Safer Alternatives for the Textile Cleaning Industry: Alternative Spotting Agents and Evaluation of Improvements in Carbon Dioxide and Wet Cleaning Technologies

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EXECUTIVE SUMMARY

In 2007, the California Air Resources Board (CARB) adopted a regulation phasing out the use of perchloroethylene (PERC), the major dry cleaning solvent, by 2023. Approximately one-third of the cleaners in the state have adopted alternatives. Alternatives to PERC dry cleaning have emerged over the last decade or so and they include various types of solvent cleaning, carbon dioxide cleaning and wet cleaning processes that rely on water and detergent. Most of the cleaners who have converted to date have adopted the hydrocarbon solvent cleaning alternative.

All cleaners, regardless of the technology they use, perform spotting before and/or after the major cleaning process. So-called Paint Oil and Grease (POG) spotting agents are used to remove spots from textiles. The most widely used spotting agents are based on halogenated solvents including trichloroethylene (TCE), PERC and a new material, n-propyl bromide (nPB). These solvents can enter the sewer through wet cleaning processes and can contaminate the waste streams in solvent cleaning processes. Safer alternatives to the halogenated spotting agents are needed.

From an overall health and environmental standpoint, the best alternatives to PERC dry cleaning are carbon dioxide cleaning and water-based processes. Cleaners are reluctant to use these technologies, however. Carbon dioxide cleaning equipment is very expensive and the process does not clean aggressively. Cleaners are reluctant to use water-based processes because they are concerned the garments will shrink and they do not want the higher finishing labor that results from using traditional wet cleaning.

This project was sponsored by the Bay Area Air Quality Management District (BAAQMD) and was conducted by the Institute for Research and Technical Assistance (IRTA), a small technical nonprofit organization. The purpose of the project was to identify, test and demonstrate alternative safer spotting agents and to examine and test methods of making carbon dioxide and water-based cleaning processes more acceptable to cleaners.

During the project, IRTA tested three alternative water-based spotting agents and one alternative soy based spotting agent with four textile cleaning facilities. All of the alternative spotting agents performed well and each of the cleaners thought at least one of the alternatives was more effective than or as effective as their currently used spotting chemicals. In an earlier project, IRTA tested one soy based spotting agent and one water-based spotting agent that also performed well. IRTA conducted a cost analysis and comparison of the alternatives and the most commonly used TCE based spotting agent. All of the alternatives were less costly than the TCE cleaner. The alternative spotting agents can be ordered from the suppliers. Table E-1 summarizes the cost comparison and provides information on where the alternatives can be ordered. Mirachem 500, PWF-10, Super Scrub and Cold Plus are water-based cleaners and Soy Gold 1000 and Nature's Choice are soy based cleaners.

Table E-1
Cost of Current and Alternative Spotting Agents and Ordering Information

Spotting Agent	Cost Per Gallon	Supplier	Contact Information
Picrin	$45.45	-	-
Mirachem 500	$24.00	Mirachem	www.mirachem.com (602) 272-6066
Soy Gold 1000	$36.10	CleaningTechnologies	(714) 337-6569
PWF-10	$21.25	Cleaning Technologies	(714) 337-6569
Super Scrub	$18.50	Cleaning Technologies	(714) 337-6569
Cold Plus	$45.25	Kelleher Equipment	(562) 422-1257
Nature's Choice	$45.25	Kelleher Equipment	(562) 422-1257

During the project, IRTA contacted potential carbon dioxide equipment manufacturers and determined that two groups may decide to manufacture a less costly machine over the next few years. IRTA also tested two methods of increasing the cleaning capability of carbon dioxide. These included the use of tonsil filtration in place of carbon filtration which could eliminate the need for distillation and detergent use and the use of an alternative detergent. The cleaning tests indicated that tonsil may increase the cleaning capability and that the alternative detergent did not clean more effectively but may be preferred by come cleaners.

IRTA also examined methods of facilitating the use of water-based alternatives. IRTA evaluated the use of the Green Jet machine which can be used in conjunction with traditional wet cleaning. The results indicate that this technology can be used for as much as 50 percent of the garment stream and that it can reduce the finishing labor required for traditional wet cleaning.

IRTA tested two alternative methods of drying that would not use the high heat employed in dryers today. These methods could reduce the shrinkage that results in traditional wet cleaning and would lead to lower finishing labor requirements. IRTA obtained test systems based on vacuum drying and microwave drying and tested the drying time for a variety of different fabrics. Both technologies offer promise for reducing drying time and each system could be used for both washing and drying garments as an alternative to traditional wet cleaning washers and dryers. For the vacuum system, hydrogen peroxide could be used as the cleaning agent. The next step for the vacuum system is to build a prototype full sized unit for further garment testing and optimization.

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I. INTRODUCTION AND BACKGROUND

According to the California Air Resources Board (CARB), there are about 5,000 textile cleaning facilities in California. About two-thirds of these facilities use perchloroethylene (PERC) for dry cleaning garments. CARB adopted a a regulation in January 2007 that calls for a complete phaseout of PERC by 2023. The South Coast Air Quality Management District (SCAQMD) adopted a slightly different regulation that will result in a complete phaseout of PERC in the Southcoast Basin somewhat earlier, in 2020. Most landlords in California do not allow cleaners to use PERC when they renew their lease. Because of these regulatory and non-regulatory pressures on cleaners, approximately one-third of the cleaners in California have already converted from PERC to a variety of alternatives. The vast majority of these cleaners have adopted hydrocarbon. Other technologies, including Green Earth, which is a silicon based solvent, Rynex, which is a glycol ether, carbon dioxide and water-based technologies that rely on water and detergent are also used to a smaller extent.

From an overall health and environmental standpoint, the preferred alternatives to PERC are carbon dioxide and water-based technologies. Even so, very few cleaners use these alternatives exclusively. The major barrier to the more widespread use of carbon dioxide cleaning is that the capital cost of the equipment is very high. Water-based cleaning alternatives are not used widely for several reasons. First, cleaners believe that many garments shrink in water-based processes. Second, the labor cost for finishing garments that are wet cleaned is higher and finishing labor is a major component of the cost in textile cleaning facilities. Third, cleaners are unwilling to learn the new practices required for wet cleaning which is a much less forgiving process than dry cleaning with PERC.

Regardless of the technology that cleaners employ, they all perform spotting as part of the garment cleaning process. Cleaners use spotting agents to remove spots prior to cleaning the garments in the machine and/or after the garments have been cleaned in the machine. Many of the spotting agents historically contained PERC and now contain trichloroethylene (TCE). Both PERC and TCE are carcinogens, they are classified as Toxic Air Contaminants (TACs) in California, they are listed on Proposition 65 as substances known to cause cancer to the state of California and they are listed hazardous wastes under the Resource Conservation and Recovery Act (RCRA). The Bay Area Air Quality Management District (BAAQMD) recently adopted a regulation that phases out the use of halogenated spotting chemicals. CARB is planning a rulemaking over the next year to restrict the use of these spotting chemicals as well.

The Institute for Research and Technical Assistance (IRTA) is a nonprofit organization established in 1989. IRTA works with companies and whole industries to identify, test, develop and demonstrate low-VOC, low toxicity solvent alternatives. IRTA also conducts testing on new and emerging technologies. The BAAQMD contracted with IRTA to find and test safer alternative water-based and soy based spotting agents and to evaluate methods of making carbon dioxide and water-based processes more acceptable to cleaners. This document reports the results of the research.

PREVIOUS RELATED IRTA WORK

Over the last few years, IRTA completed three projects related to the research described in this report. The first project, sponsored by U.S. EPA and CARB, involved performing a technology assessment of the alternatives to PERC dry cleaning (IRTA, 2005a). IRTA worked with several cleaners who had converted to alternatives and developed case studies that provided analysis and comparison of the costs of using PERC and the alternatives. The case studies included cleaners who had converted to carbon dioxide and water-based cleaning processes.

The second project was sponsored by U.S. EPA and Cal/EPA's Department of Toxic Substances Control (DTSC) (IRTA, 2007). This project focused on developing and testing alternative low-VOC, low toxicity spotting agents. Several alternatives were tested in textile cleaning facilities that used PERC alternatives in their cleaning process.

The third project, sponsored by CARB, involved developing case studies of cleaners who had converted to water-based and carbon dioxide processes and holding demonstrations at each of the cleaning facilities (IRTA, 2008). The project was part of CARB's AB 998 process in which CARB provides grants to cleaners who replace a PERC dry cleaning machine with water-based or carbon dioxide systems.

PROJECT APPROACH

The motivation for this project, in part, was to find and commercialize if necessary, alternatives to the TCE and PERC Paint, Oil and Grease (POG) spotting agents used by virtually all cleaners. In the earlier DTSC/EPA study, IRTA tested water-based, soy based and solvent based alternative POG spotting agents with a number of cleaning facilities. Two of the products, a water-based cleaner and a soy based cleaner, are commercialized and available for purchase. In the current BAAQMD project, IRTA focused on testing additional water-based cleaners and a soy based cleaner that have been used in other industries for cleaning but are not yet available for purchase as spotting agents through textile cleaning suppliers. Two of the water-based and one soy based product tested with cleaners are being evaluated by a spotting agent supplier. The soy based cleaner and three water-based cleaners can be purchased from the suppliers of the formulations. This document summarizes the results of the earlier work and the current research.

During both projects, IRTA identified several commercial solvent spotting agents that do not contain TCE or PERC. In many cases, however, the Material Safety Data Sheets (MSDSs) for spotting agents in this industry are incomplete and cite proprietary ingredients. IRTA is reluctant to test or encourage the use of spotting agents that have unidentified components.

During the project, IRTA investigated and performed testing of several methods that could make water-based cleaning processes more acceptable to cleaners. The first method is to pair wet cleaning equipment with a system called the Green Jet. Rather than immersing the garments in water and detergent, this system uses a spray of water and detergent to clean the garments. Because they have not been immersed, the garments processed through the Green Jet are much easier to finish and the finishing labor is reduced. The Green Jet does not clean aggressively but several cleaners are using it together with wet cleaning and their customers are satisfied. This document discusses the Green Jet technology and presents case studies of cleaners who have used it.

As mentioned earlier, cleaners are concerned about shrinkage of garments in heated drying systems and this is a deterrent to using the wet cleaning process. To address this concern, IRTA examined two technologies for garment cleaning that do not involve high sustained heat in the drying process. One of the drying methods that was investigated was a microwave dryer. The other drying method was a vacuum dryer. IRTA conducted tests of garment swatches in a prototype microwave dryer and a prototype vacuum wash and dry system. The results of this testing are presented in the document.

IRTA worked with cleaners who operate carbon dioxide machines to test an alternative detergent that held some promise of increasing the cleaning capability of the process. In addition, IRTA conducted tests of a material called tonsil that could be used instead of detergent in the process. IRTA also investigated whether it is possible to design and sell a carbon dioxide machine at a much lower price. The results of this analsysis are also presented in this document.

STRUCTURE OF DOCUMENT

Section II of the report discusses the results of the spotting chemical alternatives testing. Section III of the document presents the results of the testing that could lead to improvements in the carbon dioxide process. Section IV describes the methods of improving the use of water-based cleaning through adoption of low-cost wet cleaning equipment and the Green Jet system. It also summarizes the results of the testing performed with the vacuum and microwave systems to improve the current process for wet cleaning. Finally, Section V summarizes the results and conclusions of the analysis. Section VI includes references that summarize earlier related IRTA and non-IRTA work.

II. SPOTTING AGENT ALTERNATIVES TESTING

MOTIVATION FOR FINDING ALTERNATIVE SPOTTING AGENTS

In the earlier PERC alternatives assessment project conducted by IRTA and sponsored by CARB, IRTA worked with Los Angeles County Sanitation Districts (LACSD) to analyze the waste and effluent streams from a number of PERC alternative processes. IRTA collected samples from facilities using alternative technologies and LACSD analyzed the samples in their lab.

The wet cleaning process uses a washer and a humidity controlled dryer to clean and partially dry the garments. The wash and rinse effluent from four separate wet cleaning facilities was sampled and analyzed in two rounds of sampling. In the first round of sampling, the results indicated that PERC or TCE were found in the effluent at three of the facilities. The source of the PERC could be from garments previously cleaned in the solvent, from a PERC machine on the premises or from spotting chemicals using PERC. The source of the TCE is likely from spotting chemicals used in the process. The one wet cleaner using TCE eliminated the spotting agent for the second round of testing. In the second round of testing, two of the cleaners still had PERC in the effluent and one still had TCE.

Wastewater agencies in Southern California have implemented programs to prevent PERC from entering the sewer. LACSD was especially concerned at the presence of the PERC and TCE in the wet cleaning effluent. As more cleaners convert to this technology, there could be an increase in PERC and TCE loading to the sewer. This is a problem for the water agencies since even small quantities of the halogenated solvents can contaminate large water streams.

The sampling from the waste streams from cleaners using solvent based PERC alternatives did not indicate the presence of PERC or TCE. These streams, however, required very high dilution for analysis and the solvents may have been present below detection levels. Indeed, in a later project conducted by IRTA and sponsored by DTSC (IRTA, 2005b), IRTA sampled the waste streams from eight facilities using hydrocarbon solvent, the major alternative adopted by cleaners to date. At least one of the waste streams at each of the eight facilities contained PERC or TCE. Again, the source of the PERC may be in question but the source of the TCE is very probably spotting agents containing the chemical. Many cleaners who use the other PERC alternatives also use spotting agents containing PERC and TCE and it is likely their waste streams would also show the presence of the solvents.

The hydrocarbon solvent waste streams would not be classified as hazardous waste based solely on the presence of the hydrocarbon. It PERC or TCE are present in the waste streams, however, since they are listed hazardous wastes, the waste stream would be classified as hazardous waste. The cost of disposal could be much higher. The same holds true for the other PERC alternatives.

As cleaners convert away from PERC over the next several years, they will adopt alternatives. Spotting chemicals containing PERC or TCE will have negative consequences on the alternative processes. It is not good public policy to facilitate sewer disposal of the solvents. More and more cleaners are likely to adopt wet cleaning as dedicated facilities or in conjunction with a solvent cleaning process. These cleaners should adopt alternative spotting agents so they do not provide a new pathway for the solvents to the sewer. Cleaners adopting solvent alternatives may face higher disposal costs for their waste streams if they are contaminated with the solvents. They should adopt alternative spotting agents to ensure they do not have a higher disposal cost. In all cases, cleaners should be reluctant to face liability from sewer, groundwater or soil contamination of halogenated solvents which are very expensive to clean up. They should also use low toxicity spotting chemicals that provide better protection for their health and the health of their workers.

<u>Background on Spotting Agent Use</u>

A number of solvents are used today in so-called POG spotting agents. These include glycol ethers, mineral spirits, methyl ethyl ketone, acetates and various alcohols. Cleaners often find these solvents to be ineffective and many spotters prefer spotting agents that contain PERC and/or TCE. A typical spotting board with spotting agents is shown in Figure 2-1. PERC was extensively used in POG spotting agents in the past. Because cleaners were aware that PERC was under increasing scrutiny in the dry cleaning industry, the spotting chemicals were reformulated with TCE. Although TCE is also toxic, the industry perceived it as being less toxic than PERC. More recently, suppliers are offering spotting agents containing another halogenated chemical, n-propyl bromide (nPB). This chemical is a reproductive toxin and causes nerve damage; it is listed on Proposition 65 in California.

Figure 2-1.Typical Spotting Board

There are a handful of suppliers that provide POG spotting agents to the industry. These include R.R. Street & Company, Laidlaw, Caled and Adco. These suppliers package the POG spotting agents in quantities ranging from one gallon containers to 55-gallon drums. Distributors purchase the spotting agents from the suppliers, often repackaging them in smaller quantities and they then sell them to cleaners. Distributors in California include United Fabricare, HNS, McGregor and MDL.

MSDSs for several spotting agents containing TCE and a few containing PERC are shown in Appendix A. The most widely used POG spotting agent is Picrin which is offered by R.R. Street & Company. A product sheet describing its use and an MSDS are shown in the appendix. The MSDS indicates that Picrin contains about 100 percent TCE.

An MSDS for a product called Volatile Dry Spotter (V.D.S.) offered by Laidlaw is shown in Appendix A. The MSDS indicates that the product contains approximately 98 percent TCE.

Another product, called Fast P-R, is offered by Caled. A product sheet and an MSDS for this product are shown in Appendix A. The MSDS indicates that the concentration of TCE in the product is approximately 95 percent.

Adco offers a product called PURO which apparently contains TCE. A product sheet and a description of the contents of the product from the State Coalition for Remediation of Drycleaners are shown in Appendix A. The contents sheet indicates that the concentration of TCE is less than 100 percent. Another product offered by Adco called Semi-Wet apparently contains 50 percent TCE. A product sheet and a content sheet description are shown in Appendix A.

A contents sheet from the State Coalition for Remediation of Drycleaners for an R.R. Street product called 2-1 Formula is shown in Appendix A. The contents sheet indicates that the product contains less than 50 percent TCE.

A contents sheet from the State Coalition for Remediation of Drycleaners for a product offered by Pariser Industries, Inc., is shown in Appendix A. According to the contents sheet, the product, called P.O.G., contains 21.8 percent PERC.

An MSDS for a product offered by Fabritec International, called 6748 VOL Volatile Spotter, is shown in Appendix A. According to the MSDS, the product contains between 30 and 60 percent of an unidentified halogenated hydrocarbon which is likely to be TCE or PERC.

A contents sheet from the State Coalition for Remidiation of Drycleaners for a product offered by A.I. Wilson Chemical Co. called TarGo, is shown in Appendix A. The product contains 10 percent TCE.

Enviro Tech International, Inc offers a variety of nPB products under the tradename DrySolv for the dry cleaning industry. The company has a spotting agent, called DrySolv POG, that apparently contains nPB. An MSDS for nPB is shown in Appendix A.

Regulations on Halogenated Spotting Chemicals

On March 4, 2009, the BAAQMD amended Regulation 11, Rule 16 "Perchloroethylene and Synthetic Solvent Dry Cleaning Operations" to prohibit the use of any spotting solvent and/or solution containing any halogenated compound. It includes spotting agents containing TCE and PERC but would also include spotting agents containing nPB, which is a halogenated solvent. The prohibition goes into effect on July 1, 2010.

CARB has indicated they plan to develop a regulation on spotting chemicals over the next year under their consumer products regulations. They have performed a survey of the industries that make and supply spotting agents to the industry. It is likely that CARB will prohibit the use of TCE and PERC since they are forbidding the use of these solvents in other consumer product regulations as they are amended. CARB may also set a VOC limit for spotting chemicals in their new regulation. The CARB regulation would apply statewide.

ALTERNATIVE SPOTTING AGENT TESTING

In the earlier study, IRTA tested a variety of alternative spotting agents. The aim was to find safer alternatives to PERC and TCE. IRTA tested a few water-based cleaners, a few soy based cleaners and some alternative solvents. In the testing, IRTA first performed screening tests on a variety of garment types and a range of contaminants. The alternatives that performed well in the screening tests were then further tested in the field with seven cleaning facilities. All of the facilities were cleaners that had converted away from PERC in the major dry cleaning step. The spotters at all of the facilities liked at least one of the alternative spotting agents as well as their current POG spotting agent. Several of the alternatives that worked well were blended by IRTA or were not available commercially to the garment cleaning industry.

One of the spotting agents tested by IRTA in the earlier project is a water-based material that is commercially available as a spotting agent. An MSDS for the agent, which is called Cold Plus, is shown in Appendix B. Another spotting agent based on soy, called Nature's Choice, is also commercially available. An MSDS for this spotting agent is shown in Appendix B.

Preliminary Spotting Tests

In the current project, IRTA decided to limit the alternatives testing to water-based and soy based cleaners that had not been tested in the earlier project. IRTA also decided to test one chemical, propylene carbonate, that was recently deemed exempt from VOC regulations in the jurisdiction of the SCAQMD in Southern California. IRTA performed screening tests with several of these materials on a variety of garments contaminated with a range of different spots. Some of the garments used in the preliminary testing are shown in Figure 2-2. The garments, after they were spotted with the chemicals were cleaned in a wet cleaning machine and a hydrocarbon machine. The machine used for wet cleaning is shown in Figure 2-3 and the hydrocarbon machine is shown in Figure 2-4.

Figure 2-2. Some Garments used in Preliminary Testing

Figure 2-3. Machine used for Wet Cleaning in Preliminary Spotting Tests

Most cleaners pre-spot garments and the screening tests were designed to make sure the spotting agent would not leave a ring or visible residue on the garments after cleaning in the main cleaning process. The soy based cleaner is not water soluble so garments on which it was tested were not subsequently cleaned in the wet cleaning process. The soy cleaner was thought to be applicable for pre-spotting only for hydrocarbon, other solvent or carbon dioxide cleaning.

Figure 2-4. Hydrocarbon Machine Used in Preliminary Spotting Tests

The screening tests were also designed to see if the alternative spotting agents could remove spots effectively. Garments in a range of different fabrics that are commonly found in garment cleaning facilities and generally considered dry clean only were tested. The fabric types included:

- silk and raw silk
- 100 percent cotton
- tencel
- 57 percent rayon/43 percent acetate
- 100 percent wool
- 70 percent wool/20 percent angora/10 percent nylon
- 100 percent linen

Three of the water-based cleaners and one soy-based cleaning agent performed well in the preliminary testing. The propylene carbonate was judged to be too aggressive for use as a spotting chemical; it dissolved lining materials in some of the garments used for the screening tests. A few of the water-based cleaners that were tested did not perform well for this application. The screening tests verified that all four of the spotting agents that performed effectively would be suitable for pre-spotting. The three water-based cleaners would also be suitable for post-spotting. This type of spotting is used to remove spots after the main cleaning process if they were not removed in the pre-spotting and the main cleaning process. Cleaners post-spot the garments by applying the spotting agent and then rinsing the spotted area with steam so the spotting agents used for post-spotting must be water soluble. One of the alternatives, the soy cleaner, would not be suitable for post spotting since it is not water soluble.

The three water-based cleaners that performed well in the screening tests are not currently commercialized for spotting agent use. They are used, however, in industrial cleaning. Over the last 15 years, IRTA has tested these water-based cleaners in a variety of different cleaning applications. All three of the cleaners are used extensively in parts cleaners for cleaning automotive parts. They are also used in other industrial cleaning operations and have been sold for a number of years in these applications. MSDSs for the three water-based cleaners are shown in Appendix B. They include Mirachem 500, PWF-10 and Super Scrub. Two of the cleaners, Mirachem 500 and PWF-10, have a close to neutral pH whereas the Super Scrub is alkaline with a fairly high pH.

The soy based cleaner that was tested did well in the screening tests. An MSDS for this cleaner, called Soy Gold 1000, is also shown in Appendix B. This product, like the three water-based cleaners, is not commercialized for sale as a spotting chemical. It is used in industrial cleaning applications. IRTA tested it in another project and it was very effective in removing ink.

Spotting Agent Scaled-Up Testing

IRTA recruited garment cleaning shops that were willing to test alternative spotting agents for several months. The three water-based cleaners and one soy based cleaner were tested extensively with four cleaners who used alternatives to PERC in the main cleaning process. Two used hydrocarbon, one used wet cleaning exclusively and one used carbon dioxide exclusively. One of the cleaners has multiple shops and one has two shops. The other two cleaners run only one shop. The cleaners that participated in the testing included:

- Royal Cleaners in Santa Monica
- Norton Cleaners in Placentia
- TLC Cleaners in Hollywood
- Flair Cleaners in Studio City

The three water-based cleaners were tested at all four facilities for pre-spotting and also for post-spotting when necessary. The cleaners were all tested at a 75 percent concentration in water. The soy based cleaner was tested for pre-spotting at Royal Cleaners which uses carbon dioxide, TLC Cleaners which uses hydrocarbon and Flair Cleaners which also uses hydrocarbon. The soy cleaner was also tested at Norton Cleaners even though it was expected that it would not rinse out in the wet cleaning process. The soy cleaner was tested at 100 percent concentration. IRTA worked with the spotters and/or owners at these facilities and visited them often during the testing phase. When a spotter or owner indicated they liked one of the alternatives better than the others, IRTA provided larger quantities of that cleaner for longer term use. The spotting agents that were tested were provided either in spray bottles or in squeeze bottles.

Royal Cleaners. Royal Cleaners uses carbon dioxide in the main cleaning process. The spotter performs pre-spotting and post-spotting and always rinses the garment after spotting with steam and dries with compressed air. He found he could use all four alternatives for pre-spotting with rinsing and drying. IRTA asked him to test the four alternatives without rinsing and drying for pre-spotting. He was able to use them all in this manner.

According to the spotter, both Mirachem and PWF-10 were able to effectively remove wine, ink, blood, grease and oil stains. He did not think that Super Scrub was as effective as the other two agents. He preferred Mirachem overall and actually thought it performed better than his current POG spotting agent. He also thought PWF-10 was a very good spotting agent and equal to his current POG agent. A picture of the spotter using the Mirachem cleaner is shown in Figure 2-5. He tried all three water-based cleaners for spot removal on wedding gowns and indicated that all three were very effective. A picture of spotting a wedding gown is shown in Figure 2-6. He also indicated the soy cleaner was effective and was soluble in the carbon dioxide so it could be used for pre-spotting.

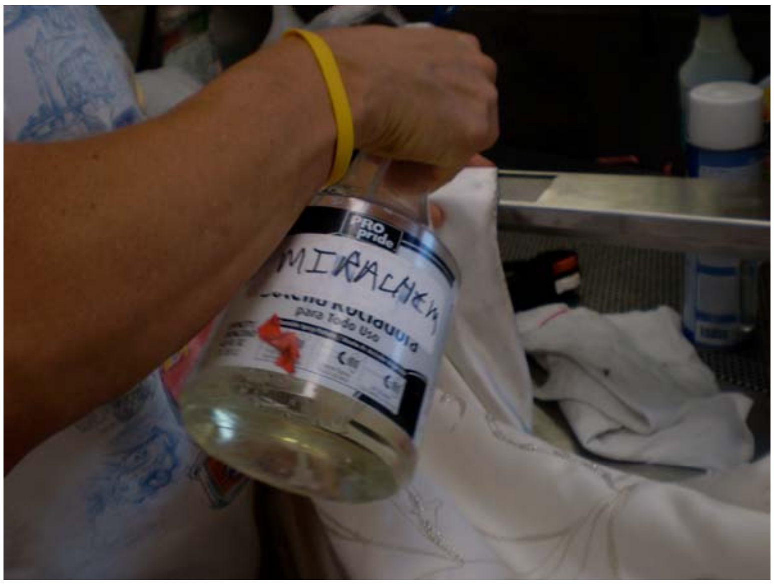

Figure 2-5. Spotter using Mirachem

Figure 2-6. Spotting Wedding Gown

Norton Cleaners. This cleaner uses wet cleaning exclusively as the main cleaning process. The spotting procedure used at Norton Cleaners is to apply the spotting agent, then add a little water to it. The spotting agents were tested on a range of fabrics and a variety of different spots, including oil and grease. The owner found that the soy cleaner could be used for pre-spotting if it was flushed out with steam. If left on the garment without rinsing, however, the soy did not come out when put through the wet cleaning machine. He preferred the water-based cleaners and found them more forgiving than the soy cleaner. A picture of the owner spotting a wedding dress with one of the water-based cleaners is shown in Figure 2-7.

Figure 2-7. Norton Cleaners Owner Spotting Wedding Dress

The Norton Cleaners owner did several experiments with the water-based spotting agents. He applied them to a blue polyester/cotton shirt, let them soak in without dilution and let them sit overnight. He put the shirt through the wet cleaning machine the next day. Super Scrub left a ring but the other two cleaners did not. The owner liked all three water-based cleaners but preferred Mirachem overall. He found the Super Scrub to be a close second but indicated that this cleaner needed to be rinsed out with steam for pre- or post-spotting.

TLC Cleaners. This cleaner uses hydrocarbon and a picture of the machine at the shop is shown in Figure 2-8. At this facility, like the others, the spotting agents were tested on many garment types and spots. The owner thought that all four cleaners were effective spotting agents.

The soy cleaner performed well for pre-spotting and was rinsed out without a ring in the hydrocarbon machine. Of the three water-based cleaners, the owner preferred the PWF-10 but also thought Mirachem was a good cleaner. In his opinion, the Super Scrub was not as good as the other two but was very good for cleaning cuffs and collars.

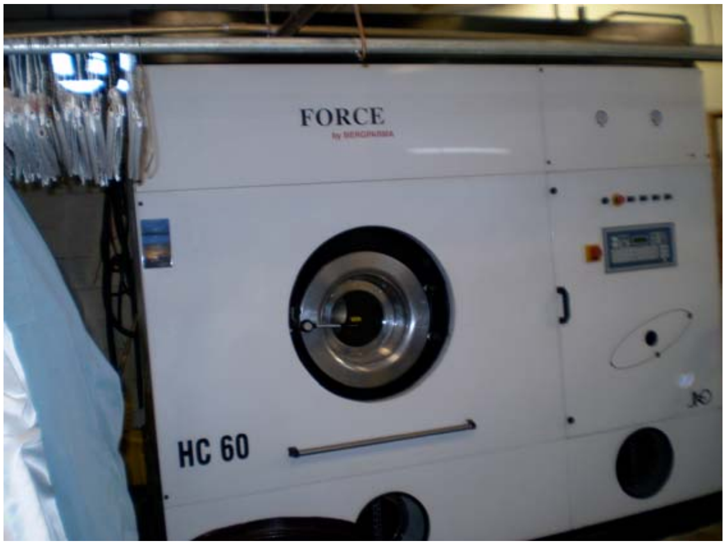

Figure 2-8. Hydrocarbon Machine at TLC Cleaners

Flair Cleaners. This shop is the highest volume shop that participated in the testing; the cleaner uses hydrocarbon as the main cleaning process. The spotter at Flair Cleaners routinely applies the spotting agent, rinses it out with steam, then dries it with compressed air. He deviated from this practice in his tests with soy. He left the soy wet to see if it would rinse out in the hydrocarbon machine and it did, without leaving a ring. The spotter found the soy cleaner to be effective.

The spotter indicated that oil and grease were very effectively removed from garments with the water-based cleaners. He judged that all three cleaning agents performed well. He thought the cleaners were more effective than his current POG spotting agent for cleaning spots on silk in particular. The spotter liked Super Scrub the best of the three water-based cleaners and thought it was especially effective on collars and cuffs. A picture of the spotter using one of the water-based cleaners is shown in Figure 2-9.


Figure 2-9. Spotter Using Water-Based Cleaner at Flair Cleaners

SUMMARY OF RESULTS OF SPOTTING CHEMICAL TESTS

In the earlier DTSC/EPA project conducted by IRTA, several alternative spotting agents were found to perform well. These included some water-based cleaners and a variety of solvent based cleaners. One of the water-based cleaners, Cold Plus, is a commercial product. Another soy based product, Nature's Choice, is also commercially available.

The four cleaning facilities that participated in the work to test the alternative spotting agents in the current project indicated that all the cleaners performed acceptably. Each of the spotters or owners preferred different cleaning agents and saw varying advantages to them. The Mirachem water-based cleaner was preferred by two of the spotters/owners; one preferred PWF-10 and the other preferred Super Scrub. One of the cleaners who preferred Mirachem indicated that the Super Scrub was very good for collars and cuffs. All four spotters/owners thought the soy cleaner performed well.

As mentioned earlier, none of the four chemicals is currently commercialized as a spotting chemical but all are commercially available in other applications. IRTA is working with a spotting chemical distributor to further test the alternative cleaners to see if the company would be interested in commercializing them as spotting chemicals. Suppliers of three of the four alternatives agreed to provide samples for testing to the distributor. The Mirachem manufacturer declined to provide a sample of the Mirachem 500 to undergo the testing. The three other cleaners are currently being tested. All four cleaners can be purchased by cleaning facilities from the manufacturers/suppliers, however.

COST OF CURRENT AND ALTERNATIVE SPOTTING AGENTS

IRTA performed a cost analysis and comparison of the four alternatives. For the analysis, IRTA used two baseline spotting agents for comparison. These include Picrin, which is 100 percent TCE; it is currently priced at $45.45 per gallon. They also include Pyratex which, according to the MSDS, is composed of four materials listed as trade secrets. The first material is an aliphatic carboxylic ester, the second is a glycol ether and the third is an aliphatic ketone. The fourth trade secret material is not identified. The current cost of Pyratex is $37.45 per gallon, which is slightly lower than the cost of Picrin.

IRTA collected price information from the current suppliers for the four alternative spotting agents that were tested. This information was based on what the suppliers would sell the cleaner for in one gallon containers. The suppliers of all four chemicals indicated the price they would charge for each of the cleaners at 100 percent concentration and at 75 percent concentration would be equivalent.

The Mirachem supplier indicated the company would provide a four pack of one gallon containers of Mirachem 500 for $95. This price includes shipping and handling. On this basis, the price per gallon for the cleaner would amount to about $24. The cleaner can be ordered from the supplier in a four pack by calling the facility at (602) 272-6066 or through the company's website at www.mirachem.com.

The other three spotting agents, Soy Gold 1000, Super Scrub and PWF-10, can be ordered from Cleaning Technologies by phone at (714) 337-6569. According to the supplier, the cost of the Soy Gold 1000 in a one gallon quantity is $29.85. The cost of PWF-10 in a one gallon quantity is $15 and the cost of the Super Scrub in a one gallon quantity is $12.25. This does not include the shipping cost which depends on the location of the cleaner. The supplier, located in Anaheim, California, indicated he would provide a four pack of one gallon containers and would ship it to the Bay Area. The cost for ground transport to the bay area for the four pack, which can be composed of any combination of the three cleaners, is $25. On this basis, a four pack of Soy Gold 1000 would cost $36.10 per gallon if shipping is included. The cost of a four pack of the PWF-10 is $21.25 and the cost of a four pack of the Super Scrub is $18.50.

The water-based cleaner, Cold Plus, tested in the earlier project can be purchased from the supplier, Kelleher Equipment, by calling (562) 422-1257. The cost of the cleaning agent is $39 per gallon. Assuming the same shipping cost to the Bay Area of $25 for a four pack, the cost of this spotting chemical is $45.25 per gallon. The soy based cleaner, Nature's Choice, tested in the earlier project is sold for the same price as the Cold Plus. The cost of the cleaner, including shipping to the Bay Area, is $45.25 per gallon.

The information on the alternative spotting chemicals is summarized in Table 2-1 below. The cost of the safer alternative spotting agents is compared with the cost of Picrin and Pyratex, commonly used POG spotting agents. Suppliers of the currently used spotting agents or similar formulations are not identified because these agents are widely available from many supplier sources.

Table 2-1
Cost of Current and Alternative Spotting Agents

Spotting Agent	Cost Per Gallon	Supplier	Contact Information
Picrin	$45.45	-	-
Pyratex	$37.45	-	-
Mirachem 500	$24.00	Mirachem	www.mirachem.com (602) 272-6066
Soy Gold 1000	$36.10	Cleaning Technologies	(714) 337-6569
PWF-10	$21.25	Cleaning Technologies	(714) 337-6569
Super Scrub	$18.50	Cleaning Technologies	(714) 337-6569
Cold Plus	$45.25	Kelleher Equipment	(562) 422-1257
Nature's Choice	$45.25	Kelleher Equipment	(562) 422-1257

The figures of Table 2-1 indicate that the currently used POG spotting agents are the highest cost materials. The three alternative water-based cleaners tested in this project are the lowest cost materials. The soy cleaner tested during this project is also relatively low in cost.

TECHNICAL, HEALTH AND ENVIRONMENTAL CHARACTERISTICS OF ALTERNATIVE SPOTTING AGENTS

The POG spotting chemicals used historically fall into two general categories. The first category is halogenated spotting chemicals. These are spotting agents that contain some amount of a halogenated chemical. Traditionally, these POGs contained either PERC or TCE. As discussed earlier, PERC and TCE are classified as HAPs by EPA, TACs by CARB and are listed on Proposition 65. Both chemicals are carcinogens and TCE is classified as a VOC. More recently, one supplier is offering n-propyl bromide (nPB) which is also a halogenated chemical. nPB is a reproductive toxin and it causes nerve damage. The chemical is listed on Proposition 65 and is classified as a VOC.

The second category of spotting agents is non-halogenated solvents. These are materials that are based on traditional non-halogenated solvents. There are a variety of these POG spotting agents offered today. They are often based on petroleum or hydrocarbon solvents or glycol ethers of various kinds. They are commonly mixtures of a range of different solvents. Some of these agents may have toxicity problems and most of them are classified as VOCs.

The alternatives discussed in this document are water-based cleaners or non-traditional solvent cleaners based on soy. These alternatives have been used in other industries but are generally not used as spotting agents in this industry. One of the water-based cleaners, Cold Plus, is being sold as a spotting agent. This cleaner is a good spotting agent and it has received Clean Air Solvent Certification from the SCAQMD. This means that the VOC content of the cleaner is less than 25 grams per liter VOC which is very low. For comparison, the VOC content of a hydrocarbon solvent is about 750 grams per liter. Cold Plus also contains no HAPs or TACs.

The other three water-based cleaners are also certified Clean Air Solvents. The Mirachem cleaner must be diluted to one-third its full strength concentration to meet the 25 gram per liter limit required by the certification program. The VOC content of the concentrate is 75 grams per liter. The other two cleaners have lower VOC content and meet the 25 grams per liter limit at full strength.

IRTA tested all three of these water-based cleaners at 75 percent concentration (one-fourth water, three-fourths cleaner concentrate). The Mirachem cleaner would likely work very well at full strength; at this concentration, it would have a VOC content of 75 grams per liter. The supplier suggests that PWF-10 would work most effectively if a little water (even as little as five or 10 percent) were added. At any of these concentrations, it would have a VOC content less than 25 grams per liter. The Super Scrub, in contrast to the other two cleaners, is relatively alkaline. It has a fairly high pH. For this reason, it should be diluted somewhat. It could remove color on certain garments and dilution could prevent this. At any dilution level, the Super Scrub would have a VOC content less than 25 grams per liter. All three water-based cleaners can be used for pre-spotting and post-spotting with a steam rinse. The rinse can be avoided in pre-spotting if the textile cleaning process is wet cleaning.

The two soy based cleaners that are alternatives are both also certified Clean Air Solvents. Again, this means that the concentrate of the Soy cleaners has less than 25 grams per liter VOC. The Soy Gold 1000 is straight soy whereas the Nature's Choice is a soy cleaner that contains a high concentration of a surfactant. The presence of the surfactant allows the Nature's Choice to be water rinseable whereas the Soy Gold 1000 is not. The disadvantage of the Nature's Choice is that, after some time, the soy and the surfactant separate and the cleaner takes on a brown color rather than yellowish. The cleaner was formulated for the lithographic printing industry and was designed to be very easily rinsed with water. The amount of surfactant in the cleaner is very high and exceeds the solubility limit of the soy. The cleaner must be shaken periodically to keep the blend intact. The Soy Gold 1000 does not separate since it contains no surfactant but this cleaner cannot be used for post spotting and rinsed with steam. It is very good for pre-spotting and is soluble in both carbon dioxide and hydrocarbon so it does not need to be rinsed before it is put in the dry cleaning machine. The soy cleaners may leave a ring if left on the garment for several hours before being put in the dry cleaning machine.

As discussed earlier, the BAAQMD has passed a regulation that forbids the use of halogenated spotting chemicals. This regulation will not allow the use of TCE, PERC and nPB spotting agents. It does allow the use of non-halogenated solvents, however, because it does not contain a restriction on VOC content. Spotting chemical suppliers are very secretive about the ingredients in their products. It is not easy to find out what all of the components of a POG agent contains. Some of the components may have toxicity problems but it is not possible to evaluate this unless the ingredients are identified. For this reason, even though many of the non-halogenated alternatives could comply with the BAAQMD regulation and some may have low toxicity, IRTA cannot recommend they be used. In contrast, IRTA is familiar with the ingredients in the water-based cleaners and soy based cleaner tested during the project. These alternatives are low in VOC content and low in toxicity. IRTA is comfortable recommending their use from a health and environmental standpoint.

CARB plans to develop a regulation on spotting chemicals over the next several months and the regulation will apply throughout California, even in the jurisdiction of the BAAQMD. CARB will probably forbid the use of the halogenated chemicals and set a VOC content limit for the spotting agents. At this stage, since the regulatory development has not been initiated, it is not possible to determine what the VOC content limit in the regulation will be. In some consumer product categories that have been regulated in the past, CARB has set an interim VOC limit and then a final, lower VOC limit that becomes effective a year or two later. The final VOC limit is often three percent which is equivalent to about 25 grams per liter VOC. Local air districts generally regulate the VOC content by establishing a grams per liter (or pounds per gallon) limit whereas CARB, in their consumer product categories, establishes a percentage VOC content limit. CARB also allows the use of low vapor pressure (LVP) materials and defines them as non-VOCs if they meet certain criteria. The local air districts consider these materials to be VOCs.

If there is an interim VOC limit in the CARB regulation, spotting chemical formulators may be able to use hydrocarbon or petroleum solvents combined with water or other chemicals exempt from VOC regulation or chemicals that meet the LVP definition. They can also use straight LVP materials. Examples of such materials are propylene glycol ethers which could be effective spotting agents. If the final VOC limit is three percent, then only formulations with three percent of a VOC could be used. This means that water-based cleaners, soy based cleaners, LVPs and exempt chemicals and their combinations would be the only chemicals that could be used for spotting. Again, because IRTA would probably not be able to determine the ingredients of the LVP and exempt chemical formulations, IRTA cannot recommend any of them. All of the water-based cleaners and the soy based cleaners that are potential alternatives would satisfy the three percent limit with one exemption. The VOC content of the Mirachem water-based cleaner is 75 grams per liter. It would have to be diluted to one-third concentration to satisfy a CARB limit of three percent. The cleaner might not be aggressive enough to serve as a spotting agent at this low concentration.

Table 2-2 summarizes the environmental characteristics of the alternatives discussed here. It also provides some information on the technical characteristics of the spotting agents.

Table 2-2
Environmental and Technical Characteristics of Alternative Spotting Agents

Spotting Agent	VOC Content of Concentrate (g/L)	Certified Clean Air Solvent	Technical /Use Guidance
Mirachem 500	75	Yes	can be used at full concentration; may not meet final CARB VOC limit without dilution; use for pre- and post-spotting with rinse
PWF-10	<25	Yes	should be diluted; use for pre-and post-spotting with rinse
Super Scrub	<25	Yes	should be diluted; may remove color on some garments; use for pre- and post-spotting with rinse
Cold Plus	<25	Yes	use as is; use for pre- and post-spotting with rinse
Soy Gold 1000	<25	Yes	use as is; use for pre-spotting for cleaners with hydrocarbon and carbon dioxide; can't be rinsed
Nature's Choice	<25	Yes	use as is; use for pre- and post-spotting with rinse and pre-spotting without rinse for cleaners with hydrocarbon and carbon dioxide

III. METHODS OF FACILITATING THE USE OF CARBON DIOXIDE GARMENT CLEANING

There are only a few carbon dioxide cleaners in California. The main deterrent to adoption of carbon dioxide as a PERC garment cleaning alternative is the cost of a machine. Historically, the cost of a carbon dioxide machine has ranged from about $150,000 to $250,000 depending on the manufacturer. Although there have been other manufacturers in the past, there is only one manufacturer, Sailstar, that still provides machines upon special order. One other European manufacturer, Electrolux, may import machines into the U.S. in the future. IRTA investigated methods of reducing the machine cost so more widespread adoption of the technology would be possible.

Carbon dioxide is a much less aggressive cleaning method than PERC dry cleaning. IRTA also investigated methods of improving the cleaning capability of the carbon dioxide. This involved conducting tests with an absorbent and evaluating and comparing the use of carbon dioxide with two different detergents.

REDUCING THE COST OF A CARBON DIOXIDE MACHINE

IRTA held discussions during the project with several manufacturers or potential manufacturers of carbon dioxide machines. The Sailstar machine, the only machine currently available for sale in the U.S., holds 60 pounds of garments and sells for about $150,000. IRTA wanted to explore the possibility of building a smaller machine--about half the size--that would be suitable for the vast majority of cleaners. The reason for building a smaller machine is that it would be less costly. Sailstar has no plans to build a smaller machine. Electrolux does sell a smaller (about 33 pounds) carbon dioxide machine in Europe but the cost is much higher, at about $250,000. Alliance, another carbon dioxide machine manufacturer no longer offers machines for sale.

IRTA also had discussions with a representative of two groups that may eventually decide to manufacture a carbon dioxide machine. One of these groups plans to develop a prototype sometime next year. The group has a concept that, if proven out, would allow a carbon dioxide machine to be priced at less than $80,000. If the machines were that low cost, many cleaners would likely be willing to adopt carbon dioxide.

IMPROVING THE CLEANING CAPABILITY OF CARBON DIOXIDE

The carbon dioxide process is very gentle; it does not clean aggressively. If the cost of the carbon dioxide equipment is lower in the future, the industry may more widely adopt the process. Even if the cost of the equipment remains high, carbon dioxide cleaners might like to improve the cleaning capability of the process. IRTA investigated methods of improving the cleaning capability of carbon dioxide using two approaches.

Carbon Dioxide Cleaning With Tonsil

The most widely adopted alternative to PERC is hydrocarbon dry cleaning. Most of the cleaners in California who have already converted away from PERC use the process. In Southern California, in particular, many hydrocarbon cleaners use the hydrocarbon process with a material called tonsil, which is an absorbent. An MSDS for tonsil is shown in Appendix C. The absorbent is made of natural calcium bentonite material that is acid activated.

The tonsil suppliers claim that tonsil has four advantages. First, it absorbs moisture in the hydrocarbon solvent and makes it much easier to control bacterial growth. Second, it makes distillation unnecessary. Because distillation is not necessary, the hyrocarbon equipment sold for use with tonsil does not include a distillation system. The footprint of the hydrocarbon machine that uses tonsil is much smaller than the footprint of the machine with a distillation system. A picture of a hydrocarbon machine with distillation is shown in Figure 3-1 and a picture of a hydrocarbon machine without distillation is shown in Figure 3-2. A comparison shows the machine in Figure 3-2 is much smaller. Third, cleaners that use tonsil do not have to use detergent. Fourth, the tonsil readily scavenges dyes that would cause bleeding and transfer of the dye to other garments.

Figure 3-1. Hydrocarbon Dry Cleaning Machine with Distillation

Figure 3-2. Hydrocarbon Dry Cleaning Machine with Tonsil

Tonsil cleaners and their customers are pleased with the results of the tonsil. The white garments are very white, probably because the tonsil acts as a bleaching agent. Many skeptics complain that cleaners must use detergent and must perform distillation but the cleaners using tonsil have been using the alternative process, in some cases for more than five years, and have had excellent results.

IRTA wanted to examine the effects of the tonsil use in carbon dioxide equipment and thought it might have two benefits. First, since carbon dioxide cleaners do use distillation to separate the oils from the carbon dioxide, using tonsil might make distillation unnecessary. This could reduce the size and cost of the carbon dioxide machine. Second, as discussed above, the detergent used in the carbon dioxide cleaning process does not seem to aid in the cleaning capability of the carbon dioxide. The use of tonsil could make the use of detergent unnecessary and improve the cleaning capability of the carbon dioxide.

Carbon dioxide machines must operate under pressure to liquify the carbon dioxide. The pressure in a machine is about 700 pounds per square inch. The filters used in carbon dioxide machines are generally carbon canister filters similar to the filters used in other dry cleaning machines. They must be constructed more robustly, however, because when they are put under pressure, the carbon cannot leak out. Changing out filters in a carbon dioxide machine is a bigger effort than changing them out in a typical dry cleaning machine because of the pressure.

IRTA worked with a tonsil supplier and a carbon dioxide filter manufacturer to test the tonsil in a filter in two different carbon dioxide machines. The first test was conducted at Royal Cleaners in a Sailstar machine and the second test was conducted at Hangers Cleaners in a Micell machine. Sailstar is the only remaining manufacturer of carbon dioxide machines. A picture of the machine at Royal Cleaners with the filter housing is shown is in Figure 3-3. Figure 3-4 shows the tonsil being poured into the specially designed filter housing for testing in the machine. Figure 3-5 shows a picture of the Hangers Cleaners machine where the tonsil filters were installed. IRTA worked with the cleaners, the tonsil supplier and the filter manufacturer to change out the filters from carbon to tonsil. IRTA asked the cleaners to not use detergent and not perform distillation during the test. The cleaners tested the tonsil filter for a few weeks.


Figure 3-3. Royal Cleaners Carbon Dioxide Machine


Figure 3-4. Pouring Tonsil into Test Filter

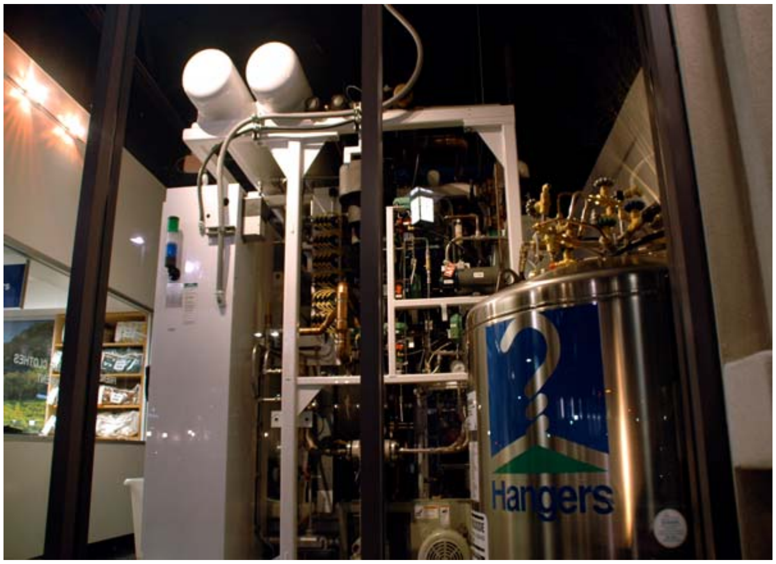

Figure 3-5. Hangers Cleaners Carbon Dioxide Machine

Comparison of Cleaning Performance. IRTA used a traditional set of cleaning performance tests in the evaluation. IRTA relied on the Cleaning Performance Test (CPT) developed by the Drycleaning & Laundry Institute (DLI) to test the cleaning capability of the machine with the carbon filter and the machine with the tonsil filter. The DLI is a large national trade association of dry cleaners and allied industries businesses.

The DLI developed the CPT for their members so cleaners could assess the cleaning capability of their specific dry cleaning system. DLI indicates that one of the limitations of the CPT is that it measures the effect of the total cleaning process. They cannot be used under plant conditions to measure the contribution of individual component parts of the process. As an example, DLI states that the CPT cannot be used under plant conditions to evaluate a detergent only. Other factors like the solvent used or the characteristics of the equipment could also influence the results. With the limitations in mind, IRTA processed a load of garments under plant conditions to compare the CPT results for a load of garments cleaned with the carbon filter and a load of garments cleaned with the tonsil filter. The results, rather than being useful for an absolute evaluation, were meaningful only in a comparative sense.

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

The DLI instructions indicate that the CPT towels should not be prespotted. DLI indicates that water soluble soil removal will be low in most cases and this is expected for solvent cleaning operations. DLI also recommends that the CPT towel be run in a light colored load. Dark fabrics usually carry much more soil than light fabrics; dark lint can have a strong effect on white swatches; and dark fabrics may have dyes which bleed.

Results of the Cleaning Performance Tests. The CPT test results are presented on a ranking scale. Table 3-1 shows this ranking scheme. The results are presented below the ranking scale and are given a numerical rating and a class rating (excellent, good, fair and poor.)

Table 3-1
DLI Cleaning Performance Test Report

	% Graying		Yellowing		% Whiteness		Water	Rug
	Poly/C	C	Poly/C	C	Poly/C	C	Soluble	Soil
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-59	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73

With the ranking scheme in mind, Table 3-2 presents the results of the test with the carbon cannister at Hangers Cleaners. In this case, the cleaning process involved using detergent and performing distillation.

Table 3-3 presents the results of the test with the tonsil filtration. During this test, the cleaner did not use detergent or use distillation.

In both cases, the DLI made an interpretation/recommendation. DLI indicated "the soil removal, both solid soil (rug soil) and water-soluble soil, is poor. If there is no soil in the process to redeposit then the whiteness, yellowness, and graying results will be excellent. These excellent results are not the result of the process performing well in these areas but the process's lack of performance in soil removal."

Table 3-2
Results of the Carbon Filtration Test at Hangers Cleaners

	% Graying Poly/C	% Graying C	Yellowing Poly/C	Yellowing C	% Whiteness Poly/C	% Whiteness C	Water Soluble	Rug Soil
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-59	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73
Your Test Results	E	E	G	G	E	G	P	P

Table 3-3
Results of the Tonsil Filtration Test at Hangers Cleaners

	% Graying Poly/C	% Graying C	Yellowing Poly/C	Yellowing C	% Whiteness Poly/C	% Whiteness C	Water Soluble	Rug Soil
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-59	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73
Your Test Results	E	E	E	E	E	E	P	P

Comparing the results of the carbon and tonsil filtration, both processes resulted in poor water soluble and rug soil removal and there are no differences in that regard. The DLI indicates that if the rug soil removal is poor, there is low detergent content in the solvent. While no detergent was used in the tonsil filtration test, detergent was used in the carbon filtration test. Since the rug soil removal was poor in both cases, there seems to be no difference in the carbon dioxide process if detergent is used or not. The tonsil filter did get better results in the yellowing for poly/cotton and cotton and the whiteness for cotton. This could be because the tonsil is a bleaching agent and it would be expected that it would result in whiter garments.

Qualitative Input from Carbon Dioxide Cleaners. Both cleaners provided qualitative input on how they believed the tonsil and carbon performed. One of the cleaners, who cleaned 4,700 pounds of garments during the tonsil test, indicated that he believed that detergent was needed for the tonsil filter; more spotting was necessary after the garments were cleaned in the machine. The DLI results above indicate that poor rug soil removal demonstrates low detergent use but both tests had poor rug soil removal. The other cleaner indicated that he needed to change out the filter during the tonsil test much earlier than he needed to change out the filter during the carbon test. Although this is more of an inconvenience, it does mean that the tonsil filter is likely to be more effective in filtering out material than the carbon filter.

<u>Carbon Dioxide Detergent Comparison</u>

Many of the carbon dioxide cleaners in the state are using a detergent called Clip COO which is made by Kreussler Co. An MSDS for this detergent is shown in Appendix C. According to the MSDS, it contains a glycol ether, two linear ethoxylated alcohols non-ionic surfactants and a fungicide. Most of the cleaners using this detergent have been using it for several years. Linde, another detergent manufacturer had developed a new detergent for use with carbon dioxide and IRTA decided to conduct testing with the same two carbon dioxide cleaners who had tested the tonsil. Linde supplied the two cleaners with samples of the new detergent and the cleaners tested it for several weeks. An MSDS for the alternative detergent is shown in Appendix C. As indicated in the MSDS, the detergent contains a fatty alcohol ethoxylate and a glycol ether.

<u>Detergent Test Results.</u> IRTA arranged for one of the cleaners to run the DLI test swatches with the currently used detergent and the alternative detergent for a comparison. Table 3-4 shows the DLI test results for the Kreussler baseline detergent and Table 3-5 shows the results for the alternative Linde detergent.

Table 3-4
Kreussler Detergent Cleaning Results

	% Graying		Yellowing		% Whiteness		Water	Rug
	Poly/C	C	Poly/C	C	Poly/C	C	Soluble	Soil
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-59	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73
Your Test Results	1	2	0	0	99	98	0	8
	E	E	E	E	E	E	P	P

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Table 3-5
Linde Detergent Cleaning Results

	% Graying		Yellowing		% Whiteness		Water	Rug
	Poly/C	C	Poly/C	C	Poly/C	C	Soluble	Soil
Ranking								
Excellent: Top 25%	0-4	0-3	<1	<1	>90	>94	91-100	87-100
Good: Mid 25%	5	4-5	1	1	88-90	90-94	52-90	81-86
Fair: Mid 25%	6	6	2	2	85-87	82-89	18-59	73-80
Poor: Bottom 25%	>6	>6	>2	>2	<85	<82	0-17	<73
Your Test Results	2	3	1	1	97	96	0	34
	E	E	G	G	E	G	P	P

The results show that the alternative Linde detergent was not as good as the baseline Kreussler detergent for the poly/cotton and the cotton yellowing and the cotton whiteness. Although the results for both cleaning tests were poor for rug soil, the numerical value demonstrates that the Linde detergent did better in rug soil removal.

Qualitative Input from Cleaners on Alternative Detergent. One of the cleaners indicated that he couldn't tell any difference on dark loads but on light loads, he thought the alternative detergent cleaned better. He also thought the hand (feel) of the garments was very good for the alternative detergent. The other cleaner and his employees liked the new detergent. The presser indicated that the garments had a better hand and were softer. He also said the new detergent had an odor but that it dissipated. The old detergent left rings in the garments but the new one did not. The owner indicated that the garments felt the same and that the new detergent had an odor but the odor disappeared in the pressing.

IV. METHODS OF FACILITATING THE USE OF WATER-BASED GARMENT CLEANING

Most of the cleaners in California that have converted away from PERC have adopted the hydrocarbon process. Very few have converted to wet cleaning and use it exclusively. Cleaners have cited several problems with wet cleaning that are deterrents to adopting the process. First, cleaners indicate they do not believe that all garments they will receive can be wet cleaned. In principle, 100 percent of the garment stream could be wet cleaned; it would be very time consuming to clean every garment this way, however. A small percentage of the garments would very likely have to be cleaned in a different way.

Second, in the wet cleaning process, humidity controlled dryers are generally used and the garments that have been wet cleaned should not be fully dried. They should retain a residual moisture content. This means that garments that are not finished instantly must be hung in the facility. For cleaners who process a large volume of garments, this is very inconvenient since most cleaners' leased space is constrained.

Third, finishing wet cleaned garments requires tensioning equipment and the finishing labor is higher. The garments are immersed in water and dried with heat and they are more wrinkled than they are when they are dry cleaned. The garments may also experience dimensional change (which generally means shrinkage) during wet cleaning and the tensioning equipment is used to stretch the garment back to its original size and shape. The finishing labor cost is one of the highest costs for a cleaner. Increasing this already high cost is difficult for the industry.

In light of the issues that are preventing more widespread adoption of wet cleaning, IRTA investigated two approaches. First, IRTA examined an available water-based cleaning method that can be used by cleaners in conjunction with less costly wet cleaning equipment that would reduce the finishing labor compared with wet cleaning alone. Second, IRTA examined and tested alternative drying methods that do not rely on heat for drying. If high heat were not used for drying, the garments could be fully dried and would not shrink and they would not be as difficult to finish because there is lower heat. The two technologies that were investigated were vacuum drying and microwave drying. The two approaches are analyzed further in this section.

GREEN JET PAIRED WITH WET CLEANING

There is an existing system available today that can be combined with low cost wet cleaning equipment to reduce the finishing labor problem. In the Green Jet system, the garments are sprayed with a mixture of detergent and water rather than immersing them in water and detergent as is the case with wet cleaning. Because the garments are not immersed, they are not as wrinkled and do not require more labor for finishing. The garments from the Green Jet system can be finished with the same equipment used for finishing solvent cleaned garments.

The Green Jet is not an aggressive cleaning method and it is suitable only for garments that are not heavily soiled. For this reason, the Green Jet should not be used alone and should be combined with wet cleaning equipment. The wet cleaning equipment cleaners are often using today is expensive and less costly equipment can be used with the Green Jet because the garments that are difficult to finish can be put through the Green Jet. Heavily soiled garments that are difficult to finish can be more heavily spotted and processed through the Green Jet.

IRTA identified two cleaners who have been successfully using the Green Jet system paired with wet cleaning. One of the cleaners has been using the system for seven years and the other has been using it for almost two years. IRTA developed one of the case studies in an earlier project (IRTA, 2008) and one of them during the current project. IRTA estimated the costs of using the systems together with each of the cleaners and the assumptions used in the development of the cost information are presented below. One of the cleaners did not want to be identified so the information is provided anonymously. The case studies, which are separate stand-alone documents, are presented in Appendix D.

Mastercraft Solvent Free Dry Cleaning

Mastercraft is located in Fresno, California. The store has had a wet cleaning system and a Green Jet machine since 2002. Until a few years ago, the shop used a washer and dryer that was not humidity controlled and also relied on traditional finishing equipment. A few years ago, the owner purchased a humidity controlled dryer and tensioning equipment. The store cleans about 60,000 pieces or pounds of garments per year.

The owner of Mastercraft had two plants until May of 2002. One of the plants, called the Cedar plant, had a PERC dry cleaning machine. The other plant, called Fig Garden, had a wet cleaning system comprised of a washer and a dryer that was not humidity controlled. Prior to May 2002, half the garments or 30,000 pounds, were cleaned at the Cedar plant in the PERC machine and half were cleaned at the Fig Garden plant in the wet cleaning machine. Mastercraft also has a washer that is used for laundering shirts but not for dry clean only garments.

In 2002, the owner purchased a Green Jet machine for the Fig Garden Plant, closed the Cedar plant and stopped using the PERC machine. At that time, half the garments or 30,0000 pounds were cleaned in the wet cleaning machine and half were cleaned in the PERC machine. Currently, half the garments are cleaned in the wet cleaning machine and half are cleaned in the Green Jet machine. A picture of the Green Jet machine at Mastercraft is shown in Figure 4-1.

The cost analysis performed here compares the cost of using the wet cleaning equipment and the PERC machine with the cost of using the wet cleaning equipment and the Green Jet machine. Because about half the garments have been cleaned with the wet cleaning equipment over the entire period, the analysis focuses on comparing the cost of using the PERC machine with the cost of using the Green Jet machine.

Figure 4-1. Green Jet Machine at Mastercraft

The capital cost of the Green Jet machine was $16,500. The installation cost amounted to $2,000 for a total capital cost of $18,500. Assuming a 15-year life for the equipment and a cost of capital of five percent, the annualized cost of using the Green Jet machine is $1,295.

The PERC machine used by the facility was a converted machine or a machine converted from a vented system to a closed loop system. Emissions from such systems are generally fairly high. The owner estimates that the cost of purchasing PERC amounted to about $300 per month or $3,600 annually.

Mastercraft also purchased detergent for use with the PERC machine. The owner estimates that the detergent costs amounted to $25 per month or $300 per year.

A detergent called DWX 44 is used in the Green Jet machine. The shop uses seven ounces of the detergent per 35 pound load. Based on 60,000 pounds of garments cleaned per year and half of them cleaned in the Green Jet, the shop cleans 857 loads per year in the Green Jet equipment. Mastercraft uses 375 pounds of detergent per year. The MSDS for DWX 44 indicates a density of 8.34 pounds per gallon. On this basis, about 45 gallons of detergent is used annually. A 2.5 gallon container is priced at $65. The annual cost of the Green Jet detergent is $1,170.

The owner estimates that the electricity cost has not changed since the conversion from PERC to Green Jet. The cost includes the electricity cost for the lighting, for the wet cleaning equipment and for the PERC machine used previously and the Green Jet machine used today. The electricity cost for the facility is currently about $8,000 per year and it will be assumed that this was also the cost when the PERC machine was used. For purposes of analysis, it will be assumed that half the electricity cost, or $4,000 per year, is attributable to the PERC machine or the Green Jet machine and half is attributable to the wet cleaning machine.

When the PERC machine was used, the gas cost amounted to about $5,000 per year. Assuming half the gas was used for the pressing equipment, the cost of the gas used for the PERC machine amounted to about $2,500 annually. There is no gas used by the Green Jet machine so it will be assumed that the gas cost today is zero.

One employee spends an average of 3.5 hours per day in spotting. Assuming a six day workweek, the spotting labor amounts to 1,092 hours per year. At a spotting labor rate of $10.00 per hour, the annual cost of spotting is $10,920. Mastercraft's owner indicates that overall spotting labor did not change when the shop converted from PERC to the Green Jet. He estimates that half the spotting labor was for garments cleaned in the PERC machine and half for the garments that were wet cleaned. On this basis, the spotting labor cost for the PERC machine was $5,460. Half the garments are cleaned in the Green Jet machine and half in the wet cleaning machine today. The owner estimates that somewhat more of the spotting labor is devoted to the garments cleaned with the Green Jet. For purposes of analysis, it was assumed that 40 percent of the total spotting labor is for garments that are wet cleaned and 60 percent for garments that are cleaned in the Green Jet machine. The spotting labor cost for the Green Jet machine is $6,552.

The owner also indicates that the total finishing labor has not changed with the conversion. Employees spend an average of 90 hours per week or 4,680 hours per year finishing the garments. At a labor rate of $8.75 per hour, the annual finishing labor cost is $40,950. The owner estimates that about 55 percent of the finishing labor was required for the wet cleaning finishing and 45 percent when PERC was used and today when the Green Jet is used. The finishing labor cost with PERC and with the Green Jet is $18,428.

When Mastercraft used PERC, an employee spent four hours every two months or 24 hours per year on routine maintenance activities that involved changing out the filters. Assuming a labor rate of $10 per hour, the labor cost was $240 annually. The total annual maintenance labor cost amounted to $2,040. With the Green Jet machine, the maintenance cost involves cleaning out the air jets. An outside company services the machine and spends two hours every three months or eight hours per year in this activity. At an hourly rate of $40, the annual cost of this routine maintenance is $320.

The maintenance equipment cost for the PERC machine was the cost of filter replacement. The owner estimates that six filters were replaced seven times per year for a total of 42 replacements annually. IRTA estimates the cost of a typical filter at about $35. On this basis, maintenance equipment costs for the facility when the PERC machine was used amounted to $1,470 per year. With the Green Jet machine, there is no maintenance equipment cost.

When PERC was used, the owner estimates that Mastercraft had compliance costs that amounted to $370 per year. These costs included daily, weekly and monthly record keeping for the machine, the waste disposal records, the PERC usage records, employee training and preparation of the annual report. There are no compliance costs for the Green Jet.

Whan Mastercraft used PERC, the facility disposed of filter waste. The waste disposal cost amounted to $1,839 annually. There are currently no waste disposal costs with the Green Jet system.

Table 4-1 summarizes the cost comparison for the PERC and the Green Jet technologies. The annual cost of using the Green Jet system is about 21 percent lower than the annual cost of using the PERC machine.

Table 4-1
Annualized Cost Comparison for Mastercraft Solvent Free Dry Cleaning

	PERC	Green Jet
Annualized Capital Cost	-	$1,295
Solvent Cost	$3,600	-
Detergent Cost	$300	$1,170
Electricity Cost	$4,000	$4,000
Gas Cost	$2,500	-
Spotting Labor Cost	$5,460	$6,552
Finishing Labor Cost	$18,428	$18,428
Maintenance Labor Cost	$2,040	$320
Maintenance Equipment Cost	$1,470	-
Compliance Cost	$370	-
Waste Disposal Cost	$1,839	-
Total Cost	$40,007	$31,765

Anonymous Cleaner

This cleaner was opened by a couple in October of 2008. The landlord would not allow the use of a solvent. The store uses a Milner machine and a Green Jet machine for cleaning all the garments. The Milner machine, shown in Figure 4-2, is used for wet cleaning about three-fourths of the garments. The Green Jet, which relies on spraying water and detergent rather than immersion, is used to clean about one-fourth of the garments; a picture of the machine is shown in Figure 4-3. The garments from the Green Jet machine are easier to finish than the wet cleaned garments.

At this stage, the shop processes about 45 garments in two loads per day through the Green Jet. The cost of the Green Jet equipment was $22,000. Assuming a 15 year useful life for the equipment and a four percent cost of capital, the annualized cost of the machine is $1,525.

Figure 4-2. Milner Wet Cleaning Machine at Anonymous Dry Cleaner

Figure 4-3. Green Jet at Anonymous Dry Cleaner

From October, 2008 through August 2009, the cleaner used about 6.5 gallons of the DWX 44 detergent in the Green Jet machine. On this basis, the annual use of the detergent amounts to 7.8 gallons. The cost of the detergent to a cleaner is $88.75 per 2.5 gallon container so the annual cost of purchasing detergent is $277.

The Green Jet does not use gas. It has a compressor that uses electricity. The owner estimates that the electricity use for the Green Jet machine is about $50 per month. This translates to an annual cost of $600.

The owners do all the spotting and finishing in the shop themselves so there is no cost for the spotting and finishing labor. IRTA wanted to include the cost in the event that another owner might not perform the spotting and finishing. The owner estimates the spotting labor for the garments that are processed in the Green Jet at one hour per day. The shop operates for six days per week. Assuming a labor rate of $10 per hour, which is typical for this industry, the cost of the spotting labor amounts to $2,600 annually.

The cleaner has a variety of finishing equipment including tensioning equipment. Some of this equipment is shown in Figures 4-4, 4-5 and 4-6. For pressing, the owner estimates that the garments processed through the Green Jet machine require about one hour per day to finish. Again assuming a labor rate of $10 per hour, the annual cost of finishing labor is $2,600.

Figure 4-4. Finishing Equipment at Anonymous Cleaner

Figure 4-5. More Finishing Equipment at Anonymous Cleaner

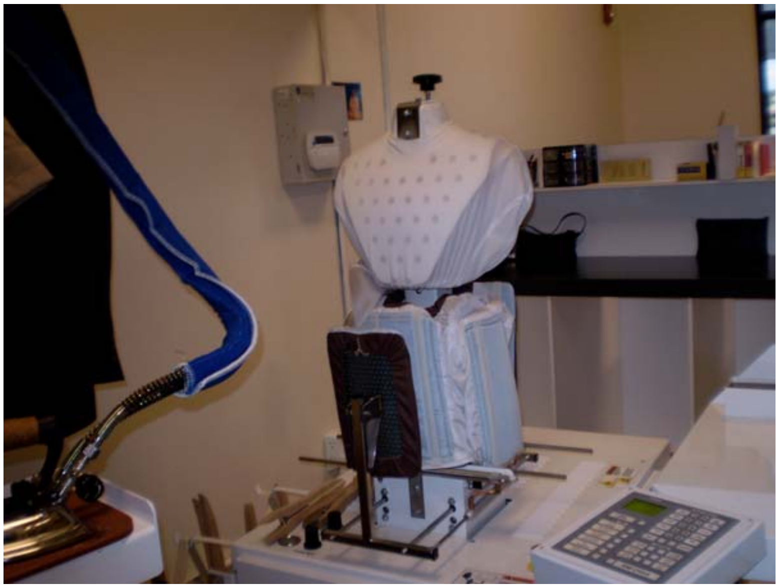

Figure 4-6. Additional Finishing Equipment at Anonymous Cleaner

The machine requires very little maintenance. The owner estimates the maintenance labor at one hour per year. Assuming a labor rate of $10 per hour, this cost is $10 per year. According to the owner, there is no maintenance equipment cost for the system.

The shop uses only water-based cleaning and requires no environmental permits. There are no compliance or waste disposal costs.

Table 4-2 shows the annualized cost for the Green Jet. Since the shop is new, there is no comparison with PERC dry cleaning. Note that the costs are only for the Green Jet and do not include the costs of the wet cleaning operation.

Table 4-2
Annualized Cost Comparison for Anonymous Cleaner

	Green Jet
Annualized Capital Cost	$1,525
Detergent Cost	$277
Electricity Cost	$600
Spotting Labor Cost	$2,600
Finishing Labor Cost	$2,600
Maintenance Labor Cost	$10
Total Cost	$7,612

VACUUM DRYING

A major problem with the wet cleaning systems used today for garment cleaning is that they rely on heat for drying. Heated drying can shrink the garments, require them to be removed from the dryers before they are fully dry and make finishing more difficult.

Vacuum drying is used in a variety of industrial applications. This type of drying is ideal for materials that would be damaged or changed if exposed to high temperatures. This is the case for garments. In effect, the low pressure in a vacuum dryer forces the moisture out of the garments.

IRTA decided to pursue vacuum drying as a potential drying method for the wet cleaning process that could minimize or eliminate the issues that arise with the heated drying used today. IRTA worked with a company called HyperFlo (www.hyperflo.com), a company that produces an innovative line of vacuum equipment for a variety of different types of industrial operations. The company has a small vacuum test unit that HyperFlo provided to IRTA for testing. A picture of the small test unit is shown in Figure 4-7.

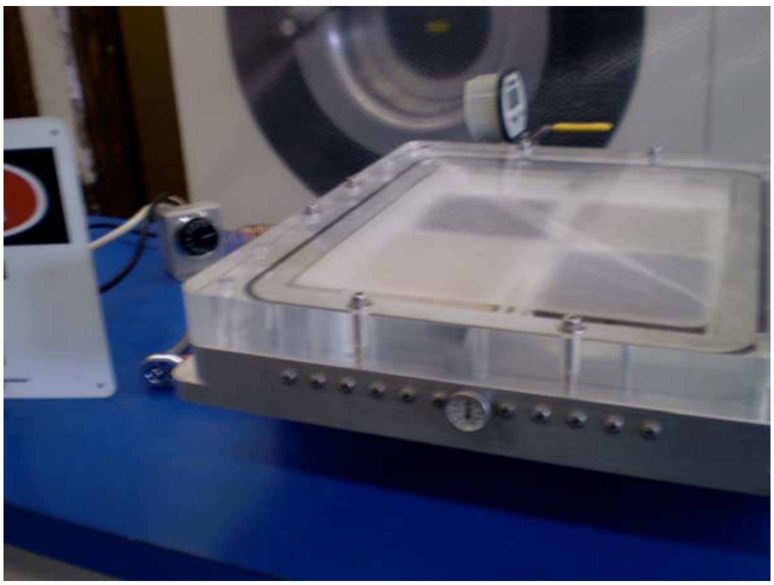

Figure 4-7. Small Vacuum Test Unit

The initial testing involved wetting swatches composed of a range of different fabrics with water and documenting the drying time and condition of the swatches. A variety of fabrics were tested. Pictures of different swatches in the test unit are shown in Figures 4-8 and 4-9. A limitation of the testing was that the swatches had to be laid flat in the small system and agitation was possible only by physically turning the vacuum on and off and it was inadequate. IRTA was particularly interested in seeing if the vacuum dryer could reduce the drying time of heavier fabrics that can easily be damaged in a heated dryer and require a long drying time.

IRTA conducted drying tests on a range of fabric types including cotton, linen, silk, nylon, polyester, rayon, tinsel, acetate and wool and combinations of the materials. The vacuum system seemed to dry garments fairly rapidly. In one case, the test on a gray 100 percent wool swatch, a plaid 100 percent cotton swatch, a black/beige checked 96 percent wool/4 percent lycra swatch and a beige 86 percent silk/12 percent nylon/two percent lycra swatch indicated that all the fabrics were easily dried within nine minutes. During the testing, some of the fabrics that were tested took a little longer to dry and some dried very quickly.

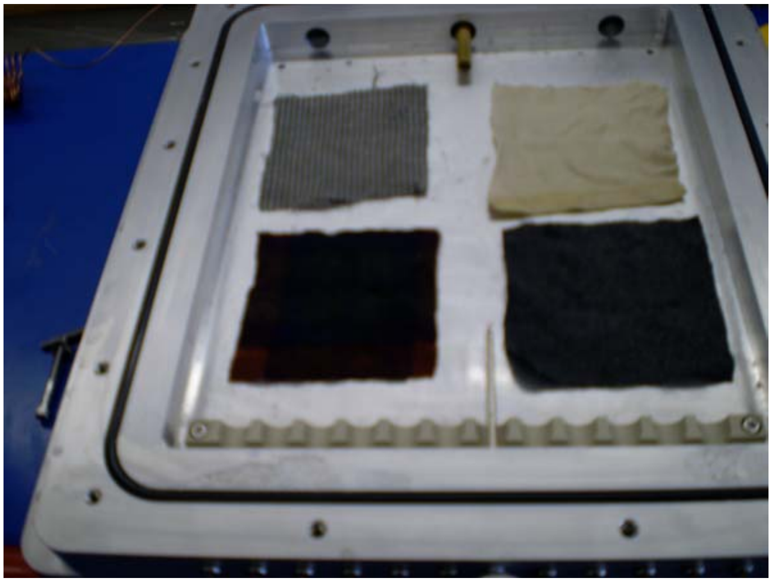

Figure 4-8. Swatch Testing in Vacuum Test Unit

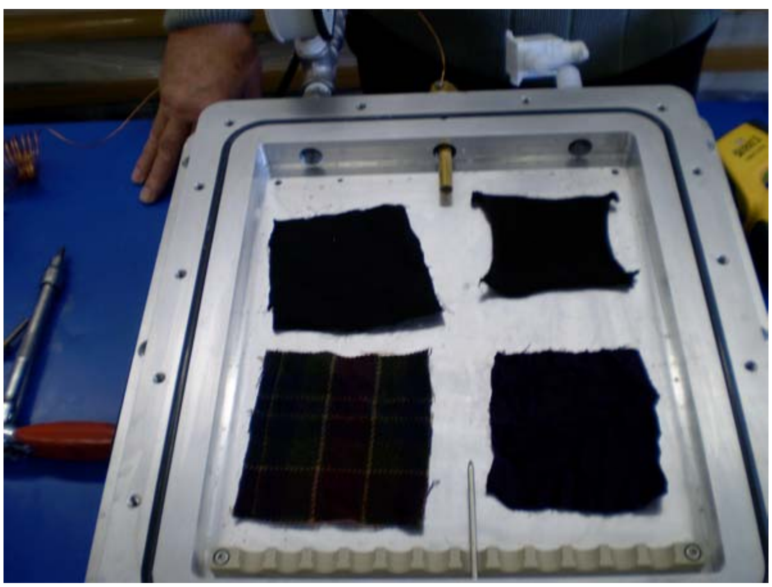

Figure 4-9. Additional Swatch Testing in Vacuum Test Unit

IRTA also decided to test the small vacuum system for both washing and drying the swatches. Two cleaning methods were examined. First, IRTA investigated the cleaning capability of hydrogen peroxide at low concentration. Second, IRTA obtained detergents from Kyzen, a company that formulates water-based cleaners for the industrial cleaning sector. When using a vacuum system, commonly used detergents with surfactants cannot be used because the surfactants are destroyed in the process. This means that detergents without surfactants must be used. Kyzen provided four of these detergents for testing.

MSDSs for one of these detergents, Micronox MX2422, is provided in Appendix E. The detergents were diluted to about three percent in water for the testing.

IRTA put various soils on the garments, including pen ink, oil, mustard and ketchup. The hydrogen peroxide in various concentrations and the detergents were tested in the system. Because there was virtually no agitation, the spots on the garments were not completely removed but, under the circumstances, using a larger system for both washing and drying garments seemed promising.

The next step was to conduct some testing in a larger scale system. IRTA visited HyperFlo and some tests on swatches were conducted in a larger vacuum system used for demonstration at the facility. A picture of the test unit is shown in Figure 4-10. Figure 4-11 shows a picture of the fixture used for the swatches with two swatches in it. Figure 4-12 shows this fixture inside the test unit. One of the swatches is 100 percent linen and the other swatch is a velour striped acrylic. A variety of different swatches were tested; another set of swatches in the test unit is shown in Figure 4-13.

Figure 4-10. HyperFlo Test Unit

During the testing, hydrogen peroxide and detergents were tested for the wash cycle. It was determined that the hydrogen peroxide wash cycle would be the best cycle to use in a scaled up test. The wash cycle with the hydrogen peroxide in very dilute form (0.1 percent) could be only two minutes long. The test results for the drying cycle indicated that the drying cycle for thinner fabrics could be as short as two minutes and, for the thickest and heaviest garments, could be less than 20 minutes. The wash and dry cycles combined would likely be no more than about 20 minutes. No rinse or extraction steps would be needed.

At this stage, more testing in a prototype vacuum system designed specifically for cleaning garments would be required before the vacuum wash/dry system could be deemed a success. The prototype system would have to have a larger drum so several full size garments could be tested. It would require a small amount of agitation so the fabrics could be adequately dried in the vacuum system. Testing would have to be conducted using various concentrations of hydrogen peroxide and appropriate detergents for the cleaning step and the drying time for garments of many different fabric types would have to be measured. The testing would allow optimization of the prototype unit which would be redesigned and commercialized.

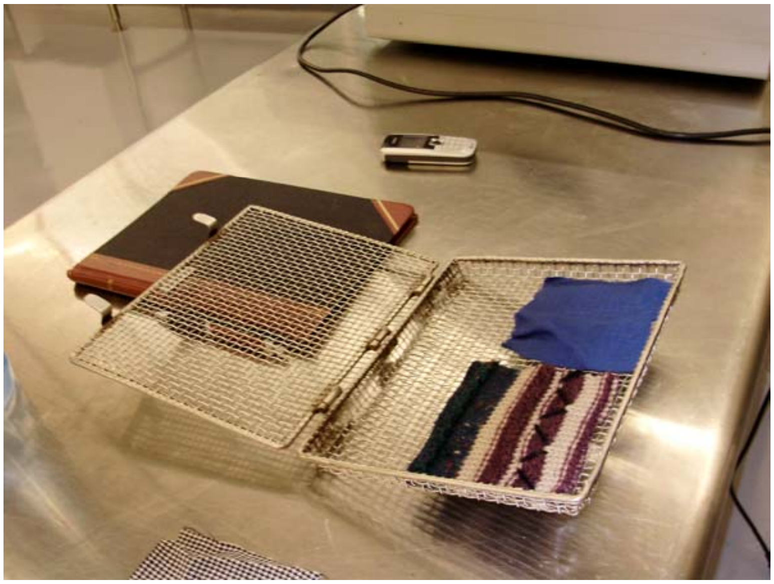

Figure 4-11. Swatch Fixture

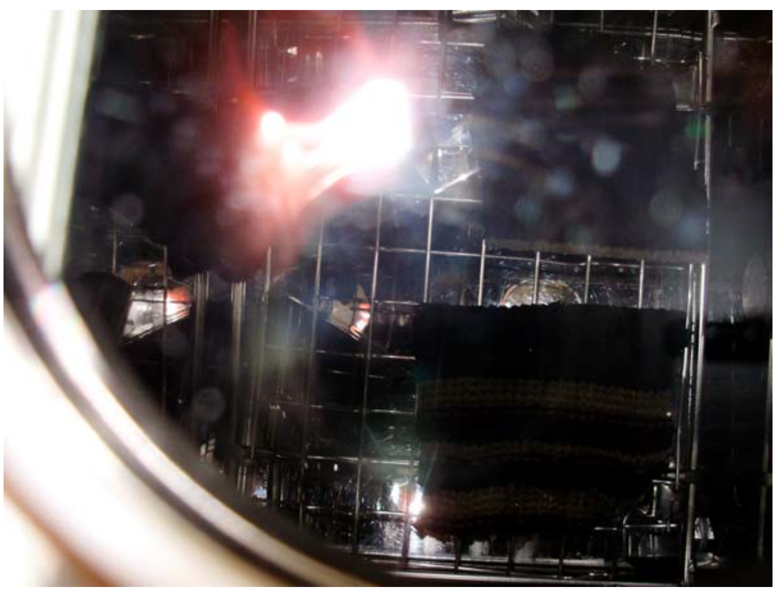

Figure 4-12. Fixture in Test Unit

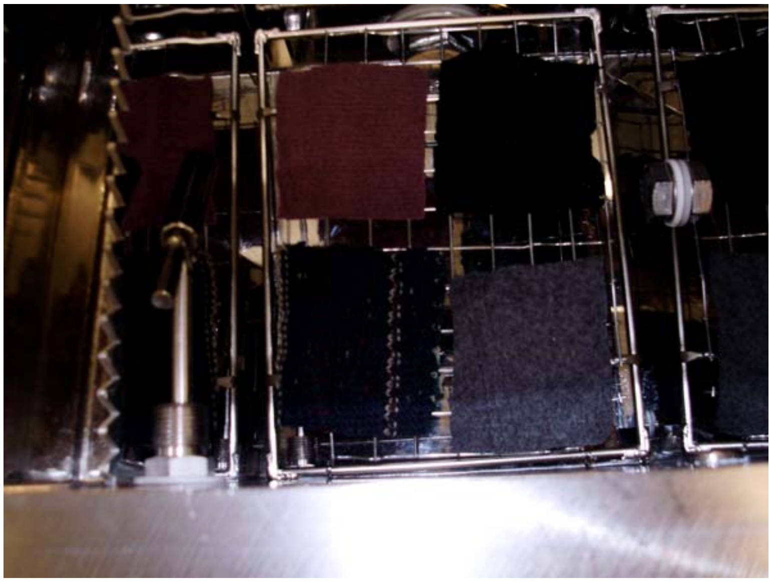
Figure 4-13. Another Set of Swatches

MICROWAVE DRYING

In conventional drying, hot air at about 250 degrees F passes over the clothing, transferring its heat to the surface of the clothing and causing the water in the cloth to vaporize. The vapor joins the hot air stream and is transported out of the dryer. Near the end of the cycle, when the clothing is seeing a higher temperature, the strands of the clothing are degraded by the elevated temperature. The lint generated in the lint screen is short sections of threads that have been broken from the main piece of clothing. In microwave drying, microwave energy is absorbed only lightly by the clothing but strongly by the water within the clothing. The microwave energy passes through the clothing to heat the water and evaporate it within the clothing. An airflow of warm air at 110 degrees F is maintained over the clothing to carry away the moisture after it is given off from the clothing. The clothing dries at the cool temperatures of 105 to 110 degrees F throughout the entire drying cycle.

Between 1990 and 1997, the Electric Power Research Institute (EPRI) investigated microwave drying as a potential technology for drying in home laundry equipment. (EPRI, 1996a; EPRI 1996b) EPRI was interested in this method of drying because drying fabrics with microwave energy can reduce the drying time by half and the drying temperature. This would make all fabrics last longer and look better. EPRI built prototype units and performed work on residential sized microwave dryers capable of holding seven to 12 pounds of dry clothing. EPRI also considered the technology for commercial laundry application.

During EPRI’s work, they encountered problems with certain metal items like lead pencils and butane cigarette lighters. Metal items in a microwave system can cause arcing. EPRI tested a hazard detection system, including sensors and a controller that would safely shut down the dryer in the event of a problem.

In microwave drying, garments experience lower drying temperatures and since they can be dried in about half the time, they do not experience the longer agitation time for heated drying. Both heat and agitation can lead to garment shrinkage. Because much lower heat and less agitation can be used in a microwave drying application, IRTA wanted to investigate the technology for drying garments after they have been washed in a wet cleaning washer.

IRTA obtained a prototype microwave system from Gerling, the company that had built the test dryers for EPRI during the research investigations. This dryer did not have the sensors that were added to other test units but there was a timer on it that stopped the cycle periodically. Another limitation of the dryer was that it had virtually no agitation so garments were projected to take longer to dry than if some sort of agitation system were included. Figure 4-14 shows a picture of the microwave unit that was tested. Figure 4-15 shows the test unit with the door open. A picture of the inside of the test unit is shown in Figure 4-16.

Figure 4-14. Microwave Dryer used in Testing

IRTA tested various types of fabrics that would normally be labeled dry cleaning only in the dryer to determine if the drying time was shorter. The dryer was fairly small and was not designed to hold large garments. Even so, IRTA did test full sized garments in the test unit. A plaid wool shirt, shown in Figure 4-17, dried in about 20 minutes. A patterned golf shirt, shown in Figure 4-18, dried in about eight minutes. A pair of heavy green corduroy pants, shown in Figure 4-19, dried in 11 minutes. The corduroy pants had a metal zipper, a metal snap and studs on each side. The earlier EPRI work indicated that if metal zippers were closed, there was no problem with the metals arcing. Other metal ornaments like snaps and studs should not arc either. The test unit did not arc while drying this garment, verifying EPRI's earlier observations.

Figure 4-15. Microwave Dryer with Open Door

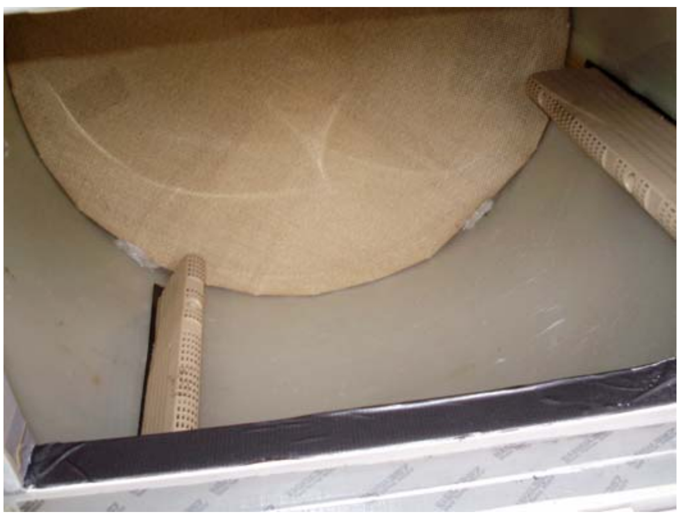

Figure 4-16. View of Inside of Microwave Dryer Test Unit

Figure 4-17. Plaid Wool Shirt

4-18. Patterned Golf Shirt

Figure 4-19. Green Corduroy Pants

IRTA tested the drying time with smaller swatches of material. A 100 percent red wool swatch, shown in Figure 4-20, and a 100 percent gray wool swatch, also shown in Figure 4-20, were tested. These materials were labeled dry cleaning only. Both the gray and the red wool swatches dried in less than three minutes. In a heated dryer, both would take much longer to dry.

IRTA wanted to examine what would happen if the test unit were used to dry fabrics with metallic thread. IRTA tested swatches of two different types of fabrics. The first was a black/silver metallic paisley brocade that was composed of 56 percent nylon, 25 percent polyester and 19 percent metallic. The second was a hairy metallic silver fabric composed of 70 percent nylon and 30 percent metallic. The swatches are shown in Figure 4-21. It is unlikely that any professional garment cleaning operation would dry garments made of either of these fabrics in a heated dryer because the nylon base fabric would probably be destroyed. In the microwave dryer, the black/silver swatch dried quickly. The plain silver swatch was destroyed, probably because it was made of nylon and metallic.

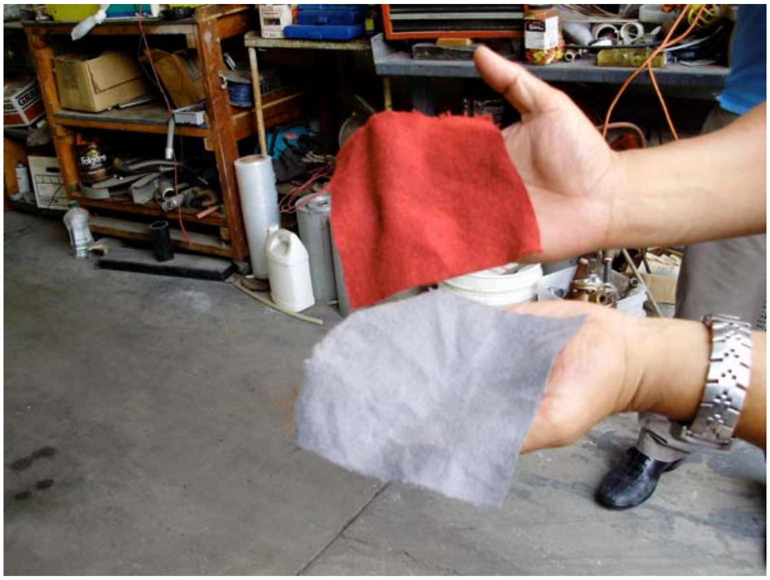
Figure 4-20. Grey and Red Wool Swatches


Figure 4-21. Metallic Thread Swatches

IRTA wanted to further investigate drying garments with metallic thread. IRTA obtained some additional swatches. One was a navy and red swatch composed of 65 percent polyester/34 percent rayon/ one percent metallic; the swatch is shown in Figure 4-22. The second swatch was olive with metallic thread embroidery shown in Figure 4-23. The base material was 60 percent linen and 40 percent rayon; the embroidery was 70 percent polyester/30 percent metallic. The third swatch was a black velvet which was 100 percent polyester with metallic gold thread. This swatch is shown in Figure 4-24. The fourth swatch was a black and gold metallic vine brocade composed of 57 percent nylon/25 percent metallic/18 percent polyester. This is shown in Figure 4-25. The first three swatches dried in less than three minutes. The black and gold brocade swatch ignited and was destroyed. This swatch, like the hairy metallic silver fabric, is made of nylon and metallic. The brocade was also destroyed in the unit.

Figure 4-22. Red/Black Metallic Thread Swatch

Figure 4-23. Olive Swatch with Metallic Embroidery

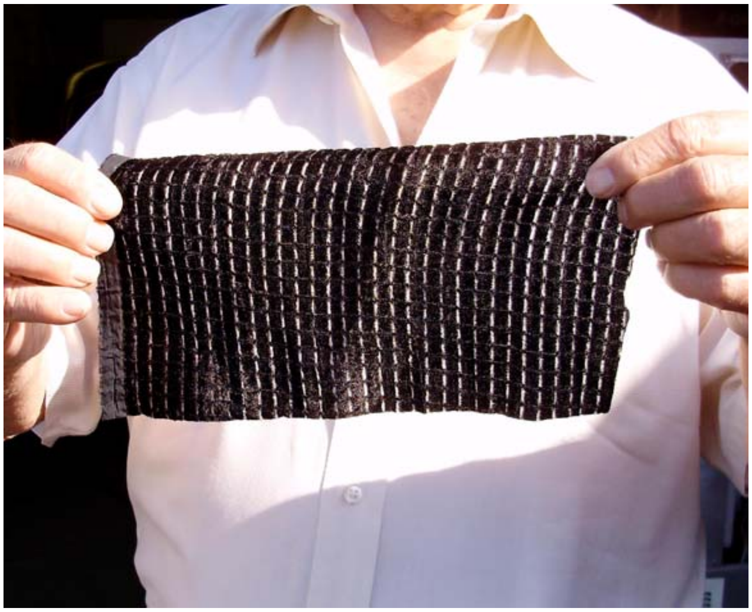
Figure 4-24. Black Velvet Swatch with Metallic Thread


Figure 4-25. Black/Gold Brocade Metallic Swatch

During the testing, it was verified that common metals like zipper components, studs and snaps can be dried without problems in the microwave dryer. It was also verified that some garments with metallic thread can be successfully dried in the dryer. Fabrics composed of nylon and/or metallic would probably pose a problem in a microwave dryer.

The microwave dryer, like the vacuum system, could be modified to perform both washing and drying in one system. It does hold some promise for the garment cleaning industry. For safety reasons, metallic thread containing garments should probably be dried in a standard heated dryer and not in the microwave system. The microwave dryer concept is farther from commercialization than the vacuum system described earlier.

V. SUMMARY AND CONCLUSIONS OF THE TESTING AND ANALYSIS

PERC dry cleaning will be phased out completely in California by 2023. Cleaners routinely use spotting chemicals before and after the main cleaning process to remove spots from the garments they clean for consumers. These spotting chemicals have historically been composed of PERC and TCE which are halogenated solvents. Both chemicals are carcinogens. A new halogenated spotting chemical, nPB, has recently been introduced into the market; this chemical is a reproductive toxin and it causes nerve damage. About one-third of the cleaning facilities in the state have converted away from PERC dry cleaning but many of them continue to use the PERC and TCE based spotting chemicals and some may start to use the nPB spotting agent. Cleaners who have adopted wet cleaning provide a pathway to the sewer if they use the halogenated spotting agents and they could contaminate their sites. Cleaners who have adopted alternative solvent technologies could face higher disposal costs for their waste streams and could also contaminate their sites.

There is a strong need for alternative safer spotting agents. As part of this project, IRTA tested three alternative water-based spotting agents and one alternative soy based spotting agent with four cleaning facilities. In earlier work, IRTA had tested one additional water-based cleaner and a soy based cleaner with several cleaning facilities. All of the alternatives performed well and all are less costly than Picrin, the major TCE based spotting chemical used today. All of these alternative spotting chemicals can be purchased from suppliers and the contact information is provided in Section II of this document.

The BAAQMD has adopted a regulation that bans the use of halogenated spotting chemicals. All of the safer alternatives, the four water-based cleaners and the two soy cleaners, could be used in the Bay Area and would allow the cleaners to comply with the regulation. CARB is planning to adopt a regulation on spotting chemicals over the next year. The agency is likely to restrict the use of halogenated spotting agents and establish a VOC limit for spotting chemicals. The alternatives tested and evaluated during this project would probably be suitable alternatives when the CARB regulation is in place.

Most cleaners who have converted away from PERC dry cleaning have adopted hydrocarbon cleaning. The hydrocarbon is a VOC and may eventually be regulated for that reason. From an overall health and environmental standpoint, the best alternative technologies are carbon dioxide cleaning and water-based cleaning processes. Cleaners are reluctant to use these technologies and there are very few cleaners using them today. In this project, IRTA examined methods of making carbon dioxide and water-based cleaning more acceptable to cleaners.

Carbon dioxide cleaning machines are very expensive and the process does not clean aggressively. IRTA determined that two groups may decide to build carbon dioxide machines in the future that are much lower in cost than the systems offered today. IRTA tested two alternative methods for improving the cleaning capability of carbon dioxide.

The first method, using tonsil in place of detergent and distillation, did show slightly improved cleaning in the cleaning tests that were conducted. The second method, using a new detergent, did not show improved cleaning in the cleaning tests that were conducted. The two cleaners who tested the new detergent did prefer certain things about the performance, however.

Cleaners have not embraced water-based cleaning processes because they are concerned that they will shrink the garments and cause higher finishing costs. Heated drying and immersion in water-based cleaning can contribute to these problems. IRTA identified a technology, Green Jet, which can be paired with small low-cost wet cleaning equipment to clean all types of garments and minimize the finishing cost increases. Garments are not immersed in the Green Jet machine and it can be used for as much as 50 percent of the garment stream. Case studies for two cleaners using the Green Jet technology are presented.

IRTA examined two alternative drying methods that should minimize or eliminate the problems with traditional wet cleaning. Extensive tested was conducted with a small vacuum test system and a larger test unit at the manufacturer's site. Garments were dried more quickly in this system which would reduce the cycle time and could dry with lower heat so shrinkage could be avoided. The results of the testing indicate that use of a vacuum system for both washing and drying holds promise as a viable method of water-based cleaning for this industry. Dilute hydrogen peroxide or non-surfactant containing detergents could be used in the cleaning step. Further work on a larger prototype system would be necessary so the equipment and process variables could be optimized for commercialization.

IRTA also tested microwave drying in a test unit. Although the system is further from commercialization for this industry than the vacuum system, it also offers promise. Garments were dried more quickly in the test unit and with lower heat. The microwave system could also be used for both washing and drying. Garments containing zippers, snaps and studs were successfully dried. Some garments made of nylon with metallic thread dissolved in the system and would have to be processed in a different manner.

VI. REFERENCES

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