are underway. One change that is being considered is removal of the filters from the equipment.

TECHNICAL COMPARISON OF ALTERNATIVE TECHNOLOGIES

Table 2-1 summarizes certain features of each of the alternative technologies and compares them to PERC and to each other. The cleaning technologies are defined as aggressive, gentle or very gentle. A cleaning system is aggressive if it removes contaminants from garments effectively. A cleaning system is gentle if it removes contaminants from garments less effectively. Note that gentle cleaning systems can be used on a wider range of garments than aggressive cleaning systems.

Each of the technologies in the table is classified as an in-kind or a not-in-kind technology. PERC is a solvent based technology. The other solvent based technologies

are classified as in-kind technologies. Although cleaners must learn some different procedures to use these technologies, they still involve using a solvent for cleaning. The garments are placed in a machine containing the solvent and they are washed and dried and removed from the machine at the end of the cycle. The other technologies are classified as not-in-kind technologies. These are technologies that use water or carbon dioxide as the cleaning medium and cleaners must learn more new practices to use them.

The health and environmental characteristics are not provided in the table. These are discussed in Section IV.

Table 2-1
Comparison of Alternative Cleaning Processes

<u>Technology</u>	<u>Cleaning Capability</u>	<u>Advantages</u>	<u>Disadvantages</u>
PERC	aggressive	process easy to use	not good for delicates
Hydrocarbon	gentle	can clean delicates good hand in-kind technology	can have bacteria growth longer cycle time
Pure Dry	gentle	can clean delicates good hand in-kind technology	can have bacteria growth longer cycle time possible change in composition
Green Earth	gentle	can clean delicates very good hand in-kind technology	longer cycle time
Glycol Ether	aggressive	cleans water soluble and oil based soils in-kind technology	longer cycle time water separation difficult distillation boil over
Traditional Wet Cleaning	aggressive	can clean delicates	finishing more difficult not-in-kind technology
Icy Water	aggressive	can clean delicates may not need tensioning equipment	longer drying cycle not-in-kind technology
Green Jet	very gentle	can clean delicates less finishing	doesn't clean well not-in-kind technology
Carbon Dioxide	gentle	good hand	detergent issues problems with acetate expensive equipment not-in-kind technology

III. CASE STUDIES OF ALTERNATIVE CLEANING TECHNOLOGIES

This section presents 14 case studies of alternative technologies that have been adopted by cleaners. Table 3-1 summarizes the facilities that provided performance and cost information for the case studies. The facilities are listed in alphabetical order. They include one cleaner that uses the Rynex glycol ether technology, two cleaners that use the hydrocarbon technology, one cleaner that uses the Pure Dry hydrocarbon technology, three cleaners that use the Green Earth technology, three cleaners that use traditional wet cleaning, two cleaners that use carbon dioxide, one cleaner that uses the icy water technology and one cleaner that uses the Green Jet system. Nine of the 14 cleaners that were analyzed converted from PERC to the alternative technology. Five of the 14 cleaners started up their shops with the new technology and did not use PERC at the shop previously. Some of these cleaners, however, have operated PERC dry cleaning plants in the past.

**Table 3-1
Case Study Cleaners**

Cleaning Facility	Technology	PERC Used Previously
Blackburn's Town & Country Cleaners	Glycol Ether	No
Crown Drapery Cleaners	Hydrocarbon	Yes
Cypress Natural Cleaners	Wet Cleaning	No
Doheny Dry Cleaners	Green Earth	Yes
Fay Cleaners	Wet Cleaning	Yes
Hangers Cleaners	Carbon Dioxide	No
Hollyway Cleaners	Green Earth	Yes
Imperial Dry Cleaners & Lndry	Icy Water	Yes
Larsen's Cleaners	Green Earth	Yes
Nature's Best Cleaners	Wet Cleaning	Yes
Royal Cleaners of Brentwood	Carbon Dioxide	Yes
Sterling Dry Cleaners	Hydrocarbon	Yes
Sunny Fresh Cleaners	Pure Dry Hydrocarbon	No
Village Dry Cleaners	Green Jet	No

The information was collected from the cleaning facilities over the period from October 2003 to June 2005. The analysis and the case studies represent each facility at a point in time and are a snapshot. In some cases, the cleaning facilities have made changes since the data were collected. These changes were not incorporated into the analysis or the case studies. Many of the technologies discussed here are still evolving and there may be additional changes in the future.

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 alternative technologies.

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. A few cleaners purchased chillers to facilitate use of the alternative technology. The two cleaners that adopted the carbon dioxide technology purchased or leased equipment for storing the carbon dioxide. The companies that adopted wet cleaning purchased tensioning equipment used to finish the garments. All of these costs were included in the capital cost of the alternative technology. The SCAQMD had a grant program for cleaners to assist them in purchasing alternative technologies, as mentioned earlier. Some of the case studies analyzed here took advantage of the grant program and the capital cost of the equipment was reduced accordingly.

The capital costs of the alternatives 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 assumptions outlined above.

Capital costs for the alternatives were included in the case study analysis presented below but capital costs for the PERC process were not included. Companies purchased their PERC equipment many years ago and IRTA wanted to adopt a uniform method of evaluating the costs. In Section V, which presents the model plant analysis, IRTA focuses on the PERC capital costs and compares them with the capital costs of the alternative processes.

Operating Costs

Operating costs for the cleaners participating in the project included:

- Solvent Cost
- Licensing Fee
- 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 PERC dry cleaning and cleaning with the alternatives were compared.

The solvent or cleaner cost (in the case of a blend of solvents) is the cost per gallon of the fluid used to perform cleaning. This cost does not include detergent or water.

One of the technologies, Green Earth, has an annual licensing fee. This \$2,500 fee was included for the cleaners using the Green Earth technology.

Detergent cost is the cost of purchasing detergent which is added to the solvent, cleaner or water-based cleaner 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. A few of the facilities involved in the project have air conditioning, all have lighting and several 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 with the alternative technologies.

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. As discussed in more detail later, the owners and family members in small cleaning facilities often perform some or all of the spotting and finishing for the business. In these 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. The 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. This cost does not include maintenance labor for breakdowns or repairs. Maintenance equipment costs are the costs of equipment used in routine operation of the equipment.

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

The hazardous waste disposal cost is the cost to the facility for disposing of hazardous waste.

CASE STUDY ANALYSIS

The performance and cost analysis conducted for each of the 14 participating facilities is presented below. As discussed above, nine of the facilities used PERC before they adopted the alternative technology and five of the facilities did not. For eight of the facilities that did use PERC, a cost comparison is presented. Stand alone case studies for each of the facilities are presented in Appendix B.

IRTA collected the cost information, generally from the owners of the facilities that adopted the alternative technologies. In some cases, when the values did not appear to be reasonable, IRTA contacted the facilities again and the owners checked their records and were able to provide modified figures. As discussed later, the costs provided by two facilities could not be verified. In one case, IRTA does not present the costs. In the other case, IRTA presents the costs but does not use them in the subsequent analysis.

Blackburn's Town & Country Cleaners

Blackburn's Town & Country Cleaners, located in Porterville, California, is the only dry cleaning facility in the state that relies on the Rynex cleaning solvent. Rynex is a propylene glycol ether and the identity of the chemical is stated to be a trade secret on the MSDS. The facility cleans 46,800 pounds of clothing per year.

Bob Blackburn purchased and installed a machine using Rynex about 18 months ago. He visited a New York dry cleaner that was using Rynex as part of the investigation into the new technology. He was impressed by what he saw there and decided to start up his new facility with Rynex. Mr. Blackburn did not use PERC at the new facility but he was a PERC dry cleaner for many years at other locations.

Bob Blackburn purchased a 55 pound Bergparma machine for use with Rynex for \$56,000. The installation cost for the dry cleaning machine was \$3,500. The total capital and installation cost for the machine amounted to \$59,500. Assuming an average life of 15 years for the machine and a cost of capital of four percent, the total annualized cost of the purchase and installation amounts to \$4,125 per year.

The cleaning facility uses 52 gallons of Rynex annually. At a cost of \$15 per gallon, the cost of purchasing solvent amounts to \$780 per year.

The Rynex is an aggressive cleaner that carries water well. Mr. Blackburn has found that he does not need to use detergent.

The dry cleaning facility currently has an electricity bill of about \$1,000 per month or \$12,000 per year. This includes the electricity cost of a swamp cooler that cools the entire shop. The gas bill for the shop is \$800 per month or \$9,600 per year.

The spotting labor with the Rynex is very low because the chemical can remove solvent and water soluble soils. For Blackburn’s shop, spotting labor is only about one hour per week or 52 hours per year. At the shop’s average labor rate of \$10 per hour, the annual spotting labor cost amounts to \$520.

Rynex and water are infinitely miscible. It is difficult to separate the Rynex from water so sometimes the garments, after the cleaning cycle, have a residue of water. In those cases, finishing would be more difficult than with a dry cleaning agent like PERC which does not carry much water. In spite of this potential problem, Blackburn’s finishing labor is low. It averages about 30 hours per week or 1,560 hours per year. Assuming a labor rate of \$10 per hour, the annual finishing labor cost is \$15,600.

The equipment purchased by the cleaning facility has never worked optimally with the Rynex cleaner. Maintenance labor is very high, at 21 hours per week. The facility owner believes that if the machine performed properly, maintenance labor would amount to about one hour per day. Assuming the 21 hours of maintenance labor per week or 1,092 hours per year and a labor rate of \$10 per hour, the annual maintenance cost is \$10,920.

The facility has not purchased any maintenance equipment since they started up the operation. The company has not disposed of any hazardous waste since startup. There have been no regulatory costs associated with using the Rynex process since startup.

Table 3-2 shows the annualized costs of operating the Rynex process.

**Table 3-2
Annualized Costs for Blackburn’s Town & Country Cleaners**

	Cost
Annualized Capital/Installation Cost	\$4,125
Cleaner Cost	\$780
Detergent Cost	-
Electricity Cost	\$12,000
Gas Cost	\$9,600
Spotting Labor Cost	\$520
Finishing Labor Cost	\$15,600
Maintenance Cost	\$10,920
Compliance Cost	-
Hazardous Waste Disposal Cost	-
Total Cost	\$53,545

Note: When the cost analysis was performed, the facility had not yet disposed of hazardous waste.

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 3-3 shows the annualized cost comparison of using PERC and hydrocarbon for Crown Cleaners.

**Table 3-3
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

Cypress Natural Cleaners

Cypress Natural Cleaners is located in Cypress, California. The shop converted from the Valclene process which relies on CFC-113 to a wet cleaning process several years ago. The shop operates six days a week and cleans 31,200 pounds of clothing per year. The costs of the Valclene process were not available.

When Cypress converted to wet cleaning, the shop purchased a 65 pound wet cleaning machine for \$15,000. This capital cost included installation. Cypress also purchased tensioning equipment for finishing for \$8,000. The total capital cost amounted to \$23,000. Assuming a 15 year life for the equipment and a four percent cost of capital, the annualized capital cost is \$1,595.

Cypress uses about seven gallons of detergent, sizing and conditioner per month or 84 gallons per year. The average cost of the materials is \$15 per gallon. The annual detergent/supplies cost for the shop is \$1,260.

The facility pays \$150 per month for electricity. This amounts to an electricity cost of \$1,800 per year.

The cost of gas is \$350 per month or \$4,200 per year.

Cypress spends 12 hours per week or 624 hours per year spotting. Assuming a labor cost of \$10 per hour, the annual spotting cost is \$6,240.

The shop spends 45 hours per week or 2,340 hours per year finishing the garments. Assuming a labor cost of \$10 per hour, the annual finishing cost amounts to \$23,400.

Cypress spends one hour per week or 52 hours per year in maintenance labor. At a labor rate of \$10 per hour, the cost of maintenance labor is \$520 per year.

The facility does not purchase any maintenance equipment, does not generate waste and does not spend time on compliance.

Table 3-4 presents the annualized costs for the wet cleaning process at Cypress.

**Table 3-4
Annualized Costs for Cypress Natural Cleaners**

	Wet Cleaning
Annualized Capital Cost	\$1,595
Detergent/Supplies Cost	\$1,260
Electricity Cost	\$1,800
Gas Cost	\$4,200
Spotting Labor Cost	\$6,240
Finishing Labor Cost	\$23,400
Maintenance Labor Cost	\$520
Total Cost	\$39,015

Doheny Dry Cleaners

Doheny Cleaners, located in Hollywood, historically used PERC. The PERC machine was retrofitted to use Green Earth. The shop cleans 78,000 pounds of clothing per year.

The PERC machine was retrofitted to use Green Earth at a cost of \$15,000. Assuming a life for the equipment of 15 years and a four percent cost of capital, the annualized capital cost is \$1,040.

Doheny used five gallons per month or 60 gallons per year of PERC. At a cost of \$6.50 per gallon, the annual PERC purchases amounted to \$390. Doheny uses four gallons per month or 48 gallons per year of Green Earth solvent. At a cost of \$16.50 per gallon, the cost of the solvent is \$792.

Doheny pays a licensing fee of \$2,500 per year to use the Green Earth solvent.

Doheny uses the same amount of detergent, eight gallons per month or 96 gallons per year, with Green Earth as with PERC. At a cost of \$30 per gallon for the detergent, Doheny's detergent cost is \$2,880 per year.

Doheny's electricity use has not changed with the conversion from PERC to Green Earth. The bill is \$800 per month or \$9,600 per year.

When Doheny used PERC, the gas bill was \$850 per month or \$10,200 per year. With Green Earth solvent, the gas bill increased to \$1,000 per month or \$12,000 per year.

The spotting labor with PERC amounted to 40 hours per week or 2,080 hours per year. Assuming a labor rate of \$12 per hour, the annual cost of the spotting labor is \$24,960. Spotting labor has doubled with Green Earth to 80 hours per week or 4,160 hours per year. Again, assuming a labor rate of \$12 per hour, the cost of spotting labor is now \$49,920 annually.

When Doheny used PERC, the finishing and maintenance labor was 160 hours per week or 8,320 per year. Using a labor rate of \$12 per hour, the annual cost of finishing labor was \$99,840. After Doheny converted to Green Earth, the finishing and maintenance labor did not change.

With PERC, Doheny changed out six filters every three months or 24 filters per year. Assuming a filter cost of \$35, the maintenance equipment cost was \$840 annually. With Green Earth, Doheny changes out nine filters every three months or 36 filters per year. Again, assuming a cost of \$35 per filter, the annual cost of filters is now \$1,260.

When Doheny used PERC, compliance labor amounted to two hours per week or 104 hours per year. At a labor rate of \$12 per hour, the compliance cost was \$1,248 per year. When the facility converted to Green Earth, the compliance cost was reduced by half to \$624 annually.

Waste disposal has not changed with the conversion to Green Earth. Doheny generates one drum of filters every three months or four drums per year. At a disposal cost of \$300 per drum, the waste disposal cost amounts to \$1,200 annually.

Table 3-5 shows the cost comparison of PERC and Green Earth for Doheny.

**Table 3-5
Annualized Cost Comparison for Doheny Dry Cleaners**

	PERC	Green Earth
Annualized Capital Cost	-	\$1,040
Solvent Cost	\$390	\$792
Licensing Fee	-	\$2,500
Detergent Cost	\$2,880	\$2,880
Electricity Cost	\$9,600	\$9,600
Gas Cost	\$10,200	\$12,000
Spotting Labor Cost	\$24,960	\$49,920
Finishing/Maintenance Labor Cost	\$99,840	\$99,840
Maintenance Equipment Cost	\$840	\$1,260
Compliance Cost	\$1,248	\$624
Waste Disposal Cost	\$1,200	\$1,200
Total Cost	\$151,158	\$181,656

Fay Cleaners

Fay Cleaners, located in Long Beach, California used PERC in the past and now has a wet cleaning machine. When PERC was used at Fay, the shop processed 39,000 pounds of clothing per year. The shop now processes the same amount of clothing, all through the wet cleaning process.

Fay purchased a 45 pound wet cleaning machine for \$52,000 and tensioning equipment for \$10,000. The installation cost for the machine was included in the \$52,000 price. The cleaner received a \$10,000 grant from the South Coast Air Quality Management District. The net cost of the capital equipment was \$52,000. Assuming a 15 year life for the equipment and a four percent cost of capital, the annualized capital cost of the equipment is \$3,605.

Fay used five gallons of PERC per month or 60 gallons per year. At a cost of \$8 per gallon, the solvent cost was \$480 annually.

Fay did not purchase detergent when the PERC process was used. The detergent requirement for the wet cleaning process is 15 gallons per month or 180 gallons per year. At a cost of \$13 per gallon, the annual detergent cost is now \$2,340.

When Fay used PERC, the electricity cost was \$300 per month or \$3,600 per year. The electricity cost has decreased to \$200 per month or \$2,400 per year with the wet cleaning process.

With PERC, the gas bill for Fay amounted to \$250 per month or \$3,000 per year. With wet cleaning, the gas bill has increased to \$350 per month or \$4,200 per year.

Spotting labor for Fay when PERC was used was 12 hours per week or 624 hours per year. At a labor rate of \$10 per hour, the spotting labor cost was \$6,240 annually. With wet cleaning, the spotting labor has increased to 15 hours per week or 780 hours per year. Again, assuming a labor rate of \$10 per hour, the spotting labor cost is now \$7,800 annually.

When Fay used PERC, the finishing labor and maintenance labor was 48 hours per week or 2,496 hours per year. At a labor rate of \$10 per hour, the finishing labor cost was \$24,960. After Fay converted to the wet cleaning process, the finishing labor and maintenance labor increased to 60 hours per week or 3,120 hours per year. Using the labor rate of \$10 per hour, the finishing labor cost is now \$31,200.

Fay indicates that no filters were used in the PERC machine so there was no maintenance equipment cost.

The compliance requirement when Fay used PERC was one hour per week or 52 hours per year. At a labor rate of \$10 per hour, the compliance cost was \$520 annually. There are no compliance costs with wet cleaning.

When Fay used PERC, the shop disposed of one 55 gallon drum every four months. At a cost of \$200 per drum, the annual disposal cost was \$600. There is no disposal requirement with wet cleaning.

Table 3-6 shows the annualized cost comparison for PERC and wet cleaning for Fay.

**Table 3-6
Annualized Cost Comparison for Fay Cleaners**

	PERC	Wet Cleaning
Annualized Capital Cost	-	\$3,605
Solvent Cost	\$480	-
Detergent Cost	-	\$2,340
Electricity Cost	\$3,600	\$2,400
Gas Cost	\$3,000	\$4,200
Spotting Labor Cost	\$6,240	\$7,800
Finishing/Maintenance Labor Cost	\$24,960	\$31,200
Compliance Cost	\$520	-
Waste Disposal Cost	\$600	-
Total Cost	\$39,400	\$51,545

Note: The capital cost figure includes a \$10,000 grant from SCAQMD.

Hangers Cleaners

Hangers Cleaners, located in San Diego, California, operates with a 60 pound carbon dioxide machine. The shop is a new location and PERC was not used there although the owner of the facility did use PERC at other locations in the past. Hangers cleans approximately 117,000 pounds of clothing per year.

The San Diego business purchased the Hangers franchise and the 60 pound machine for \$25,000 and \$150,000 respectively. The franchise fee allows the San Diego Hangers facility to open other facilities in San Diego County. The owner plans to open at least two other shops so only one-third of the franchise fee, or \$8,333, is assumed to apply to this facility. The shop also purchased a chiller for \$15,000. Installation was an additional \$1,000. The total capital investment amounted to \$174,333. Assuming a useful life for the equipment of 15 years and a four percent cost of capital, the annualized cost of the capital investment is \$12,087.

Hangers uses 20,790 pounds of carbon dioxide per year. The Hangers owner indicates that he pays \$1.80 per load of clothing processed or 3.6 cents per garment. Assuming each garment on average is one pound, the annual cost of purchasing carbon dioxide is \$4,212. The shop also pays \$125 per month or \$1,500 per year for carbon dioxide storage containers. The cost of using the carbon dioxide is \$5,712 per year.

Hangers purchases 520 gallons per year of detergent for addition to the carbon dioxide. Assuming the cost of the detergent of \$24.36 per gallon, the annual cost of detergent amounts to \$12,667.

The cost of electricity is \$2,000 per month or \$24,000 per year. The electricity cost includes air conditioning and lighting for the entire shop. The cost of gas at the facility is \$900 per month or \$10,800 per year.

Spotting labor at Hangers is 10 hours per week or 520 hours per year. At a labor cost of \$11.50 per hour, the annual cost of spotting labor is \$5,980.

Finishing labor is 144 hours per week or 7,488 hours per year. Assuming a finishing labor rate of \$9 per hour, the cost of finishing labor is \$67,392 per year.

The maintenance labor at Hangers is one hour per week or about 52 hours per year. At the maintenance labor rate of \$11.50 per hour, the annual maintenance labor cost is \$598.

Hangers spends \$1,800 per year for carbon filters and \$417 per year for bag filters. The total annual maintenance equipment cost amounts to \$2,217.

Hangers disposes of 45 gallons of waste every two months. At a cost of \$270 per pickup, the annual cost of disposal is \$1,620.

Table 3-7 shows the annualized costs for Hangers.

Table 3-7
Annualized Costs for Hangers Cleaners

	Carbon Dioxide
Annualized Capital Cost	\$12,087
Carbon Dioxide Cost	\$5,712
Detergent Cost	\$12,667
Electricity Cost	\$24,000
Gas Cost	\$10,800
Spotting Labor Cost	\$5,980
Finishing Labor Cost	\$67,392
Maintenance Labor Cost	\$598
Maintenance Equipment Cost	\$2,217
Waste Disposal Cost	\$1,620
Total Cost	\$143,073

Hollyway Cleaners

Hollyway cleaners is located in Hollywood, California. The shop has two 60 pound Green Earth machines. In the past, Hollyway had two PERC machines, one a 35 pound machine and the other a 60 pound machine. IRTA did not perform a cost analysis for Hollyway Cleaners because the data could not be verified. A stand alone case study for the cleaner is included in Appendix B.

Imperial Dry Cleaners & Lndry

Imperial Dry Cleaners & Lndry is located in Los Angeles. The shop has a 55 pound Feori wet cleaning machine, the so-called “icy water” technology, and a 55 pound PERC machine. In the past, the shop had a 35 pound PERC machine and the 55 pound PERC machine that is still used. This analysis compares the costs of using the two PERC machines on the one hand and the Feori machine and the PERC machine on the other hand. Imperial cleans 312,000 pounds of clothing per year.

Imperial purchased the 55 pound Feori machine for \$29,500 and two dryers for \$20,000 each. The dryers include technology that allows dry cleaning of clothing. The installation cost amounted to \$4,500. Imperial did not believe they needed tensioning equipment with the icy water technology but did purchase it for \$10,000 because it is required under the SCAQMD grant. Imperial received a \$10,000 grant from SCAQMD to help with the purchase of the equipment. The total capital investment amounted to \$74,000. Assuming a useful life for the equipment of 15 years and a four percent cost of capital, the annualized capital cost is \$5,131.

When Imperial had two PERC machines, the shop used 60 gallons of PERC per month or 720 gallons per year. At a PERC price of \$7 per gallon, the annual PERC cost was \$5,040. The cost of purchasing PERC currently is half the cost or \$2,520 per year.

When Imperial used PERC exclusively, detergent use was 20 gallons per month or 240 gallons per year. At a cost of \$14.50 per gallon, the annual detergent cost was \$3,480. With the new wet cleaning machine, Imperial switched detergents and now uses eight gallons per month or 96 gallons per year of the PERC detergent. At a cost of \$30.80 per gallon, the PERC detergent cost is now \$2,957 per year. Imperial uses three gallons per week of detergent and one gallon per week of a degreaser for the wet cleaning machine. The cost of the detergent and the degreaser is \$25 and \$30 per gallon respectively. On this basis, the supplies for the wet cleaning machine amount to \$5,460 annually. The total cost for the PERC and wet cleaning detergent is \$8,417 per year.

The electricity bill, at \$2,000 per month or \$24,000 per year, is the same as it was when the shop had two PERC machines.

The gas bill, at \$2,000 per month or \$24,000 per year, has also remained the same.

The spotting labor is the same as it was before. It amounts to 60 hours per week or 3,120 hours per year. At a labor rate of \$10 per hour, the annual spotting labor cost is \$31,200.

The finishing labor is also the same as it was previously. It is 200 hours per week or 10,400 hours per year. At a labor rate of \$10 per hour, the finishing labor cost is \$104,000 per year.

When Imperial used PERC exclusively, the maintenance labor was three hours per week or 156 hours per year. At a labor rate of \$10 per hour, the annual cost of maintenance amounted to \$1,560. The maintenance labor was cut in half when the facility purchased the wet cleaning machine so the cost is now \$780 per year.

When Imperial used PERC exclusively, both PERC machines used spin disc filters. One cartridge filter was used to clean the whites. The cartridge filter was changed out every six months or twice a year. At a filter cost of \$35, the annual maintenance equipment cost amounted to \$70. Imperial now cleans the whites in the wet cleaning machines and has no filters.

The compliance cost for the facility has not changed. Imperial devotes two hours per week or 104 hours per year to compliance. At a labor rate of \$10 per hour, the compliance cost amounts to \$1,040 annually.

When Imperial used PERC exclusively, the facility generated two 55 gallon drums of sludge waste every three months or eight drums per year. The facility also generated one drum every six months or two drums a year of filter waste. At a disposal cost of \$275 per drum, the annual disposal cost was \$2,750. At this stage, Imperial generates one drum of waste every three months or four drums per year and has no filter waste. At a disposal cost of \$275 per drum, the yearly waste disposal cost is now \$1,100.

Table 3-8 shows the annualized cost comparison for Imperial.

**Table 3-8
Annualized Cost Comparison for Imperial Dry Cleaners & Lndry**

	PERC	PERC and Wet Cleaning
Annualized Capital Cost	-	\$5,131
Solvent Cost	\$5,040	\$2,520
Detergent Cost	\$3,480	\$8,417
Electricity Cost	\$24,000	\$24,000
Gas Cost	\$24,000	\$24,000
Spotting Labor Cost	\$31,200	\$31,200
Finishing Labor Cost	\$104,000	\$104,000
Maintenance Labor Cost	\$1,560	\$780
Maintenance Equipment Cost	\$70	-
Compliance Cost	\$1,040	\$1,040
Waste Disposal Cost	\$2,750	\$1,100
Total Cost	\$197,140	\$202,188

Note: The capital cost figure includes a \$10,000 grant from SCAQMD.

Larsen's Cleaners

Larsen's Cleaners is located in Irvine, California. The shop currently operates a 75 pound Green Earth machine. Larsen's used Valclene for three years in 1990. The shop converted to PERC and used the solvent for about 10 years. About a year ago, the cleaner converted to Green Earth. Larsen's cleans about 54,000 pounds of clothing per year and this volume has not changed since the conversion to Green Earth.

Larsen's owner submitted information to the landlord on Green Earth cleaning and the landlord indicated that Green Earth was the preferred cleaning agent from an environmental perspective. Larsen's purchased a 75 pound machine for use with Green Earth for \$80,000. This price is for the machine, a cooling tower, tax, installation and freight. Assuming a life for the machine of 15 years and a cost of capital of four percent, the annualized capital cost is \$5,547.

The dry cleaning facility previously used 70 gallons of PERC per year. At a cost of \$6 per gallon, the annual cost of purchasing PERC amounted to \$420. Larsen's now uses about 40 gallons of Green Earth each year at a cost of \$17 per gallon. The annual cost of purchasing the Green Earth solvent is \$680.

Larsen's pays a licensing fee of \$2,500 to use Green Earth.

When the facility used PERC, Larsen's purchased five gallon containers of detergent three or four times each year. Assuming three five gallon containers per year and a cost of \$30 per gallon for the detergent, the annual cost of the detergent amounted to \$450.

With Green Earth, the shop uses the same amount of detergent but the cost is \$45 per gallon. On this basis, the annual cost of detergent with Green Earth is \$675.

The electricity cost for Larsen's was \$750 per month or \$9,000 per year with PERC and this cost has not changed since the shop converted to Green Earth. The gas cost of \$800 per month or \$9,600 per year similarly did not change when the facility converted to the new solvent.

When Larsen's used PERC, the spotting labor amounted to nine hours per week or 468 hours per year. Assuming Larsen's labor rate of \$10 per hour, the annual cost of spotting with PERC was \$4,680. When the shop converted to Green Earth, the spotting labor approximately doubled to 18 hours per week or 936 hours per year. Again, assuming the \$10 per hour labor rate, the cost of spotting labor is now \$9,360.

The finishing labor with PERC was 39 hours per week or 2,028 hours per year. At a labor rate of \$10 per hour, the finishing labor cost was \$20,280. After the conversion to Green Earth, the finishing labor remained about the same as it was with PERC. The finishing labor cost with Green Earth is also assumed to be \$20,280.

Maintenance labor at Larsen's with PERC was one hour per week or 52 hours per year. At a labor rate of \$10 per hour, the annual maintenance labor cost is \$520. The maintenance labor has doubled with Green Earth because there are filters that must be changed and the system must be cleaned more often. Maintenance labor with the Green Earth is now \$1,040.

When Larsen's used PERC, the machine had spin disk filters so there was no maintenance equipment cost. The Green Earth equipment has three filters. Although Larsen's has not changed out the filters yet, the owner estimates they will be changed out every 12 months. Assuming a price for filters of \$35, the annual maintenance equipment cost is now \$105.

The compliance cost with PERC amounted to about one hour per week or 52 hours per year. Assuming a labor rate of \$10 per hour, the annual compliance cost was \$520. The compliance cost has been cut in half with Green Earth because there is less bookkeeping and reporting; it amounts to \$260 annually.

When Larsen's used PERC, the shop generated one 55 gallon drum and one 16 gallon drum of hazardous waste per year. The cost of disposal for the 55 gallon drum was \$250 and the cost of disposal for the 16 gallon drum was \$75. The total cost of disposal was \$325. Larsen's waste disposal with the Green Earth is about the same as with PERC.

Table 3-9 shows the annualized cost comparison of using PERC and Green Earth for Larsen's Cleaners.

Table 3-9
Annualized Cost Comparison for Larsen's Cleaners

	PERC	Green Earth
Annualized Capital Cost	-	\$5,547
Solvent Cost	\$420	\$680
Detergent Cost	\$450	\$675
Licensing Fee	-	\$2,500
Electricity Cost	\$9,000	\$9,000
Gas Cost	\$9,600	\$9,600
Spotting Labor Cost	\$4,680	\$9,360
Finishing Labor Cost	\$20,280	\$20,280
Maintenance Labor Cost	\$520	\$1,040
Maintenance Equipment Cost	-	\$105
Compliance Cost	\$520	\$260
Waste Disposal Cost	\$325	\$325
Total Cost	\$45,795	\$59,372

Nature's Best Cleaners

Nature's Best Cleaners is located in Alta Loma, California. For several years, the store relied on perchloroethylene (PERC). About five years ago, the facility converted to a wet cleaning process. Nature's Best cleans about 104,000 pounds of clothing per year.

When the owner of Nature's Best found out his site was contaminated, he decided to investigate alternatives to PERC. He focused on wet cleaning. He spent four years looking into equipment and processes and spent \$450,000 on equipment before he settled on the equipment he uses today. Because there is a learning curve with wet cleaning, the first year he used the wet cleaning process, he paid out \$10,000 in damages. At this stage, he has five stores and four of them have wet cleaning equipment and one has a hydrocarbon machine.

Nature's Best purchased a 42 pound wet cleaning machine for \$36,000. The shop spent an additional \$16,000 on tensioning equipment and \$15,000 for installation. The total capital cost amounted to \$67,000. Assuming a 15 year life for the equipment and a four percent cost of capital, the annualized capital cost is \$4,645.

When Nature's Best used PERC, the shop purchased 10 gallons per month or 120 gallons per year of the solvent. At a cost of \$6 per gallon, the total annual PERC purchases amounted to \$720.

When Nature's Best used PERC, the shop paid \$0.13 per load or \$451 per year for detergent. The shop now spends \$0.06 per load or \$173 per year for detergent for the wet cleaning process.

The electricity cost when PERC was used was \$600 per month or \$7,200 per year. The electricity cost now that wet cleaning is used is only \$180 per month or \$2,160 annually.

The gas cost with PERC amounted to \$700 per month or \$8,400 per year. With wet cleaning, the gas cost is lower at \$600 per month or \$7,200 per year.

When Nature’s Best used PERC, the spotting labor was 40 hours per week or 2,080 hours per year. Assuming the shop’s labor cost of \$10 per hour, the annual spotting labor cost is \$20,800. With wet cleaning, the spotting labor has decreased to 40 minutes per day or 208 hours per year assuming the facility operates six days per week. Assuming the labor rate of \$10 per hour, the spotting labor cost is now \$2,080.

With PERC, Nature’s Best spent 80 hours per week or 4,160 hours per year finishing the garments. At the labor rate of \$10 per hour, the finishing labor cost amounted to \$41,600. The owner claims that finishing labor is the same with wet cleaning.

When PERC was used, the maintenance labor was two hours per week or 104 hours per year. Assuming the labor rate of \$10 per hour, the maintenance labor cost was \$1,040 per year. Maintenance labor with wet cleaning has remained the same.

When the shop used PERC, eight filters were replaced every 20,000 pounds of clothing cleaned or about five times a year. Assuming a cost of \$35 per filter, the maintenance equipment cost was \$1,400 per year. There is no maintenance equipment cost with wet cleaning.

With PERC, Nature’s Best spent about 15 minutes per day or 78 hours per year on compliance. Assuming a labor cost of \$10 per hour, the compliance cost was \$780 per year. There is no compliance cost with wet cleaning.

When PERC was used, Nature’s Best disposed of one 55 gallon drum every three months. At a cost of \$250 per drum, the annual waste disposal cost amounted to \$1,000 per year. There is no waste disposal cost with wet cleaning. Table 3-10 summarizes the cost comparison of PERC and wet cleaning for Nature’s Best.

Table 3-10
Annualized Cost Comparison for Nature’s Best Cleaners

	PERC	Wet Cleaning
Annualized Capital Cost	-	\$4,645
Solvent Cost	\$720	-
Detergent Cost	\$451	\$173
Electricity Cost	\$7,200	\$2,160
Gas Cost	\$8,400	\$7,200
Spotting Labor Cost	\$20,800	\$2,080
Finishing Labor Cost	\$41,600	\$41,600
Maintenance Labor Cost	\$1,040	\$1,040
Maintenance Equipment Cost	\$1,400	-
Compliance Cost	\$780	-
Waste Disposal Cost	\$1,000	-
Total Cost	\$83,391	\$58,898

Royal Cleaners of Brentwood

Royal Cleaners, located in Santa Monica, California, had a 55 pound PERC machine in the past and now has a 60 pound carbon dioxide machine. The shop cleans 104,000 pounds of clothing per year.

Royal purchased a 60 pound carbon dioxide machine for \$150,000. The cost of a carbon dioxide storage tank was \$5,000. The installation cost was \$25,000. Royal also received a grant from the South Coast Air Quality Management District of \$20,000. The total capital cost was \$160,000. Assuming a 15 year life for the equipment and a cost of capital of four percent, the annualized cost of the equipment is \$11,093.

When Royal used PERC, the facility used 100 gallons per year. At a cost of \$6.50 per gallon, the annual cost of PERC was \$650. Royal uses 200 pounds of carbon dioxide per week or 10,400 pounds per year. Assuming a cost of 18 cents per pound, the cost of carbon dioxide amounts to \$1,872 per year.

When Royal used PERC, the shop used one gallon per week or 52 gallons per year of detergent. At a cost of \$25 per gallon, the annual cost of detergent was \$1,300. With carbon dioxide, Royal uses two gallons of detergent per week or 104 gallons per year. At a detergent cost of \$40 per gallon, the annual detergent cost is now \$4,160.

With PERC, Royal's electricity cost was \$400 per month or \$4,800 per year. With carbon dioxide, the electricity cost has increased to \$650 per month or \$7,800 per year.

The gas cost for the facility has not changed. It amounts to \$275 per month or \$3,300 per year.

With PERC, Royal's spotting labor was 12 hours per week or 624 hours per year. Assuming a labor rate of \$13 per hour, the annual spotting labor cost was \$8,112. The spotting labor cost with carbon dioxide has doubled to \$16,224 per year.

When Royal used PERC, the finishing labor was 144 hours per week or 7,488 hours per year. At a labor rate of \$13 per hour, the finishing labor cost was \$97,344 per year. When Royal converted to carbon dioxide, the finishing labor cost did not change.

With PERC, the maintenance labor amounted to one hour per week or 52 hours per year. At the labor rate of \$13 per hour, the maintenance labor cost was \$676 annually. With carbon dioxide, normal maintenance labor is still one hour per week or 52 hours per year. Additional labor of one hour every two weeks for carbon dioxide filling is now required. The annual cost of maintenance labor is now \$1,014 per year.

When Royal used PERC, the shop replaced 12 filters every three months or 48 filters per year. Assuming a cost of \$35 per filter, the maintenance equipment cost was \$1,680 per year. There is no maintenance equipment cost with carbon dioxide.

The compliance costs with PERC and carbon dioxide are the same. The shop spends three hours per week in compliance activities and two hours per month at meetings. Assuming a labor rate of \$13 per hour, the annual compliance cost is \$2,340.

With PERC, Royal’s waste disposal costs amounted to \$550 every three months or \$2,200 per year. Although Royal has not yet disposed of waste with the carbon dioxide, the shop expects to dispose of one drum every six months. At a cost of \$250 per drum, the waste disposal costs would total \$500 per year. Table 3-11 shows the annualized cost comparison for Royal.

Table 3-11
Annualized Cost Comparison for Royal Cleaners of Brentwood

	PERC	Carbon Dioxide
Annualized Capital Cost	-	\$11,093
Solvent/Carbon Dioxide Cost	\$650	\$1,872
Detergent Cost	\$1,300	\$4,160
Electricity Cost	\$4,800	\$7,800
Gas Cost	\$3,300	\$3,300
Spotting Labor Cost	\$8,112	\$16,224
Finishing Labor Cost	\$97,344	\$97,344
Maintenance Labor Cost	\$676	\$1,014
Maintenance Equipment Cost	\$1,680	-
Compliance Cost	\$2,340	\$2,340
Waste Disposal Cost	\$2,200	\$500
Total Cost	\$122,402	\$145,647

Note: The capital cost figure includes a \$20,000 grant from SCAQMD.

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 two 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 3-12 shows the annualized cost comparison of PERC and hydrocarbon for Sterling.

Table 3-12
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

Sunny Fresh Cleaners

Sunny Fresh Cleaners is located in San Marcos, California. The shop opened about a year ago and uses the Pure Dry process. Sunny Fresh Cleaners cleans about 31,200 pounds of clothing per year.

The cleaner purchased a 35 pound hydrocarbon machine that was specified by the Pure Dry process vendor. The cost of the machine was \$53,000 and installation was another \$5,000. Assuming a 15 year life for the equipment and a four percent cost of capital, the annualized capital cost is \$4,021.

Sunny Fresh uses 30 gallons per year of the Pure Dry solvent. At a cost of \$15 per gallon, the annual cost of solvent purchases amounts to \$450. The shop uses no separate detergent.

The combined cost of electricity and gas for Sunny Fresh is \$500 per month or \$6,000 per year.

Spotting labor at Sunny Fresh is two hours per week or 104 hours per year. At the shop's labor rate of \$9.50 per hour, the annual spotting labor cost is \$988. Finishing labor at Sunny Fresh amounts to 48 hours per week or 2,496 hours per year. Again, assuming a labor rate of \$9.50 per hour, the annual cost of finishing labor is \$23,712.

Maintenance requires 0.5 hours per week or 26 hours per year. Using the \$9.50 per hour labor rate, annual maintenance labor is \$247.

Sunny Fresh replaces one filter every 1,500 pounds of clothing cleaned. On this basis, the shop uses an average of 20.8 filters per year. At a cost of \$35 for each filter, the filter replacement cost is \$728 per year.

The shop generates one 55 gallon drum of waste every six months. At a disposal cost of \$250 per drum, the annual disposal cost amounts to \$500. Sunny Fresh has no compliance costs. Table 3-13 shows the annualized costs for Sunny Fresh.

Table 3-13
Annualized Costs for Sunny Fresh Cleaners

	Pure Dry
Annualized Capital Cost	\$4,021
Solvent Cost	\$450
Electricity and Gas Cost	\$6,000
Spotting Labor Cost	\$988
Finishing Labor Cost	\$23,712
Maintenance Labor Cost	\$247
Maintenance Equipment Cost	\$728
Waste Disposal Cost	\$500
Total Cost	\$36,646

Village Dry Cleaners

Village Dry Cleaners, located in Santa Clarita, California, uses a 35 pound Green Jet machine. The shop cleans 31,200 pounds of clothing per year. Village started up using the Green Jet process and PERC was never used there.

Village purchased a 35 pound Green Jet machine for \$17,000. Installation was included in the price. Assuming a 15 year life for the equipment and a four percent cost of capital, the annualized capital cost is \$1,179.

Village uses five gallons of detergent per month or 60 gallons per year in the Green Jet machine. At a cost of \$34 per gallon, the annual detergent cost amounts to \$2,040.

The shop pays \$300 per month for electricity or \$3,600 per year.

Village pays \$400 per month for gas or \$4,800 per year.

The spotting labor at Village amounts to three hours per day six days per week. Assuming a spotting labor rate of \$10 per hour, the annual cost of spotting labor is \$9,360 per year.

The finishing labor totals five hours per day six days per week. Assuming a finishing labor rate of \$10 per hour, the annual finishing labor cost is \$15,600.

Maintenance labor amounts to one hour per week or 52 hours per year. At a labor rate of \$10 per hour, the annual cost of maintenance labor is \$520.

Village estimates that routine equipment replacement amounts to \$1,000 per year.

Table 3-14 shows the annualized capital cost for Village's Green Jet system.

Table 3-14
Annualized Costs for Village Dry Cleaners

	Green Jet System
Annualized Capital Cost	\$1,179
Detergent Cost	\$2,040
Electricity Cost	\$3,600
Gas Cost	\$4,800
Spotting Labor Cost	\$9,360
Finishing Labor Cost	\$15,600
Maintenance Labor Cost	\$520
Maintenance Equipment Cost	\$1,000
Total Cost	\$38,099

RESULTS OF THE CASE STUDY ANALYSIS

Table 3-15 summarizes the results of the case study analysis for 13 of the cleaners. The first column lists the cleaner's name. The second column lists the technology used by the cleaner. In some cases, where the cleaner used PERC prior to converting to the alternative technology, there are two entries, one for PERC and one for the alternative technology. 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 alternative technology. Note that there are no capital costs for the PERC process and these are included later in the model plant analysis. 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 alternative technology and not for PERC dry cleaning.

IRTA included a facility, Hollyway Cleaners that converted from PERC to Green Earth in this document. The cost information provided by Hollyway could not be verified so the cost analysis is not presented. Since there are no cost data, Hollyway is not included in Table 3-15 .

The values of Table 3-15 illustrate that spotting labor costs and finishing labor costs are a very large portion of the total costs that were considered here for nearly all cleaners. Utilities also represent a relatively high cost. It is important to include these costs in a comparison of PERC and the alternatives to see if there are differences.

IRTA believed it was important to include a large exclusive wet cleaner in the analysis to examine whether there might be differences between large and small wet cleaning facilities. At the start of the project, IRTA visited a very large exclusive wet cleaner. This cleaner, however, decided he could not operate the facility in a cost effective manner with wet cleaning. The only other large wet cleaner in the area is Nature's Best. This facility provided cost information that could not be verified. The Nature's Best information is provided in Table 3-15 but is not used in the subsequent analysis.

Comparison of PERC With Alternative Technologies

Table 3-16 summarizes some of the information from the larger Table 3-15. It includes information from the seven facilities (excluding Nature's Best and Hollyway Cleaners) that used PERC and then converted to one of the alternatives. The facilities are presented in the table in order of decreasing pounds of clothing cleaned per year.

**Table 3-15
Annualized Cost Summary for Case Study Cleaners**

Dry Cleaner	Cleaning Method	Pounds Per Year Cleaned	Costs																	Cost per pound cleaned	Cost per pound cleaned no machine
			Annualized Capital	Solvent	Licensing Fee	Detergent	Electricity	Gas	Spotting Labor	Finishing Labor	Maintenance Labor	Maintenance Equipment	Compliance	Hazardous Waste Disposal	Total						
Blackburn's	Glycol Ether	46,800	\$4,125	\$780	-	\$0	\$12,000	\$9,600	\$520	\$15,600	\$10,920	\$0	\$0	\$0	\$0	\$0	\$0	\$53,545	\$1.14	\$1.06	
	PERC	168,000	\$0	\$4,800	-	\$5,720	\$11,760	\$5,400	\$31,200	\$62,400	\$1,300	\$1,260	\$2,600	\$2,600	\$3,600	\$1,600	\$1,300,040	\$0.77	\$0.77		
Crown	Hydrocarbon	168,000	\$7,280	\$3,544	-	\$0	\$9,600	\$5,100	\$31,200	\$62,400	\$520	\$1,062	\$650	\$1,600	\$1,600	\$122,956	\$0.73	\$0.69			
	Wet Cleaning	31,200	\$1,595	\$0	-	\$1,260	\$1,800	\$4,200	\$6,240	\$23,400	\$520	\$0	\$0	\$0	\$0	\$39,015	\$1.25	\$1.20			
Cypress Metro	PERC	78,000	\$0	\$390	-	\$2,880	\$9,600	\$10,200	\$24,960	\$99,840	\$0	\$940	\$1,248	\$1,200	\$151,158	\$1.94	\$1.94				
	Green Earth	78,000	\$1,040	\$792	\$2,500	\$2,880	\$9,600	\$12,000	\$49,920	\$99,840	\$0	\$1,260	\$624	\$1,200	\$181,656	\$2.33	\$2.32				
Doherty	PERC	39,000	\$0	\$480	-	\$0	\$3,600	\$3,000	\$6,240	\$24,960	\$0	\$0	\$520	\$600	\$39,400	\$1.01	\$1.01				
	Wet Cleaning	39,000	\$3,605	\$0	-	\$2,340	\$2,400	\$4,200	\$7,800	\$31,200	\$0	\$0	\$0	\$0	\$51,545	\$1.32	\$1.23				
Fay	Wet Cleaning	31,200	\$1,595	\$0	-	\$1,260	\$1,800	\$4,200	\$6,240	\$23,400	\$520	\$0	\$0	\$0	\$39,015	\$1.25	\$1.20				
	PERC	312,000	\$0	\$5,040	-	\$3,480	\$24,000	\$24,000	\$31,200	\$104,000	\$1,560	\$70	\$1,040	\$2,750	\$197,140	\$0.63	\$0.63				
Imperial	Wet Water and PERC	312,000	\$5,131	\$2,520	-	\$8,417	\$24,000	\$24,000	\$31,200	\$104,000	\$780	\$0	\$1,040	\$1,100	\$202,188	\$0.65	\$0.63				
	PERC	55,000	\$0	\$420	-	\$450	\$9,000	\$9,600	\$4,680	\$20,280	\$520	\$0	\$520	\$325	\$45,795	\$0.83	\$0.83				
Larsen's	Green Earth	55,000	\$5,547	\$680	\$2,500	\$675	\$9,000	\$9,600	\$9,360	\$20,280	\$1,040	\$105	\$260	\$325	\$59,372	\$1.08	\$0.98				
	PERC	104,000	\$0	\$720	-	\$451	\$7,200	\$8,400	\$20,800	\$41,600	\$1,040	\$1,400	\$780	\$1,000	\$83,391	\$0.80	\$0.80				
Nature's Best	Wet Cleaning	104,000	\$4,645	\$0	-	\$173	\$2,160	\$7,200	\$2,080	\$41,600	\$1,040	\$0	\$0	\$0	\$58,898	\$0.57	\$0.52				
	PERC	104,000	\$0	\$650	-	\$1,300	\$4,800	\$3,300	\$8,112	\$97,344	\$676	\$1,680	\$2,340	\$2,200	\$122,402	\$1.18	\$1.18				
Royal	Carbon Dioxide	104,000	\$11,093	\$1,872	-	\$4,160	\$7,800	\$3,300	\$16,224	\$97,344	\$1,014	\$0	\$2,340	\$500	\$145,647	\$1.40	\$1.29				
	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				
Sterling	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				
	Pure Dry	31,200	\$4,021	\$450	-	\$0	\$6,000	\$0	\$988	\$23,712	\$247	\$728	\$0	\$500	\$36,646	\$1.17	\$1.05				
Village	Green Jet	31,200	\$1,179	\$0	-	\$2,040	\$3,600	\$4,800	\$9,360	\$15,600	\$520	\$1,000	\$0	\$0	\$39,099	\$1.22	\$1.18				

**Table 3-16
Annualized Cost Comparison of PERC and Non-PERC Alternatives**

Facility	Technology	Pounds Per Year	Total Cost	Total Cost Per Pound	Operating Cost Per Pound
Imperial	PERC	312,000	\$197,140	\$0.63	\$0.63
	PERC/icy water	312,000	\$202,188	\$0.65	\$0.63
Sterling	PERC	254,800	\$249,361	\$0.98	\$0.98
	hydrocarbon	254,800	\$259,384	\$1.02	\$0.99
Crown	PERC	168,000	\$130,040	\$0.77	\$0.77
	hydrocarbon	168,000	\$122,956	\$0.73	\$0.69
Royal	PERC	104,000	\$122,402	\$1.18	\$1.18
	carbon dioxide	104,000	\$145,647	\$1.40	\$1.29
Doheny	PERC	78,000	\$151,158	\$1.94	\$1.94
	Green Earth	78,000	\$181,656	\$2.33	\$2.32
Larsen's	PERC	54,000	\$45,795	\$0.83	\$0.83
	Green Earth	54,000	\$59,372	\$1.08	\$0.98
Fay	PERC	39,000	\$39,400	\$1.01	\$1.01
	wet cleaning	39,000	\$51,545	\$1.32	\$1.23

Five of the facilities increased their operating cost per pound cleaned through the conversion, one reduced the cost and the cost for one facility remained the same. For those facilities that increased their cost, the cost increase ranged from about one percent for Sterling to 31 percent for Fay. The magnitude of the cost increase for Fay excluding the equipment cost amounted to about \$8,500 per year. The data suggest that some cleaners will experience a cost increase in converting from PERC to an alternative but it is not a large cost increase.

Large Cleaners

Table 3-17 presents the costs for the large cleaning facilities, those cleaners that process more than 100,000 pounds of garments per year.

The total cost per pound of clothing cleaned with PERC ranges from \$0.63 to \$1.18. The total cost per pound of clothing cleaned for the alternatives ranges from \$0.65 to \$1.40. Royal and Hangers have the highest total cost per pound of clothing cleaned for the alternatives and both clean with carbon dioxide. The equipment for use with carbon dioxide is more costly than the equipment for any of the other alternatives so this is not surprising. Hangers and Royal also have the highest operating cost per pound of clothing cleaned for the alternatives. Both Royal and Hangers are located in very high end areas and would be expected to charge higher prices for cleaning.

Table 3-17**Annualized Cost Comparison for Large Cleaners**

Facility	Technology	Pounds Per Year	Total Cost	Total Cost Per Pound	Operating Cost Per Pound
Imperial	PERC	312,000	\$197,140	\$0.63	\$0.63
	PERC/icy water	312,000	\$202,188	\$0.65	\$0.63
Sterling	PERC	254,800	\$249,361	\$0.98	\$0.98
	hydrocarbon	254,800	\$259,384	\$1.02	\$0.99
Crown	PERC	168,000	\$130,040	\$0.77	\$0.77
	hydrocarbon	168,000	\$122,956	\$0.73	\$0.69
Hangers	carbon dioxide	117,000	\$143,073	\$1.22	\$1.12
Royal	PERC	104,000	\$122,402	\$1.18	\$1.18
	carbon dioxide	104,000	\$145,647	\$1.40	\$1.29

The total operating cost for the other facilities for the alternatives are all less than \$1 per pound. These large facilities are very efficient operations regardless of the technology they use.

Small Cleaners

Table 3-18 shows the costs for the small cleaning facilities, those cleaning less than 100,000 pounds of clothing per year. The total cost per pound of clothing cleaned and the operating cost per pound of clothing cleaned are more than \$1 per pound for PERC and all other technologies with the exception of Larsen's. In general, the costs for the small facilities are higher than the costs for the large facilities with the exception of Hangers and Royal. It is reasonable to assume that smaller facilities are less efficient than large facilities.

Table 3-18**Annualized Cost Comparison for Small Cleaners**

Facility	Technology	Pounds Per Year	Total Cost	Total Cost Per Pound	Operating Cost Per Pound
Doheny	PERC	78,000	\$151,158	\$1.94	\$1.94
	Green Earth	78,000	\$181,656	\$2.33	\$2.32
Larsen's	PERC	54,000	\$45,795	\$0.83	\$0.83
	Green Earth	54,000	\$59,372	\$1.08	\$0.98
Blackburn's	Rynex	46,800	\$53,545	\$1.14	\$1.06
Fay	PERC	39,000	\$39,400	\$1.01	\$1.01
	wet cleaning	39,000	\$51,545	\$1.32	\$1.23
Cypress	wet cleaning	31,200	\$39,015	\$1.25	\$1.20
Sunny Fresh	Pure Dry	31,200	\$36,646	\$1.17	\$1.05
Village	Green Jet	31,200	\$38,099	\$1.22	\$1.18

Spotting and Finishing Labor Costs

Table 3-19 shows the spotting and finishing labor costs for the facilities both for PERC and the alternative technologies. In this table, the facilities are listed from largest to smallest in terms of pounds of clothing cleaned annually.

**Table 3-19
Annualized Cost Comparison for Spotting and Finishing Labor Costs**

Facility	Technology	Pounds Per Year	Spotting Labor Cost	Finishing Labor Cost	Total Cost
Imperial	PERC	312,000	\$31,200	\$104,000	\$197,140
	PERC/icy water	312,000	\$31,200	\$104,000	\$202,188
Sterling	PERC	254,800	\$44,096	\$145,517	\$249,361
	hydrocarbon	254,800	\$44,096	\$145,517	\$259,384
Crown	PERC	168,000	\$31,200	\$62,400	\$130,040
	hydrocarbon	168,000	\$31,200	\$62,400	\$122,956
Hangers	carbon dioxide	117,000	\$5,980	\$67,392	\$143,073
Royal	PERC	104,000	\$8,112	\$97,344	\$122,402
	carbon dioxide	104,000	\$16,224	\$97,344	\$145,647
Doheny	PERC	78,000	\$24,960	\$99,840	\$151,158
	Green Earth	78,000	\$49,920	\$99,840	\$181,656
Larsen's	PERC	54,000	\$4,680	\$20,280	\$45,795
	Green Earth	54,000	\$9,360	\$20,280	\$59,372
Blackburn's	Rynex	46,800	\$520	\$15,600	\$53,545
Fay	PERC	39,000	\$6,240	\$24,960	\$39,400
	wet cleaning	39,000	\$7,800	\$31,200	\$51,545
Cypress	wet cleaning	31,200	\$6,240	\$23,400	\$39,015
Sunny Fresh	Pure Dry	31,200	\$988	\$23,712	\$36,646

Spotting labor costs range from one percent of total costs for Blackburn's glycol ether process to 17 percent for Sterling's hydrocarbon process. The two Green Earth cleaners, Larsen's and Doheny, experienced a doubling of spotting labor costs when they converted from PERC. Hanger's and Royal both have fairly low spotting labor costs with their carbon dioxide processes, four and eleven percent of total costs respectively.

Sunny Fresh, with the Pure Dry process, also has low spotting costs, at three percent of total costs. The spotting costs for the cleaners that converted from PERC to hydrocarbon, Crown and Sterling, stayed the same.

Finishing labor costs account for a significant fraction of total costs. They range from 34 percent of total costs for Larsen's Green Earth cleaning process to 80 percent for Royal's carbon dioxide costs. When Larsen's and Doheny converted from PERC to Green Earth cleaning, the finishing labor cost remained the same. Finishing labor costs for Crown and Sterling remained the same when the shops converted from PERC to hydrocarbon. When Fay converted to wet cleaning, the finishing labor cost increased somewhat. When Imperial converted to icy water, the finishing cost stayed the same.

As discussed earlier, owners and family members often perform spotting and finishing activities at small cleaning facilities. Although these individuals are generally not paid for their work, their labor is a real cost for the facilities. The spotting and finishing labor costs explicitly include the labor hours the owners and family members devote to spotting and finishing.

Alternative Technology Cost Comparison

Table 3-20 shows the cost comparison for all of the alternative technologies evaluated during the project in order of lowest to highest total cost per pound of clothing cleaned.

The total cost per pound in Table 3-20 is lowest for the icy water technology. Referring back to Table 3-15, the spotting labor cost and finishing labor cost for Imperial are lower than they are for other facilities on a per pound basis. As mentioned earlier, spotting and finishing labor costs are the highest costs for the facilities analyzed. Note also that Imperial has a PERC machine and an icy water machine in contrast to the other facilities that do not have a PERC machine.

Crown has the second lowest total cost per pound in Table 3-20. Referring back to Table 3-15, this is because the cleaner is using hydrocarbon with tonsil. There are no detergent costs and the utility costs are lower because the facility does not distill the solvent. Crown's electricity and gas costs both declined when the facility converted from PERC to hydrocarbon. Sterling, the other hydrocarbon facility that was analyzed, does not use tonsil and the electricity and gas costs increased after the conversion. Even so, Sterling is a very efficient cleaner and the shop has the third lowest cost on a per pound basis.

Larsen's, a cleaner that converted from PERC to the Green Earth technology, has the fourth lowest total cost per pound. Larsen's did experience an increase in the spotting labor cost after the conversion to PERC but had no increase in finishing labor cost. Doheny, the other facility that converted to Green Earth cleaning, also experienced a substantial increase in spotting labor.

The hydrocarbon and Green Earth solvents are both more gentle solvents than PERC. The industry is aware that, as a consequence, the spotting labor cost should increase when

these alternatives are adopted. The spotting labor cost did not increase when Crown and Sterling converted to hydrocarbon but the spotting labor cost for Larsen's and Doheny did increase upon conversion to Green Earth.

**Table 3-20
Annualized Total Cost Comparison for Cleaners**

Facility	Technology	Pounds Per Year	Total Cost	Total Cost Per Pound	Operating Cost Per Pound
Imperial	PERC/icy water	312,000	\$202,188	\$0.65	\$0.63
Crown	hydrocarbon	168,000	\$122,956	\$0.73	\$0.69
Sterling	hydrocarbon	254,800	\$259,384	\$1.02	\$0.99
Larsen's	Green Earth	54,000	\$59,372	\$1.08	\$0.98
Blackburn's	Rynex	46,800	\$53,545	\$1.14	\$1.06
Sunny Fresh	Pure Dry	31,200	\$36,646	\$1.17	\$1.05
Hangers	carbon dioxide	117,000	\$143,073	\$1.22	\$1.12
Village	Green Jet	31,200	\$38,099	\$1.22	\$1.18
Cypress	wet cleaning	31,200	\$39,015	\$1.25	\$1.20
Fay	wet cleaning	39,000	\$51,545	\$1.32	\$1.23
Royal	carbon dioxide	104,000	\$145,647	\$1.40	\$1.29
Doheny	Green Earth	78,000	\$181,656	\$2.33	\$2.32

Blackburn's, using the Rynex technology, has the fifth lowest cost. The facility does not use detergent because of the good cleaning ability of the glycol ether. The spotting labor cost is very low, again because the solvent cleans oil based and water soluble soils effectively. The reason Blackburn's is not the lowest cost technology is because the shop has a very high maintenance labor cost. This labor cost is high because the solvent contains water which boils over during distillation.

Sunny Fresh, with the Pure Dry process, has the sixth lowest cost. The shop does not use detergent and has a relatively low spotting labor cost.

Hangers and Village have the next highest cost. Hangers uses the carbon dioxide technology which has a high equipment cost. The cost of the carbon dioxide technology is also fairly high but the spotting labor cost is low. The electricity cost for Hangers is very high, primarily because the facility is air conditioned; most cleaning facilities in southern California are not air conditioned. Village uses the Green Jet technology which is not an aggressive cleaning method. The detergent costs and the spotting labor costs for this technology are high. The finishing labor cost is low because the garments are not immersed in water but, rather, are misted with a mixture of water and detergent.

The next two highest cost facilities are Cypress and Fay, which use the traditional wet cleaning process. The spotting labor cost with wet cleaning is slightly higher than with PERC and the finishing labor cost is higher than with PERC. Since spotting and finishing labor costs represent a significant portion of total costs for cleaners, the total cost per pound for traditional wet cleaning facilities is slightly higher.

Royal, a facility using carbon dioxide, has the next highest cost. As was the case for Hangers, the equipment cost and the cost of carbon dioxide are high. The finishing labor cost is high for Royal.

The highest cost facility is Doheny, a cleaner using the Green Earth technology. Doheny's total cost per pound is high both when the facility used PERC and after the conversion to the Green Earth solvent. Spotting costs are high for the facility because the Green Earth technology is not very aggressive. The facility also has high finishing costs compared with other facilities.

IV. HEALTH AND ENVIRONMENTAL EFFECTS OF ALTERNATIVES AND OTHER ISSUES AFFECTING THEIR USE

This section focuses on the health and environmental impacts of the alternatives to PERC dry cleaning. The section first presents some information on the toxicity of the alternatives and then discusses the results of an analysis project IRTA conducted with the Los Angeles County Sanitation Districts (LACSD). Finally, the section discusses the grant programs established in California to assist cleaners in adopting the alternatives

TOXICITY/ENVIRONMENTAL EFFECTS OF ALTERNATIVES

From an overall health standpoint, traditional wet cleaning, the icy water technology, the Green Jet technology and carbon dioxide cleaning are the best technologies. The first three of these technologies rely on water containing detergent as the cleaning medium. The detergent is low in toxicity. Carbon dioxide is not toxic but it is classified as a global warming gas. Use of the carbon dioxide dry cleaning process, however, does not result in a net gain of global warming gases. The carbon dioxide is taken from other processes where it would otherwise be emitted.

The other alternative cleaning processes rely on chemicals to perform the cleaning. At the request of CARB, the Office of Environmental Health Hazard Assessment (OEHHA) is evaluating the toxicity of the alternative solvents used in this industry. OEHHA is reviewing the existing toxicity information for the hydrocarbon used in the hydrocarbon and Pure Dry processes, the glycol ether used in the Rynex process and a chemical called D5 that is used in the Green Earth cleaning process.

The Occupational Safety and Health Administration (OSHA) has not established an exposure limit for the hydrocarbon which is used in the hydrocarbon dry cleaning process. The chemical is an isoparaffin and, as the MSDS shown in Appendix A indicates, Exxon Mobil recommends an exposure limit for the chemical of 171 ppm. The isoparaffin is classified as a VOC which contributes to smog.

A similar hydrocarbon is used in the Pure Dry process. In addition, as discussed earlier in Section II, the process also has two chemical additives, a perfluorocarbon or PFC for flash point suppression and a hydrofluoroether (HFE) which is used to enhance drying. The PFC and, to a smaller extent, the HFE, contribute to global warming. PFCs have been banned in industrial cleaning applications by EPA because of their high global warming potential.

The MSDS for Rynex indicates that it is a mixture of azeotropes of substituted aliphatic glycol ethers. The Rynex Principal was issued a patent (U.S. Patent Application 20020083531) for dry cleaning solvents containing a mixture of dipropylene glycol tert-butyl ether (DPTB) and water on July 4, 2002. Lyondell offers a mixture of 90 percent DPTB and two other glycol ethers called DPTB-90. This may be the glycol ether used in the Rynex process. OSHA has not established an exposure level for the chemical and

Lyondell does not recommend one on the MSDS. DPTB is classified as a VOC which contributes to smog.

D5 is not classified as a VOC and is exempt from VOC regulations. As indicated on the MSDS shown in Appendix A, GE Silicones, one of the manufacturers of D5, recommends an exposure level for the solvent of 10 ppm which is much lower than the level for most other solvents. This level is apparently based on liver toxicity observed in animal toxicity tests. According to the MSDS, “these biochemical pathways are more sensitive in rodents than in humans.” OEHHA evaluated the data and found there were increases in liver weight for male and female rodents. On this basis, the agency calculated a proposed chronic reference exposure level of 46 ppb for D5.

The D5 MSDS indicates that, in a chronic toxicity and carcinogenicity inhalation study in rats, “a statistically significant increase in the trend for uterine endometrial tumors was observed in female rats exposed for 24 months at the highest dose level of 160 ppm.” The MSDS also states that “whether or not this increase in incidence is truly related to the exposure to D5 is questionable and yet to be determined.” The toxicity testing of D5 has been completed and submitted to OEHHA in California for evaluation.

ANALYSIS OF WASTE STREAMS

For the EPA and CARB project, IRTA and LACSD conducted an investigation of some of the waste streams of the alternative technologies. IRTA collected samples from appropriate facilities using the alternative technologies and LACSD analyzed the samples in their lab. The protocol for the sampling and analysis program is described below and the results of the analysis are presented and discussed.

Protocol for Sampling and Analysis Program

The waste streams generated in the PERC dry cleaning process include the distillation still bottom, filtration waste, separator water and lint. Under RCRA, spent PERC solutions are listed hazardous wastes. Thus, waste streams that are derived from PERC are classified as hazardous wastes and must be disposed of properly. Dry cleaners generally dispose of their PERC-containing waste as hazardous wastes and they are transported by registered hazardous waste haulers. In some cases, separator water is handled differently. It can be evaporated and most cleaners use this method of disposal.

No work has been done to date to characterize the waste streams from the PERC dry cleaning alternative processes. IRTA and LACSD decided to perform a limited investigation. Waste streams from the PERC chemical alternatives including hydrocarbon, glycol ethers, D5 and carbon dioxide are not listed hazardous wastes under RCRA so they would not automatically be classified as 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 their respective STLC are classified as

hazardous waste. IRTA and LACSD decided to analyze the waste streams for copper, lead, nickel and zinc. The still bottoms and separator water from the alternative cleaning processes were analyzed for soluble metals. The STLCs for the four selected metals are shown in Table 4-1.

Table 4-1
STLC Levels in Title 22 for Certain Metals

Substance	STLC (milligrams per liter)
Copper and/or copper compounds	25
Lead and/or lead compounds	5.0
Nickel and/or nickel compounds	20
Zinc and/or zinc compounds	250

California also has additional criteria for waste streams. If the waste exhibits the toxicity characteristic by being aquatically toxic, it is classified as hazardous waste. This involves exposing fathead minnows for 96 hours to a sample of the waste and calculating the LC-50, which is the concentration of 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. The LACSD lab tested the still bottoms from the distillation process from the hydrocarbon, glycol ether, Green Earth and carbon dioxide processes and the separator water from the hydrocarbon, glycol ether and Green Earth processes. The carbon dioxide process does not generate separator water.

The still bottoms and separator water from the chemical alternative processes were also tested for toxic volatile and semi-volatile organics. These are organics, including chlorinated solvents like PERC, that are considered to be toxic.

IRTA and LACSD also developed a protocol to test the effluent from wet cleaning processes. Both the wash and the rinse effluent from four wet cleaning facilities were sampled. The samples were analyzed for the same metals identified above. They were also tested for toxic organic compounds and for aquatic toxicity.

Results of the Chemical Alternative Process Sampling

IRTA sampled the distillation still bottoms and separator water at one hydrocarbon facility, one Green Earth cleaning facility and one glycol ether cleaning facility. Table 4-2 shows the results of the analysis of the distillation still bottom samples collected from facilities using the alternative chemical processes.

The values of Table 4-2 show that in only one case did the metals concentration exceed the allowed STLC. The STLC for lead is 5.0 milligrams per liter according to Table 4-1. The lead concentration found in the still bottoms from the Green Earth process was 5.18 which exceeds the STLC. The source of the lead concentration is unknown.

**Table 4-2
Alternative Chemical Process Analysis Results--Still Bottoms**

Process	Soluble Metals (milligrams per liter)				Aquatic Toxicity LC-50 (milligrams per liter)
	Copper	Lead	Nickel	Zinc	
Hydrocarbon	0.62	< 5.00	< 1	36.2	> 750
Green Earth	1.32	5.18	< 1	15.9	123
Glycol Ether	6.4	< 5.00	< 1	38.4	97.6
Carbon Dioxide	-	-	-	-	61

The values of Table 4-2 also show that the aquatic toxicity LC-50 was higher than the threshold cutoff level for the hydrocarbon process. This means that the still bottoms from the hydrocarbon process do not exhibit the characteristic of toxicity due to its aquatic toxicity. In contrast, the still bottoms from the Green Earth, glycol ether and carbon dioxide processes did exhibit aquatic toxicity since the LC-50 values were all less than 500 milligrams per liter. This indicates that the still bottoms from these processes would be hazardous wastes whereas the still bottoms from the hydrocarbon process would not be hazardous wastes.

In the carbon dioxide process, the still bottoms are composed of the contaminants from the cleaning process and residual detergent. There is likely to be very little carbon dioxide in the still bottoms since carbon dioxide is a gas at room temperature. The source of the aquatic toxicity is likely to be the concentrated detergent. In earlier studies on water-based cleaners, IRTA and LACSD found that certain surfactants exhibit aquatic toxicity because they can penetrate the fishes gills. Some surfactants are aquatically toxic before they are used but are not after they have been used for cleaning. Other surfactants are not aquatically toxic before they are used but are after they have been used for cleaning. In this instance, the detergent used by the cleaner where the sampling was conducted clearly was aquatically toxic after it was used for cleaning.

Table 4-3 shows the results of the analysis of the separator water samples collected from the same facilities. Note that no separator water sample was collected from the carbon dioxide facility since separator water is not generated in the cleaning process.

**Table 4-3
Alternative Chemical Process Analysis Results--Separator Water**

Process	Soluble Metals (milligrams per liter)				Aquatic Toxicity LC-50 (milligrams per liter)
	Copper	Lead	Nickel	Zinc	
Hydrocarbon	1.46	0.3	< 0.2	0.46	> 750
Green Earth	1.3	< 4	< 4	< 1.0	> 750
Glycol Ether	11.4	< 2	< 2	2.5	> 750

The values of Table 4-3 illustrate that the concentrations of soluble metals in the separator water from the alternative chemical processes were all lower than the STLCs

specified in Table 4-1. The values also show that the separator waters from the three processes did not exhibit the characteristic of toxicity due to its aquatic toxicity. This indicates that the separator water from the alternative processes will not be hazardous wastes. Since many cleaners use evaporators for the separator water, this practice could simply be continued.

It is not surprising that the separator waters for the three alternative processes were not aquatically toxic whereas the still bottoms for two of the processes--Green Earth and glycol ether cleaning--were aquatically toxic. Separator water, if the physical separation has been performed properly, is very dilute in the chemicals of interest. In contrast, there can be higher concentrations of the dry cleaning chemical in still bottoms.

The analysis results for both the still bottoms and the separator water for the alternative chemical processes showed that there were no toxic volatile and semi-volatile organics that exceeded the detection limits. The samples were very dirty, however, and the LACSD lab had to dilute them extensively so the analysis could be performed. Thus the fact that no toxic volatile and semi-volatile organics were detected does not necessarily mean they were not present in the samples. They may have even been present at levels that exceeded regulatory limits.

Results of the Wet Cleaning Process Sampling

Two different rounds of sampling were conducted for the wet cleaning effluent analysis. In the first round, samples were collected from the wash and rinse water in the process. They were analyzed for the same four metals listed above and for toxic volatile and semi-volatile organics. Table 4-4 presents the results of the analysis.

**Table 4-4
Wet Cleaning Effluent Results -- First Round Analysis**

	Toxic Organics (micrograms per liter)				Soluble Metals (milligrams per liter)							
	PERC		TCE		Copper		Lead		Nickle		Zinc	
	Wash	Rinse	Wash	Rinse	Wash	Rinse	Wash	Rinse	Wash	Rinse	Wash	Rinse
Wet Cleaner #1	5300	1100	<200	<40	0.11	<0.05	<0.2	<0.2	<0.2	<0.2	0.16	0.06
Wet Cleaner #2	<40	<40	5100	3200	0.1	0.09	<0.2	<0.2	<0.2	<0.2	0.14	0.2
Wet Cleaner #3	<200	<40	<200	<40	<0.05	<0.05	<0.2	<0.2	<0.2	<0.2	0.09	0.45
Wet Cleaner #4	<1000	140	<1000	<40	<0.05	<0.05	<0.2	<0.2	<0.2	<0.2	0.17	0.09

The results indicate that in all four cases, the wash and rinse samples did not contain metal concentrations that exceeded the STLCs. The results of the analysis for toxic volatile and semi-volatile organics indicated that in three cases, wet cleaner #1, wet cleaner #2 and wet cleaner #4, PERC or trichloroethylene (TCE) were found. TCE, like

PERC, is a chlorinated solvent with very good cleaning capability for oil based stains. Like PERC, TCE is classified as a Toxic Air Contaminant in California. No other toxic organics were found in the effluent streams. Concentrations of PERC exceeding 0.7 milligrams per liter and concentrations of TCE exceeding 0.5 milligrams per liter are classified as hazardous waste. It is illegal to discharge hazardous waste to the sewer.

IRTA investigated further to determine the origin of the PERC and TCE in the wet cleaning effluents. Wet cleaner #1 and wet cleaner #4 had both a PERC dry cleaning machine and a wet cleaning machine when the samples were taken. Wet cleaner #2 and wet cleaner #3 had only wet cleaning machines when the samples were taken. At wet cleaner #1 and #4, the cleaners may have cleaned certain garments first in the PERC machine and then in the wet cleaning machine. PERC could have remained on the garments during the wet cleaning and was discharged in the effluent stream. One of these facilities, wet cleaner #4, also uses spotting chemicals containing PERC. Another explanation for the presence of PERC is that in facilities with both PERC and wet cleaning machines, the PERC may simply be present in the air and discharge streams. Wet cleaner #2 was using a spotting chemical that contained TCE so the origin of the TCE in the effluent stream is clear.

During the second round of effluent testing at the four wet cleaning facilities, the samples were again analyzed for PERC and TCE. In addition to the toxic organics, all four wash and rinse streams were also analyzed for aquatic toxicity. It is illegal to discharge hazardous waste so if the wet cleaning effluent streams exhibited aquatic toxicity, the effluent would have to be captured and disposed as hazardous waste.

Table 4-5 presents the results of the second round of wet cleaning effluent testing.

**Table 4-5
Wet Cleaning Effluent Results--Second Round Analysis**

Cleaner	Toxic Organics (microgram per liter)				Aquatic Toxicity (milligrams per liter)	
	PERC		TCE		wash	rinse
	wash	rinse	wash	rinse		
Wet Cleaner #1	480	< 100	510	< 100	> 750	> 750
Wet Cleaner #2	< 20	< 20	< 20	< 20	> 750	> 750
Wet Cleaner #3	< 200	< 200	< 100	< 100	> 750	> 750
Wet Cleaner #4	83	82	< 20	< 20	> 750	> 750

Before the second round of effluent sampling, wet cleaner #1 had removed its PERC machine. In addition, the spotting and finishing supervisor at wet cleaner #1 left the facility and a new supervisor was hired. The values of Table 4-5 show that the effluent from this facility still contained PERC and it also contained TCE. It is likely that the PERC and TCE are present in spotting chemicals used by the new spotting supervisor. Wet cleaner #2 stopped using the TCE spotting chemical and TCE was not found in the effluent. Wet cleaner #4 still had a PERC machine but did not put the garments through the PERC machine first during the sampling. Even so, the effluent from this shop

showed a small concentration of PERC. The PERC could be present in spotting chemicals.

Table 4-5 shows that the wash and rinse effluents from all four of the wet cleaning facilities did not exhibit aquatic toxicity. As discussed earlier, it is likely the concentrated detergent in the carbon dioxide still bottom caused the still bottom to exhibit aquatic toxicity. The wet cleaning effluent is more dilute than the still bottom from the carbon dioxide facility so even if the detergents contribute to the toxicity, they might not be present in sufficient concentration to cause a problem. It might also be that the facilities that participated in the sampling did not happen to use detergents that cause aquatic toxicity.

Summary of Sampling Results

Still bottom samples from four dry cleaning facilities using chemical alternatives to PERC were analyzed for certain metals, toxic organics and aquatic toxicity. Lead that exceeded hazardous waste cutoff levels was found in the still bottoms from the Green Earth facility. No toxic organics were found in the still bottoms. The still bottom from the hydrocarbon facility did not exhibit aquatic toxicity but the still bottoms from the Green Earth, glycol ether and carbon dioxide facilities did exhibit aquatic toxicity.

Separator water samples from three dry cleaning facilities using chemical alternatives to PERC were analyzed for certain metals, toxic organics and aquatic toxicity. In all cases, the metals concentrations and the toxic organic concentrations were below detection limits. In all three cases, the separator water did not exhibit aquatic toxicity.

The wash and rinse effluents from four wet cleaning facilities were analyzed for certain metals, toxic organics and aquatic toxicity in two rounds of sampling. None of the samples contained metals concentrations that exceeded hazardous waste levels. PERC and/or TCE were found in the effluent from three of the wet cleaning facilities. In some cases, the concentrations of these toxics exceeded hazardous waste levels. The origin of the TCE and at least some of the PERC is spotting chemicals that are used to prespot garments. A few of the facilities had both wet cleaning and PERC machines and the PERC may have been entrained in garments cleaned in the wet cleaning machine. The analysis indicated that effluent samples from all four facilities did not exhibit aquatic toxicity despite the presence of PERC and/or TCE.

OTHER ISSUES

Three other issues may affect the decisions cleaners make in switching to the alternatives. First, the SCAQMD modified their PERC dry cleaning rule on December 6, 2002 to phase out the use of PERC dry cleaning machines by December 31, 2020. In the South Coast Basin, where about half the PERC dry cleaners in California operate, cleaners have begun adopting alternatives. The SCAQMD regulation requires that by November 1, 2007, all PERC machines must have both primary and secondary controls. The CARB survey data indicates that only about one-third of the statewide dry cleaners currently

operate machines with secondary controls. Some cleaners may adopt an alternative system instead of buying a new PERC machine with secondary control. The SCAQMD regulation also requires dry cleaners to meet certain risk limits. Most cleaners with a PERC machine will not meet the limit and this may also spur conversion to alternative processes. CARB is evaluating the state regulation to determine if it should be strengthened. If CARB adopts a more stringent regulation or decides to phase out PERC dry cleaning, many dry cleaning facilities in the rest of the state would eventually convert to alternative processes.

Second, two programs have been established to provide grants to encourage cleaners to convert to alternative technologies. SCAQMD implemented a financial assistance program for PERC dry cleaners for purchasing equipment for use with the alternatives. The District provided grants to cleaners of \$20,000 for carbon dioxide cleaning, \$10,000 for wet cleaning and \$5,000 for hydrocarbon or glycol ether cleaning. No grants are provided for the Green Earth technology pending evaluation by OEHHA on the toxicity of the solvent. The SCAQMD has used all of the original funds in the program at this time but may allocate additional funds to the program in the future.

CARB is also establishing a grant program under the auspices of Assembly Bill 998 (AB 998), the Non-Toxic Dry Cleaning Incentive Program. AB 998 requires CARB to develop and administer a fee-funded grant and demonstration program. CARB began assessing a fee of \$3 a gallon on the manufacturers and importers of PERC for dry cleaning operations on January 1, 2004. The fee is designed to increase by \$1 per gallon per year from 2005 to 2013 until it reaches \$12 per gallon. The majority of the fees will be used to provide \$10,000 grants to assist dry cleaners in switching to non-toxic and non-smog forming cleaning technologies. The technologies evaluated here that are eligible for grants include carbon dioxide, traditional wet cleaning, icy water and Green Jet. The hydrocarbon and glycol ether technologies are not eligible for grants under this program because they are VOCs and contribute to smog formation. The Green Earth technology is also not eligible for grants; the solvent is not classified as a VOC but there are toxicity issues that remain to be resolved.

Third, the fee on PERC required by AB 998 is making it more expensive for dry cleaners to continue using PERC. Cleaners may be induced to adopt the alternatives if they are unwilling to accept the increase in operating costs. For the case studies of facilities analyzed here, if the \$12 per gallon price increase were used in the analysis comparing PERC and the alternative, some facilities would show a lower operating cost for the alternative than with PERC. These facilities include Imperial, Hollyway and Sterling. This issue is considered further in the model plant analysis in the next section.

V. MODEL PLANT ANALYSIS

This section presents the results of a model plant analysis conducted during the project. This analysis is based on the information gathered during visits to 32 facilities using the alternative technologies and on the more detailed analysis for the 14 case study facilities. The aim of the model plant analysis is to characterize two typical PERC facilities, a small and a large facility, and evaluate the cost to these facilities of adopting the alternatives. The purpose of the model plant analysis is to generalize the costs of using an alternative technology to the industry as a whole. The information is useful for making decisions but it also may have limitations. It is largely based on the 14 case study facilities that were analyzed in this project. Other facilities using alternative technologies that were not analyzed might have different experiences and costs. The assumptions and the results of the model plant analysis are presented and discussed below.

MODEL PLANT DESCRIPTION

Based on the data collected from the facilities during the project, IRTA developed two model plants. The small model plant is a PERC dry cleaner that cleans 40,000 pounds of clothing annually. The large model plant is a PERC dry cleaner that cleans 100,000 pounds of clothing annually. Additional assumptions are presented below.

Small PERC Model Plant Assumptions

- 40,000 pounds of clothing per year
- 35 pound dry-to-dry closed loop machine with secondary control
- 27 loads per week or 1,380 loads per year
- purchased machine for \$41,087 based on CARB survey data and paid \$2,500 for installation
- 60 gallons of PERC used annually. Cost of PERC assumed to be \$10 per gallon.
- 50 gallons of detergent used annually. Cost of detergent assumed to be \$25 per gallon.
- annual electricity cost of \$3,600 based on similar sized case study plants
- annual gas cost of \$3,000 based on similar sized case study plants
- spotting labor of 2.46 hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$6,400.
- finishing labor of 9.85 hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$25,600.
- Maintenance labor of one hour per week based on similar sized case study plants. Annual cost amounts to \$520.
- Maintenance equipment cost assumed to be zero since the facility uses spin disk filters.
- Compliance labor of one hour per week at \$10 per hour based on similar sized case study plants. Annual cost amounts to \$520.
- Shop generates two drums of waste at a disposal cost of \$275 per drum based on case studies of similar size. Annual disposal cost amounts to \$550.

Large PERC Model Plant Assumptions

- 50 pound dry-to-dry closed loop machine with secondary control
- 43 loads per week or 2,222 loads per year
- purchased machine for \$48,481 based on CARB survey data and paid \$2,500 for installation
- 110 gallons of PERC used annually. Cost of PERC assumed to be \$10 per gallon.
- 125 gallons of detergent used annually. Cost of detergent assumed to be \$25 per gallon.
- annual electricity cost of \$7,500 based on similar sized case study plants that do not have air conditioning or computers. PERC machine rated at 29 kW.
- annual gas cost of \$3,400 based on similar sized case study plants
- spotting labor of five hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$13,000.
- finishing labor of 19 hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$49,400.
- Maintenance labor of two hours per week based on similar sized case study plants. Annual cost amounts to \$1,040.
- Maintenance equipment cost assumed to be zero since the facility uses spin disk filters.
- Compliance labor of two hours per week at \$10 per hour based on similar sized case study plants. Annual cost amounts to \$1,040.
- Shop generates four drums of waste at a disposal cost of \$350 per drum based on case studies of similar size. Annual disposal cost amounts to \$1,400.

Model Plant Analysis of Plants Using Alternative Technologies

Appendix C includes the detailed assumptions for the small and large model plants using the alternative technologies. In general, the assumptions were based on the practices of similar sized facilities using the alternative technologies.

Results of Model Plant Analysis

Table 5-1 presents the results of the model plant analysis for the small facility that cleans 40,000 pounds of clothing annually. IRTA did not analyze the icy water technology for the case of the small plant. IRTA did not analyze the Pure Dry technology separately because it is considered a derivative of the hydrocarbon process. IRTA did not analyze the carbon dioxide technology for the small plant case; because of the high capital cost, it was assumed that small cleaners would not adopt the technology. The values for the PERC plant are shown as the first row in the table.

The values of Table 5-1 show that the hydrocarbon process that uses tonsil is the lowest cost alternative technology. In fact, the annual cost of using this process is lower than the annual cost of using PERC. The equipment cost for the process is about the same as the equipment cost for a PERC machine because the machine does not require a distillation

**Table 5-1
Small Model Plant Annualized Costs
Cleaning Volume -- 40,000 Pounds**

Cleaning Method	Cost														
	Annualized Capital	Solvent	Licensing Fee	Detergent	Electricity	Gas	Spotting Labor	Finishing Labor	Maintenance Labor	Maintenance Equipment	Compliance	Hazardous Waste Disposal	Total	Cost per pound cleaned	Cost per no machine pound cleaned
PERC	\$3,022	\$600	-	\$1,250	\$3,600	\$3,000	\$6,400	\$25,600	\$520	\$0	\$520	\$550	\$45,062	\$1.13	\$1.05
Hydrocarbon	\$3,467	\$256	-	\$1,250	\$4,538	\$3,154	\$6,400	\$25,600	\$520	\$0	\$520	\$550	\$46,255	\$1.16	\$1.07
Hydrocarbon with Tonsil	\$2,981	\$768	-	\$0	\$2,939	\$2,833	\$6,400	\$25,600	\$260	\$210	\$520	\$800	\$43,311	\$1.08	\$1.01
Green Earth	\$3,467	\$720	\$2,500	\$1,250	\$4,538	\$3,225	\$12,800	\$19,720	\$520	\$0	\$0	\$550	\$49,290	\$1.23	\$1.15
Green Jet	\$1,179	\$0	-	\$2,618	\$2,400	\$1,800	\$15,600	\$20,020	\$520	\$0	\$0	\$0	\$44,137	\$1.10	\$1.07
Traditional Wet Cleaning	\$2,427	\$0	-	\$2,100	\$2,400	\$4,200	\$7,800	\$29,900	\$520	\$0	\$0	\$0	\$49,347	\$1.23	\$1.17
Glycol Ether	\$3,467	\$750	-	\$0	\$10,260	\$8,208	\$520	\$25,600	\$9,360	\$0	\$520	\$550	\$59,235	\$1.48	\$1.39

unit. Many facilities using tonsil do not purchase detergent and their electricity and gas costs are lower than the electricity and gas costs of a PERC facility because distillation of the solvent is not necessary.

The annual cost of using Green Jet is also lower than the annual cost of using PERC. The cost of the Green Jet equipment is low. The electricity and gas cost for the process are lower than the electricity and gas cost of a PERC plant. The spotting labor is higher than the spotting labor for the PERC plant because Green Jet is not an aggressive cleaning method. The finishing labor is lower than the finishing labor for PERC because the garments are not immersed in water so they are not wrinkled.

The third lowest cost alternative process is hydrocarbon and the annual cost per pound of clothing cleaned is slightly higher than the same cost for the PERC process. Electricity and gas costs are somewhat higher than for the PERC process and spotting and finishing labor costs are the same as the costs for PERC.

The fourth lowest cost alternative technology is the Green Earth cleaning method. The electricity and gas costs are higher than they are for the PERC process because the cycle time is longer and the solvent does not dry as readily as PERC. The spotting labor cost is twice as high as the spotting labor cost for PERC, but the finishing labor cost is lower.

The fifth lowest cost alternative technology is traditional wet cleaning. The equipment cost is lower than the equipment cost for PERC. The detergent cost for the wet cleaning process is higher. The electricity cost for wet cleaning is lower than the electricity cost for PERC but the gas cost is higher. Both the spotting labor cost and the finishing labor cost are somewhat higher than for PERC.

The sixth lowest cost alternative technology is the glycol ether process. There is no detergent cost for this technology. Electricity and gas costs are higher than for PERC because the solvent has a high boiling point which requires a longer cycle time and more drying time. The spotting labor cost is very low because the solvent can clean oil and water soluble stains. The maintenance labor cost for the glycol ether process is very high because of the separation problem of water and the glycol ether.

The total annual cost of using five of the alternative technologies--hydrocarbon, hydrocarbon with tonsil, Green Jet, Green Earth cleaning and wet cleaning--are comparable to the total annual cost of using PERC. The cost of using the glycol ether is 31 percent higher than the cost of using PERC. In terms of absolute value, the cost of using the glycol ether is about \$14,000 per year more than the cost of using PERC.

Table 5-2 presents the annualized costs of the large model plant which cleans 100,000 pounds of clothing per year. IRTA did not analyze the costs of the large model plant for the Green Jet technology, the glycol ether technology or the Pure Dry technology. IRTA did not analyze the costs of the large model plant for wet cleaning; it was assumed that the labor cost would be too high to allow efficient operation for a large cleaner.

**Table 5-2
Large Model Plant Annualized Costs
Cleaning Volume -- 100,000 Pounds of Clothing Annually**

Cleaning Method	Cost													Cost per pound cleaned	Cost per pound cleaned
	Annualized Capital	Solvent	Licensing Fee	Detergent	Electricity	Gas	Spotting Labor	Finishing Labor	Maintenance Labor	Maintenance Equipment	Compliance	Hazardous Waste Disposal	Total		
PERC	\$3,535	\$1,100	-	\$3,125	\$7,500	\$3,400	\$13,000	\$49,400	\$1,040	\$0	\$1,040	\$1,400	\$84,540	\$0.85	\$0.81
Carbon Dioxide	\$12,480	\$2,679	-	\$8,704	\$10,500	\$3,173	\$26,000	\$49,400	\$520	\$0	\$0	\$500	\$113,956	\$1.14	\$1.01
Hydrocarbon	\$4,007	\$472	-	\$3,125	\$9,450	\$3,876	\$13,000	\$49,400	\$1,040	\$0	\$1,040	\$1,400	\$86,810	\$0.87	\$0.83
Hydrocarbon with Tonsil	\$3,522	\$1,423	-	\$0	\$6,122	\$3,211	\$13,000	\$49,400	\$520	\$632	\$1,040	\$1,600	\$80,470	\$0.80	\$0.77
Green Earth	\$4,007	\$1,328	\$2,500	\$3,125	\$9,450	\$3,655	\$26,000	\$38,038	\$1,040	\$0	\$0	\$1,400	\$90,543	\$0.91	\$0.87
Icy Water	\$5,755	\$0	-	\$9,375	\$7,500	\$3,400	\$13,000	\$49,400	\$1,040	\$0	\$0	\$0	\$89,470	\$0.89	\$0.84

The first row of Table 5-2 summarizes the annualized costs for the large PERC model plant. As was the case for the small model plant, the lowest cost alternative technology is the hydrocarbon technology with tonsil. The cost per pound cleaned for this technology is lower than the cost per pound cleaned with PERC. Three of the other alternative technologies--hydrocarbon, Green Earth and the icy water technology--are only slightly higher on a cost per pound basis than PERC cleaning. The equipment cost and detergent cost of the icy water technology are higher than for PERC. These are offset, to some extent, by lower costs for compliance and waste disposal. The spotting and finishing labor cost for the icy water technology are equivalent to the spotting and finishing labor costs for PERC. The cost per pound for carbon dioxide is higher than the cost per pound of the other technologies. The cost for carbon dioxide is higher than the cost for PERC primarily because of higher capital equipment costs and higher spotting labor costs.

The cost per pound cleaned for hydrocarbon with tonsil is about six percent lower than the cost per pound for PERC. The cost per pound for hydrocarbon is about two percent higher than the cost per pound for PERC. This translates into slightly more than \$2,000 per year. The cost per pound of the icy water technology is about five percent higher than for PERC or about \$5,000 annually. The cost per pound of the Green Earth technology is seven percent higher than the cost per pound for PERC; this translates into about \$6,000 annually. The cost per pound for carbon dioxide is 34 percent higher than the cost per pound for PERC; this amounts to \$34,000 annually.

LIMITATIONS OF MODEL PLANT ANALYSIS

As mentioned earlier, the model plant analysis conducted here is heavily based on the specific case study plants that were studied in this project. Other facilities using the alternative technologies could have different costs. In certain cases, the glycol ether and the icy water technology, there is only one facility in California currently using the technology. Furthermore, the facility using the icy water technology has a PERC machine as well. For the large model plant analysis, IRTA was not able to use the data from the one facility using traditional wet cleaning that is large. The values provided by the cleaner could not be verified.

COST IMPLICATIONS OF PERC PRICE INCREASE AND GRANT PROGRAMS

In the model plant analysis, IRTA used a price of \$10 per gallon for PERC. CARB increased the fee on PERC in August, 2004 by \$3 per gallon. The price of PERC is now reported to be \$19 per gallon which is higher than the \$3 per gallon fee would cause. In the case of ozone depleting substances, Congress placed a tax on the materials to discourage use. The price increased much further than the tax, apparently because of market uncertainty. A similar effect seems to be observed in the dry cleaning industry with PERC. In the years to come, as the fee is raised each year, the market price of PERC in the dry cleaning industry could increase much further than the fee would suggest.

The increase in the price of PERC will change the cost comparison for the small and large model plant analyses presented in Tables 5-1 and 5-2. In the small model plant, for example, the plant uses 60 gallons of PERC annually. The model plant assumed a cost of \$10 per gallon for PERC. The cost is \$19 per gallon currently and it will increase one dollar each year until 2013. Assuming a cost of \$25 per gallon for the analysis, the annual costs for the small model plant will increase from \$45,062 to \$45,962. Making the same assumption, for the large model plant, which uses 110 gallons of PERC annually, the annualized cost would increase from \$84,540 to \$86,190. This raises the cost per pound of clothing cleaned for the small model plant from \$1.13 to \$1.15. It raises the cost per pound of clothing cleaned for the large model plant from \$0.85 to \$0.86.

In the model plant analysis, in the case of the small model plant, the hydrocarbon alternative with tonsil has a lower cost per pound of clothing cleaned than PERC. The same holds true in the case of the large model plant. SCAQMD provided grants of \$5,000 to cleaners who adopted the technology. Although SCAQMD has exhausted the funds in their grant program, they may allocate funds in the future for this purpose. CARB does not provide grants for the technology. For a small or large cleaner located in the South Coast Basin, the cost of using the hydrocarbon alternative with tonsil would be reduced even further below the cost of using PERC. Assuming SCAQMD starts another grant program and that the \$5,000 grant is annualized over the 15 year period at a four percent cost of capital, the total annualized cost for the small and large model plants would be reduced by \$347.

The Green Jet technology has a lower cost per pound of clothing cleaned than PERC for the small model plant. SCAQMD did not provide grants for this technology but CARB does provide \$10,000 grants. A CARB grant to purchase the Green Jet equipment would reduce the total annualized cost of the Green Jet process by \$693. This technology was not evaluated for the large model plant.

In both the small and large model plant analysis, the total annualized cost of the hydrocarbon technology without tonsil taking into account the price increase in PERC is higher than the total annualized cost for PERC. For the small model plant, the annualized cost of hydrocarbon is \$46,255 compared with \$45,962 for PERC. For the large model plant, the total annualized cost of hydrocarbon at \$86,810 is lower than the annualized cost for PERC of \$86,190, taking into account the PERC price increase. CARB does not provide grants for the hydrocarbon process. The SCAQMD grant program provided \$5,000 in grants to cleaners that adopted the hydrocarbon process. For a cleaner located in the South Coast Basin, a grant from SCAQMD would reduce the total annualized cost of the hydrocarbon process without tonsil by \$347. For a cleaner in another part of the state, the annualized cost of the hydrocarbon without tonsil for the small plant would be slightly higher than the annualized cost for PERC. The annualized cost of the hydrocarbon without tonsil for the large model plant would be lower than the annualized cost of using PERC.

The Green Earth technology for the small and large model plants has a higher cost per pound of clothing cleaned than PERC. For the small model plant, the cost of the Green Earth technology is \$1.23 per pound which can be compared with the cost of PERC of \$1.15 per pound. For the large model plant, the cost of the Green Earth technology is \$0.91 per pound whereas the cost of PERC is \$0.86 per pound. SCAQMD did not and CARB does not provide grants for the technology pending analysis by OEHHA on the toxicity of the compound. The cost of the Green Earth technology for both the small and large model plant would be higher than the cost of PERC.

The glycol ether technology has a higher cost per pound of clothing cleaned than does PERC for the small model plant. The cost of the glycol ether technology is \$1.48 per pound whereas the cost of PERC is \$1.13 per pound for the small model plant. Cleaners that wish to adopt this technology would receive a grant of \$5,000 from SCAQMD if the agency reinstated the grant program but would not receive a grant from CARB. For a cleaner in the South Coast Basin, the cost of adopting the glycol ether technology would still be higher than for PERC for the small model plant. The technology was not analyzed for the large model plant.

The icy water technology, in the case of the large model plant, has a higher total annualized cost, \$89,470, than does PERC at \$86,190. This technology was eligible for \$10,000 grants from SCAQMD and from CARB. A cleaner replacing a PERC machine with the icy water technology in the South Coast Basin could receive grant funding of \$20,000. Amortizing the grant funding over a 15 year period with a cost of capital of four percent, the total annualized cost for the icy water technology would be reduced to \$88,083. A cleaner replacing a PERC machine in another part of the state could receive grant funding of \$10,000, reducing the total annualized cost of the technology to \$88,777.

The total annualized cost for traditional wet cleaning, at \$49,347, is higher than the annualized cost for PERC of \$45,962 for the small model plant. In the South Coast Basin, a cleaner received grants of \$10,000 from SCAQMD and could receive a grant of \$10,000 from CARB. The annualized cost of wet cleaning for the small model plant would amount to \$47,960 which is still slightly higher than the annualized cost for PERC. Outside the South Coast Basin, the total annualized cost would be \$48,654, again higher than the annualized cost for PERC.

For the large model plant, the annualized cost of carbon dioxide amounts to \$113,956 compared with PERC at \$86,190. In the South Coast Basin, a cleaner could obtain a \$20,000 grant from SCAQMD if the program were reinstated and a \$10,000 grant from CARB.. In the South Coast Basin, the grants would reduce the carbon dioxide annualized cost to \$111,876 and outside the Basin, the annualized cost would be \$112,571. The large carbon dioxide model plant would still have higher costs than the large PERC model plant.

Table 5-3 presents the results of the cost analysis for the alternative technologies taking into account the increased PERC price of \$25 per gallon and the grants provided by SCAQMD and CARB.

The values of Table 5-3 show that a small cleaner in the South Coast Basin would reduce their cost per pound of clothing cleaned by converting to hydrocarbon with tonsil or the Green Jet technology. Their cost would remain about the same if they converted to hydrocarbon. Conversion to the Green Earth technology would result in a seven percent increase. Conversion to traditional wet cleaning would result in a four percent increase. Conversion to the glycol ether technology would result in a 28 percent increase.

The values show that a large cleaner in the South Coast Basin would reduce their cost per pound of clothing cleaned by converting to hydrocarbon with tonsil. A cleaner would have about the same cost for hydrocarbon without tonsil as for PERC. The cost of icy water and Green Earth are only slightly higher than the cost for PERC. The cost per pound of clothing cleaned in the South Coast Basin is about 30 percent higher for carbon dioxide than for PERC.

Table 5-3
Annual Cost Comparison of Alternative Technologies With Higher PERC Price and Under Grant Program

Process	Annualized Cost Per Pound		
	No Grant	CARB Grant	CARB and SCAQMD Grants
Small Plant			
PERC	\$1.15	\$1.15	\$1.15
hydrocarbon with tonsil	\$1.08	\$1.08	\$1.07
Green Jet	\$1.10	\$1.09	\$1.09
hydrocarbon	\$1.16	\$1.16	\$1.15
Green Earth	\$1.23	\$1.23	\$1.23
wet cleaning	\$1.23	\$1.22	\$1.20
glycol ether	\$1.48	\$1.48	\$1.47
Large Plant			
PERC	\$0.86	\$0.86	\$0.86
hydrocarbon with tonsil	\$0.80	\$0.80	\$0.80
hydrocarbon	\$0.87	\$0.87	\$0.86
icy water	\$0.89	\$0.89	\$0.88
Green Earth	\$0.91	\$0.91	\$0.91
carbon dioxide	\$1.14	\$1.13	\$1.12

VI. SUMMARY AND CONCLUSIONS

PERC is the most widely used solvent today in the dry cleaning industry. The chemical is coming under increased scrutiny by regulatory agencies, it has contaminated many dry cleaning sites and landlords are reluctant to renew leases in locations where PERC dry cleaning is used. As a consequence, cleaners in California are increasingly adopting alternative technologies for cleaning.

This document focuses on the alternative cleaning technologies. Viable alternatives that were evaluated in this project are those technologies cleaners have adopted in place of PERC dry cleaning. The technologies that were assessed include:

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

IRTA analyzed the performance and cost of the alternatives in 14 case study facilities. Nine of these facilities converted from PERC to one of the alternative technologies. The costs for the PERC and alternative process were evaluated and compared. Five of the facilities started up operation with a new technology and the costs for the new technologies were evaluated. Stand alone case studies were developed for each of the 14 facilities.

For some of the case study facilities, the costs of the alternatives are comparable or lower than the costs for PERC dry cleaning. These include the icy water technology, hydrocarbon with tonsil and hydrocarbon. The Green Earth technology has a slightly higher cost than PERC dry cleaning and carbon dioxide and traditional wet cleaning both have higher costs than PERC dry cleaning for the case study plants. The large cleaners that clean 100,000 pounds of clothing per year or more are more efficient, regardless of the technology used than small cleaners that clean less than 100,000 pounds of clothing annually. Spotting and finishing labor costs for all case study facilities account for a significant fraction of the total costs. Thus, changes in the spotting and finishing labor for the alternative technologies influence the cost strongly.

Technologies that use detergent and water--traditional wet cleaning, Green Jet, icy water--and carbon dioxide have an advantage from an overall health standpoint. OEHHA is evaluating the toxicity of the chemical alternatives including hydrocarbon, Green Earth and glycol ether technologies.

The project involved sampling various waste streams from facilities using the alternative processes. LACSD analyzed the still bottoms and separator water from one cleaner each

using the hydrocarbon, Green Earth and glycol ether processes. LACSD also analyzed the still bottom from one cleaner using the carbon dioxide process. Lead that exceeded the hazardous waste limit was found in the Green Earth still bottom sample. Still bottoms from three of the samples--Green Earth, glycol ether and carbon dioxide--exhibited aquatic toxicity which indicates they are classified as hazardous waste. The still bottom from the hydrocarbon facility did not exhibit aquatic toxicity. None of the separator water samples exhibited aquatic toxicity. LACSD found no toxic volatile and semi-volatile organics in any of the samples above detection limits.

Four wet cleaning effluent samples were analyzed for volatile and semi-volatile toxic organics and aquatic toxicity. None of the samples exhibited aquatic toxicity but three of the samples contained PERC and/or TCE. The presence of PERC and TCE indicates that the effluent may be classified as hazardous waste and cannot be discharged to the sewer. In some cases, the likely source of the PERC and TCE is spotting chemicals. Additional work on alternative spotting chemicals is required to resolve this issue.

The results of the sampling and analysis are interesting but they also have limitations. First, samples were taken from only a few facilities and they may not represent the industry as a whole. Second, some of the samples required substantial dilution before they could be analyzed because they were so dirty. This indicates that the toxics may have been present but after dilution, they did not remain at detection levels.

IRTA developed two model plants based on the information obtained from the case study facilities. The model plant analysis was intended to provide information on the alternative technologies to cleaners that wish to convert from PERC dry cleaning to one of the alternative technologies. Two model plants were analyzed, one a small cleaner cleaning about 40,000 pounds of clothing per year and the other a large cleaner cleaning about 100,000 pounds of clothing per year. The effects of the increased price of PERC and the grant programs offered by SCAQMD and CARB were factored in to the analysis.

The findings of the model plant analysis indicate that after taking into account price increases in PERC and the grants, cleaners with small plants would have lower or comparable costs if they converted from PERC to hydrocarbon with tonsil, hydrocarbon or Green Jet. They would have slightly higher costs if they converted to Green Earth or traditional wet cleaning. Converting from PERC to the glycol ether was more costly than PERC. Large cleaners would have lower or comparable costs if they converted from PERC to hydrocarbon with tonsil or hydrocarbon. Such facilities would have slightly higher costs if they converted to icy water or Green Earth. The costs to a large facility for converting from PERC to carbon dioxide would be higher.

The model plant analysis conducted during this project has limitations. First, the analysis is based on the information IRTA acquired from the case study plants using the alternative technologies. These case study facilities have certain experiences and costs and other facilities using the alternative technologies may have different experiences and costs. The analysis generalizes from the case study plants to the industry as a whole and is based on a limited number of plants. Second, there may be a learning curve in using

the alternative technologies, particularly not-in-kind technologies like traditional wet cleaning and carbon dioxide cleaning. Some of the case study plants that were analyzed had been using the alternatives for less than a year. The costs for some technologies are likely to decline over time as the cleaners adjust to the new practices.

Table 6-1 summarizes and compares certain features of PERC dry cleaning and the alternative technologies based on the results of the case studies and the model plant analyses. The table lists PERC and each of the alternative technologies in the first column. The table classifies the cleaning capability of each technology as aggressive, gentle or, in one case, very gentle. Three cost elements are compared in Table 6-1. The spotting labor cost, the finishing labor cost and the capital equipment cost for each technology is ranked as high, medium or low. The final two columns in the table identify other issues—advantages and disadvantages—of each of the technologies.

The project findings indicate that a number of viable alternatives to PERC dry cleaning are available and are being used by cleaning facilities in California. The costs of the technologies, in some cases, are lower or comparable to PERC dry cleaning. The costs of some of the technologies are higher than the cost of using PERC dry cleaning. It is worth noting that all of the owners of the case study facilities analyzed during the project indicated they were pleased with the alternative technology they had adopted. This was true even for technologies where the cleaner had a higher cost. This indicates that cleaners throughout California can convert successfully to the alternative technologies.

Table 6-1 Performance and Cost Comparison of PERC and Alternative Technologies

Cleaning Method	Cleaning Capability	Cost			Advantages	Other Issues	Disadvantages
		Spotting Labor	Finishing Labor	Capital			
PERC	aggressive	medium	medium	medium	process easy to use		not good for delicates
Hydrocarbon	gentle	medium	medium	medium	can clean delicates, good hand, in-kind technology		can have bacteria growth, longer cycle time
Hydrocarbon with Tonsil	gentle	medium	medium	medium	can clean delicates, good hand, no distillation or detergent, in-kind technology		longer cycle time
Pure Dry	gentle	medium	medium	medium	can clean delicates, good hand, in-kind technology		can have bacteria growth, longer cycle time, possible change in composition
Green Earth	gentle	high	low	medium	can clean delicates, very good hand, in-kind technology		longer cycle time
Glycol Ether	aggressive	low	medium	medium	cleans water soluble and oil-based soils, in-kind technology		longer cycle time, water separation difficult, distillation boil over
Traditional Wet Cleaning	aggressive	medium	high	low	can clean delicates		finishing more difficult, not-in-kind technology
Icy Water	aggressive	medium	medium	medium	can clean delicates, may not need tensioning equipment		longer drying cycle, not-in-kind technology
Green Jet	very gentle	high	low	low	can clean delicates, less finishing		doesn't clean well, not-in-kind technology
Carbon Dioxide	gentle	high	medium	high	good hand		detergent issues, problems with acetate, expensive equipment, not-in-kind technology

Appendix A
Material Safety Data Sheets

MSDS for Hydrocarbon Solvent

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
A Division of Exxon Mobil Corporation

DE-2000 FLUID

PAGE: 1
DATE PREPARED: 26 September 2001
MSDS NUMBER: 50242543

SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME : DE-2000 FLUID

CHEMICAL NAME
Synthetic Aliphatic Hydrocarbon, Hydrocracked

CHEMICAL FAMILY:
Aliphatic Hydrocarbon

PRODUCT DESCRIPTION:
Clear colorless liquid.

CONTACT ADDRESS:
ExxonMobil Chemical Company
P.O. Box 5272, Houston, Texas 77252-3272

** EMERGENCY TELEPHONE NUMBERS: (24 Hours) **
** CERENTEC (800) 424-9300 **
** ExxonMobil Chemical Company (800) 726-2015 **

NON EMERGENCY TELEPHONE NUMBERS : (8am -5pm M-F)
FOR GENERAL PRODUCT INFORMATION CALL : (281) 970-6000
FOR HEALTH AND MEDICAL INFORMATION CALL : (281) 970-6884

SECTION 2 COMPOSITION/INFORMATION ON INGREDIENTS

This product is hazardous as defined in 29 CFR 1910.1200
OSHA HAZARD:
Combustible

SECTION 3 HAZARDS IDENTIFICATION

POTENTIAL HEALTH EFFECTS

*** CONTACT
Slightly irritating but does not injure eye tissue.

SKIN CONTACT
Low order of toxicity
Frequent or prolonged contact may irritate and cause dermatitis
skin contact may aggravate an existing dermatitis condition.

INHALATION
High vapor/aerosol concentrations are irritating to the eyes and
the respiratory tract, may cause headache, dizziness, anesthesia,
drowsiness, unconsciousness, and other central nervous system effects,
including death.

INGESTION
Small amounts of this product aspirated into the respiratory system during
ingestion or vomiting may cause mild to severe pulmonary injury, possibly

Continued...

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
A Division of Exxon Mobil Corporation

PAGE: 2
DATE PREPARED: 28 September 2002
MSDS NUMBER: 92847584

BP-2000 FILTD

progressing to death.
Minimal toxicity

SECTION 4 FIRST AID MEASURES

EYE CONTACT

Flush eyes with large amounts of water until irritation subsides. If irritation persists, get medical attention.

SKIN CONTACT

Flush with large amounts of water; use soap if available.
Remove grossly contaminated clothing, including shoes, and launder before reuse.

INHALATION

Using proper respiratory protection, immediately remove the affected victim from exposure. Administer artificial respiration if breathing is stopped. Keep at rest. Call for prompt medical attention.

INGESTION

If swallowed, DO NOT induce vomiting. Keep at rest. Get prompt medical attention.

SECTION 5 FIRE-FIGHTING MEASURES

FLASH POINT: 147 Deg F. MELBOD. FCC ASTM D56. NOTE: Typical
FLAMMABLE LIMITS: LEL: 1.3 UEL: 8.9 @ 77 Deg F. NOTE: Approximate
AUTOIGNITION TEMPERATURE: 546 Deg F. NOTE: Approximate

GENERAL HAZARD

Combustible liquid, can form conductible mixtures at temperatures at or above the flashpoint.
Static Discharge, material can accumulate static charges which can cause an incendiary electrical discharge.
"Empty" containers retain product residue (liquid and/or vapor) and can be dangerous. DO NOT pressure, cut, weld, braze, solder, drill, grind, or expose such containers to heat, flame, sparks, static electricity, or other sources of ignition, THEY MAY EXPLODE AND CAUSE INJURY OR DEATH. Empty drums should be completely drained, properly dugged and promptly returned to a drum reconditioner, or properly disposed of.

FIRE FIGHTING

Use water spray to cool fire exposed surfaces and to protect personnel. Isolate "fuel" supply from fire.
Use foam, dry chemical, or water spray to extinguish fire.
Avoid spraying water directly into storage containers due to danger of boilover.

Continued...

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
A Division of Exxon Mobil Corporation

DF 2000 FLOOD

PAGE: 3
DATE PREPARED: 29 September 2001
MSDS NUMBER: 93842593

this liquid is volatile and gives off invisible vapors. Either the liquid or vapor may settle in low areas or travel some distance along the ground or surface to ignition sources where they may ignite or explode.

DECOMPOSITION PRODUCTS UNDER FIRE CONDITIONS
No unusual

SECTION 6 ACCIDENTAL RELEASE MEASURES

LAND SPILL

Eliminate sources of ignition. Prevent additional discharge of material, if possible to do so without hazard. For small spills implement cleanup procedures; for large spills implement cleanup procedures and, if in public area, keep public away and advise authorities. Also, if this product is subject to CERCLA reporting (see Section 15 REGULATORY INFORMATION) notify the National Response Center. Prevent liquid from entering sewers, watercourses, or low areas. Contain spilled liquid with sand or earth. Do not use combustible materials such as sawdust. Recover by pumping (use an explosion proof or hand pump) or with a suitable absorbent. Consult an expert on disposal of recovered material and ensure conformity to local disposal regulations.

WATER SPILL

Eliminate sources of ignition. Warn occupants and shipping in surrounding and downwind areas of fire and explosion hazard and request all to stay clear. Remove from surface by skimming or with suitable adsorbents. If allowed by local authorities and environmental agencies, sinking and/or suitable dispersants may be used in non-confined waters. Consult an expert on disposal of recovered material and ensure conformity to local disposal regulations.

SECTION 7 STORAGE AND HANDLING

ELECTROSTATIC ACCUMULATION HAZARD:

Yes, use proper bonding and/or grounding procedure. Additional information regarding safe handling of products with static accumulation potential can be ordered by contacting the American Petroleum Institute (API) for API Recommended Practice 2004, entitled "Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents" (American Petroleum Institute, 1220 N. Street Northwest, Washington, DC 20004), or the National Fire Protection Association (NFPA) for NFPA 77 entitled "Static Electricity" (National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269 9101).

STORAGE TEMPERATURE, DegF: Ambient
LOADING/UNLOADING TEMPERATURE, DegF: Ambient

Continued...

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company

A Division of Exxon Mobil Corporation

PAGE:

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DATE PREPARED: 26 September 2007

MSDS NUMBER: 91842183

DE-1000 FLUID

STORAGE/TRANSPORT PRESSURE, psig: Atmospheric

LOADING/UNLOADING VISCOSITY, cSt: 3.5

STORAGE AND HANDLING:

Keep containers closed. Handle and open containers with care. Store in a cool, well ventilated place away from incompatible materials. Do NOT handle or store near an open flame, heat or other sources of ignition. Protect material from direct sunlight. Material will accumulate static charges which may cause an electrical spark (ignition source). Use proper bonding and/or grounding procedures. Do NOT pressure, cut, heat, or weld containers. Empty product containers may contain product residue. Do NOT reuse empty containers without commercial cleaning or reconditioning.

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE CONTROLS

The use of local exhaust ventilation is recommended to control process emissions near the source. Laboratory samples should be handled in a lab hood. Provide mechanical ventilation of confined spaces. See respiratory protection recommendations.

PERSONAL PROTECTION

For open systems where contact is likely, wear safety glasses with side shields, long sleeves, and chemical resistant gloves. Where contact may occur, wear safety glasses with side shields. Where concentrations in air may exceed the limits given in this Section and engineering, work practice or other means of exposure reduction are not adequate, NIOSH approved respirators may be necessary to prevent overexposure by inhalation.

WORKPLACE EXPOSURE GUIDELINES

ExxonMobil RECOMMENDS THE FOLLOWING OCCUPATIONAL EXPOSURE LIMITS:
a TWA of 1200 mg/m3 (171 ppm) based on total hydrocarbon.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

SPECIFIC GRAVITY, at 60°F: 0.77 at 60
VAPOUR PRESSURE, mmHg at 60°F: 5.49 at 60
SOLUBILITY IN WATER, wt % at 60°F: Less than 0.01 at 77
VISCOSITY OF LIQUID, cSt at 60°F: 3.1 at 77 Approximate
SP. GRAV. OF VAPOR, at 1 atm (Air=1): 5.90 Calculated
FREEZING/MELTING POINT, DegF: Less than -75
EVAPORATION RATE, n-Pentane=1: Less than 0.1
BOILING POINT, DegF: 276 to 401

Continued.

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
A Division of Exxon Mobil Corporation

DF-3000 FLTD

PAGE: 5
DATE PREPARED: 16 September 2001
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SECTION 10 STABILITY AND REACTIVITY

STABILITY
Stable
CONDITIONS TO AVOID INSTABILITY
Not Applicable
HAZARDOUS POLYMERIZATION:
Will not occur
CONDITIONS TO AVOID HAZARDOUS POLYMERIZATION:
Not Applicable
MATERIALS AND CONDITIONS TO AVOID INCOMPATIBILITY:
Strong oxidizing agents.
HAZARDOUS DECOMPOSITION PRODUCTS:
None

SECTION 11 TOXICOLOGICAL INFORMATION

Please refer to Section 1 for available information on potential health effects.

SECTION 12 ECOLOGICAL INFORMATION

No specific ecological data are available for this product. Please refer to Section 6 for information regarding accidental release and Section 15 for regulatory reporting information.

SECTION 13 DISPOSAL CONSIDERATIONS

Please refer to Sections 5, 6, and 15 for disposal and regulatory information.

SECTION 14 TRANSPORT INFORMATION

DEPARTMENT OF TRANSPORTATION (DOT):
DOT SHIPPING DESCRIPTION: PETROLEUM DISTILLATE, N.O.S., UN 1268, III
Note: In containers of 119 gallons capacity or less this product is not regulated by DOT.

SECTION 15 REGULATORY INFORMATION

TSCA:
This product is listed on the TSCA Inventory at CAS Registry Number 64742-93-9
CERCLA:
This product is classified as an oil under Section 311 of the Clean Water Act (40 CFR 110) and the Oil Pollution Act of 1990. Discharge or spills which produce a visible sheen on either surface water, or in waterways/sewers which lead to surface water, must be reported to the National Response Center at 800-424-2802

Continued...

MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
A Division of Exxon Mobil Corporation

DF-2000 FLUID

PAGE: 5
DATE PREPARED: 26 September 2007
MSDS NUMBER: 214425A1

CERCLA:

If this product is accidentally spilled, it is not subject to any special reporting under the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). We recommend you contact local authorities to determine if there may be other local reporting requirements.

SARA TITLE III:

Under the provisions of Title III, Sections 111/112 of the Superfund Amendments and Reauthorization Act, this product is classified into the following hazard categories:

Fire:

This information may be subject to the provisions of the Community Right-to-Know Reporting Requirements (40 CFR 370) if threshold quantity criteria are met.

SECTION 15 OTHER INFORMATION

NOTES:

Care must be taken to ensure garments cleaned with solvents are completely dry before being worn. Drycleaning solvent not totally removed from adsorbent clothing (e.g., shoulder pads, waist bands, etc.) that remains in contact with the skin for prolonged periods may cause skin irritation including redness, swelling and possibly blistering.

Contains approximately 10 ppm BHT as an antioxidant to protect product quality.

HAZARD RATING SYSTEMS:

This information is for people trained in:

- National Paint & Coatings Association's (NPCA)
Hazardous Materials Identification System (HMIS)
- National Fire Protection Association (NFPA 704)
Identification of the Fire Hazards of Materials

	NPCA-HMIS	NFPA 704	KEY
HEALTH	1	1	4 - Severe
FLAMMABILITY	2	2	3 - Serious
REACTIVITY	0	0	2 - Moderate
			1 - Slight
			0 - Minimal

CAUTION: HMIS ratings are based on a 0-4 rating scale with 1 representing minimal hazards or risks, and 4 representing significant hazards or risks. Recommended HMIS ratings should not be used in the absence of a fully implemented HMIS hazard communication program.

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MATERIAL SAFETY DATA SHEET
ExxonMobil Chemical Company
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DF-2000 FLUID

PAGE: 7
DATE PREPARED: 28 September 2001
MSDS NUMBER: 92842883

REVISION SUMMARY

Since September 27, 2001 this MSDS has been revised in Section(s)
3

REFERENCE NUMBER:
HDKA C 25733

SUPERSEDED ISSUE DATE:
September 27, 2001

THIS INFORMATION RELATES TO THE SPECIFIC MATERIAL DESIGNATED AND MAY NOT BE VALID FOR SUCH MATERIAL USED IN COMBINATION WITH ANY OTHER MATERIALS OR IN ANY PROCESS. SUCH INFORMATION IS TO THE BEST OF OUR KNOWLEDGE AND BELIEF ACCURATE AND RELIABLE AS OF THE DATE COMPILED. HOWEVER, NO REPRESENTATION, WARRANTY OR GUARANTEE IS MADE AS TO ITS ACCURACY, RELIABILITY, OR COMPLETENESS. IT IS THE USER'S RESPONSIBILITY TO SATISFY HIMSELF AS TO THE ACCURACY AND COMPLETENESS OF SUCH INFORMATION FOR HIS OWN PARTICULAR USE. WE DO NOT ACCEPT LIABILITY FOR ANY LOSS OR DAMAGE THAT MAY OCCUR FROM THE USE OF THIS INFORMATION NOR DO WE OFFER ANY WARRANTY AGAINST PATENT INFRINGEMENT.

Last Page

MSDS for Tonsil



SAFETY DATA SHEET according to EC directive 93/112/EC
TONSIL 414 FF PB 25KG

Update
10.06.2001

Print Date
13.02.2003

Version
1

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND THE COMPANY/UNDERTAKING

Product information

Commercial Product Name : TONSIL 414 FF PB 25KG
Company : SOD-Chemie AG
Unternehmensbereich
Bleaching Earths and Adsorbents
Osterriederstrasse 15
85368 Meusburg
Telephone : +49 8761 820
Telefax : +49 8761 82169
Contact Point : BBA-D +49 8761/82-320
Emergency telephone number : +49 (0)613284463 only for working place emergency (contact only in german or english)

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical nature : natural Ca-bentonite, acid-activated

Components	CAS-No.	Symbol(s)	R-phrases(s)	Concentration
free crystalline silica *) in fine dust	14808-60-7			< 2,00 %
fine dust < 7,1 µm				< 5,00 %
breathable content of crystalline silica *) in whole product				< 0,10 %

(* including quartz, cristobalite, tridymite)

3. HAZARDS IDENTIFICATION

Avoid inhalation and/or exceeding of occupational limit value.

4. FIRST AID MEASURES

General advice : none
Eye contact : Rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes.
Skin contact : Wash off with soap and plenty of water.
Inhalation : Move to fresh air.
Ingestion : Rinse mouth.
Notes to physician :
Treatment : none



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TONSIL 414 FF PB 25KG

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10.09.2001

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13.02.2003

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5. FIRE-FIGHTING MEASURES

- Specific hazards during fire fighting : none
Special protective equipment for fire-fighters : none
Suitable extinguishing media : The product itself does not burn.
Use extinguishing measures appropriate to the environment.
Extinguishing media which must not be used for safety reasons : none

6. ACCIDENTAL RELEASE MEASURES

- Environmental precautions : none
Methods for cleaning up : Take up uncontaminated material and pass on for further processing.
Take up contaminated material by mechanical means, load into clean containers, and dispose of in accordance with legal regulations.
Additional advice : Avoid dust formation.

7. HANDLING AND STORAGE

Handling

- Safe handling advice : Avoid formation of dust and aerosols
Advice on protection against fire and explosion : No special precautions required.

Storage

- Requirements for storage areas and containers : Keep container tightly closed and dry.
Advice on common storage : no restrictions

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

- Additional technical information on the plant : Local exhaust



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10.08.2001

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13.02.2003

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Components with workplace control parameters

Components	CAS-No.	Value	Basis / Remarks
QUARTZ (alveolar content)*	14808-60-7	0,15 mg/m ³ 02 2000 0,05 mg/m ³ 1999 0,05 mg/m ³ 06 1997 0,1 mg/m ³	Germany TRGS 900 Limit Values TRK Data ACGIH Threshold Limit Values Note List NIOSH Pocket Guide to Chemical Hazards OSHA Table Z-1-A 1989
QUARTZ IN DUST	14808-60-7	0,15 mg/m ³ 02 2000 0,05 mg/m ³ 1999 0,05 mg/m ³ 06 1997 0,1 mg/m ³	Germany TRGS 900 Limit Values TRK Data ACGIH Threshold Limit Values Note List NIOSH Pocket Guide to Chemical Hazards OSHA Table Z-1-A 1989
limiting value of inert dust (alveolar content)		1,5 mg/m ³	TRGS900 MAK
limiting value of inert dust		4 mg/m ³	TRGS900 MAK

(* including cristobalit and tridymit)

Personal protective equipment

Respiratory protection	: In case of formation of dust: Dust-mask/filter P2
Hand protection	: In case of formation of dust: PVC or other plastic material gloves
Eye protection	: safety glasses
Skin and body protection	: none
Hygiene measures	: Wash off with warm water and soap.
Protective measures	: Prophylactic use of protective ointment (barrier cream) is recommended

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	: powder
Colour	: white to grey
Odour	: none

Other data

melting point	: n.a.
boiling point	: n.a.
Flash point	: n.a.
Ignition temperature	: n.a.
Autoignition temperature	: none
Upper explosion limit	: n.a.



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TONSIL 414 FF PB 25KG

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13.02.2003

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Lower explosion limit	: n.a.
Vapour pressure	: n.a.
Density	: n.av.
Bulk density	: 608 g/l
Water solubility	: insoluble
pH	: 5,2 - 7 at 100 g/l Method: Aqueous suspension
Oxidizing properties	: Other data: none
Explosive properties	: Remarks: none

10. STABILITY AND REACTIVITY

Hazardous reactions (Conditions to avoid)	: None known
Hazardous reactions (Materials to avoid)	: None known
Information about decomposition	: No decomposition if stored and applied as directed.

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Acute oral toxicity	: LD50 rat Dose: > 5.000 mg/kg The product has not been tested in animal experiments. The toxicological data has been taken from products of similar composition.
---------------------	---

Irritation, Sensitization, Other data Toxicology

Eye irritation	: Result: moderately irritating to mucous membranes.
Sensitization	: Result: not sensitizing
Repeated dose toxicity	: no data available
Human experience	: Dust may render the skin dry and chappy. In the event of long-term excess of the TLV value and extended inhalation effect, fine dust containing quartz may cause silicosis. Due to dust raising, light irritation of eyes and/or mucous membranes is possible.



SAFETY DATA SHEET according to EC directive 93/112/EC
TONSIL 414 FF PB 25KG

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10.08.2001

Print Date
13.02.2003

Version
1

12. ECOLOGICAL INFORMATION

Elimination information (persistence and degradability)

Decomposition : Result: not biodegradable
Product is of mineral origin.

Distribution to environmental compartments : no data available

Ecotoxicity effects

Further information : no data available
Ecotoxicity

13. DISPOSAL CONSIDERATIONS

Product : Can be landfilled or incinerated, when in compliance with the Environmental Protection (Duty of Care) Regulations 1991. Contact waste disposal services.

Contaminated packaging : Can be re-used after emptying and cleaning.

14. TRANSPORT INFORMATION

Land transport : Not classified as dangerous in the meaning of transport regulations.

Sea transport : Not classified as dangerous in the meaning of transport regulations.

Air transport : Not classified as dangerous in the meaning of transport regulations.

15. REGULATORY INFORMATION

General advice : The product does not need to be labelled in accordance with EC directives or respective national laws.

Hazardous components which must be listed on the label:

preparation : Not applicable

Other information : S22 - Do not breathe dust (recommendation)
Follow the usual precautions required when handling chemicals.



SAFETY DATA SHEET according to EC directive 93/112/EC
TONSIL 414 FF PB 25KG

Update
10.08.2001

Print Date
13.02.2003

Version
1

16. OTHER INFORMATION

Responsible for SDS: Environmental Protection Contact person: Dep.
CEQ Tel.: 05761/82-654

The information presented herein is believed to be accurate, but is not
warranted.

It does not represent any assurance of properties of the product.
The specifications are to be drawn from the corresponding leaflet.

A vertical bar (|) in the left margin indicates an amendment from the previous version.

Legend

n.a.: not applicable
n.av.: not available
n.r.: not relevant

MSDS for Pure Dry Solvent

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



PAGE: 1
DATE PREPARED: 7/02/2003
PRODUCT CODE: 2262001

SECTION 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: PUREDRY[®]
PRODUCT CODE: 2262001
EFFECTIVE DATE: 6/02/2003

CONTACT ADDRESS: Niran Technologies, Inc.
West Orange, NJ 07052

24-HOUR EMERGENCY: 1-800-424-9300

SECTION 2 COMPOSITION / INFORMATION ON INGREDIENTS

Isoparaffins, Perfluorocarbons and Hydrofluoroethers

SECTION 3 HAZARDS IDENTIFICATION

CLEAR LIQUID, VIRTUALLY ODORLESS. NO SIGNIFICANT HAZARDS FOR EMERGENCY RESPONSE ARE KNOWN.*

EMERGENCY OVERVIEW

POTENTIAL HEALTH EFFECTS

EYE CONTACT

Contact with the eyes during product use may cause moderate irritation. Corneal injury is unlikely.

SKIN CONTACT

Prolonged or repeated exposure may cause drying of the skin resulting in irritation and dermatitis. A single exposure is not likely to result in the material being absorbed through skin in harmful amounts.

INGESTION

Ingestion is not a likely route of exposure to this product. However, may be harmful if swallowed.

INHALATION

Vapor concentrations or aerosol discharges may cause irritation to the eyes, nose, throat and respiratory tract. High vapor concentrations may result in headaches, anesthesia and central nervous system depression.

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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SECTION 4 FIRST AID MEASURES

EYE CONTACT

Flush eyes with plenty of water while holding eyelids open. If redness, burning, blurred vision or swelling persists, get medical attention.

SKIN

Wash off with soap in flowing water or shower.

INHALATION

A single prolonged inhalation (hours) exposure is not likely to cause adverse effects. In case of difficulty in breathing or tightness of the chest or dizziness, give 100% oxygen or CPR as required and transport to a medical facility.

INGESTION

Do not induce vomiting unless directed to do so by medical personnel. Drink a large amount of milk, egg whites, or gelatin (water if these are not available).

SECTION 5 FIRE FIGHTING MEASURES

FIRE FIGHTING INSTRUCTIONS

During a fire, smoke may contain the original material in addition to unidentified toxic and or irritating compounds that may include hydrogen fluoride and perfluorinated acid fluorides. Contain water run-off, if possible. Fire water run-off, if not contained and collected, may cause environmental damage. (See STABILITY AND REACTIVITY- SECTION 11 for hazardous combustion and thermal decomposition information).

OTHER FLAMMABILITY INFORMATION

This material does not readily ignite or burn. Container may vent or rupture due to fire. Vapors are heavier than air and may travel a long distance and accumulate in low lying areas.

EXTINGUISHING MEDIA

This material does not readily burn. If exposed to fire from another source use suitable extinguishing agent for that fire.

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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PROTECTIVE EQUIPMENT FOR FIRE FIGHTERS

Wear positive pressure, self-contained breathing apparatus (SCBA) and protective fire fighting clothing includes fire fighting helmet, coat, pants, boots and gloves.

FLAMMABLE PROPERTIES

FLASH POINT (PMCC) ⁽¹⁾
350 °F

AUTOIGNITION TEMPERATURE

Test Standard

The test was performed in accordance with ASTM Method E 659 "Standard Test Method for Autoignition Temperature of Liquid Chemicals"

The test identifies the lowest temperature at which the sample will spontaneously ignite under the test conditions

Test Method

The autoignition temperature is measured in a 500 ml glass flask which is heated in an electrical furnace. A small sample of test material is injected into the heated flask using a syringe and its ignition behavior is observed. The temperature and sample size are then varied to determine the lowest ignition temperature.

AUTOIGNITION TEMPERATURE
(346 – 349) °C

LIMITS OF FLAMMABILITY

Test Standard

The test was performed in accordance with ASTM Method E-681, "Standard Test Method for Concentration Limits of Flammability of Chemicals".

This test identifies the minimum and maximum concentration of a combustible substance in air at atmospheric pressure through which a flame will just propagate away from the ignition source.

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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The test apparatus consists of a round bottom flask, which is approximately 5-liters in volume and can be heated to 300°C. A type-K thermocouple was placed inside the flask to measure the temperature of the reactants. The temperature of the flask was controlled by controlling the temperature of the heater. Two electrodes were placed inside the flask at the approximate center and having a spark gap of 6mm. The electrodes were connected to a high voltage power supply capable of delivering 10,000 volts @ 25mA across the electrode gap. This spark was used as the ignition source. The vessel was fitted with a magnetic stirrer to ensure uniform mixing of the gases.

The vessel was heated to the desired temperature and after a period of equilibration, the vessel was evacuated and a measured amount of liquid introduced into the vessel. The stirring mechanism was then activated to agitate the liquid and produce a larger surface area for evaporation. Air was then allowed to ingress the system until atmospheric pressure was achieved. The gas mixture was then left for 5 minutes to form a homogeneous mixture and to allow thermal equilibrium. The high energy ignition source was then activated for 1 second and the test vessel was observed to detect ignition.

FLAMMABLE LIMITS (% v/v)
Low Flammable Limit (LEL) - .52
Upper Flammable Limit (UEL) - 6.4

SECTION 6 ACCIDENTAL RELEASE MEASURES

ACTION TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED PROTECTIVE MEASURES:

Eliminate potential sources of ignition.
Wear appropriate personal protective equipment when responding to spills as specified in Section 5.

SPILL MANAGEMENT

Shut off source of leak. Dike and contain spill. Keep out of sewers, storm drains, surface waters, basements and soil.

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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SECTION 7 ACCIDENTAL RELEASE MEASURES-CONTINUED

CLEANUP

Pump up or soak up with sand or other absorbent. Application of vapor suppressant foams may be appropriate.

SECTION 8 HANDLING AND STORAGE

HANDLING

Keep unconfined liquid and vapor away from heat and open flames to avoid decomposition products.

STORAGE

Keep containers tightly closed when not in use to avoid evaporation. Do not cut, drill, grind, weld or perform similar operations on or near empty containers.

SECTION 9 EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS

Good ventilation should be sufficient for most conditions.

PERSONAL PROTECTIVE EQUIPMENT

EYE-FACE PROTECTION

Use chemical goggles.

SKIN PROTECTION

Use gloves impervious to this material when prolonged or frequently repeated contacts should occur.

RESPIRATORY PROTECTION

No occupational exposure limits have been developed for this material. Where exposure through inhalation may occur from use, National Institute for Occupational Safety and Health (NIOSH) / Mine Safety and Health Administration (MSHA) approved respiratory protection equipment is recommended.

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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SECTION 10 PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE / PHYSICAL STATE

Clear Liquid

ODOR

Slight solvent odor

VAPOR PRESSURE

2.1 mm Hg @ 77 F

VAPOR DENSITY

NA

BOILING POINT

298 F, 147 C

SOLUBILITY IN WATER

Insoluble

SPECIFIC GRAVITY (WATER = 1)

.80 @ 77 F

KB VALUE

37-40

PH

NA

DENSITY (LBS/GAL)

6.71

DENSITY (KG/M3)

804.1

VISCOSITY

1.2Cp @ 77 F

SURFACE TENSION

22 @ 77 F

SECTION 11 STABILITY AND REACTIVITY

CHEMICAL STABILITY

Stable under recommended storage and use conditions.

HAZARDOUS POLYMERIZATION

Will not occur

MATERIAL SAFETY DATA SHEET



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SECTION 11 STABILITY AND REACTIVITY-CONTINUED

HAZARDOUS THERMAL DECOMPOSITION / COMBUSTION PRODUCTS CONDITIONS TO AVOID

Avoid open flames, welding arcs or other high temperature sources which might induce thermal decomposition. (NOTE: Decomposition of components of this product can form hydrogen fluoride and perfluoroisobutylene (PFIB)). Formation of PFIB will only occur at temperatures exceeding 570° F and PFIB will only accumulate with continuous exposure to excessive heat in a sealed vessel. The formation rate for PFIB is about 1000 times less than the rate for primary thermal decomposition products such as HF or CO. During normal use conditions, no health hazard is associated with the use of PureDry due to PFIB exposure.

INCOMPATIBILITY

(materials to avoid) NONE known

SECTION 12 TOXICOLOGICAL INFORMATION

PRODUCT INFORMATION

ACUTE DERMAL TOXICITY

Dose level, 1,000 mg/kg (rats). All animals survived exposure to PureDry. Acute Dermal LD50 > 1,000 mg/Kg (rats).

ACUTE INHALATION TOXICITY

Exposure level 20.68 mg/L (nominal). All animals survived exposure to the test atmosphere. Inhalation LC50 > 20.68 mg/L (rats).

ACUTE ORAL TOXICITY

Dose level 500 mg/Kg. All animals survived exposure to PureDry. Acute Oral LD50 > 500 mg/Kg (rats).

PRIMARY EYE IRRITATION

Ocular Irritation MMTS 0.7 (Average irritation score) Not considered an eye irritant (rabbits).

PRIMARY SKIN IRRITATION

Primary Dermal Irritation Index (PDII) 3.7 (Average irritation score) (rabbits).

Not a primary irritant. Very slight to well-defined erythema and very slight edema persisted at all abraded and intact dose sites at 72 hours.

MATERIAL SAFETY DATA SHEET



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SECTION 13 ECOLOGICAL INFORMATION

BIODEGRADABILITY

5 Day Biochemical Oxygen Demand (BOD5)
0.9g/l PureDry

SECTION 14 DISPOSAL CONSIDERATIONS

Treatment, storage, transportation, and disposal must be in accordance with applicable Federal, state/provincial, and local regulations. Recover nonusable free liquid and dispose of in approved and permitted incinerator or in an approved and permitted biological treatment system. Recover contaminated water and dispose of in an approved permitted biological treatment system. remove nonusable solid material and/or contaminated soil for disposal in an approved and permitted landfill. Do no flush to surface water or sanitary sewer system.

SECTION 15 TRANSPORTATION INFORMATION

SHIPPING INFORMATION

Not regulated as a hazardous material by DOT, IMO, or IATA.

SECTION 16 REGULATORY INFORMATION

NOT MEANT TO BE ALL-INCLUSIVE-SELECTIVE REGULATIONS REPRESENTED

CERCLA

Spill requirements
Non regulated

SARA

Title III release reporting required
Non regulated

VOC

Per Title I, Clean Air Act Amendments of 1980
YES

HAP

Compound per Title III, Clean Air Act Amendments of 1980
NO

MATERIAL SAFETY DATA SHEET

Niran Technologies, Inc.



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-Hydrogen fluoride has an ACGIH Threshold Limit Value of 3 parts per million (as fluoride) as a Ceiling Limit and an OSHA PEL of 3 ppm of fluoride as an eight hour Time-Weighted Average and 6 ppm of fluoride as a Short Term Exposure Limit. The odor threshold for HF is 0.04 ppm, providing good warning properties for exposure.

Perfluoroisobutylene has an ACGIH threshold limit value of 0.01 parts per million parts of air as a ceiling limit or 0.082 milligrams per cubic meter as a ceiling limit.

- (1) During vacuum distillation of solvent operator must maintain the distillate temperature below 80 °F as solvent exits the condensor or solvent Flashpoint may change to 140 ° - 200 °F range (Class IIIA). Lowering of the Flashpoint will have no effect on the superior cleaning capability and benefits of PUREDRY.

REVISION SUMMARY

Since MAY 2, 2003 this MSDS has been revised to incorporate Registered Trademark PureDry®, Registration Date May 27, 2003; Registration No. 2,718,776 and to revise Section 5: Fire Fighting Measures, and Section 11: Stability and Reactivity.

REFERENCE NUMBER: N-103

SUPERSEDES ISSUE DATE: MAY 2, 2003

THE INFORMATION CONTAINED HEREIN IS BASED ON INFORMATION CONSIDERED ACCURATE AND RELIABLE AS OF THE DATE COMPILED. IT RELATES SPECIFICALLY TO ITS USE AS A DRY-CLEANING FLUID IN MACHINES DESIGNED FOR ITS USE AND MAY NOT BE VALID FOR SUCH MATERIAL USED IN COMBINATION WITH OTHER MATERIALS OR IN OTHER PROCESSES. NO WARRANTY IS EXPRESSED OR IMPLIED REGARDING THE ACCURACY OF THESE DATA OR THE RESULTS TO BE OBTAINED FROM THE USE THEREOF.

MSDS for Green Earth Solvent



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name **Cyclopentasiloxane**

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Manufactured By **GES Waterford Plant**
 260 Hudson River Rd
 Waterford NY 12188
Revised: **11/06/2003**
Preparer: **PRODUCT STEWARDSHIP COMPLIANCE AND STANDARDS**
Chemical Family/Use: **Silicone siloxane**
Formula: **Cyclic siloxanes.**
CHEMTREC **1-800-424-9300**

HMIS

FLAMMABILITY	2	REACTIVITY	0	HEALTH	0
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NFPA

FLAMMABILITY	2	REACTIVITY	0	HEALTH	1
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2. COMPOSITION/INFORMATION ON INGREDIENTS

PRODUCT COMPOSITION	CAS REG NO.	WGT. %
---------------------	-------------	--------

A. HAZARDOUS

DECAMETHYLCYCLOPENTASIL OXANE	541-02-6	> 90 %
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B. NON-HAZARDOUS

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:

CAUTION! Combustible liquid and vapor. May cause irritation of skin and eyes. Adverse liver effects reported in animals. Attention: Not for injection into humans. May generate formaldehyde at temperatures greater than 150 C(300 F). See Section 3 of MSDS for details.
 Liquid: Clear None

POTENTIAL HEALTH EFFECTS :

INGESTION :



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name **Cyclopentasiloxane**

Not an anticipated route of exposure.

SKIN :
May cause mild skin irritation.

INHALATION :
None known.

EYES :
May cause mild eye irritation.

MEDICAL CONDITIONS AGGRAVATED
None known.

SUBCHRONIC (TARGET ORGAN) :
Liver

CHRONIC EFFECTS / CARCINOGENICITY :
This product or one of its ingredients present 0.1% or more is NOT listed as a carcinogen or suspected carcinogen by NTP, IARC, or OSHA.

ROUTES OF EXPOSURE :
None known.

OTHER :
Attention: Not for injection into humans. This product contains methylpolysiloxanes which can generate formaldehyde at approximately 300 degrees Fahrenheit (150°C) and above, in atmospheres which contain oxygen. Formaldehyde is a skin and respiratory sensitizer, eye and throat irritant, acute toxicant, and potential cancer hazard. An MSDS for formaldehyde is available from GE Silicones. Additional information on the toxicological effects of this material or it's ingredients can be found in Section 11 - Toxicological Information.

4. FIRST AID MEASURES

INGESTION :
Do not induce vomiting. If victim is conscious, give 1-3 glasses of water to drink. Never give anything by mouth to an unconscious person. Get medical attention if irritation persists.

SKIN :
Wash with soap and water. Get medical attention if irritation or symptoms from Section 3 develop.



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name Cyclopentasiloxane

INHALATION :

If inhaled, remove to fresh air. If not breathing give artificial respiration using a barrier device. If breathing is difficult give oxygen. Get medical attention.

EYES :

In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.

NOTE TO PHYSICIAN :

None known.

5. FIRE-FIGHTING MEASURES

FLASH POINT	76.60 °C 170.60 °F
METHOD:	PMCC
IGNITION TEMPERATURE	Unknown
FLAMMABLE LIMITS IN AIR - LOWER (%)	Unknown
FLAMMABLE LIMITS IN AIR - UPPER (%)	Unknown

SENSITIVITY TO MECHANICAL IMPACT: No

SENSITIVITY TO STATIC DISCHARGE :

Sensitivity to static discharge is expected; material has a flash point below 200 F.

EXTINGUISHING MEDIA :

All standard firefighting media

SPECIAL FIRE FIGHTING PROCEDURES :

Combustible, Firefighters must wear NIOSH/MSHA approved positive pressure self-contained breathing apparatus with full face mask and full protective clothing.

6. ACCIDENTAL RELEASE MEASURES

ACTION TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED :

Wash walking surfaces with detergent and water to reduce slipping hazard. Wear proper protective equipment as specified in the protective equipment section. Wipe, scrape, or soak up in an inert material and put in a container intended for flammable materials for disposal.

7. HANDLING AND STORAGE



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name Cyclopentasiloxane

STORAGE

Store away from heat, sources of ignition, and incompatibles. Keep container tightly closed.

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE:

Avoid contact with skin and eyes. Avoid inhalation of vapors or mists. Keep away from children. Use ground strap and appropriate precautions for dispensing flammable liquids.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

ENGINEERING CONTROLS :

ShowersEyewash stationsExhaust ventilation

RESPIRATORY PROTECTION:

If exposure limits are exceeded or respiratory irritation is experienced, NIOSH/MSHA approved respiratory protection should be worn. Supplied air respirators may be required for non-routine or emergency situations. Respiratory protection must be provided in accordance with OSHA regulations (see 29CFR 1910.134).

PROTECTIVE GLOVES :

Rubber or plastics gloves

EYE AND FACE PROTECTION :

safety glasses with side-shields

OTHER PROTECTIVE EQUIPMENT :

Wear suitable protective clothing and eye/face protection.

Exposure Guidelines

Chemical	CAS REG NO.	ACGIH	OSHA	Supplier
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9. PHYSICAL AND CHEMICAL PROPERTIES

BOILING POINT - C & F	210.00 °C 410 °F
VAPOR PRESSURE (20 C) (MM HG) :	3 MM HG
VAPOR DENSITY (AIR=1) :	no data available
FREEZING POINT:	Unknown
MELTING POINT :	Unknown
PHYSICAL STATE:	Liquid
ODOR:	None
COLOR :	Clear



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name Cyclopentasiloxane

EVAPORATION RATE (BUTYL ACETATE=1):	< 1
SPECIFIC GRAVITY (WATER=1) :	0.95
DENSITY (KG/M3) :	958.60 KG/M3
ACID / ALKALINITY (MEQ/G) :	<3 PPM A
pH	NA
VOLATILE ORGANIC CONTENT (VOL)	100.00 %(m)
SOLUBILITY IN WATER (20 C) :	Insoluble
SOLUBILITY IN ORGANIC SOLVENT (STATE SOLVENT) :	Soluble in toluene
VOC EXCL. H2O & EXEMPTS (G/L) :	0.00

10. STABILITY AND REACTIVITY

STABILITY :
Stable

HAZARDOUS POLYMERIZATION :
WILL NOT OCCUR

HAZARDOUS THERMAL DECOMPOSITION / COMBUSTION PRODUCTS :
carbon dioxide (CO2)formaldehydeCarbon monoxideSilicon dioxide.

INCOMPATIBILITY (MATERIALS TO AVOID)
None known.

CONDITIONS TO AVOID :
Keep away from heat and sources of ignition.

11. TOXICOLOGICAL INFORMATION

ACUTE ORAL:
>20,000 mg/kg (rat)

ACUTE DERMAL:
>10 ml/kg(Rat)

ACUTE INHALATION:
LC50 rat8.67 mg/l (rat)

OTHER:
Decamethylcyclopentasiloxane Rodents repeatedly exposed to decamethylcyclopentasiloxane (D5)



GE Silicones

MATERIAL SAFETY DATA SHEET

SB32 55G-Drum(420.0LBS-190.5KG)

Trade Name Cyclopentasiloxane

via inhalation or ingestion developed increased liver weights relative to unexposed control animals. When the exposure was stopped, livers returned to normal. Microscopic examination of the liver cells did not show any evidence of pathology. Liver enlargement was due to an increase in metabolizing enzymes, and a temporary increase in the number and size of normal cells (hyperplasia and hypertrophy). These biochemical pathways are more sensitive in rodents than in humans. Inhalation exposures that are typical in industrial use (5-10 ppm) showed no toxic effects in rodents. A two-year combined chronic toxicity and carcinogenicity inhalation study was conducted with decamethylcyclopentasiloxane (D5) in Fisher-344 rats by whole body inhalation. A statistically significant increase in the trend for uterine endometrial tumors was observed in female rats exposed for 24 months at the highest dose level of 160 ppm. The same effects were not seen at the other dose levels of 10 and 40 ppm. No adverse effects were seen at male rats at any level. Whether or not this increase in incidence is truly related to the exposure to D5 is questionable and yet to be determined. Based on our present knowledge, it is unlikely that industrial, commercial, or consumer uses of products containing D5 would result in a significant risk to humans. The GE Recommended Exposure Guideline for D5 is 10 ppm.

SENSITIZATION:

Magnusson-Kigmann guinea pigs negative

SKIN IRRITATION

rabbit: No skin irritation

EYE IRRITATION

rabbit: No eye irritation

MUTAGENICITY

Salmonella/Microsome-test: No indication of mutagenic effects.

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGY

This product is a small, lipophilic, low molecular weight volatile compound. Due to its high volatility, product has a short half-life in the aquatic compartment, and is unlikely to be found in the terrestrial compartment. As a low molecular weight lipophilic compound it has the potential to bioaccumulate.

CHEMICAL FATE

no data available

DISTRIBUTION

no data available

MSDS for Rynex

RYNEX Material Safety Data Sheet:

RYNEX BIODEGRADABLE DRY CLEANING FLUID

Rynex Corporation
7600 Jericho Turnpike
Woodbury, New York 11797
(516) 364-0800
MSDS Preparation Date: 2/11/97

SECTION 1: PRODUCT IDENTIFICATION

Trade Name: Rynex Biodegradable Dry Cleaning Solution
Product Name: Rynex Biodegradable Dry Cleaning Solution
Chemical Name: Chemical identity withheld as trade secret under OSHA Hazard Communication Standard 29 (CFR) 1910.1200 (i)(1)
Generic Name: Mixture of Azeotropes of substituted aliphatic glycol ethers

SECTION 2: INGREDIENTS

Components are not considered to be hazardous under OSHA Hazard Communication Standard. The product is a mixture of biodegradable azeotropes of substituted aliphatic glycol ethers. No occupational exposure limits have been established for this material or its components.

SECTION 3: HAZARD IDENTIFICATION

EMERGENCY OVERVIEW: Low to Moderate Health Hazard.

Skin Contact: Flood affected skin with water while removing and isolating all contaminated clothing. Gently wash all affected skin areas thoroughly with soap and water. If symptoms such as redness or irritation develop, call a physician.

Inhalation:

Leave the contaminated area; take deep breaths of fresh air. If symptoms (such as wheezing, coughing, shortness of breath, or burning in the mouth, throat, or chest) develop, call a physician or transport the subject to a hospital. Provide proper respiratory protection to rescuers entering an unknown atmosphere. Whenever possible, self-contained Breathing Apparatus (SCBA) should be used; if not available, use a level of protection greater than or equal to that advised under Respirator Recommendation.

Eye contact:

Flush subject's eyes with water or normal saline solution for 20 to 30 minutes while simultaneously calling a hospital or other medical facility. Do not put any ointments, oils, or medication in the subject's eyes without specific instructions from a physician. Transport the subject after flushing eyes to a hospital or First Aid / Medical Unit if so advised by a medical specialist.

Ingestion:

<http://www.rynex.com/msds.html>

6/24/2004

If the subject is conscious and not convulsing, give 1 or 2 glasses of water to dilute the chemical and call a hospital or physician. Be prepared to transport the subject to a hospital if advised by a physician. If the subject is convulsing or unconscious, do not give anything by mouth, ensure that the subject's airway is open and lay the subject on his/her side with the head lower than the body. DO NOT INDUCE VOMITING. Transport the subject to a hospital.

Symptoms:

Symptoms of exposure to this compound via inhalation include coughing, shortness of breath, dizziness, drunkenness and collapse. Eye contact causes irritation. Prolonged skin contact may cause irritation.

Summary:**Acute (short-term) Health Effects:**

Slight inhalation hazard
Eye irritant
Slight Ingestion hazard
Slight skin irritant
Slight skin absorption hazard

Chronic (long-term) Health Effects:

A 3 month inhalation study of this material in rats gave no indication of chronic toxicity

Carcinogenicity: This product has not been classified a carcinogen by the International Agency for Research on Cancer (IARC), the Occupational Safety and Health Administration (OSHA), or the National Toxicology Program (NTP).

Target Organs: Not available

Primary Routes of Entry (Exposure):

Inhalation: Prolonged overexposure may cause coughing, shortness of breath, dizziness and intoxication.

Eye Contact: May cause eye irritation.

Skin Absorption: Extensive/ prolonged or repeated exposure to this material can result in significant absorption.

Skin Irritation: May produce skin irritation.

Ingestion: This material may be a slight health hazard if ingested in large quantities.

Summary of Chronic Hazards: A three month inhalation study of this material in rats gave no indication of chronic toxicity.

Special Health Effects: Medical information regarding special health effects is not conclusive.

SECTION 4: FIRST AID MEASURES

Inhalation: If overcome by exposure, remove subject to fresh air immediately. Give oxygen or artificial respiration as needed. Obtain emergency medical attention. Prompt action is essential.

Eye Contact: In case of eye contact, immediately rinse with clean water for 20-30 minutes. Retract eyelids often. Obtain emergency medical attention.

Skin contact: Remove contaminated clothing as needed. Wash skin thoroughly with mild soap and water. Flush with lukewarm water for 15 minutes. If sticky, use waterless cleaner

first.

Ingestion: If a large quantity swallowed, give lukewarm water (pint 1/2 liter) if subject completely conscious/alert. DO NOT INDUCE VOMITING. Risk of damage to lungs exceeds poisoning risk. Obtain emergency medical attention.

Physicians Emergency Medical Treatment Procedures: Continue to rinse eye with clean water for 20-30 minutes, retracting eyelids often. Contact ophthalmologist immediately. Maintain airway. Provide oxygen and or ventilation assistance, if needed. Treat symptomatically. Treatment of overexposure should be directed at the control of symptoms and the clinical condition of the patient. After adequate first aid, no further treatment is required unless symptoms reappear.

Physicians Detoxification Procedure: No additional information found.

SECTION 5: FIRE FIGHTING MEASURES

Flash Point: Greater than 200 degrees F Closed Cup

Flammable Limits: LEL 1.7 - UEL 6.7 @ 80 degrees C standard atmosphere

Auto-ignition Temperature: Greater than 535F Freezing point -40degC

Unusual Fire/Explosion Hazards: None expected. Do not enter fire area without proper protection. Fight fire from a safe distance. When heated above the flash point, releases flammable vapors. When heated to decomposition it emits toxic fumes of carbon monoxide, carbon dioxide and unidentified organic compounds in black smoke.

Extinguishing Media: Water fog, water spray, fire fighting foam, Carbon dioxide, dry chemical.

SECTION 6: ACCIDENTAL SPILL/RELEASE MEASURES

Spills and leakage:

If you should spill this chemical, use absorbent to pick up all liquid spill material. Seal the absorbent as well as any of your clothing which may be contaminated, in a vapor-tight plastic bag for eventual disposal. Wash any surfaces you may have contaminated with a soap and water solution. Do not reenter the contaminated area until the Safety Officer (or other responsible person) has verified that the area has been properly cleaned.

Disposal and Recycling: Wastes generated from the use of this dry cleaning fluid are not hazardous as defined by the Resource Conservation and Recovery Act (RCRA; 40 CFR 261). Comply with state and local regulations for disposal of spent cleaning fluid. If you are unsure of the regulations, contact your local Public Health Department, or the local office of the Environmental Protection Agency (EPA). Material can be recycled for continuous reuse by distillation. Contact your distributor for additional information.

SECTION 7: HANDLING AND STORAGE

Storage Handling: Store in tightly closed containers away from heat, sparks, open flame and strong oxidizing agents.

SECTION 8: EXPOSURE CONTROL/PERSONAL PROTECTION

Ventilation: Local exhaust ventilation should be provided. General dilution ventilation should be provided. The need for ventilation systems should be evaluated by a professional industrial hygienist, while the design of specific ventilation systems should be conducted by a professional engineer.

Recommended glove materials:

Glove Type - Butyl rubber; Model Number - North B-161; Thickness - 0.40 mm; Estimated

Protection Time - 480 minutes
Glove Type - Nitril; Model Number - Pioneer A-14; Thickness - 0.56 mm; Estimated
Protection Time - 480 minutes
Glove Type - PE/EVAL/PE; Model Number - Safety 4 4H; Thickness - 0.07 mm; Estimated
Protection Time - 240 minutes
Glove Type - Viton; Model Number - North F-091; Thickness - 0.30 mm; Estimated
Protection Time - 360 minutes

Recommended respirator:

Wear an approved half face respirator equipped with an organic vapor/acid gas cartridge (specific for organic vapors, HCl, acid gas and SO₂) with a dust/mist filter when engineering controls are not available).

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point: 152 degrees C @ 200Mb.

Evaporation Rate: (Butyl acetate = 1): Not available

pH: -7

Saturation in Air (%): Not available

Solids Content: Not applicable

Specific Gravity (Water = 1): Less than 0.95

Vapor Density (Air = 1): Not available

Vapor Pressure: 32mmHg @ 77 degrees F

Viscosity: AP 4CS

Appearance and Odor: Clear liquid, light solvent odor

SECTION 10: STABILITY AND REACTIVITY

Stability: Product is stable. Hazardous polymerization will not occur.

Reactivity: This product is not reactive.

Hazardous Decomposition Products: When heated to decomposition it emits toxic fumes of carbon monoxide, carbon dioxide and unidentified organic compounds in black smoke

SECTION 11: TOXICOLOGICAL AND EPIDEMIOLOGICAL DATA

Toxicity:

LD50 - orl - rat - 3.7 gm/kg

LD50 - skn - rbt - >2.0 gm/kg

LC50 - ihl - rat - >2680 mg/ml3/4H

SAX TOXICITY EVALUATION: SHORT-TERM TOXICITY -14 DAY (Inhalation), ON TEST

- RATS: FISCHER 344; MICE RB - DOSE: 5/SEX/SPECIES/GROUP - 90 DAY (Inhalation), ASSIGNED
- RATS: FISCHER 344; MICE: DOSE: R: 20/SEX/GROUP M: 10/SEX/GROUP LONG-TERM CARCINOGENICITY -104 WEEK (Inhalation), ASSIGNED
- RATS: FISCHER 344; MICE: -DOSE: 59/SEX/SPECIES/GROUP

SPECIAL STUDIES

- CHEMICAL DISPOSITION (Gavage)
- RATS:FISCHER 344 -REPORT

<http://www.rynex.com/msds.html>

6/24/2004

GENETIC TOXICOLOGY

- IN VITRO CYTOGENETICS
- NEGATIVE (CHROMOSOME ABERRATIONS) NEGATIVE (SISTER CHROMATID EXCHANGES)
- SALMONELLA, SELECTED

ORGAN SYSTEMS TOXICITY -CONTINUOUS BREEDING (Dosed-Water), SELECTED

- **MALE/FEMALE RATS: SPRAGUE-DAWLEY -DOSE: TASK 1: 0, 0.1, 0.2, 0.5, 1, OR 2%**
- **OTHER TOXICITY DATA:** Not available

SECTION 12: ECOLOGICAL INFORMATION

Ecotoxicity: AQTX/TLM96: Not available

SECTION 13: DISPOSAL CONSIDERATIONS

Disposal Summary: This product is not regulated as a hazardous waste by the U.S. Environmental Protection Agency (EPA) under Resource Conservation and Recovery Act (RCRA) regulations. Comply with state and local regulations for disposal. If you are unsure of the regulations, contact your local Public Health Department, or the local office of the EPA.

SECTION 14: TRANSPORT INFORMATION

U.S. Department of Transportation Shipping Classification: Not classified a hazardous material.

SECTION 15: REGULATORY INFORMATION**U. S. Regulations:**

OSHA Regulations: None. Chemical specific U.S. Occupational Safety and Health Administration (OSHA) regulations (1910.1002 to 1910.1050) presented under 29CFR do not apply to this material or its components.

ACGIH: None

NIOSH Criteria Document: None NFPA Hazard Rating: Health (H): 2, Flammability (F): 1, Reactivity (R): 0

H2: Materials hazardous to health, but areas may be entered freely with full-faced mask self-contained breathing apparatus which provides eye protection (see NFPA for details).

F1: Materials which must be moderately heated before ignition will occur (see NFPA for details).

R0: Materials which are normally stable even under fire exposure conditions and which are not reactive with water (see NFPA for details). **TCSA:** This product and its components are listed on the Toxic Substances Control Act Chemical Substance Inventory (TSCA)

Other Environmental Information: There are no chemicals in this product regulated by SARA 302/304, 311,312 313, CERCLA, orTSCA12(b).

Department of Transportation: Not regulated

California Safe Drinking Water and Toxic Enforcement Act of 1988 - Proposition 65
This material is not known to contain any chemicals currently listed as carcinogens or reproductive toxins under California Proposition 65 at levels that would be subject to the proposition.

SECTION 16: OTHER INFORMATION

As of the date of preparation of this document, the foregoing information is believed to be accurate and is provided in good faith to comply with applicable federal and state law(s). However, no warranty or representation with respect to such information is intended or given.



MSDS for Detergent Used in Icy Water and Green Jet Technologies

MATERIAL SAFETY DATA SHEET

(Prepared According to 29 CFR 1910.1200) Date Prepared: November 14, 2001
 Prepared by: Robert V. Johnson Date Printed: February 5, 2002

Revised: February, 02

SECTION 1 - PRODUCT AND COMPANY IDENTIFICATION:		
Company Name: KLEERWITE CHEMICAL		24 Hour Emergency Phone: 1-800-535-5053 (InfoTrac)
P. O. BOX 10428, BURKE, VA 22009-0428, 703-451-3964; FAX: 703-451-7362		
Trade Name: DWX-44	Product Type: DETERGENT	
SECTION 2 - INGREDIENT INFORMATION: Not considered hazardous under 29 CFR 1910.1200		
This product is 100% Biodegradable. Contains no petroleum solvents or V.O.C.'s. Contains no products on the Federal H.A.P. list.		
CHEMICAL NAME/COMMON NAME	CAS NO.	PERCENTAGE
WATER	7732-18-5	75 - 85%
SURFACTANT BLEND - NON HAZARDOUS	MIXTURE	15 - 25%
SARA HAZARD TITLE III, SECTION 313-Contains no ingredient listed as a Hazardous Substance (40 CFR-355)		
SECTION 3 - HEALTH HAZARD DATA:		
Primary Routes of Exposure	Eye <input checked="" type="checkbox"/>	<input checked="" type="checkbox"/> Skin <input checked="" type="checkbox"/> Oral <input type="checkbox"/> Inhalation <input type="checkbox"/> Other <input type="checkbox"/>
Overexposure Effects: Irritating to mucous membranes, eyes and skin. May cause slight eye irritation.		
Threshold Limit Value: Not Established.		
H.M.S Values: Health (Blue) -1; Flammability (Red) - 0; Reactivity (Yellow) -0; Personal Protection - A		
Carcinogen or Suspect Carcinogen Ingredients	<input type="checkbox"/> NTP <input type="checkbox"/> IARC <input type="checkbox"/> OSHA	<input checked="" type="checkbox"/> None
SECTION 4 - FIRST AID MEASURES:		
Eyes: Remove contact lenses. Flush eyes with water for 15 minutes, get prompt medical attention.		
Skin: Flush skin with water. Remove contaminated clothing.		
Ingestion: Rinse mouth and give several glasses of water. Do not induce vomiting. NEVER give anything by mouth to an unconscious person. Get medical attention.		
Inhalation: Seek well-ventilated area. If irritation persists seek medical attention.		
SECTION 5 - FIREFIGHTING MEASURES:		
Flash Point (T.C.C.): Not applicable Flammable Limits Upper: Not Flammable; Lower: Not Flammable		
Extinguishing Media: Foam, CO ₂ , Water fog, BC/ABC Extinguisher may be used in area where material is stored.		
Special Firefighting Procedures: None known		
Unusual Fire and Explosion Hazards: None known		
SECTION 6 - ACCIDENTAL RELEASE MEASURES:		
If Released or Spilled: Stop leaks. Soak up spill with rags or towels.		
Waste Disposal Methods: Dispose of spill byproducts according to State and Federal Regulations. Not a hazardous waste under CERCLA or RCRA, 40CFR: 261		
SECTION 7 - STORAGE AND HANDLING INFORMATION:		
Store in a cool, dry area. Do not allow product to freeze. Do not get in the eyes, on skin or on clothing. Do not take internally.		
SECTION 8 - SPECIAL PROTECTION INFORMATION		
Respiratory Protection: Not needed under normal condition of use. Ventilation Requirements: <input checked="" type="checkbox"/> Local Exhaust <input type="checkbox"/> Mechanical		
Protective Gloves: Recommended for prolonged contact Eye Protection: Not necessary Other protective Clothing: None needed		
SECTION 9 - PHYSICAL AND CHEMICAL PROPERTIES:		
Boiling point (°F):	Above 200°F	Density (lb/gal): 8.34
		Specific Gravity (H ₂ O = 1): 1.0
		pH (1%) = 8.5
Vapor Pressure (mm Hg):	<0.01 mm Hg	Vapor Density (Air = 1): >1.0
		Evaporation Rate (vs. Ether): <input type="checkbox"/> Faster <input checked="" type="checkbox"/> Slower
Solubility in water:	<input checked="" type="checkbox"/> Complete <input type="checkbox"/> Insoluble <input type="checkbox"/> Emulsifiable (or Dispersible)	<input type="checkbox"/> Slight (or Partial)
Appearance and Odor: Odorless, clear liquid.		
SECTION 10 - STABILITY AND REACTIVITY:		
Stability: Stable Incompatibility: Oxidizers Hazardous Decomposition Products: None known.		
SECTION 11 - TRANSPORTATION INFORMATION:		
Proper Shipping Name: COMPOUNDS, CLEANING LIQUID		
D.O.T. Hazard Class: NOT REGULATED UN Number: N/A Packaging Group: N/A Label Required: NONE		

This information is provided without any representation or warranty, express or implied, regarding its accuracy or correctness. Conditions or methods of handling, storage, use and disposal of the product are beyond our knowledge. For this and other reasons, we do not assume responsibility and expressly disclaim liability for loss, damage and expense arising out of or in any way connected with the handling, storage, use or disposal of the product.

Appendix B
Stand Alone Case Studies

BLACKBURN'S TOWN & COUNTRY CLEANERS STARTS UP WITH RYNEX

Bob Blackburn, owner of Blackburn's Town & Country Cleaners in Porterville, California, started up his operation with a new perchloroethylene (PERC) alternative called Rynex. The shop has been operating for about a year. Mr. Blackburn has been involved in the dry cleaning industry and operated PERC equipment for many years; he has taught dry cleaning techniques for the last several years.

When Mr. Blackburn was considering opening a new facility, he decided he did not want to use PERC. He investigated alternatives and was very interested in the Rynex process which uses a propylene glycol ether as the cleaning agent. He arranged to visit a dry cleaner in New York who had been using the process for some time. "I was very impressed with the Rynex process when I saw how well it worked for the New York dry cleaner," says Mr. Blackburn.

Mr. Blackburn purchased a Bergparma machine, the machine recommended by the Rynex supplier. He has been happy with the Rynex cleaner but has had to modify the machine in many ways since it was installed. "Equipment maintenance should take about one hour per day," says Mr. Blackburn. "Instead, maintenance labor is much higher, at 21 hours a week."

Mr. Blackburn has found that Rynex is a good cleaner and does not need detergent to clean the clothing effectively. He does no pre-spotting and only a little post-spotting. Says Mr. Blackburn, "the finishing with the Rynex solvent is about the same as it is for PERC."

The cycle with Rynex is longer, at about one hour and 10 minutes, than the 45 minute cycle for a PERC machine. The Rynex solvent takes longer to dry than PERC. The longer cycle is not a problem because the shop only runs about four loads per day and cleans 46,800 pounds of clothing a year.

"I like the Rynex solvent very much," says Mr. Blackburn. "It's a forgiving solvent and an excellent cleaner."

Annualized Costs for Blackburn's Town & Country Cleaners

	Cost
Annualized Capital/Installation Cost	\$4,125
Cleaner Cost	\$780
Electricity Cost	\$12,000
Gas Cost	\$9,600
Spotting Labor Cost	\$520
Finishing Labor Cost	\$15,600
Maintenance Cost	\$10,920
Total Cost	\$53,545

**CROWN DRAPERY CLEANERS SUCCESSFULLY CONVERTS TO THE
HYDROCARBON DRY CLEANING PROCESS**

Crown Drapery Cleaners is located in Huntington Beach, California. The current owner, Matt Borgerson, managed the shop for many years and purchased it from the owner a few years ago. The shop had two 55 pound perchloroethylene (PERC) machines and Mr. Borgerson replaced them with two 35 pound hydrocarbon machines over a year ago. Crown cleans 168,000 pounds of clothing annually.

“I didn’t want to use PERC anymore,” said Mr. Borgerson. “When I bought the shop, there was PERC contamination and I cleaned up the site. The PERC machines were 18 years old and I didn’t want to replace them with new PERC machines. I did some research and decided to go with the hydrocarbon process. I bought high speed extract machines which have a shorter cycle time than the PERC.” The hydrocarbon machines have a 35 minute cycle time and Mr. Borgerson was able to buy hydrocarbon machines with less capacity than the PERC machines.

Crown uses an absorbent material called Tonsil which scavenges dyes when they bleed, makes distillation unnecessary and allows the shop to avoid the use of detergent. “I save almost \$6,000 per year in detergent costs,” says Mr. Borgerson. “I don’t have to do messy distillations and I never have to clean the water separator.” Crown’s gas bills went down when Crown adopted the hydrocarbon process even though Mr. Borgerson added a new washer and hot water heater. The electricity bill is also lower even though Mr. Borgerson added two chillers when he purchased the hydrocarbon machines. “I like the tonsil very much,” he says. “I would recommend it to everyone.”

“A lot of industry people told me spotting would take longer because the hydrocarbon is not as aggressive as PERC,” says Mr. Borgerson. “I was surprised to find my spotting labor is the same with the new process as it was with PERC.”

“The hydrocarbon process is better for the environment and it’s also lower cost than PERC”, says Mr. Borgerson. “I made the right decision.”

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

CYPRESS NATURAL CLEANERS IS WET CLEANING PIONEER

Joe Whang is the owner of Cypress Natural Cleaners, located in Cypress, California. For the last six years, Cypress has operated a wet cleaning machine, one of the first shops in the nation that exclusively relies on wet cleaning. The shop cleans 31,200 pounds of clothing per year.

Before the conversion to wet cleaning, Cypress used the Valclene process. This process used a chlorofluorocarbon, CFC-113, to clean the clothing. Production of CFC-113 was banned in 1996 because the chemical contributes to stratospheric ozone depletion. Six years ago, when he was faced with the ban and the increasing price of CFC-113, Mr. Whang considered the alternatives. "I did not want to use perchloroethylene (PERC) because I think it's dangerous," says Mr. Whang. "I investigated the alternatives and decided to use the wet cleaning process."

Mr. Whang purchased a wet cleaning machine and a humidity controlled dryer. "I was one of the first wet cleaners," he says. "There was a learning curve. The finishing was difficult and I decided to purchase tensioning equipment to make it easier." With wet cleaning, the garments are removed from the dryer when they still contains some moisture so they don't wrinkle badly. Mr. Whang hangs the garments overnight and finishes them the next day. "The wet cleaning detergent and tensioning equipment helps to prevent shrinkage," he says.

Cypress has successfully performed wet cleaning for the past six years. "I like wet cleaning," says Mr. Whang. "It's better for health and the environment and it effectively cleans the garments."

Annualized Costs for Cypress Natural Cleaners

	Wet Cleaning
Annualized Capital Cost	\$1,595
Detergent Cost	\$1,260
Electricity Cost	\$1,800
Gas Cost	\$4,200
Spotting Labor Cost	\$6,240
Finishing Labor Cost	\$23,400
Maintenance Labor Cost	\$520
Total Cost	\$39,015

**DOHENY DRY CLEANERS CONVERTS
PERC MACHINE TO USE GREEN EARTH**

Doheny Dry Cleaners is located in Hollywood, California. The shop historically used perchloroethylene (PERC) and now uses Green Earth. Doheny cleans 78,000 pounds of clothing per year.

“We wanted to convert to an alternative solvent but we didn’t want to pay for a new machine,” says Eric Lavi, owner of Doheny. “We took advantage of a package that costs only \$15,000 and it converts a PERC machine to use Green Earth.” With the conversion package, the still on the PERC machine is disconnected, a new filter housing is installed, an in-line filter is installed for the water separator and two temperature regulators are installed for the drying cycle. Green Earth requires a higher drying temperature than PERC.

“Finishing is a little easier with the Green Earth but the finishing labor hasn’t changed,” says Mr. Lavi. “Spotting takes much longer because Green Earth is less aggressive than PERC.” Post spotting is required on some of the garments.

Mr. Lavi says, “the cycle time for the machine has increased a lot. It takes about an hour and fifteen minutes instead of the 45 minutes it took with PERC. The Green Earth solvent takes longer to dry.”

Doheny’s overall costs have increased since the conversion. “Even if the costs are higher, I’m pleased with the conversion,” says Mr. Lavi. “We converted to a solvent that’s better for the environment.”

Annualized Cost Comparison for Doheny Dry Cleaners

	PERC	Green Earth
Annualized Capital Cost	-	\$1,040
Solvent Cost	\$390	\$792
Licensing Fee	-	\$2,500
Detergent Cost	\$2,880	\$2,880
Electricity Cost	\$9,600	\$9,600
Gas Cost	\$10,200	\$12,000
Spotting Labor Cost	\$24,960	\$49,920
Finishing/Maintenance Labor Cost	\$99,840	\$99,840
Maintenance Equipment Cost	\$840	\$1,260
Compliance Cost	\$1,248	\$624
Waste Disposal Cost	\$1,200	\$1,200
Total Cost	\$151,158	\$181,656

FAY CLEANERS CONVERTS FROM PERC TO WET CLEANING

Fay Cleaners is located in Long Beach, California. In the past, the shop used perchloroethylene (PERC) and processed about 39,000 pounds of clothing per year. Fay now uses the wet cleaning process and processes the same amount of garments.

“I didn’t want to use PERC anymore,” says Lisa Tsan, owner of Fay Cleaners. “I wanted to start using the wet cleaning process.” Fay installed a 45 pound wet cleaning machine and cleans all the clothing in that machine.

“I used PERC for a year and my customers complained that the clothes were not clean,” says Ms. Tsan. “The clothes are cleaner with wet cleaning and they smell better.”

“There is more spotting and more finishing with wet cleaning,” says Ms. Tsan. In the wet cleaning process, the garments are washed and dried for three minutes. They are hung up to dry in the facility for two hours with a fan providing air movement. The garments are then finished with the tensioning equipment.

Ms. Tsan prefers the wet cleaning process even though it requires more labor. “Wet cleaning is a good process,” she says. “It’s better for the environment.”

Annualized Cost Comparison for Fay Cleaners

	PERC	Wet Cleaning
Annualized Capital Cost	-	\$3,605
Solvent Cost	\$480	-
Detergent Cost	-	\$2,340
Electricity Cost	\$3,600	\$2,400
Gas Cost	\$3,000	\$4,200
Spotting Labor Cost	\$6,240	\$7,800
Finishing/Maintenance Labor Cost	\$24,960	\$31,200
Compliance Cost	\$520	-
Waste Disposal Cost	\$600	-
Total Cost	\$39,400	\$51,545

CARBON DIOXIDE CLEANING FACILITY STARTS UP IN SAN DIEGO

Gordon Shaw is the owner of the Hangers dry cleaning facility in San Diego. He has been a dry cleaner for many years and operated five different perchloroethylene (PERC) plants in other locations. He sold the last PERC plant about a year before he opened the new facility. When Mr. Shaw opened the Hangers shop, he started out using the carbon dioxide process and he performs the cleaning in a 60 pound machine.

Mr. Shaw did not want to use PERC at his new location. He investigated the carbon dioxide process and decided it was a good technology, particularly for the upscale clientele he anticipated the shop would serve. "I liked the Hangers total concept," says Mr. Shaw. It includes everything in the shop like the flooring, computers and counters as well as the machine."

"Carbon dioxide is a gentle cleaner because the process doesn't use heat," says Mr. Shaw. "The carbon dioxide process doesn't remove as much heavily ground in soil as the PERC process. An advantage is that it can do more delicate items than PERC. Some fabrics, like triacetate cannot be cleaned with carbon dioxide." The Hangers facility has a wet cleaning machine that is used for laundry, wedding gowns and the triacetate items that cannot be cleaned in the carbon dioxide machine.

The carbon dioxide machine operates at 700 pounds per square inch pressure to keep the carbon dioxide liquefied. The cycle is 44 minutes, about the same as a PERC machine. "Finishing is the same with carbon dioxide and PERC," says Mr. Shaw. "When I started up, the limitation of the carbon dioxide process was the detergents. They were costly and not very effective. Hangers has a new detergent and it is lower cost and it works well."

Mr. Shaw is very happy with his carbon dioxide system. He has one pickup store and plans to open more over the next few years.

Annualized Costs for Hangers Cleaners

	Carbon Dioxide
Annualized Capital Cost	\$12,087
Carbon Dioxide Cost	\$5,712
Detergent Cost	\$12,667
Electricity Cost	\$24,000
Gas Cost	\$10,800
Spotting Labor Cost	\$5,980
Finishing Labor Cost	\$67,392
Maintenance Labor Cost	\$598
Maintenance Equipment Cost	\$2,217
Waste Disposal Cost	\$1,620
Total Cost	\$143,073

HOLLYWAY CLEANERS ADOPTS GREEN EARTH

Hollyway Cleaners is located in Hollywood, California. For several years, Hollyway used perchloroethylene (PERC) in a 35 pound and a 60 pound machine. When he needed new machines, Amin Amersi, the owner of Hollyway Cleaners, decided to investigate alternative cleaning systems. The shop now has two 60 pound machines that use Green Earth. Hollyway has been using Green Earth for about four years and the facility cleans 165,000 pounds of garments per year.

“I investigated the alternatives and decided to go with Green Earth,” says Mr. Amersi. “The cycle time for the Green Earth is a little longer than it is with PERC.” PERC generally has a cycle time of about 45 minutes whereas the high speed extract machines at Hollyway have about a 55 minute cycle time.

“Green Earth is a gentler solvent than PERC,” says Mr. Amersi. “I can clean leather, fur trim, sequins and wedding dresses more effectively now.” “The only problem with the Green Earth is spotting,” he says. The spotting labor cost with the Green Earth has doubled because the solvent is less aggressive than PERC. Hollyway now must do some post spotting. According to Mr. Amersi, “we have experimented with our spotting chemicals and have changed them three or four times over the last year. We’re still looking for the best ones for the Green Earth process.”

“Finishing is a little easier,” says Mr. Amersi. “The feel of the garments with Green Earth is better.” Less time is spent in delinting the garments.

“It’s better for the industry to get away from PERC,” says Mr. Amersi. “We need to use chemicals that are better for the environment.”

IMPERIAL CLEANERS ADOPTS INNOVATIVE “ICY WATER” CLEANING TECHNOLOGY

Imperial Dry Cleaners & Lndry, located in Los Angeles, California, cleans 312,000 pounds of clothing per year. For several years, the shop had two perchloroethylene (PERC) dry cleaning machines, one a 55 pound machine and the other a 35 pound machine. A few years ago, the shop replaced the 35 pound PERC machine with a 55 pound wet cleaning machine that relies on icy water. Imperial currently cleans about 50,000 pounds of the clothing in the PERC machine and more than 250,000 pounds with the icy water machine.

The so-called icy water technology is different from traditional wet cleaning technology. It tries to prevent the shrinkage of garments by adding conditioner, using “icy” water at about 36 degrees F and by minimizing agitation. Both the washer and dryer have refrigerated condensers to reduce the temperature of the garments during the cleaning and drying cycles.

The dryer includes a “chemical” cycle where garments that are only lightly soiled are tumbled in a mixture of 50 percent water and 50 percent detergent. “I use the chemical cycle in the dryer for about half the clothing I clean each day,” says Anthony Kim, the dry cleaning operation supervisor at Imperial. “I can also clean many of the other garments in room temperature water.”

“We’re planning to get rid of the PERC machine soon,” says Alan Kim, the Manager at Imperial. “We may decide to purchase another icy water machine but we are also evaluating other cleaning technologies.” “I like the icy water system a lot,” says Anthony Kim. “I can do all the laundry in the machine as well. When I clean in the icy water, I can mix colors and fabrics.”

“We got tensioning equipment because we had to for the grant,” says Anthony Kim. We don’t need to use it because the clothing doesn’t shrink in the low temperature water and air.” The shop has traditional finishing equipment and uses that much of the time on the garments that have been cleaned and dried with the icy water machine. “Our spotting and finishing labor have remained the same as they were when we had the two PERC machines,” he says.

“We’re very pleased with the new wet cleaning technology,” says Alan Kim. “It’s better for the workers and the environment and we reduced our operating costs.”

Annualized Cost Comparison for Imperial Dry cleaners & Lndry

	PERC	PERC and Wet Cleaning
Annualized Capital Cost	-	\$5,131
Solvent Cost	\$5,040	\$2,520
Detergent Cost	\$3,480	\$8,417
Electricity Cost	\$24,000	\$24,000
Gas Cost	\$24,000	\$24,000
Spotting Labor Cost	\$31,200	\$31,200
Finishing Labor Cost	\$104,000	\$104,000
Maintenance Labor Cost	\$1,560	\$780
Maintenance Equipment Cost	\$70	-
Compliance Cost	\$1,040	\$1,040
Waste Disposal Cost	\$2,750	\$1,100
Total Cost	\$197,140	\$202,188

CUSTOMERS AND LANDLORD PREFER GREEN EARTH

Peter Lee is the owner of Larsen’s Cleaners in Irvine, California. Mr. Lee has been a dry cleaner for many years. He originally used Valclene and then converted to PERC which he used for more than 10 years. About a year ago, the shop converted to Green Earth.

“My landlord was concerned about environmental issues on the dry cleaners’ plant,” says Mr. Lee. “I studied the alternative technologies and found hydrocarbon and Green Earth to be the best. Based on environmental concerns, I thought Green Earth was better. I provided the landlord with information on the Green Earth technology. I converted to Green Earth and I like the new technology very much.”

Larsen’s Cleaners now has a 75 pound machine that uses Green Earth. “The new machine was expensive but it performs well,” says Mr. Lee. He has found the cycle time longer with Green Earth than with PERC.

Mr. Lee has had several comments from his customers since he adopted the Green Earth solvent. “They say they prefer the feel and odor of the garments with the Green Earth,” he says. “There is more spotting with Green Earth because it is not as aggressive as PERC. The garments are softer and have a better hand. “The finishing labor stayed about the same when I adopted Green Earth,” says Mr. Lee.

According to Mr. Lee, “we should all be concerned about the environment. I believe I’ve done the right thing in using Green Earth and my landlord and customers are happier too.”

Annualized Cost Comparison for Larsen’s Cleaners

	PERC	Green Earth
Annualized Capital Cost	-	\$5,547
Solvent Cost	\$420	\$680
Licensing Fee	-	\$2,500
Detergent Cost	\$450	\$675
Electricity Cost	\$9,000	\$9,000
Gas Cost	\$9,600	\$9,600
Spotting Labor Cost	\$4,680	\$9,360
Finishing Labor Cost	\$20,280	\$20,280
Maintenance Labor Cost	\$520	\$1,040
Maintenance Equipment Cost	-	\$105
Compliance Cost	\$520	\$260
Waste Disposal Cost	\$325	\$325
Total Cost	\$45,795	\$59,372

NATURE'S BEST CLEANERS CONVERTS TO WET CLEANING TECHNOLOGY

Nature's Best Cleaners, located in Alta Loma, California, cleans about 100,000 pounds of clothing per year and has five full time employees. In the past, the shop used PERC but converted to a wet cleaning process a few years ago.

About five years ago, the owner of Nature's Best, Hans Kim, began investigating alternatives. "I wanted to convert to the wet cleaning process in this location," says Mr. Kim. "I bought two other wet cleaning machines before I purchased the one I have now."

Nature's Best is one of the largest exclusive wet cleaners in the Southern California area. Mr. Kim trains other cleaners in wet cleaning. "Cleaners must be properly trained to do wet cleaning," he says. "The first year I did wet cleaning, I damaged some garments. It took me four years and a lot of effort to learn the best way to do wet cleaning. You have to know what you're doing for wet cleaning to work. Some cleaners may never be willing to learn."

"When I get structured suit jackets in my Alta Loma store, I clean them in the hydrocarbon machine in one of my other stores," says Mr. Kim. "They can be finished with my tensioning equipment but they are more easily finished with the hydrocarbon process."

Says Mr. Kim, "the spotting compounds are different with wet cleaning. They must be compatible with the process." He adds, "the oil based stains tend to remain on the garment through the wet cleaning process so we do some post spotting."

"Overall, I'm happy I switched to wet cleaning. I save money, clean better and improve the environment all at the same time," says Mr. Kim.

Annualized Cost Comparison for Nature's Best Cleaners

	PERC	Wet Cleaning
Annualized Capital Cost	-	\$4,645
Solvent Cost	\$720	-
Detergent Cost	\$451	\$173
Electricity Cost	\$7,200	\$2,160
Gas Cost	\$8,400	\$7,200
Spotting Labor Cost	\$20,800	\$2,080
Finishing Labor Cost	\$41,600	\$41,600
Maintenance Labor Cost	\$1,040	-
Maintenance Equipment Cost	\$1,400	-
Compliance Cost	\$780	-
Waste Disposal Cost	\$1,000	-
Total Cost	\$83,391	\$58,898

ROYAL CONVERTS PERC FACILITY TO CARBON DIOXIDE

Royal Cleaners has been located in Santa Monica, California since 1948. Until recently, the facility had a 55 pound perchloroethylene (PERC) machine. Several months ago, Royal moved to a new location in the same area and installed a 60 pound carbon dioxide machine. Royal cleans about 104,000 pounds of clothing each year.

“When we moved, we didn’t have room for a very large machine,” says Bobby Smerling, owner of Royal. “We decided to purchase a Sailstar carbon dioxide machine because the footprint is about half the size of the footprint of the Hangers/Chart machine.” Royal also installed a carbon dioxide storage tank.

The cycle time of the new machine is very low, at about 35 minutes. “The spotting labor is higher with the carbon dioxide system,” says Mr. Smerling. “The finishing labor is about the same as it was with PERC.” The detergents used with carbon dioxide are not as aggressive as those that are used with PERC. “We need a better detergent,” says Mr. Smerling. “Our supplier is working on that.”

Mr. Smerling is very happy with the carbon dioxide machine. “It took us about two months to learn the new machine and process,” he says. “We’re in an upscale neighborhood and our customers appreciate the environmental benefits of our new process.”

Annualized Cost Comparison for Royal Cleaners of Brentwood

	PERC	Carbon Dioxide
Annualized Capital Cost	-	\$11,093
PERC/Carbon Dioxide Cost	\$650	\$1,872
Detergent Cost	\$1,300	\$4,160
Electricity Cost	\$4,800	\$7,800
Gas Cost	\$3,300	\$3,300
Spotting Labor Cost	\$8,112	\$16,224
Finishing Labor Cost	\$97,344	\$97,344
Maintenance Labor Cost	\$676	\$1,014
Maintenance Equipment Cost	\$1,680	-
Compliance Cost	\$2,340	\$2,340
Waste Disposal Cost	\$2,200	\$500
Total Cost	\$122,402	\$145,647

STERLING CLEANERS CONVERTS FROM PERC TO HYDROCARBON

Sterling Dry Cleaners is located in a high end area in Westwood, California. The facility operated with two PERC machines for many years. About three years ago, Sterling purchased two new hydrocarbon machines, one a 60 pound machine and the other a 90 pound machine. The store cleans more than 250,000 pounds of clothing per year.

“When I needed new machines, I decided it was time to start using an alternative to PERC,” says Barry Gershenson, owner of Sterling Cleaners. “I investigated all of the alternatives and thought the hydrocarbon process was the best.”

“The cycle time for the hydrocarbon machines is longer,” says Mr. Gershenson. The PERC cycle time is typically about 45 minutes whereas the cycle time with Sterling’s hydrocarbon machines is about an hour and 15 minutes. “The advantage is that the hydrocarbon is safer with beads, trim, wedding gowns and colors and the odor is great. The garments also feel better with the hydrocarbon.”

“I expected to have to do much more spotting with the hydrocarbon,” says Mr. Gershenson. “The hydrocarbon is a less aggressive solvent than PERC. In fact, the spotting labor with the hydrocarbon is the same as it was with PERC.”

Sterling cleans the separator weekly to prevent bacteria growth. This was not a concern with PERC. The electricity cost has also increased.

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

SUNNY FRESH CLEANERS ADOPTS NEW PURE DRY TECHNOLOGY

Sunny Fresh Cleaners is located in San Marcos, California. The shop was opened about a year ago and uses the Pure Dry technology. Sunny Fresh cleans 31,200 pounds of clothing per year.

The owner of Sunny Fresh, Hormoz Motazedi, did not use perchloroethylene (PERC) at his current location but he did use the solvent for two or three years in the past. “I didn’t want to start up the new shop in San Marcos with PERC,” he says. “I wanted to use a technology that was better for the environment.”

The Pure Dry process vendors suggested that Mr. Motazedi purchase a hydrocarbon machine that was suitable for use with the cleaning agent. “I bought a 35 pound machine and it seems to work well,” says Mr. Motazedi. “I don’t have to use detergent with the solvent and I like the feel of the garments when they are clean.”

Mr. Motazedi believes that the finishing with the Pure Dry solvent is about the same as with PERC. “I think there is less spotting with Pure Dry than with PERC,” he says. “I do only about 20 minutes of spotting in a day.”

The cycle time of the machine is about 55 minutes which is a little longer than the 45 minute cycle time with PERC. This is not a limiting factor for Sunny Fresh, however, since the shop only runs between three and five loads per day.

“I like the Pure Dry technology,” says Mr. Motazedi. “It’s easy to use and I don’t have to worry about PERC anymore.”

Annualized Costs for Sunny Fresh Cleaners

	Pure Dry
Annualized Capital Cost	\$4,021
Solvent Cost	\$450
Electricity and Gas Cost	\$6,000
Spotting Labor Cost	\$988
Finishing Labor Cost	\$23,712
Maintenance Labor Cost	\$247
Maintenance Equipment Cost	\$728
Waste Disposal Cost	\$500
Total Cost	\$36,646

VILLAGE DRY CLEANERS OPTS FOR GREEN JET TECHNOLOGY FOR UPSCALE CLIENTELE

Village Dry Cleaners is located in Santa Clarita, California. The shop has a 35 pound Green Jet machine and cleans 31,200 pounds of clothing per year.

John Lee, owner of Village, has a perchloroethylene (PERC) dry cleaning facility in Valencia. “I wanted to open another store in the area,” he says. “The city code in Santa Clarita doesn’t allow PERC so I decided to look into other cleaning methods.” He ended up choosing the Green Jet technology which is most suitable for only lightly soiled garments. “It’s an upscale neighborhood so I thought the Green Jet system would be fine there,” says Mr. Lee.

The Green Jet machine performs washing and drying in one machine in a 30 minute cycle. Instead of immersing the garments in a liquid, the Green Jet system sprays a mixture of water and detergent on the clothing. Pads on the side of the machine absorb the contaminants from the garments.

Village never used PERC but Mr. Lee used PERC for many years at his other store. “Because Green Jet is less aggressive than PERC, there is a lot more spotting, about double the amount of spotting with PERC,” he says. “I take a few of the garments to my other store and clean them in the PERC machine. These are generally the heavily soiled garments.”

“I like the Green Jet technology,” says Mr. Lee. “It does a good job for my customers and the new store has worked out well.”

Annualized Costs for Village Dry Cleaners

	<u>Green Jet System</u>
Annualized Capital Cost	\$1,179
Detergent Cost	\$2,040
Electricity Cost	\$3,600
Gas Cost	\$4,800
Spotting Labor Cost	\$9,360
Finishing Labor Cost	\$15,600
Maintenance Labor Cost	\$520
Maintenance Equipment Cost	\$1,000
Total Cost	<u>\$38,099</u>

Appendix C
Assumptions for Model Plant Analysis

HYDROCARBON

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- 35 pound machine at a capital and installation cost of \$50,000 based on
- purchased and installed 35 pound machine for \$50,000 based on Crown Cleaners cost of \$47,500 for a 35 pound machine and \$2,500 for installation
- 45 gallons of hydrocarbon used annually based on lower volatility compared to PERC. Cost of PERC assumed to be \$5.69 per gallon based on average price for case studies.
- 50 gallons of detergent used annually based on usage from case studies. Cost of detergent assumed to be \$25 per gallon based on case studies.
- annual electricity cost of \$4,538 based on Sterling's increase of 26% over PERC and longer cycle time.
- annual gas cost of \$3,154 based on Sunny Fresh's utility costs normalized for 40,000 pounds of clothing with the electricity cost removed
- spotting labor of 2.46 hours per day and \$10 per hour labor cost based on similar sized case study plants based on case studies. Annual cost amounts to \$6,400.
- finishing labor of 9.85 hours per day and \$10 per hour labor cost based on similar case study plants. Annual cost amounts to \$25,600.
- Maintenance labor of one hour per week based on case study plants. Annual cost amounts to \$520.
- Maintenance equipment cost assumed to be the same as PERC.
- Compliance labor cost assumed to be the same as PERC.
- Shop generates two drums of waste at a disposal cost of \$275 per drum. Annual disposal cost amounts to \$550.

Large Model Plant Assumptions

- 100,000 pounds of clothing per year
- 50 pound hydrocarbon machine with a cost of \$55,300 based on normalized machine costs from case studies. Assuming \$2,500 installation cost, total capital cost amounts to \$57,800.
- 83 gallons of hydrocarbon used annually based on lower volatility compared to PERC and case studies. Cost of hydrocarbon assumed to be \$5.69 per gallon.
- 125 gallons of detergent used annually based on case studies. Cost of detergent assumed to be \$25 per gallon.
- annual electricity cost of \$9,450, 26 percent higher than PERC, based on Sterling case study and longer cycle time.
- annual gas cost of \$3,876, 14 percent higher than PERC, based on Sterling
- spotting labor of five hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$13,000.
- finishing labor of 19 hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$49,400.

- Maintenance labor of two hours per week based on similar sized case study plants. Annual cost amounts to \$1,040.
- Maintenance equipment cost assumed to be zero since the facility uses spin disk filters.
- Compliance labor of two hours per week at \$10 per hour based on similar sized case study plants. Annual cost amounts to \$1,040.
- Shop generates four drums of waste at a disposal cost of \$350 per drum based on case studies of similar size. Annual disposal cost amounts to \$1,400.

HYDROCARBON WITH TONSIL

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- purchased and installed 35 pound machine for \$50,000 based on Crown's cost of \$47,500 for a 35 pound machine and \$2,500 for installation. Deduct \$7,000 because no distillation unit is required. Capital cost amounts to \$43,000.
- 77 gallons of hydrocarbon used annually based on Crown's case study. Cost of hydrocarbon assumed to be \$5.69 per gallon based on average price for case studies.
- no detergent used
- annual electricity cost of \$2,939 based on Crown's decrease of 18% over PERC
- annual gas cost of \$2,833 based on Crown's cost decline of six percent
- spotting labor of 2.46 hours per day and \$10 per hour labor cost based on Sterling. Annual cost amounts to \$6,400.
- finishing labor of 9.85 hours per day and \$10 per hour labor cost based on Sterling. Annual cost amounts to \$25,600.
- Maintenance labor of one hour per week based on Crown. Annual cost amounts to \$520.
- Hydrocarbon/tonsil cleaners must purchase 1.43 55-pound bags of tonsil at \$117 per bag and 71 pounds of diatomaceous earth at \$30 per 50 pounds for a total annual maintenance cost of \$210. Based on Crown normalized to 40,000 pounds.
- Compliance labor cost assumed to be the same as PERC based on case studies.
- Shop generates two drums of hazardous waste every six months at \$400 per pickup or \$800 per year

Large Model Plant Assumptions

- 100,000 pounds of clothing per year
- 50 pound hydrocarbon machine with a cost of \$55,300 based on normalized machine costs from case studies. Assuming \$2,500 installation cost and \$7,000 reduction for distillation unit, total capital cost amounts to \$50,800.
- 250 gallons of hydrocarbon used annually based on Crown case study. Cost of hydrocarbon assumed to be \$5.69 per gallon.

- no detergent used based on Crown case study
- annual electricity cost of \$6,122, 18 percent lower than PERC, based on Crown case study
- annual gas cost of \$3,211, six percent lower than PERC, based on Crown
- spotting labor of five hours per day and \$10 per hour labor cost based on Crown. Annual cost amounts to \$13,000.
- finishing labor of 19 hours per day and \$10 per hour labor cost based on similar sized case study plants. Annual cost amounts to \$49,400.
- Maintenance labor of one hour per week based on Crown. Annual cost amounts to \$520.
- Hydrocarbon/tonsil cleaners must purchase 3.57 55-pound bags of tonsil at \$117 per bag and 178.5 pounds of diatomaceous earth at \$30 per 50 pounds for a total annual maintenance cost of \$632. Based on Crown normalized to 40,000 pounds.
- Compliance labor of two hours per week at \$10 per hour based on similar sized case study plants. Annual cost amounts to \$1,040.
- Shop generates two drums of hazardous waste every three months at \$400 per pickup. Annual disposal cost amounts to \$1,600.

GREEN EARTH TECHNOLOGY

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- 35 pound machine at a capital and installation cost of \$50,000 based on case studies.
- 45 gallons of Green Earth solvent used annually based on lower volatility compared to PERC and case studies. Cost of Green Earth assumed to be \$16 per gallon based on price for case study facilities.
- \$2,500 annual licensing fee based on case studies.
- 50 gallons of detergent used annually based on usage from case studies. Cost of detergent assumed to be \$25 per gallon based on case studies.
- annual electricity cost of \$4,538 based on longer cycle time.
- annual gas cost of \$3,225 based on 7.5 percent increase over PERC from case studies
- spotting labor of 4.92 hours per day, twice as high as PERC, and \$10 per hour labor cost based on case studies. Annual cost amounts to \$12,800.
- finishing labor of 7.58 hours per day, a decrease of 23 percent from PERC, and \$10 per hour labor cost based on Larsen's. Annual cost amounts to \$19,720.
- maintenance labor of one hour per week based on case study plants. Annual cost amounts to \$520.
- maintenance equipment cost assumed to be the same as PERC.
- compliance labor cost assumed to be zero
- shop generates two drums of waste at a disposal cost of \$275 per drum. Annual disposal cost amounts to \$550.

Large Model Plant Assumptions

- 100,000 pounds of clothing per year
- 50 pound hydrocarbon machine with a cost of \$55,300 based on normalized machine costs from case studies. Assuming \$2,500 installation cost, total capital cost amounts to \$57,800.
- 83 gallons of Green Earth used annually based on lower volatility compared to PERC and case studies. Cost of Green Earth solvent assumed to be \$16 per gallon.
- annual licensing fee of \$2,500 based on case studies.
- 125 gallons of detergent used annually based on case studies. Cost of detergent assumed to be \$25 per gallon.
- annual electricity cost of \$9,450, 26 percent higher than PERC based on longer cycle time
- annual gas cost of \$3,655, 7.5 percent higher than PERC, based on case studies
- spotting labor of 10 hours per day and \$10 per hour labor cost based on Green Earth solvent case study plants. Annual cost amounts to \$26,000.
- finishing labor of 14.6 hours per day, a 23 percent decrease from PERC, and \$10 per hour labor cost based on Hollyway. Annual cost amounts to \$38,038.
- maintenance labor of two hours per week based on case study plants. Annual cost amounts to \$1,040.
- maintenance equipment cost assumed to be zero
- compliance cost assumed to be zero
- shop generates four drums of waste at a disposal cost of \$350 per drum based on case studies. Annual disposal cost amounts to \$1,400.

GREEN JET

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- 35 pound machine at a capital and installation cost of \$17,000 based on Village
- process uses no solvent
- 77 gallons of detergent used annually based on Village. Cost of detergent assumed to be \$34 per gallon based Village.
- annual electricity cost of \$2,400 based on PERC assumptions and adjusting PERC machine 29 kW to Green Jet machine 14.4 kW.
- annual gas cost of \$1,800 based on PERC plant use and the fact that the Green Jet machine itself uses no gas
- spotting labor of 6 hours per day and \$10 per hour labor cost based on Village. Annual cost amounts to \$15,600.
- finishing labor of 7.7 hours per day based on Village and normalized for 40,000 pounds of clothing cleaned annually and \$10 per hour labor cost. Annual cost amounts to \$20,020.

- maintenance labor of one hour per week based on case study plants. Annual cost amounts to \$520.
- maintenance equipment cost assumed to be zero
- compliance labor cost assumed to be zero
- hazardous waste disposal cost assumed to be zero

TRADITIONAL WET CLEANING

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- 45 pound machine at a capital and installation cost of \$26,000. Tensioning equipment cost of \$9,000 for a total cost of \$34,000.
- process uses no solvent
- 150 gallons of detergent used annually based on Fay and Cypress normalized to 40,000 pounds of clothing cleaned per year. Cost of detergent assumed to be \$14 per gallon based on Fay and Cypress.
- annual electricity cost of \$2,400 based on Fay
- annual gas cost of \$4,200 based on wet cleaning case studies
- spotting labor of three hours per day based on case studies normalized and \$10 per hour labor cost. Annual cost amounts to \$7,800.
- finishing labor of 11.5 hours per day based on case studies normalized and \$10 per hour labor cost. Annual cost amounts to \$29,900.
- maintenance labor of one hour per week. Annual cost amounts to \$520.
- maintenance equipment cost assumed to be zero
- compliance labor cost assumed to be zero
- hazardous waste disposal cost assumed to be zero

GLYCOL ETHER CLEANING

Small Model Plant Assumptions

- 40,000 pounds of clothing per year
- 35 pound machine at a capital and installation cost of \$50,000 based on case studies
- 50 gallons of solvent used annually based on lower volatility than PERC and Blackburn case study at a cost of \$15 based on Blackburn
- process uses no detergent
- annual electricity cost of \$10,260 based on Blackburn normalized to 40,000 pounds of clothing cleaned per year
- annual gas cost of \$8,208 based on Blackburn normalized
- spotting labor of one hour per week based on Blackburn and \$10 per hour labor cost. Annual cost amounts to \$520.

- finishing labor of 9.85 hours per day based on Blackburn normalized and \$10 per hour labor cost. Annual cost amounts to \$25,600.
- maintenance labor cost is 18 hours per week based on Blackburn and \$10 per hour labor cost. Annual cost amounts to \$9,360.
- maintenance equipment cost assumed to be zero based on Blackburn
- compliance labor cost assumed to be one hour per week at \$10 labor cost. Annual cost amounts to \$520
- shop generates two drums of waste annually at \$275 per drum for an annual cost of \$550

ICY WATER TECHNOLOGY

Large Model Plant Assumptions

- 100,000 pounds of clothing per year
- 55 pound icy water machine with a cost of \$29,600 and tensioning equipment cost of \$9,000. Assuming \$4,500 installation cost, total capital cost amounts to \$43,100. Costs based on Imperial.
- process uses no solvent
- 375 gallons of detergent used annually based on use at Imperial normalized. Cost of detergent assumed to be \$25 per gallon based on Imperial.
- annual electricity cost of \$7,500 based on Imperial normalized
- annual gas cost of \$3,400 based on Imperial normalized
- spotting labor of five hours per day based Imperial normalized and \$10 per hour labor cost. Annual cost amounts to \$13,000.
- finishing labor of 19 hours per day based on Imperial normalized and \$10 per hour labor cost. Annual cost amounts to \$49,400.
- maintenance labor of two hours per week for an annual cost of \$1,040
- maintenance equipment cost assumed to be zero
- compliance cost assumed to be zero
- hazardous waste disposal cost assumed to be zero

CARBON DIOXIDE CLEANING

Large Model Plant Assumptions

- 100,000 pounds of clothing per year
- 60 pound carbon dioxide machine with a cost of \$150,000 and \$5,000 for a carbon dioxide storage tank. Assuming \$25,000 installation cost, total capital cost amounts to \$180,000.
- 14,881 pounds of carbon dioxide used annually based on average of two case studies normalized to 100,000 pounds per year.

- 272 gallons of detergent used annually based on normalized average of two case studies. Cost of detergent assumed at \$32 per gallon based on average of two case studies.
- annual electricity cost of \$10,500 based on case studies.
- annual gas cost of \$3,173 based on average of two case studies and normalized
- spotting labor of 10 hours per day based on increase at Royal. Assuming labor cost of \$10 per hour, five days per week, 52 weeks per year, annual spotting labor cost amounts to \$26,000.
- finishing labor of 19 hours per day based on Royal. Assuming a labor cost of \$10 per hour, five days per week and 52 weeks per year, annual finishing labor cost amounts to \$49,400.
- maintenance labor of one hour per week based on Hangers. Assuming labor cost of \$10 per hour and 52 weeks per year, the annual maintenance labor cost is \$520.
- maintenance equipment cost assumed to be zero
- compliance cost assumed to be zero
- two drums of hazardous waste generated each year. At a cost of \$250 per drum, annual cost amounts to \$500.