DEVELOPMENT OF SAFER CLEANING ALTERNATIVES IN THE AEROSPACE, PRINTING AND COATING INDUSTRIES

Prepared for:
U.S. Environmental Protection Agency
Office of Atmospheric Programs, Global Programs Division
Alternatives and Emissions Reductions Branch
Under Grant Assistance Agreement X-82915501

Prepared by:
Mike Morris and Katy Wolf
Institute for Research and Technical Assistance

June 2004

DISCLAIMER

The mention of any products, companies, or source reduction technologies, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products, companies, or technologies.

This project was funded by the U.S. Environmental Protection Agency (EPA). The contents of this document do not necessarily reflect the views and policies of EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ACKNOWLEDGMENTS

This analysis benefited considerably from the efforts of many persons within and outside the Institute for Research and Technical Assistance (IRTA). We would particularly like to acknowledge the valuable contributions made by Margaret Sheppard, the EPA project officer. We are especially grateful to the companies that agreed to test alternatives or use their case studies for this project. Finally, we appreciate the efforts of Amy Blume of IRTA in helping to prepare the document.

EXECUTIVE SUMMARY

Many companies in the United States used ozone-depleting solvents extensively. When production of these solvents was banned in accordance with the Montreal Protocol, companies had to identify, test and implement alternatives. Some of the alternatives posed other health and environmental problems. Many of them are classified as Volatile Organic Compounds (VOCs) that contribute to smog and some of them are toxic to workers and people who work and live in communities surrounding industrial operations.

The Institute for Research and Technical Assistance (IRTA) is a nonprofit organization established to assist companies in adopting alternatives to ozone depleting, toxic and VOC solvents. Under EPA sponsorship, IRTA conducted this project in Southern California to test and demonstrate low-VOC, low toxicity alternatives in three cleaning categories:

- Aerospace Handwipe Cleaning;
- Coating and Adhesive Application Equipment Cleaning; and
- Printing Application Equipment Cleaning

Low-VOC, low toxicity alternatives that were tested included water-based cleaners, soy based cleaners and acetone. IRTA worked with 15 companies in the three cleaning categories with 17 cleaning operations to identify, test and demonstrate suitable alternatives. The performance of the alternatives was evaluated on a case-by-case basis. IRTA conducted cost analysis to compare the cost of using the original materials with the cost of using the safer alternative.

IRTA worked with three companies that perform aerospace handwipe cleaning. A water-based cleaner performed successfully for one of the companies cleaning electronic devices. Water-based cleaners and acetone worked effectively as alternatives for the second company that repairs and refurbishes aircraft components. Acetone performed well as an alternative for cleanliness testing of gauges.

IRTA worked with eight companies that conduct spray equipment cleaning operations. For cleaning aerospace coatings, metal coatings, some autobody coatings and some architectural coatings, acetone provided to be a suitable and effective alternative. For wood furniture coatings and adhesives, water-based cleaners and acetone performed well. For some autobody coatings, acetone combined with methyl acetate was a good alternative.

IRTA worked with five companies that performed printing services of different kinds. Various alternatives including water-based cleaners, soy based cleaners and acetone blends, worked well depending on the characteristics of the printing process.

Two of the aerospace companies converted to the alternatives. One of the companies reduced their cleaning cost through conversion to the alternative. The second company increased their cost somewhat by converting to the alternatives. Five of the companies conducting spray application equipment cleaning converted to the alternatives. Four of these companies reduced their costs through the conversion. Three of the printing companies converted to the alternatives and all three reduced their costs through the conversion. Case studies that describe the conversion and include the cost comparison in each case were developed.

This document should be useful to companies that have cleaning operations similar to those that were examined here. Most of the companies participated in the project because there were regulations that affected their operations. The results would be applicable to other companies that wished to adopt safer alternatives because of regulations or because they have a commitment to better protect human health and the environment. A summary of the results for each type of process and each soil to be cleaned is in Chapter V of the report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION AND BACKGROUND

Section VI of the Clean Air Act Amendments (CAAA) of 1990 gave the U.S. Environmental Protection Agency (EPA) the authority to phase out the production of certain Class I and Class II Ozone Depleting Substances (ODSs) because they contributed to stratospheric ozone depletion. The legislation implements the Montreal Protocol, an international agreement, ratified by several countries including the U.S., that banned the production of certain ozone depleting substances in 1996. The CAAA also authorized EPA to evaluate the alternatives to the ODSs. EPA established the Significant New Alternatives Policy (SNAP) program for this purpose. The mission of the SNAP program is to investigate alternatives to the ODSs and to approve them, to approve them with restrictions on use, or to deem them unacceptable. Over the last several years, EPA has evaluated hundreds of petitions from industrial firms that wished to market alternatives to the ODSs. Numerous alternatives have been approved.

In the solvents arena, two ODSs were used extensively. 1,1,1-Trichloroethane (TCA) was widely used in solvent applications for a range of cleaning activities and as a carrier in adhesives and coatings. CFC-113, a chlorofluorocarbon, was primarily used in electronics, precision cleaning and high technology cleaning applications. TCA and CFC-113 production was banned in 1996 so companies using these solvents had to identify, test and implement alternatives. Congress also passed legislation that placed a tax on several ODSs including TCA and CFC-113 that was designed to increase over time. In many cases, companies adopted alternatives that do not contribute to stratospheric ozone depletion but they do cause other problems. Nearly all the alternatives are classified as Volatile Organic Compounds (VOCs) that cause smog and many of them pose toxicity problems.

1.1. Target Applications

This aim of this project was to assist companies in testing and, in some cases, adopting alternatives that minimize the health and environmental problems of the cleaning solvents used by most companies today. Once the alternatives were demonstrated, the information could be used by companies all across the country. The project had three areas of focus: aerospace handwipe cleaning, coating and adhesive application equipment cleaning and printing application equipment cleanup.

Aerospace companies relied heavily on TCA and CFC-113 in handwipe cleaning operations. In these operations, the cleaners were generally used with a wipe cloth or other application means to remove contaminants from parts during manufacture or assembly of aerospace components. When production of the two solvents was banned and the tax was levied on them and their price increased, the industry converted to a variety of alternatives. Alternatives that are widely used by this industry today include methyl ethyl ketone (MEK), toluene, xylene, methyl isobutyl ketone (MIBK), glycol ethers and isopropyl alcohol (IPA). All of these solvents are VOCs that contribute to photochemical smog and many of them have toxicity problems.

In the coatings and adhesives industries, TCA was once used extensively in formulations primarily because it was relatively low in toxicity based on its fairly high Permissible Exposure Limit (PEL) set by the Occupational Safety and Health Administration (OSHA) and because it was not classified as a VOC. TCA was also used to clean the lines and spray guns and other application equipment that are used to apply the paints and glues. With the production ban on TCA and price increases because of the accelerating tax, the industries converted to a variety of alternative solvents for cleaning the application equipment including MEK, toluene, xylene, mineral spirits and lacquer thinner. These solvents are VOCs and they are toxic or contain certain toxic components.

In the printing industry, TCA was historically used in ink formulations and in solvents used to clean the application equipment in lithographic and screen printing. After the production ban became effective and the price of TCA increased because of the excise tax on ozone depleting substances, printers adopted alternative cleanup solvents including methylene chloride, toluene, xylene, various types of alcohols, glycol ethers and mineral spirits. Again, most of these solvents are VOCs and they are considered toxic or contain components that are considered toxic.

1.2. Project Setting

The Institute for Research and Technical Assistance (IRTA) is a non-profit organization that was established in 1989. IRTA's mission is to assist companies in adopting low- or non-solvent technologies. IRTA is located in Glendale, California and has worked with hundreds of companies in Southern California on solvent alternatives. IRTA works with individual companies to assist them in converting to alternatives and IRTA also works on projects that identify and implement alternatives that are suitable for whole industries. IRTA runs and operates the Pollution Prevention Center (PPC). PPC members include EPA Region IX, Los Angeles County Sanitation Districts, City of Los Angeles Bureau of Sanitation, Orange County Sanitation District, Cal/EPA's Department of Toxic Substances Control, the California Department of Health Services, the South Coast Air Quality Management District, Santa Barbara County Air Pollution Control District and Southern California Edison. The PPC partners include representatives from agencies and organizations that focus on wastewater discharge, hazardous waste, air pollution, worker exposure and energy use. The PPC works on issues of mutual interest. IRTA and the PPC have extensive experience in developing and implementing safer cleaning alternatives.

During this project, IRTA worked with 15 companies in Southern California on 16 different operations to identify, develop, test and implement alternatives. Generally, these companies were small or medium sized. The air district in Southern California, the South Coast Air Quality Management District (SCAQMD), regulates air emission from companies located in four counties including Los Angeles, Orange, Riverside and San Bernardino. All of the companies participating in the project are within these four counties. The South Coast Basin is designated by EPA as an extreme non-attainment area. The SCAQMD is developing VOC regulations that will assist the region in achieving attainment. The state of California and the SCAQMD also have very stringent regulation on toxic air contaminants. Companies in Southern California, as a result, are more willing to test and adopt alternative low-VOC, low toxicity alternatives than companies in other parts of the country.

One of the SCAQMD's regulations that focuses on cleaning applications has future compliance limits for which technology has not yet been specified. This rule is SCAQMD Rule 1171 "Solvent Cleaning Operations." This regulation has future VOC compliance limits for electronics cleaning, coating and adhesive application equipment cleaning and printing application equipment cleaning. Table 1-1 shows the applications of interest as they are listed in Rule 1171. The table shows the VOC limit for each of the applications currently and it also specifies the target VOC content of the cleaning systems established in Rule 1171 for 2005.

Table 1-1
Cleaning Applications and SCAQMD Rule VOC Limits

Cleaning Application	VOC Content (grams per liter) Current	2005
Product Cleaning		
Electrical Apparatus Components & Electronic Component	500	100
Repair & Maintenance Cleaning		
Electrical Apparatus Components & Electronic Components	900	100
Cleaning of Coatings or Adhesives Application Equipment	550	25
Cleaning of Ink Application Equipment		
Screen printing	750	100
Lithographic or Letter Press Printing		
--roller wash step 1	600	100
--roller wash step 2, blanket wash & on-press components	800	100
--removable press components	25	25
Aerospace Cleaning Solvents	200 g/L or 45 mm Hg composite partial pressure	
Batch Loaded Cold Cleaning of Fluid Systems under certain conditions	no limit	25

Table 1-1 also shows the current VOC content limit for aerospace handwipe cleaning. These handwipe activities are regulated by another regulation, SCAQMD Rule 1124 "Aerospace Assembly and Component Manufacturing Operations." Finally, the table also shows the VOC limits for cleaners used in batch loaded cold cleaning equipment to clean various types of parts. Cleaning in batch loaded cold cleaners is regulated by SCAQMD Rule 1122 "Solvent Degreasers."

Table 1-1 shows that the allowed VOC content for cleaners used to clean electronic components will be reduced to 100 grams per liter VOC in July of 2005. It also shows that the allowed VOC content of cleaners used for cleaning coating and adhesive application equipment will decline to 25 grams per liter VOC in 2005. It illustrates that the allowed VOC content of cleaners used to clean screen printing and lithographic on-press application equipment will be reduced to 100 grams per liter VOC in 2005. Cleaners used to clean off-press components in lithographic printing currently are limited to 25 grams per liter VOC. Cleaners used in aerospace handwipe applications are allowed a VOC content of 200 grams per liter VOC or they can have a vapor pressure of 45 mm Hg; the aerospace handwipe cleaning category does not have a VOC reduction in 2005. Finally, cleaners used in batch loaded cold cleaners that have an open top surface area less than 1.0 square foot or that have a capacity of less than two gallons for cleaning fluid systems are currently exempt from VOC limits; in January of 2005, the VOC limit for these cleaners is 25 grams per liter.

The companies in Southern California that IRTA worked with on this project must all comply with the VOC content limits shown in Table 1-1. Since the future VOC limits become effective in 2005, IRTA only tested alternatives that would meet those limits. In the case of aerospace handwipe cleaning which has no future VOC limit, IRTA tried to test alternatives that met a 100 gram per liter VOC content limit.

1.3. Project Approach

IRTA and EPA decided to investigate low-VOC, low toxicity alternatives by working with specific companies in the South Coast Basin that conduct the operations listed in Table 1-1.

Table 1-2 shows the companies and the electronics or aerospace handwipe cleaning operation for which low-VOC, low toxicity cleaners were targeted. Tables 1-3 and 1-4 show the same type of information for coating and adhesive application equipment and printing operations.

Table 1-2
Companies Participating in EPA Project with Aerospace Handwipe Operations

Cleaning Application	Company
Electronic Components	Hydro-Aire
Fluid Systems	Fortner Engineering

Scientific Instruments	Astro Pak

Table 1-3
Companies Participating in EPA Project with Coating or Adhesives Applications

Operation	Company
Aerospace Coatings	Hydro-Aire California Propeller
Metal Coatings	Metrex
Wood Coatings	Bausman & Father
Autobody Coatings	Holmes Westway
Architectural Coatings	PCM Leisure World
Adhesives	Sanitop

Table 1-4
Companies Participating in EPA Project with Printing Applications

Operation	Company
Lithographic Printing	City of Santa Monica Print Shop Huhtamaki
Metal Screen Printing	Accurate Dial & Nameplate
Varied Screen Printing	City of Santa Monica Paint Shop
Textile Screen Printing	Quick Draw

1.4. Cleaner Performance

Performance of the alternative cleaning agent(s) at each facility in each application was evaluated on a case-by-case basis. In each instance, the plant personnel provided information on their requirements for the cleaning process. In nearly all cases, the major criterion was if the cleaning was sufficient to go on to the next processing step. For spray gun cleaning, for example, if the spray equipment is clean, it should be able to be used successfully in applying the next coating that is required. In terms of performance, a cleaning system was judged successful if it cleaned as well as or better than the cleaning process the company uses currently. When there were differences in the cleaning process, these were noted.

1.5. Cost Analysis

IRTA performed cost analysis for each of the alternatives that was successfully tested at each of the facilities participating in the project. Components included in the cost analysis were:

- capital costs where equipment needed to be purchased
- labor costs where there were differences in labor between the currently used cleaner and the alternative cleaner(s)
- cleaner costs
- electricity costs where there were differences
- regulatory fees
- disposal costs
- other relevant costs like maintenance costs, for example

For the capital costs, IRTA generally assumed a ten year useful life of equipment and amortized the capital cost over this period assuming a cost of capital of two percent. For labor costs, IRTA used the labor rate at the participating facilities. For the cleaner cost, IRTA used the cost of the cleaner paid by the facility where this cost was known. In some cases, where the facility did not elect to use the cleaning alternative, IRTA used an estimate based on the cost of the product in commerce. The cost of electricity was assumed to be 12 cents per kWh. The regulatory fees for VOC and toxics emissions were taken from SCAQMD Rule 301. The disposal costs were estimated through conversations with waste haulers.

All of the assumptions that were made in the cost analysis are described in detail in the sections for each participating facility. This method makes the costs transparent so that they could be calculated based on other assumptions.

1.6. Low-VOC, Low Toxicity Alternatives

Plant personnel also had other criteria that related to safety and regulations. Understandably, they did not want to use cleaning agents that were toxic and posed a risk or a potential risk to workers or that appeared on various toxics lists. In order to minimize the risks of the cleaning agents to the workers and the surrounding community, a hierarchy was used for the testing. If water-based cleaners could be used in the process, then water-based cleaners without solvent additives were tested first. If these did not work effectively, water-based cleaners with solvent additives or soy based cleaners were tested. These chemicals are low in toxicity and VOC content. If these did not work well, acetone and acetone blends with VOC cleaners were tested. Acetone is exempt from VOC regulations and is low in toxicity. In a few cases, other chemicals that are exempt from VOC regulations, like methyl acetate for example, were also tested. More detail on each of these alternatives is presented below. Material Safety Data Sheets for a number of these alternatives are presented in Appendix C.

1.6.1. Water-Based Cleaners

Three water-based cleaners were tested at one or more facilities in the course of the project. One of these cleaners, Spray Clean 12, is made by Applied Cleaning Technologies in Anaheim. It is an alkaline cleaner that has been certified as a Clean Air Solvent by the SCAQMD. The District indicates that the cleaner concentrate contains zero VOC. This cleaner was successfully tested for spray gun cleaning after application of wood furniture coatings.

The second water-based cleaner that was tested successfully is called Mirachem Pressroom Cleaner. It is a neutral cleaner that has received Clean Air Solvent Certification from the SCAQMD. The cleaner concentrate contains 75 grams per liter VOC. This cleaner worked well for removing ink in one of the screen printing and one of the lithographic printing cleanup applications.

A third water-based cleaner was tested at one facility for cleaning application equipment. It is called GD815 and is made by Brulin. The cleaner is certified by SCAQMD as a Clean Air Solvent and the VOC content of the concentrate is 15 grams per liter.

Hydro-Aire adopted a water-based saponifier for cleaning flux from connectors. Fortner adopted a variety of water-based cleaners for use in a range of water-based cleaning operations.

1.6.2. Soy Based Cleaners

Soy based cleaners are composed of methyl esters. IRTA asked the State of California, Department of Health Services, Hazard Evaluation System & Information Services (HESIS) group to evaluate the toxicity of the soy cleaners. Based on available data and their structure, HESIS indicated that these cleaners were likely to have low toxicity. One of the soy based cleaners tested for spray gun cleaning by IRTA, called Soy Gold 1000, is made by AG Environmental Products. This cleaner has been certified as a Clean Air Solvent by SCAQMD; the cleaner has a VOC content of less than five grams per liter. IRTA also successfully tested another soy product called Soy Gold 2000 which is made by the same company in screen and lithographic printing applications. The VOC content of this water rinsable product is less than 20 grams per liter.

1.6.3. Acetone

Acetone cleaners were widely and successfully tested by IRTA during the project in aerospace handwipe cleaning, in spray gun cleaning and in screen and lithographic printing cleanup. Acetone is exempt from VOC regulations and it is low in toxicity compared with most organic solvents.

One of the issues that arises with the use of acetone is its low flash point. National fire department regulations specify that no more than 15 gallons can be used in open containers at any given time. No more than 60 gallons can be stored in the facility at one time. If firewalls or other fire department approved building improvements are installed, more of the chemical can be used and stored. Local regulations, which might have different requirements, should also be consulted.

1.6.4. Methyl Acetate

IRTA tested methyl acetate successfully in a blend with acetone for spray gun cleaning in autobody applications. Methyl acetate is exempt from VOC regulations. It has medium toxicity but forms methyl alcohol, a listed toxic, as a metabolite. IRTA tried to maximize the use of acetone which is less toxic in the blend with methyl acetate. Methyl acetate, like acetone, has a low flash point and the same fire department regulations apply to methyl acetate and acetone.

1.7. Adopting Alternatives

Some of the companies that participated in the project elected to adopt a safer alternative that worked effectively. Companies are generally motivated to participate in projects to test alternatives if there is a pending regulation or possible future regulation that would require an alternative to be used. Some companies did adopt the alternatives IRTA tested with them. Other companies decided not to convert to the alternative at this time. They would have an alternative to adopt if and when a regulation became effective.

In the discussions for each of the facilities testing the alternatives, IRTA based the information for the performance and cost on the testing results. Some of the alternatives perform differently depending on how they are used in the process and this should be taken into account when evaluating the testing. For instance, acetone was tested as an alternative in many of the applications. Acetone has a very high vapor pressure so it evaporates readily if it is not used in a closed system. In some cases like spray gun cleaning in an enclosed spray gun cleaning system, the use of the acetone alternative is likely to be the same as the solvent used currently. In contrast, in other cases where the cleaning occurs in an open bucket, more acetone than the solvent used currently might be required. The characteristics of the process were taken into account in each case to determine the assumptions for the cost analysis.

1.8. Report Organization

This report is organized into sections that focus in more detail on each of the generic application areas. Section II describes the work that was performed on alternatives for aerospace handwipe cleaning processes. Section III addresses the testing and results of the alternatives in coating and adhesive application equipment cleaning. Section IV focuses on the alternatives that were tested in printing applications. Section V summarizes the results of the project. Appendix A provides Material Safety Data Sheets (MSDSs) for some of the coatings used by the facilities in this project. Appendix B includes stand-alone case studies for some of the companies that participated in the project and decided to make a conversion to alternatives. Appendix C provides MSDSs for some of the alternative cleaning agents that were tested during the project.

II. ALTERNATIVES IN AEROSPACE HANDWIPE CLEANING

There are hundreds of aerospace companies in the nation. In Southern California, there are numerous small and medium sized aerospace subcontractors that perform work for the larger aerospace companies and the government. As part of their operations, these subcontractors must perform cleaning during their manufacturing or repair and maintenance operations. Two ozone depleting solvents, TCA and CFC-113, were used extensively by aerospace subcontractors. When the production ban for these solvents became effective in 1996 and when the Congressional tax raised the price of using the solvents, many aerospace companies began testing and converting to alternatives. Some of the alternatives that were adopted include VOC solvents like MEK, toluene, xylene, MIBK and isopropyl alcohol. Some of these solvents are also considered to be toxic.

In the South Coast Basin, the SCAQMD has several rules that regulate aerospace cleaning activities. As discussed in the introduction, the VOC limits for these activities vary depending on the type of cleaning and the type of equipment used. During this project, IRTA tried to identify and test alternatives that had a VOC content less than 100 grams per liter for the aerospace sector.

2.1. Preliminary Laboratory Testing

Table 1-2 showed the list of companies IRTA worked with on aerospace handwipe cleaning alternatives during the project. Table 2-1 summarizes the companies that participated in the project and the specific applications that were addressed. In some cases, IRTA obtained contaminated parts from the companies and performed preliminary testing using different cleaning agents that might be suitable. The most promising cleaning agents were then taken to the facility for field testing.

Table 2-1
Aerospace Handwipe Cleaning Applications

Company	Application
Hydro-Aire	Cleaning of Electronics Components
Fortner	Cleaning of Aircraft Parts
Astro Pak	Cleaning of Gauges

2.2. Field Testing

For each of the companies participating in the project, IRTA developed a test plan for testing the alternative cleaning agent(s). In general, the test plans involved some initial testing at the site to screen potential alternatives. If the tests were successful, IRTA requested that the company perform a scaled-up longer term test of the alternatives. In two cases, Hydro-Aire and Fortner, the companies decided to convert to the alternatives and, in one case, Astro Pak, the company did not convert.

The description of the testing and the cost analysis of the alternatives for each of the facilities is described below. IRTA generally attempted to include all the costs a company would incur in the cost comparison of the alternatives with the cleaning system that is currently used. IRTA relied on input from the companies participating in the study for the cost estimates. In the two cases where the companies did convert to alternatives, stand alone case studies that describe the conversions are presented in Appendix B.

2.2.1. Hydro-Aire

Hydro-Aire is an aerospace subcontractor that manufactures braking systems and repairs pumps used in military and commercial aircraft. Hydro-Aire has been very progressive in adopting low-VOC, low toxicity alternatives.

As part of the EPA project, IRTA began working with Hydro-Aire to find alternatives in a process for cleaning pump connectors. For many years, the company used perchloroethylene (PERC) for removing rosin flux from the pump connectors in a handwipe operation. The company processed about 400 connectors each month. The connectors were cleaned with PERC, rinsed with deionized water (D.I.) and blown dry with compressed air using an air gun. The connectors were then rinsed with an MEK blend and air dried. A picture of the connectors is shown in Figure 2-1.

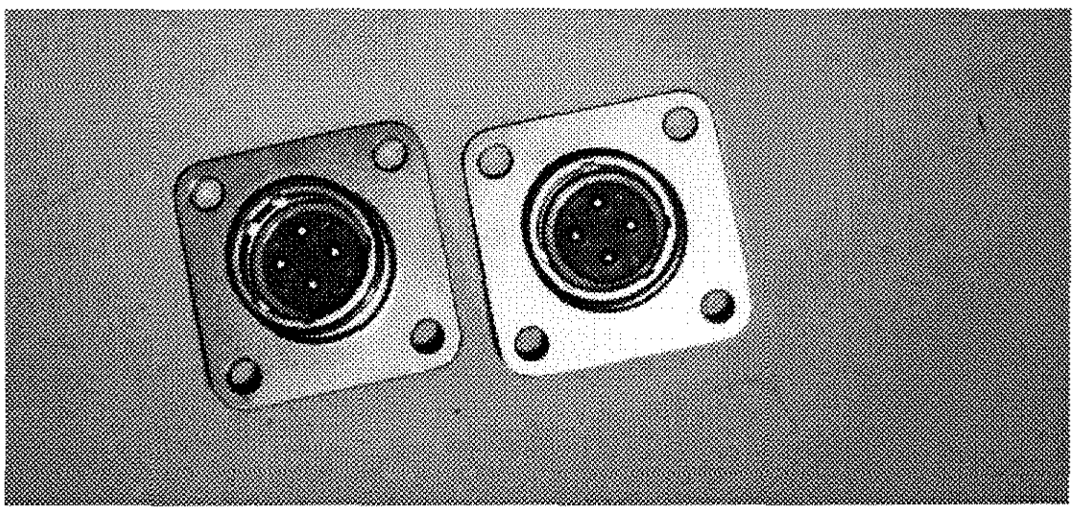

Figure 2-1. Connectors at Hydro-Aire

Under the EPA project, Hydro-Aire investigated water-based cleaning alternatives for removing the flux. After several months of testing, the company decided to use a saponifier for cleaning the rosin flux they were required to use in their contract. Hydro-Aire devised a very unusual method for cleaning the connectors. It involved using two large 30-cup coffee makers that could be heated. The first coffee maker contains a dilute solution of the saponifier that is used to remove the flux from the connectors. The second coffee maker contains plain D.I. water that is used to rinse the saponifier from the connectors. A picture of the two coffee pots used by Hydro-Aire in this operation are shown in Figure 2-2. After the connectors are rinsed, they are blown dry with compressed air. Instead of the MEK used previously, the connectors are rinsed with acetone and blown dry again.

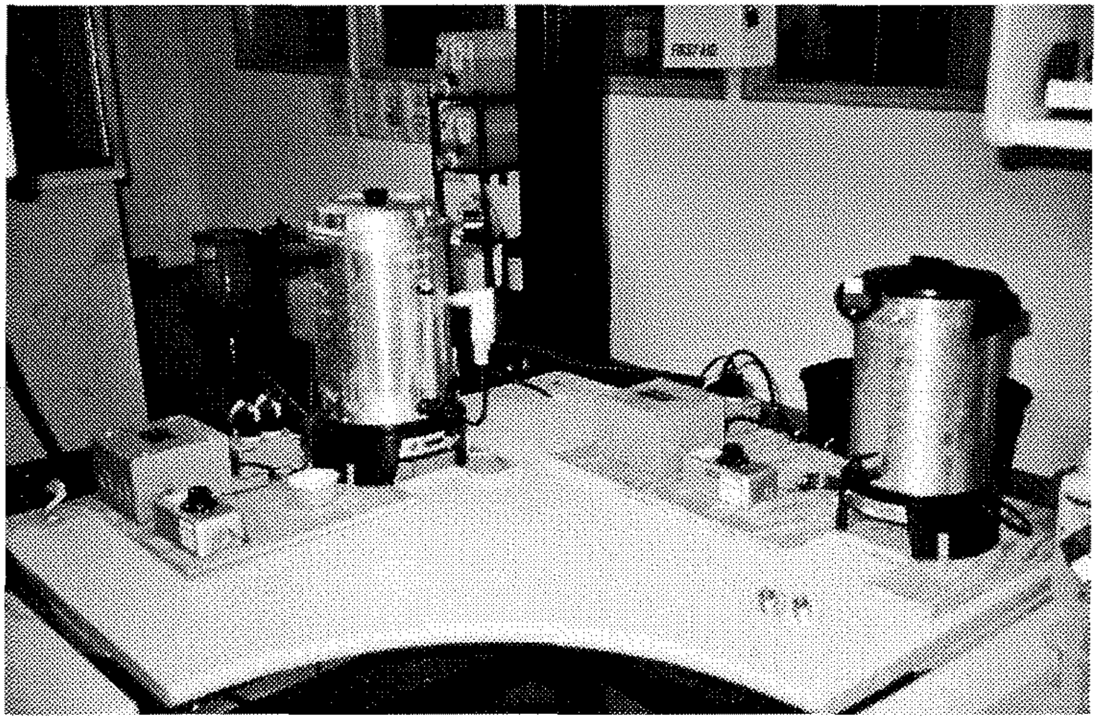

Figure 2-2. Connector Coffee Pot Cleaning System at Hydro-Aire

Hydro-Aire purchased two 30-cup coffee makers at a total cost of $200. Assuming a cost of capital of two percent and a 10-year useful life for the coffee pots for the cleaning purpose, the annualized capital cost amounts to $20.

Hydro-Aire used 80 ml of a PERC formulation called 5240 for cleaning each connector. Assuming the company processed 400 connectors per month, the annual volume of PERC required was 101 gallons. At a cost of $93.80 per gallon for the 5240, the annual cost of the formulation amounted to $9,474. For rinsing, the company used a formulation called Aero MEK. About 20 ml of this formulation were used for each connector. The annual volume of the formulation was about 25 gallons. Hydro-Aire paid $14.80 per gallon for the Aero MEK. The annual cost of the formulation amounted to $370. The total chemical costs for the operation were $9,844 per year.

The water-based saponifier, called Bio-Kleen, is used in a nine percent solution in a 3,200 ml tank and the solution is changed out three times each day. The volume of Bio-Kleen used each day is 0.23 gallons. The annual use of the cleaner, assuming 260 days per year usage, is about 60 gallons. The cost of the Bio-Kleen is $82.65 per gallon. On this basis, the annual cost of the Bio-Kleen is $4,959. The same volume of acetone is used for the rinsing as Aero MEK. At a usage rate of 20 ml per connector, the amount of acetone used annually for rinsing is 25 gallons. At a cost of $12.75 per gallon for acetone, the annual cost of acetone for rinsing is $319. The total cost for purchasing the cleaners that are used currently is $5,278.

When Hydro-Aire used the PERC based cleaner, each of the connectors required 2 minutes of handling for cleaning, rinsing and drying. The labor requirement was 13.3 hours per month or 160 hours per year. Assuming a labor cost of $19 per hour, the annual labor cost was $3,040. The new water cleaning process requires more labor, about three minutes of handling for each connector. The labor requirement is 20 hours per month or 240 hours per year. Again assuming a labor rate of $19 per hour, the annual labor cost is now $4,560.

There were no electricity costs for the PERC cleaning process. For the water-based process, each coffee pot has an electrical draw of three kW and each pot is operated for eight hours per day. Assuming the coffee pots are maintaining temperature only 25 percent of the time they are on and that they operate 260 days per year, the annual electricity requirement is 3,120 kWh. Assuming a price for electricity of 12 cents per kWh, the annual cost of electricity amounts to $374.

The PERC and Aero MEK used in the earlier operation evaporated so there was no need to dispose of hazardous waste. The Bio-Kleen solution, because it contains lead from the soldering operation, is handled as hazardous waste. About 2.5 gallons per day or, assuming 260 days per year of operation, 650 gallons per year of waste is generated. At a disposal cost of $2 per gallon, the annual disposal cost is $1,300. The acetone, now used for the rinse, does not require disposal because it evaporates.

Hydro-Aire paid an emission fee for a toxic compound to the South Coast Air Quality Management District for PERC. PERC use and emissions amounted to 101 gallons per year. Assuming a density for PERC of 13.47 pounds per gallon, Hydro-Aire emitted 1,360 pounds of PERC annually. At a cost of 26 cents per gallon, the emission fee was $354 per year.

Table 2-2 summarizes the cost comparison for the PERC and water-based processes. The values demonstrate that the new water-based cleaning total process cost is about 10 percent less than the total cost of the PERC based cleaning process.

2.2.2. Fortner Engineering and Manufacturing, Inc.

Fortner is a small company with 60 employees located in Glendale. The company has been a licensed Federal Aviation Administration (FAA) repair station since 1968. Fortner repairs aircraft components like hydraulic flight controls, actuators and linkages for Boeing, Douglas and a number of airlines.

Table 2-2
Annualized Cost Comparison for Hydro-Aire Connector Cleaning Process

	PERC Process	Water-Based Process
Capital Cost	-	$20
Cleaner Cost	$9,474	$5,278
Labor Cost	$3,040	$4,560
Electricity Cost	-	$374
Disposal Cost	-	$1,300
Emission Fee	$354	-
Total Cost	$12,868	$11,532

Fortner used a vapor degreaser for much of their cleaning. In 1998, the company converted to water-based cleaning systems and stopped using the vapor degreaser. In many of the company's operations, however, batch loaded cold cleaners that used a VOC solvent called tolusol were used. Tolusol is a blend of petroleum solvents and toluene. These cleaning operations are covered by an exemption in SCAQMD Rule 1122 that expires in 2005. IRTA began working with Fortner to find alternatives to the VOC solvent in 2000. At this stage, the company has converted nearly all of their operations to alternatives.

In the shipping and receiving area, the parts were cleaned in batch loaded cold cleaners using the tolusol. At this stage, the company uses a water-based parts cleaner for this cleaning activity.

After the parts are received from the field, they go to the tear down area where they are cleaned and dismantled. The company converted from several batch loaded cold cleaners containing tolusol to a water-based ultrasonic unit. In a few cases, the parts are cleaned with acetone. The company purchased a spray cabinet and a rust inhibition system as an alternative to the vapor degreaser and some of the parts that were cleaned in batch loaded cold cleaners are now cleaned in the spray cabinet. A picture of the spray cabinet is shown in Figure 2-3.

Many of the parts go to the honing and lapping area to be honed or lap fitted for the final assemblies. Fortner used the tolusol for cleaning the parts during the honing and lapping operations. The company purchased a glove box spray cleaning system and a small ultrasonic cleaning system that use water-based cleaners. These two cleaning systems are shown in Figures 2-4 and 2-5 respectively.

Some of the parts go through a non-destructive inspection procedure to determine if there are any cracks. Fortner was using batch loaded cold cleaners with tolusol for cleaning in this area. The workers now use the spray cabinet, an ultrasonic cleaning unit and the rust inhibitor system for cleaning.

In the hydraulic test area, the tolusol was used for cleaning. At this stage, the workers are using a parts cleaner containing a water-based cleaner in one operation. A picture of the

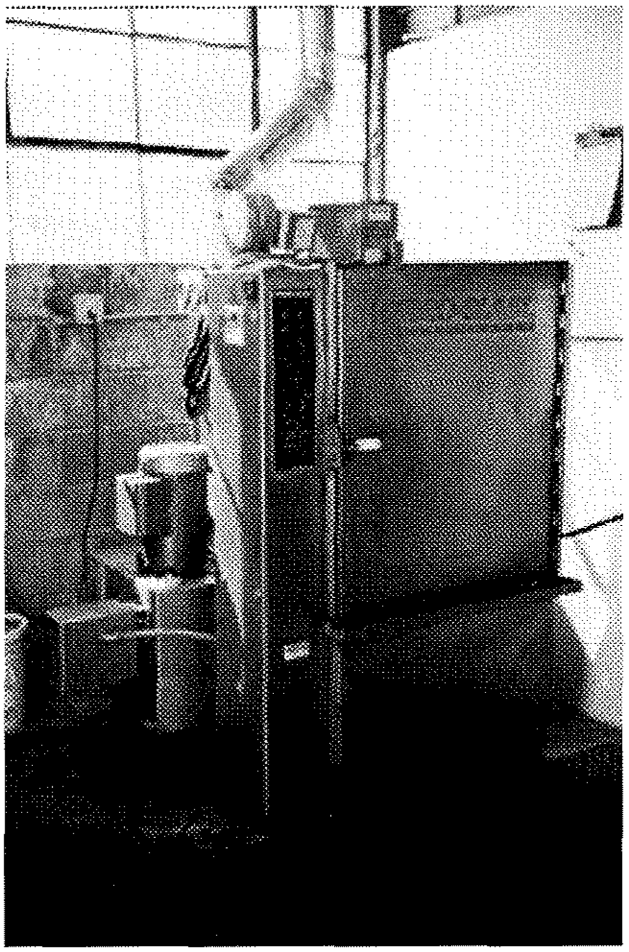

Figure 2-3. Spray Cabinet at Fortner Engineering

parts cleaner is shown in Figure 2-6. In another operation, acetone has replaced the tolusol.

In the past, Fortner purchased 1,320 gallons of tolusol annually for cleaning in several different areas. At a price of $4 per gallon, the annual cost of the tolusol amounted to $5,280. The company has a distillation unit that was used to distill the solvent so it could be reused. The three kW still was used for 90 hours per month. Assuming an electricity rate of 12 cents per kW, the annual cost of operating the still was $389.
Before the conversion to water-based cleaners, Fortner generated eight drums of hazardous waste per year. At a cost for disposal of $350 per drum, the total annual disposal costs amounted to $2,800.

Fortner purchased several water-based cleaning units when they converted away from the tolusol in batch loaded cold cleaning. The company purchased two ultrasonic cleaning systems. The cost of the larger system was $9,500 and the cost of the smaller system was $3,000. The company also purchased two plastic water-based parts cleaners for $1,000

Figure 2-4. Glove Box System at Fortner Engineering

each and one stainless steel parts cleaner for $1,500. A water-based spray glove box unit used in the honing and lapping area had a price of $5,500. Fortner also uses some of the water equipment they had purchased as an alternative to vapor degreasing for some of the cleaning that was previously done with the tolusol. The spray cabinet and rust inhibitor units are used about one-fourth time for cleaning parts that were previously cleaned with tolusol. Thus, one-fourth of the cost of the spray cabinet or $3,250 and one fourth of the cost of the rust inhibitor unit or $250 are included here. An evaporator is used to evaporate all of the spent water in the shop including mop water. Fortner estimates that the evaporator cost attributable to cleaning water generated from cleaning parts previously cleaned with tolusol is $438. The total capital costs for the conversion amount

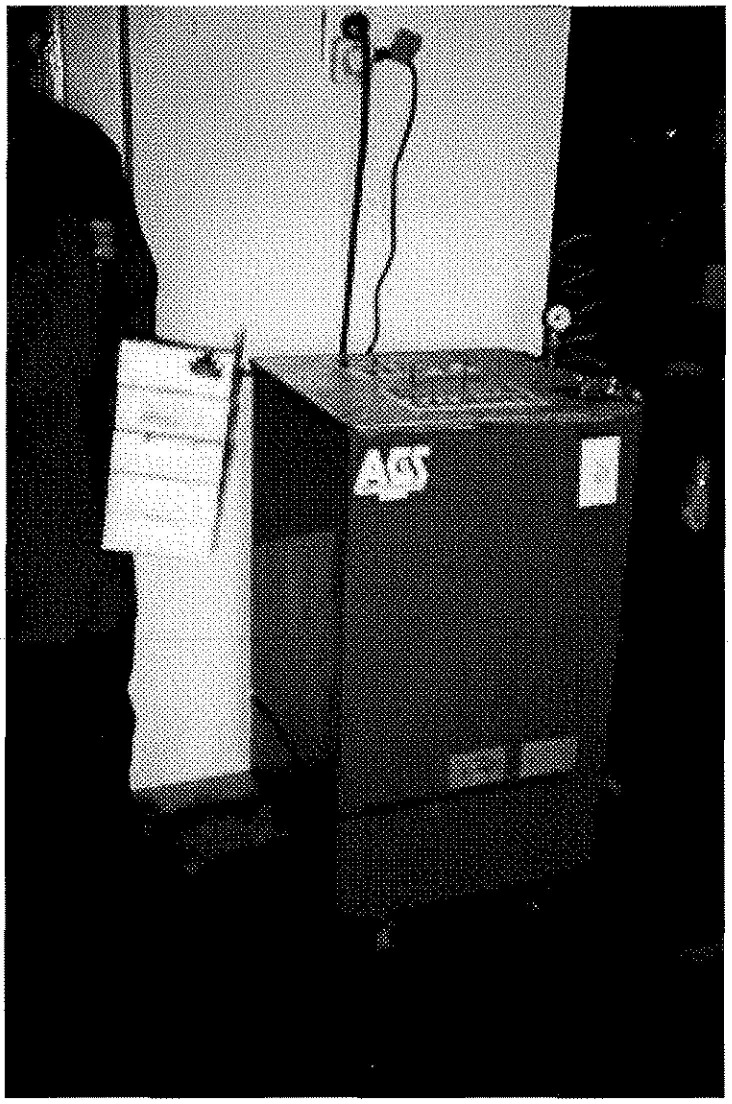

Figure 2-5. Small Ultrasonic System at Fortner Engineering

to $25,438. Fortner had to use an electrician to do some rewiring to accommodate the new water cleaning equipment. The cost was $4,000. The total capital and installation cost was $29,438. Assuming a 10-year useful equipment lifetime and a cost of capital of two percent, the annualized capital and installation cost is $3,003.

Fortner converted most of their operations from tolusol to water-based cleaners or acetone cleaning. Some operations remain, however, that will be converted over the next year or so. The company has reduced their tolusol use from 1,320 gallons per year to 528 gallons per year. At a cost of $4 per gallon, the cost of the remaining tolusol purchases is $2,112 annually. Fortner purchases 220 gallons per year of acetone at a

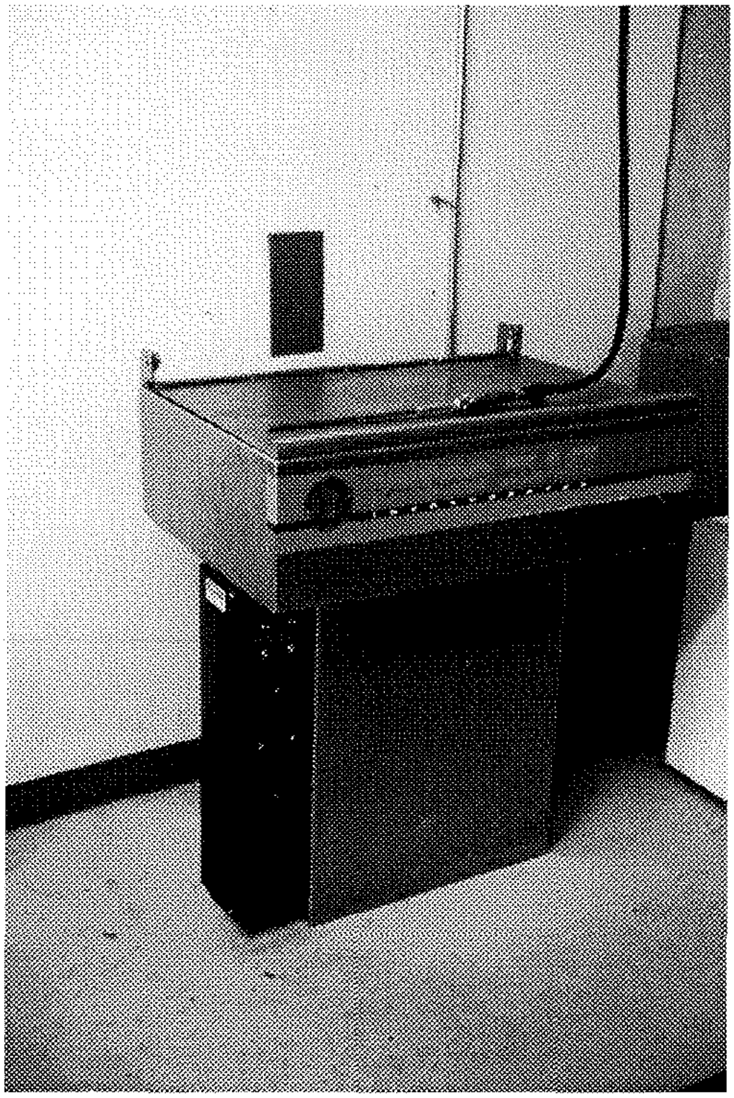

Figure 2-6. Parts Cleaner at Fortner Engineering

price of $4.50 per gallon. The total annual cost of acetone amounts to $990. Fortner purchases 45 gallons of a water-based cleaner at a cost of $9.90 per gallon and 40 gallons of another water-based cleaner at a cost of $12.90 per gallon annually. The total cost of the water-based cleaners is $962 per year. The company uses 10 gallons of rust inhibitor per year at a cost of $12.90 per gallon. Only one-fourth of this cost is attributable to this analysis; the remaining rust inhibitor is used in applications unrelated to cleaning. The annual cost of the rust inhibitor is $32. The total cost of cleaning agents amounts to $4,096 annually.

Fortner judges that the labor cost for using the solvent and the water-based cleaners is roughly the same. Some of the water cleaning systems automate the cleaning and lead to reduced labor but this is offset in some cases by a longer cleaning time.

The electricity cost increased when Fortner purchased the water-based cleaning equipment. The three parts cleaners use 1.5 kW of electrical each. The small and large ultrasonic systems are rated at 3 kW and 6 kW respectively. The glove box system is rated at 2 kW. The spray cabinet is rated at 20 kW but only one-fourth is included as an alternative to the tolusol. The rust inhibitor unit has an electrical rating of one kW but, again, only one fourth is applied as a tolusol alternative. All of this equipment is assumed to cycle on for about two hours per day. Assuming an electricity cost of 12 cents per kW, the total electricity cost for the water cleaning equipment amounts to $1,295 annually.

The evaporator is used to evaporate the water-based cleaners that are alternatives to the tolusol. The electrical rating for this operation is 11 kW. The evaporator is used for 36 hours per month but only 35 percent of the liquid is aqueous waste from the cleaning units. Assuming the heater cycles on 25 percent of the time and assuming an electricity cost of 12 cents per kW, the cost for running the evaporator is $50 per year.

After the conversion to water-based cleaners and acetone, Fortner reduced their hazardous waste generation from eight drums to two drums per year. At a disposal cost of $350 per drum, the total annual disposal cost amounts to $700.

Table 2-3 shows the cost comparison for the solvent and water-based systems. Through the conversion, Fortner reduced their use of tolusol by 792 gallons per year. The conversion increased Fortner's costs by about eight percent.

Table 2-3
Annualized Cost Comparison for Fortner Engineering Cleaning Processes

	Tolusol Cleaning	Water-Based Cleaning
Equipment/Installation Cost	-	$3,003
Cleaner Cost	$5,280	$4,096
Electricity Cost	$389	$1,345
Disposal Cost	$2,800	$700
Total Cost	$8,469	$9,144

2.2.3. Astro Pak

Astro Pak provides precision cleaning services to the aerospace, semiconductor and medical industries. The company is located in Downey, California. Astro Pak conducts precision cleaning and relies mainly on an ultrasonic water-based cleaning system for cleaning the parts. Some parts, however, are required to be cleaned by hand.

IRTA worked with Astro Pak to identify and test an alternative to isopropyl alcohol (IPA) for cleaning gauges for Boeing; these gauges are classified as scientific instruments. IRTA and Astro Pak conducted testing of several alternatives including a soy based cleaner, a water-based cleaner, acetone and a few blends of acetone and IPA. After the gauges are cleaned, Astro Pak uses non-volatile residue analysis (NVR) to determine whether the gauges are clean. The lower the NVR, the cleaner the parts.

During the testing, IPA was used as the control. The findings indicated that the parts had a lower NVR when acetone and acetone/IPA blends were used than they have with the IPA used currently. The soy based cleaner and the water-based cleaner left a residue so the NVR levels were higher.

IRTA performed the cost analysis for acetone because it was the alternative that gave the lowest NVR level. Astro Pak receives the gauges three or four times a year and each job requires the use of two to three gallons of IPA. Assuming an annual use of IPA of 10 gallons for the cleaning and assuming a cost for electronics grade IPA of $7.27 per gallon, the annual cost of cleaning the gauges with IPA amounts to $73. If acetone were used instead of IPA, Astro Pak would require 10 percent more because acetone has a higher vapor pressure than IPA. Astro Pak pays $7 per gallon for electronics grade acetone. On this basis, the annual cost for purchasing acetone for cleaning the gauges is $77.

Table 2-4 shows the cost comparison for IPA and acetone. The cost of using acetone is slightly higher than the cost of using IPA. It is important to note, however, that the acetone cleaned better than the IPA.

Table 2-4
Annualized Cost Comparison for Astro Pak for Scientific Instruments

	IPA	Acetone
Cleaner Cost	$73	$77
Total Cost	$73	$77

III. ALTERNATIVES IN COATING AND ADHESIVE APPLICATION EQUIPMENT CLEANING

Historically, most companies in Southern California used TCA for cleaning their coating and adhesive application equipment. TCA is exempt from VOC regulations and it is fairly low in toxicity so it was the preferred alternative. When the production ban for TCA went into effect in 1996 and the Congressional tax was placed on the chemical, it became very expensive to use. At that time, most companies that had previously used TCA converted to traditional VOC solvents for cleaning the application equipment. Alternatives that were adopted include MEK, toluene, xylene, mineral spirits and lacquer thinner. All of these alternatives are classified as VOCs and some are considered to be toxic.

As discussed in the introduction, SCAQMD Rule 1171 establishes VOC content limits of the solvents that can be used to clean coating and adhesive application equipment. Historically, the VOC limit for this cleaning activity was 900 grams per liter. Currently, the VOC limit for these cleaners is 550 grams per liter. Effective on July 1, 2005, the VOC limit for these cleaners declines to 25 grams per liter. During this project, IRTA worked with eight companies in the jurisdiction of the SCAQMD. IRTA tried to develop and test alternatives that met the 25 gram per liter VOC limit that will become effective in 2005. IRTA also tried to investigate alternatives that were lower in toxicity than the currently used cleaners.

3.1. Application Equipment Cleaning

Many companies apply coatings or adhesives as part of their production or maintenance process. Most often, companies use a spray gun to apply the coating or adhesive to the substrate. When the job is completed or, at the end of the day, the spray gun and the line through which the coating or adhesive flows needs to be cleaned. Some companies take the gun apart and clean the parts in a container like a bucket containing solvent. Sometimes a brush is used to scrub the parts. Other companies simply spray the solvent through the spray gun into the spray booth. Still other companies use an enclosed spray gun cleaner to clean the spray gun. The gun is mounted in the spray gun cleaner and the top of the device is closed. Solvent is flushed from a container below through the inside of the gun. The device also sprays the outside of the gun to remove any coating residue.

3.2. Preliminary Laboratory Testing

At the beginning of this project, IRTA approached Graco, a spray gun supplier, and requested that the company build a spray gun cleaning system similar to the current Graco enclosed spray gun cleaning system. IRTA requested that the Graco system be modified to contain a heater. IRTA also asked Applied Cleaning Technologies (ACT), located in Anaheim, to build a very small table top heated ultrasonic system that could be used for testing. IRTA conducted preliminary testing to determine which types of cleaners appeared appropriate for a number of different coatings and adhesives at the

ACT test center. The heated Graco unit was used for most of the preliminary testing and it was also provided to certain facilities for testing alternatives during the project. The small heated ultrasonic system was used in the field testing. Graco also provided IRTA with a typical High Volume Low Pressure (HVLP) spray gun to use in the preliminary testing at the ACT test center.

Table 1-3 showed the list of eight companies IRTA worked with during the project on coating and adhesive application equipment cleanup. IRTA obtained samples of coatings from all of these companies in order to conduct the preliminary testing. In some cases, IRTA obtained a variety of different coatings from each of the facilities; in other cases, the company only used one coating or adhesive and IRTA obtained only these samples. IRTA also obtained other coatings from two coatings suppliers, Sherwin Williams and AMT, so that additional types of coatings possibly not used by the participating companies could be tested. Table 3-1 shows the list of companies that provided coatings and adhesives for the preliminary testing classified into different coating and adhesives categories.

Table 3-1
Companies Providing Coatings and Adhesives for Preliminary Testing

Company	Type of Coating/Adhesive
Hydro-Aire	Aerospace primers and topcoats
California Propeller	Aerospace primer and topcoat
Sherwin Williams	Aerospace primers and topcoats
Metrex	Marine solventborne coating
Bausman & Father	Wood furniture waterborne and solventborne coatings
AMT	Wood furniture solventborne coatings
Holmes Body Shop	Automotive primer, basecoat and topcoat
Westway Industries, Inc.	Automotive primer, basecoat and topcoat
PCM Leisure World	Latex and enamel architectural coatings
Sanitop	Waterborne adhesive

The preliminary testing was designed to screen potential cleaners in a laboratory testing situation. The cleaners that worked best on the coatings in the laboratory testing were then provided to the companies participating in the project for testing in the field. During the preliminary testing, IRTA used the spray gun cleaner and the spray gun provided by Graco to test the alternatives. IRTA tested several different water-based cleaners, acetone, soy and a soy blended with water on all of the coatings. If none of the options worked well, IRTA modified the alternatives to find one that did work effectively. Material Safety Data Sheets (MSDSs) for some of the cleaning products that were tested are provided in Appendix C.

The results of the preliminary testing are shown in Table 3-2 for each category of cleaning. When the scaled up field tests were performed, most of the results listed in Table 3-2 held up. In a few cases, as described below, the results in the field were different.

Table 3-2
Results of Preliminary Screening Tests

Category of Cleaning	Alternative(s) Selected
Aerospace coatings	acetone
Metal coatings	acetone
Wood furniture coatings	water-based cleaners, acetone
Autobody coatings	acetone, acetone/methyl acetate blend
Architectural coatings	water, water-based cleaners, soy, acetone
Waterborne adhesive	acetone, water-based cleaners

3.3. Field Testing

For each of the companies participating in the project, IRTA developed a test plan for testing the alternative cleaning agents. In general, the test plans involved some initial testing at the site to determine if the findings from the preliminary laboratory testing would hold up in the field. If the tests were successful, IRTA asked the company to perform a scaled-up longer term test of the alternatives. In five of the cases, the companies decided to convert to the alternatives and in three other cases, they did not convert. A few companies indicated they might convert to the alternative in the future.

The description of the testing and the cost analysis of the alternatives for each of the facilities is described below. IRTA generally attempted to include all the costs a company would incur in the cost comparison of the alternatives with the cleaning system that is currently used. In instances where companies did convert to an alternative, stand alone case studies that describe the conversion are presented in Appendix B.

3.3.1. Hydro-Aire

Hydro-Aire, an aerospace subcontractor, is a division of Crane located in Burbank, California. The company has 572 employees. Hydro-Aire manufactures braking systems, pumps and airlocking devices. The company also does repair work on the pumps used in military and commercial aircraft like the C-130 transport and the C-17.

Hydro-Aire applies aerospace coatings as part of their manufacturing process. Like other aerospace companies, the company uses a chromated epoxy primer and a polyurethane topcoat. Hydro-Aire also uses some specialized coatings like a fuel tank primer that is difficult to clean. MSDSs of a typical primer and topcoat used by the company are shown in Appendix A. For several years, Hydro-Aire used aero-MEK, a blend of MEK and various other solvents for cleaning their spray equipment.

IRTA conducted initial testing with Hydro-Aire. The first cleaner IRTA tried was acetone since that cleaner worked well during the preliminary screening tests for all of the aerospace coatings. The painter indicated that the initial testing at the facility showed that acetone seemed to work well on the typical primer and topcoat used by the company. IRTA and Hydro-Aire arranged for scaled up testing using the enclosed spray gun cleaner the company currently uses for cleaning. The next time the company changed out the solvent for disposal, acetone was used in place of aero-MEK. Hydro-Aire evaluated the new cleaner on all of their coatings, including the fuel tank primer, and found it effective. The company decided to convert to acetone and has been using it for almost a year. Figure 3-1 shows a picture of the enclosed spray gun cleaner at Hydro-Aire.

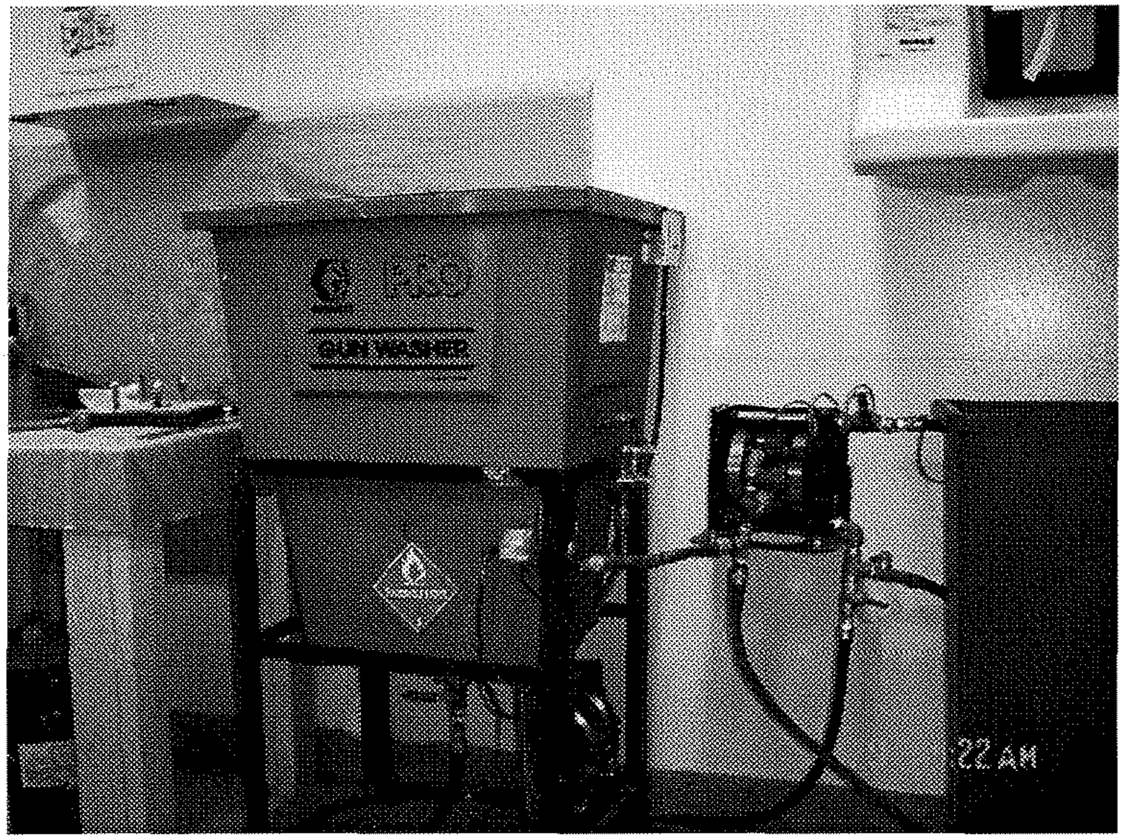

Figure 3-1. Spray Gun Cleaning System at Hydro-Aire

IRTA analyzed the cost of using acetone at Hydro-Aire and compared it to the cost of using the aero-MEK. Hydro-Aire purchased six drums of aero-MEK annually for cleaning their spray guns and for handwipe operations. About 60 gallons went toward spray gun cleaning each year. From the scaled up testing, the company estimates that it will use roughly the same amount of acetone. The company paid $4.94 per gallon for aero-MEK and pays $4.25 per gallon for acetone. On this basis, the cost to the company for purchasing aero-MEK amounted to $296 annually; the cost of purchasing acetone instead amounts to $255 annually.

The SCAQMD emission fees paid by the company were $345 per ton of VOC emitted. Assuming a density for aero-MEK of seven pounds per gallon, the fee for emitting 60 gallons is $72 per year. There are no fees for acetone since the chemical is exempt from VOC regulation.

The annualized cost comparison is shown in Table 3-3. The cost to the company for purchasing acetone is somewhat less than the cost for purchasing the aero-MEK. In addition, through the use of acetone, the company can avoid paying the VOC emission fees of $72 per year. Hydro-Aire reduced their costs by 31% through the conversion to acetone.

Table 3-3
Annualized Cost Comparison for Spray Gun Cleaning for Hydro-Aire

	Aero-MEK	Acetone
Chemical Cost	$296	$255
Regulatory Fees	$72	-
Total Cost	$368	$255

A stand alone case study for the Hydro-Aire spray gun cleaning conversion is provided in Appendix B.

3.3.2. California Propeller

California Propeller is a small aerospace subcontractor located in North Hollywood. The company purchases government surplus parts and different types of parts that have been used in the field for more than 50 years and refurbishes them. The parts include propellers and intricate governers that are used on aircraft.

The parts arrive at California Propeller and are disassembled, cleaned, inspected, reworked and painted. The company, like other aerospace firms, uses a chromated epoxy primer and a polyurethane topcoat. A spray gun is used to apply the coatings and, when it was cleaned, it was disassembled and cleaned with MEK in a bucket.

IRTA had obtained and tested samples of California Propeller's coatings during the preliminary testing at the ACT test center. During those tests, IRTA found that acetone worked well on the coatings. IRTA and the company performed scaled up testing of acetone at the facility and found that it worked well as an alternative to MEK. The company decided to convert to acetone.

California Propeller used five gallons of MEK every two months for spray gun cleaning. At a cost of $5.12 per gallon, the company was paying $154 per year for the cleaner. The same amount of acetone is now used for spray gun cleaning at a cost of $3.32 per gallon. The annual cost of purchasing acetone is $100.

Table 3-4 shows the cost comparison for California Propeller. The figures show that the company cut their costs by 35 percent by converting from MEK to acetone.

Table 3-4
Annualized Cost Comparison for Spray Gun Cleaning for California Propeller

	MEK	Acetone
Cleaner Cost	$154	$100
Total Cost	$195	$100

A stand alone case study for California Propeller is presented in Appendix B.

3.3.3. Metrex

Metrex is a small company located in Glendora, CA that has about 25 employees. The company manufactures, rebuilds and refurbishes various types of valves. Many of the valves processed by Metrex are used in a marine environment.

IRTA began work with Metrex on their spray gun cleaning as part of an EPA project. The coating Metrex applies to its cast iron valves must be highly resistant to attack by the harsh marine environment. The paint used by the company is a solventborne coating. An MSDS for the coating is shown in Appendix A.

For many years, Metrex used lacquer thinner for cleaning their spray gun. They flushed the solvent through the spray gun in a small bucket. The company has now converted to acetone for the spray gun cleaning operation. Metrex used about one-fourth of a gallon per month of lacquer thinner or three gallons per year. The cost of the lacquer thinner was $10.85 per gallon so the total cost amounted to about $33 annually. Metrex did not pay any regulatory fees for using the lacquer thinner because the emissions were very small. They now use the same amount of acetone but pay $9.16 per gallon. The total cost of using the acetone is $27 annually.

The cost comparison for Metrex is shown in Table 3-5. The use of acetone reduces the cost of the spray gun cleaning by about $6 per year.

Table 3-5
Annualized Cost Comparison for Spray Gun Cleaning for Metrex

	Lacquer Thinner	Acetone
Cleaner Cost	$33	$27
Total Cost	$33	$27

A stand-alone case study for Metrex is presented in Appendix B.

3.3.4. Bausman & Father

Bausman & Father is a very small company with only two employees including the owner. The company, located in Huntington Beach CA, strips and refinishes furniture and other wood items.
Bausman and Father uses two types of coatings: an acetone based coating and a water-based coating. For several years, the company cleaned their spray gun in a bucket after spraying the solventborne coating with lacquer thinner. A few years ago, they converted to acetone. Bausman cleaned their waterborne coating with plain water.

IRTA began working with the company on a project sponsored by EPA. As discussed in an earlier section, ACT contracted with a vendor to build a small table-top ultrasonic cleaning system that could be tested in spray gun cleaning. IRTA provided this cleaning system to Bausman. The preliminary laboratory cleaning tests performed by IRTA indicated that an alkaline water-based cleaner and acetone should both perform well on Bausman's coatings. Bausman began using the water-based cleaner, Spray Clean 12, in the small ultrasonic unit for cleaning the spray gun after spraying both the acetone and waterborne coatings. The water-based cleaner was more effective in cleaning the spray gun than the acetone. A picture of the ultrasonic unit at Bausman is shown in Figure 3-2.

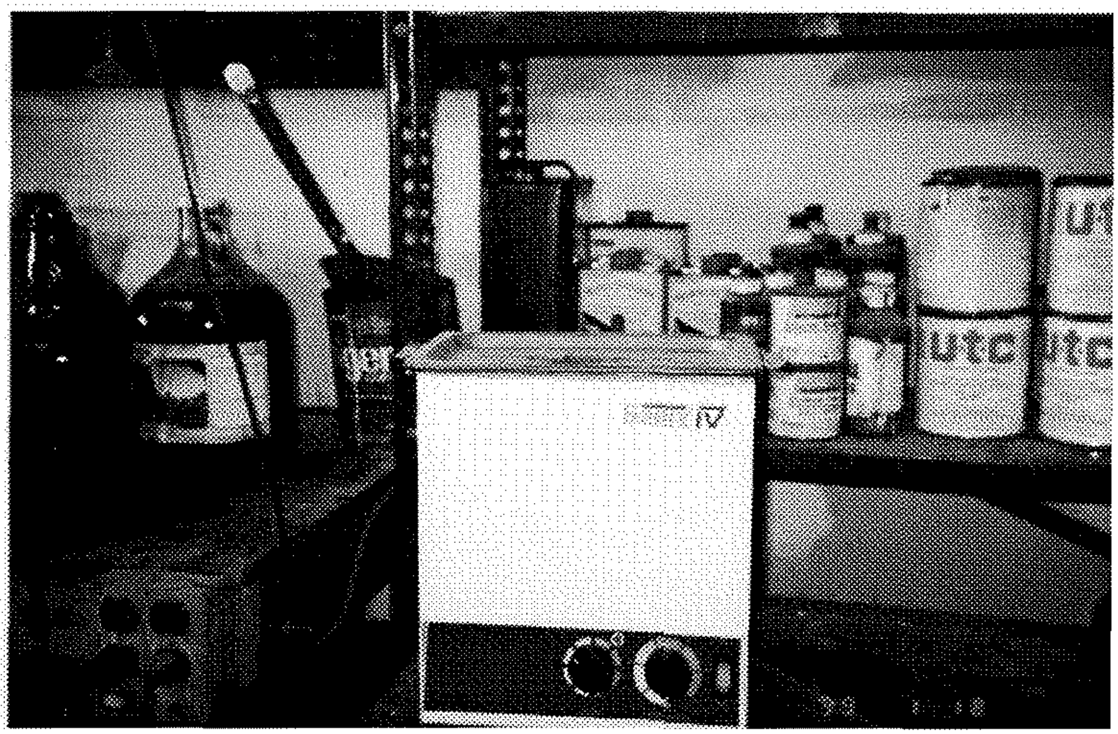

Figure 3-2. Tabletop Ultrasonic Cleaning Unit at Bausman & Father.

Bausman used about one-half gallon of acetone each time the spray gun was cleaned. The company used a total of two gallons of acetone per year. At a cost of $7 per gallon, the total annual cost of the acetone was $14.

Bausman did not have to pay for the ultrasonic system but another company would have to purchase the unit. The cost of the system is about $300. Assuming a useful life for the equipment of ten years and a two percent cost of capital, the annualized capital cost is $31. The water-based cleaner is used at a concentration of 25 percent. Assuming a cost for the cleaner concentrate of $10 and that the cleaner is changed out twice a year, the annual cleaner cost amounts to $5. The ultrasonic unit is heated and it uses 1.2 kW of electricity. Assuming it operates for eight hours (a full day) for the four cleaning cycles per year and assuming an electricity charge of 12 cents per kWh, the annual electricity cost for operating the unit is $4.

The cost comparison for Bausman is shown in Table 3-6. The cost of using the water-based cleaner is much higher than the cost of using acetone because of the capital cost of the ultrasonic unit. Even so, the total cost of cleaning is very low.

Table 3-6
Annualized Cost Comparison for Spray Gun Cleaning for Bausman & Father

	Acetone	Water-Based Cleaner
Capital Cost	-	$31
Electricity Cost	-	$4
Cleaner Cost	$14	$5
Total Cost	$14	$40

This analysis did not include the labor cost for cleaning before and after implementing the ultrasonic cleaning system. It was assumed that the labor for cleaning the spray equipment at Bausman & Father is negligible. In other cases where much more cleaning is done, the labor savings for automating the cleaning process could offset some or all of the capital cost from purchasing the unit.

A stand-alone case study for Bausman & Father is presented in Appendix B.

3.3.5. Holmes Body Shop

Holmes Body Shop is located in Santa Monica, CA. It is one of a chain of 10 body shops located from Santa Monica in the west to Riverside in the east. Like other body shops, the company repairs cars and paints them as part of their process. Holmes uses HVLP spray guns and the guns are cleaned in an enclosed spray gun cleaning unit leased by Holmes. A picture of the spray gun cleaner is shown in Figure 3-3. A service provider also maintains the equipment, supplies the cleaning solvent and disposes of the waste. MSDSs for the coatings used by Holmes are shown in Appendix A.

During the laboratory testing phase, IRTA was able to clean the spray gun contaminated with Holmes' coatings with plain acetone with only marginal effectiveness. IRTA was able to clean the coatings effectively with a blend of 80 percent acetone and 20 percent methyl acetate. Because plain acetone worked effectively on Westway's coatings (see below), IRTA provided five gallons of acetone and five gallons of the acetone/methyl acetate blend to Holmes for scaled up testing. The plain acetone did not work for Holmes but the acetone/methyl acetate blend did work well.

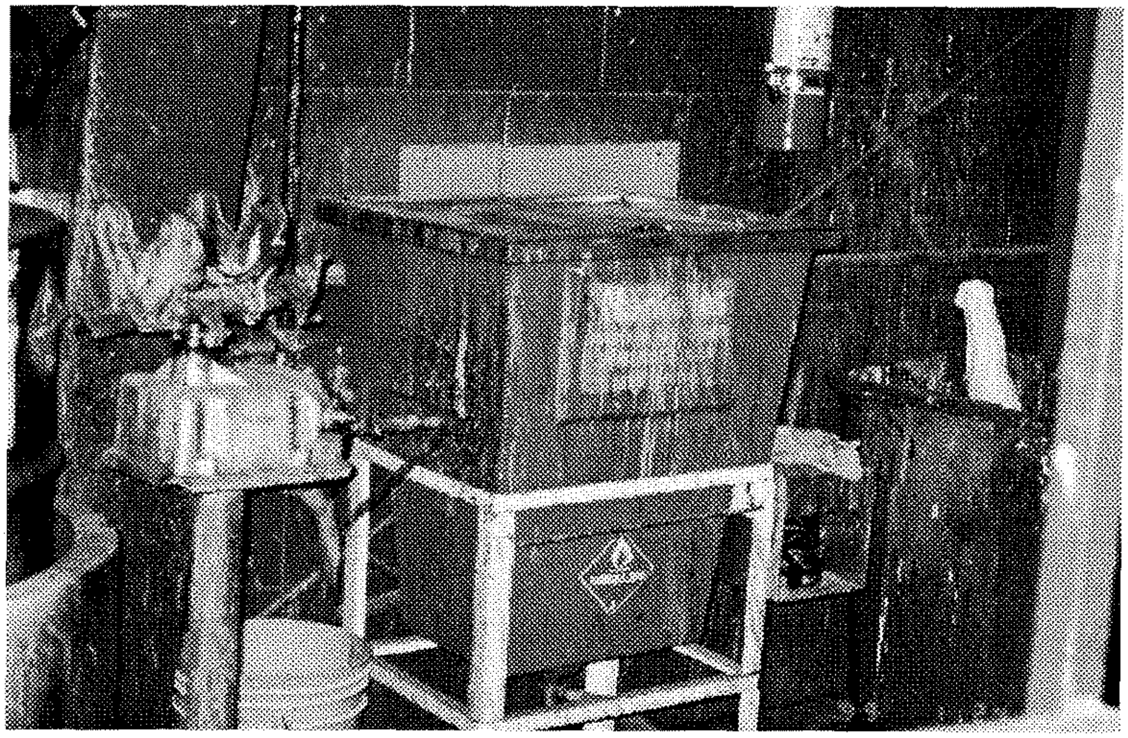

Figure 3-3. Spray Gun Cleaning System at Holmes.

If Holmes converted to the acetone/methyl acetate blend, the company would have to purchase an enclosed spray gun cleaning unit. Such units could cost in the range of $700 to $1,100. Assuming a capital cost of $1,000 for the unit and a ten year useful life, the annualized cost of the unit would be $102.

Currently, Holmes' service provider does the maintenance on the leased spray gun cleaner. The servicing cost, which includes maintenance, the cost of leasing the unit, the cost of the solvent, the changeout cost and the disposal cost, amounts to $2,290 annually. If the company converted to the new blend, the workers would have to devote about 30 minutes to changeout of the cleaner. Currently the cleaner is changed out once a month. Assuming the new blend would also have to be changed out once a month and assuming a labor cost of $10 per hour, the maintenance/changeout cost would be $60 per year.

The cost of the cleaner is currently included in the total service cost. If Holmes converted to the new blend, the cost of the cleaner would be $6.20 per gallon. The annual cleaner cost would amount to $372.

The disposal cost is currently included in the servicing cost. If Holmes converted to the new cleaner, the company would have to dispose of 60 gallons of hazardous waste each year. Assuming a disposal cost of $2 per gallon, the annual disposal cost would amount to $120 per year.

Table 3-7 shows the costs for the current and new cleaner for Holmes. The figures show that the conversion to the new alternative reduces the cost by 71 percent.

Table 3-7
Annualized Cost Comparison for Spray Gun Cleaning for Holmes Body Shop

	Current Cleaner	Acetone/Methyl Acetate Blend
Capital Cost	-	$102
Service Cost	$2,290	-
Maintenance Cost	-	$60
Cleaner Cost	-	$372
Disposal Cost	-	$120
Total Cost	$2,290	$654

3.3.6. Westway Industries, Inc.

Westway is a small body shop located in Santa Monica, CA. The company repairs cars and, as part of that activity, they paint them. Westway uses an enclosed spray gun cleaner that belongs to the facility to clean the HVLP spray guns that are used to apply the coatings. A picture of this spray gun cleaner is shown in Figure 3-4. The cleaner used by the company is lacquer thinner.

IRTA performed preliminary testing on Westway's coatings. The results indicated that the coatings could be cleaned with acetone or an 80 percent acetone/20 percent methyl acetate blend. IRTA tested acetone at the shop because it was likely to be less costly than the acetone/methyl acetate blend. The workers at Westway used the acetone for a few months and indicated that it was effective in cleaning the spray gun.

To make the conversion to acetone, the company could use the new cleaner in their spray gun cleaner so no capital investment in equipment would be required. Westway uses about five gallons of lacquer thinner each quarter. At a cost of $5.20 per gallon, the total annual cost for purchasing the lacquer thinner is $104. The cost of acetone is $4.50 per gallon. Assuming the same amount of acetone could be used, the annual cost of the acetone would be $90. Disposal costs for the 20 gallons of spent acetone or spent lacquer thinner would amount to $40 annually.

Table 3-8 shows the cost comparison of the cleanup solvents for Westway. The cost of cleaning with acetone is about 10 percent less than the cost of cleaning with lacquer thinner.

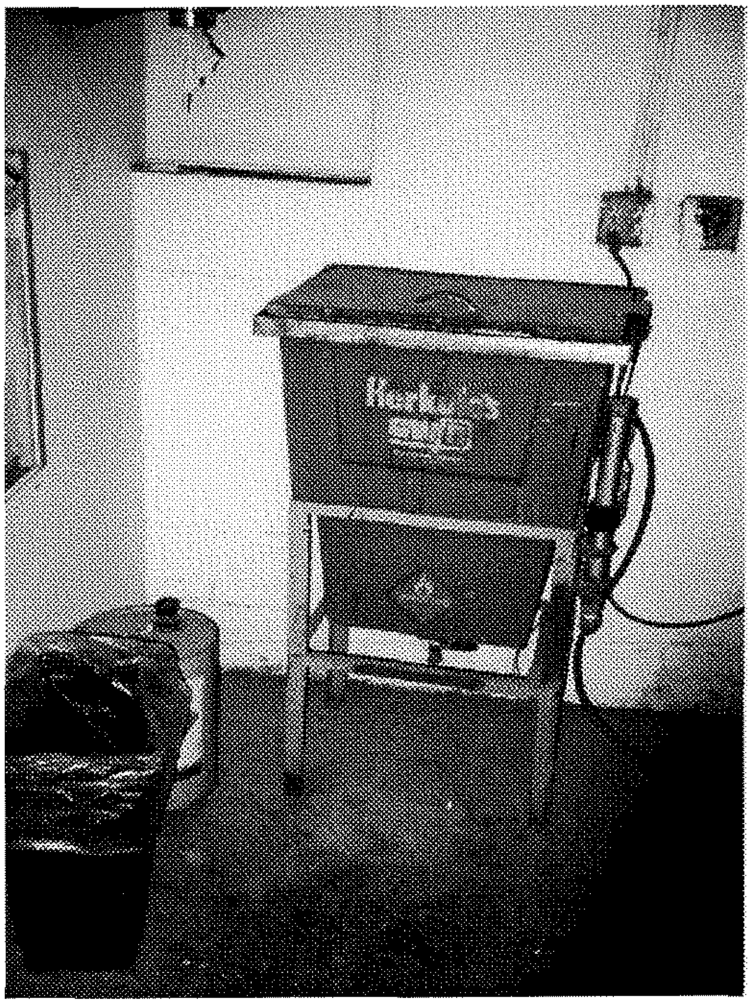

Figure 3-4. Spray Gun Cleaning System at Westway.

Table 3-8
Annualized Cost Comparison for Spray Gun Cleaning for Westway Industries, Inc.

	Lacquer Thinner	Acetone
Cleaner Cost	$104	$90
Disposal Cost	$40	$40
Total Cost	$144	$130

3.3.7. PCM Leisure World

Professional Community Management or PCM is the management company that provides the painting service to Leisure World, a retirement community where some 22,000 people live in condominiums, apartments and houses. PCM has three separate paint crews with 60 employees that repaint the buildings every seven years or so.

PCM uses latex paint for the buildings and an enamel coating for painting the front doors, windows, doorframes, railings and other metal hardware. PCM currently cleans the equipment used to apply the latex paints with a hose and plain water. The company uses lacquer thinner for cleaning the spray equipment that is used to apply the enamel coating. The spent lacquer thinner is reclaimed in a still and reused for cleaning.

During the preliminary testing, IRTA found that two low or zero VOC cleaners seemed promising for PCM. The first was a soy based cleaner called Soy Gold 1000 and the second was acetone. IRTA provided 10 gallons each of the soy based cleaner and acetone to one of the paint crews for scaled up testing. Both cleaners were capable of cleaning the application equipment but the soy cleaner took much longer.

The paint crew indicated that there was no difference in the labor required for cleaning with the lacquer thinner and the acetone. They indicated that it would take twice the amount of time to clean the equipment with soy than it would with the lacquer thinner. The painters spend about 30 minutes per day cleaning. The labor rate is $10 per hour for the 60 painters. On this basis, assuming a 260 day year, the current labor cost and the labor cost for cleaning with acetone are $78,000 per year. The labor cost for cleaning with the soy would be twice as much or $156,000.

PCM purchases one 55 gallon drum of lacquer thinner per month at $4.09 per gallon. The annual cost of the cleaner amounts to $2,699. The company would use 10 percent more acetone because it is used in the open and because less would be recovered in the still (see below). Assuming a cost of acetone of $4.24 per gallon, the annual cost of acetone would be $3,078. PCM would probably use 20 percent less soy but the company would not be able to use their still to recover the material. PCM currently recovers approximately 22 gallons of lacquer thinner from their still each month. The soy use would be 62 gallons per month. At $6 per gallon, the cost of purchasing the soy for equipment cleaning would be $4,464 per year.

The solvent still uses 5 kW per hour and is operated once a week for five hours. Assuming an electricity cost of 12 cents per kW, the annual electricity cost is $156. The cost would be lower or the same if the company used acetone and there would be no electricity cost for soy since the still cannot handle materials with high boiling points. Note that the still is used to reclaim 22 gallons of solvent. It would be less costly to purchase virgin solvent instead of using the still.

PCM currently disposes of one 55 gallon drum of hazardous waste each month at a cost of $110 per drum. The annual disposal cost amounts to $1,320. The cost for disposal of the spent acetone would be the same. More soy waste, some 62 gallons, would require disposal. Assuming the soy disposal cost is $110 per drum, the cost for disposal of the soy is $1,488 per year. The spent soy might cost less to dispose of than the other two cleaners because it might not be classified as hazardous waste. To be conservative, however, IRTA has assumed the soy would be classified as hazardous waste.

Table 3-9 shows the cost comparison for the lacquer thinner and the two alternative cleanup solvents. The total annual cost of converting to acetone is roughly the same as the current cost of using lacquer thinner. Because the labor cost increases dramatically with the use of soy, conversion to this cleaner would approximately double the cost of cleaning.

Table 3-9
Annualized Cost Comparison for Spray Gun Cleaning for PCM

	Lacquer Thinner	Acetone	Soy
Labor Cost	$78,000	$78,000	$156,000
Cleaner Cost	$2,700	$3,078	$4,464
Electricity Cost	$156	$156	-
Disposal Cost	$1,320	$1,320	$1,488
Total Cost	$82,176	$82,554	$161,952

3.3.8. Sani-Top, Inc.

Sani-Top, Inc. was a counter top manufacturer located in Gardena, California. IRTA began working with the company in early 2002. In June of 2002, the company was acquired by V-T Industries, a company headquartered in Holstein, Iowa. The Sani-Top brand name was later phased out and transitioned to the brand name V-T West, California.

When IRTA began working with Sani-Top, the company produced between 1,200 and 1,800 counter tops each day. Most of the counter tops manufactured by the company were sold to hardware stores like Home Depot where they are purchased by contractors.

Sani-Top had two automated lines for manufacturing the counter tops. The base of the counter top, made of particle board, moved down a conveyor. Adhesive was applied on the conveyor line to bond a veneer to the particle board. When IRTA began work with the company, they were completing a conversion from methylene chloride and high VOC based adhesives to waterborne adhesives. Sani-Top is located in the jurisdiction of the South Coast Air Quality Management District (SCAQMD) and the District has a rule that regulates the use of VOC solvents and toxic solvents like methylene chloride used in adhesives.

IRTA worked with Sani-Top to find alternatives in two cleaning operations. In the first operation, the workers were using perchloroethylene (PERC) to remove adhesive overspray that remained on the finished counter tops. At the end of the process, these counter tops were handwiped with PERC just before they were shipped. Sani-Top used two gallons per week of the solvent at a cost of about $9 per gallon. The total cost of purchasing the PERC each year amounted to $936. The SCAQMD charges a fee on emissions of toxic chemicals, including PERC. The annual emissions fee for the PERC totaled $315. The total yearly cost of using PERC in this operation was $1,251.

IRTA tested two alternatives with Sani-Top. The first alternative was a blend that contained 80% acetone and 20% water. The second formulation was a water-based alkaline cleaner called Spray Clean 12 diluted to 50% concentration with water. Both cleaners were as effective as the PERC in removing the adhesive overspray. The company estimated, during the testing, that they would use two gallons of each of these cleaners per week. The cost of the acetone blend is $3.20 per gallon and the cost of the water-based cleaner is $5 per gallon. The annual cost of using the acetone blend and the water-based cleaner would be $333 and $520 per year respectively.

Table 3-10 shows the cost comparison for PERC, the acetone blend and the water-based cleaner. The cost of using both of the alternatives is significantly less than the cost of using PERC. Conversion to the acetone blend would reduce the company's cleaning cost by about 73%. Conversion to the water-based cleaner would reduce the cleaning cost by 56%.

Table 3-10
Annualized Cost Comparison for Sani-Top Adhesive Overspray Cleaning Process

	PERC	Acetone Blend	Water-Based Cleaner
Cleaner Cost	$936	$333	$520
Emission Fees	$315	-	-
Total Cost	$1,251	$333	$520

The second cleaning operation at Sani-Top was a weekly cleaning of the adhesive spray system. The whole system was torn down and cleaned each week. The fluid nozzles and caps in the system were cleaned every day. For this operation, the company used 55 gallons annually of a cleaner called Sani-Pine which was apparently based on a pine terpene which is a VOC. The cost of this cleaner was $245 for a 55 gallon drum.

IRTA tested an alternative water-based cleaner with virtually zero VOC content in this operation. Sani-Top tested the cleaner, the same cleaner tested for cleaning the adhesive overspray, at 50% concentration. At this concentration, the cleaner was not strong enough. The cleaner worked well at 100% concentration. Assuming a usage rate of 55 gallons per year, the cost of the alternative cleaner would be $550 per year.

Table 3-11 shows the cost comparison for the Sani-Pine and the water-based cleaner. The cost of using the low-VOC water-based cleaner is substantially higher than the cost of using the Sani-Pine higher VOC content cleaner. Since the Sani-Pine was a water-based material, the company decided not to convert to the alternative water cleaner.

Table 3-11
Annualized Cost Comparison for Sani-Top Conveyor Line Cleaning Process

	Sani-Pine	Water-Based Cleaner
Cleaner Cost	$245	$550
Total Cost	$245	$550

Several months after V-T Industries acquired Sani-Top, the company converted the adhesive operation to use a polyvinyl acetate adhesive. They also adopted a different water-based cleaner for both cleaning operations. Prior to this conversion, Sani-Top used the acetone blend for several months but did not convert to the water-based cleaner for the conveyor line cleaning operation.

If the company had converted the overspray cleaning operation to the acetone blend and the conveyor line cleaning operation to the water-based cleaner, the total cost of cleaning would be reduced from $1,496 to $883 annually. Conversion of both processes leads to a net savings of more than $600 per year.

IV. ALTERNATIVES IN PRINTING APPLICATION EQUIPMENT CLEANING

During this project, IRTA worked with five different printing facilities located in Southern California. Two of the facilities are lithographic printers and three are screen printers. Historically, both lithographic and screen printing facilities relied on TCA for cleaning their presses, screens and other types of application equipment. When the TCA production ban became effective and the Congressional tax on ozone-depleting substances increased the cost of using TCA, printing companies converted to traditional VOC solvents for cleaning the application equipment. In screen printing, alternatives to TCA include mineral spirits, blends of solvents like MEK, toluene, xylene, glycol ethers and terpenes. In lithographic printing cleanup, mineral spirits, alcohols and glycol ethers were widely used. All of these solvents are classified as VOCs and some of them are toxic.

In Southern California, SCAQMD Rule 1171 establishes limits for cleaners that can be used to clean ink application equipment. Currently, the VOC limit for cleaners in the screen printing category is 750 grams per liter. Effective on July 1, 2005, the VOC limit for these cleaners declines to 100 grams per liter. Rule 1171 also specifies a VOC limit for the cleaners used in off-press and on-press cleaning in lithographic printing. The limit for cleaners used in off-press cleaning is 25 grams per liter VOC. The current limits for on-press cleaning are 600 or 800 grams per liter depending on the type of cleaning activity; effective July 1, 2005, this limit declines to 100 grams per liter. During the project, IRTA focused on testing alternatives that would meet the 25 gram per liter VOC limit for off-press lithographic printing cleanup and the 100 gram per liter VOC limits for on-press lithographic and screen printing equipment cleanup that becomes effective in 2005. IRTA also tried to test cleaners that were lower in toxicity than the cleaners used currently.

4.1. Printing Process Descriptions

In screen printing, printers apply an emulsion to the screen which is cured with light. The emulsion functions as the stencil in the printing. Ink is forced through the screens and the pattern printed on the substrate reflects the areas that do not contain emulsion. Some emulsions are water soluble and some are both water and solvent resistant. A material called blockout is used to touch up the screens where the emulsion is worn off. Again, blockout can be water soluble or it can be both water and solvent resistant. When the printing job is completed, screen printers remove the ink from the screen. In some cases, the screen is simply saved because the printer expects to have future printing jobs from the customer. In other cases, after the ink is removed, the emulsion and blockout are removed from the screen and it is ready for use in a new job.

In lithographic or offset printing, the image to be printed is placed on a plate. The plate comes into contact with rollers wet by a water or dampening solution and rollers that are wet with ink. The dampening solution wets the non-printing areas of the plate and prevents the ink from wetting these areas. The ink wets the image areas which are transferred to the blanket. The inked image is transferred to a substrate. Printers generally use a roller wash to clean the rollers at the end of the day or when a color change occurs. Printers clean the blankets at various times during the day, often during a run and always after the run.

4.2. Preliminary Laboratory Testing

Table 1-4 showed the list of printing companies IRTA worked with during the project. IRTA obtained samples of inks from all of these companies in order to conduct preliminary screening tests. In a few cases, IRTA obtained samples for several ink types from certain companies. In other cases, where the company only used one type of ink, IRTA obtained a sample of only that ink. In addition, IRTA performed screening tests at two screen ink suppliers' facilities on several typical inks used in the screen printing industry so additional inks could be tested.

The preliminary testing was designed to screen potential cleaners in a laboratory testing situation. IRTA was given two screens by one of the companies and these were used in the testing. IRTA obtained a blanket which is used for lithographic printing and used that blanket in the laboratory testing. In general, IRTA tested cleaners on the inks provided by the companies. In the screening testing, IRTA found that water-based cleaners and soy based materials worked well for cleaning the plastisol textile screen ink. Acetone worked well for other screen inks including the difficult to remove solventborne inks. The same cleaners worked well on lithographic printing inks.

Table 4-1 shows the companies that participated in the project and provided ink for the preliminary testing. The City of Santa Monica Print Shop and Huhtamaki are lithographic printers and Accurate Dial, The City of Santa Monica Paint Shop and Quickdraw are screen printers. The table also shows the type(s) of ink used by each facility.

Table 4-1
Companies Providing Inks for Preliminary Testing

Company/Organization	Type of Ink
City of Santa Monica Print Shop	Soy based ink
Huhtamaki	Electron beam curable ink
Accurate Dial	Metal solventborne screen ink
City of Santa Monica Paint Shop	Solventborne paper/metal inks
Quickdraw	Plastisol textile ink

4.3. Field Testing

For each of the companies participating in the EPA project, IRTA developed a test plan for testing the alternative cleaning agents. In general, the test plans involved some initial testing at the site to determine if the findings from the preliminary laboratory testing would hold up in the field. If the tests were successful, IRTA asked the company to perform a scaled-up longer term test of the alternatives. In two cases, the companies decided to convert to the alternatives and, in the other cases, they did not convert. A few companies indicated they might convert to an alternative in the future.

IRTA is conducting a technology assessment/development project sponsored by SCAQMD to identify suitable alternative low-VOC cleaners for on-press lithographic printing application equipment. Two of the facilities IRTA worked with on this project, Huhtamaki and the City of Santa Monica Print Shop, are also participating in the SCAQMD project. In the case of Huhtamaki, the information presented here is a final result for off-press cleaning and an interim result for on-press cleaning. In the case of the City of Santa Monica Print Shop, the information presented here is a final result.

IRTA is continuing to work with one of the screen printers, Quickdraw, in another project sponsored by the Los Angeles County Sanitation Districts, the City of Los Angeles Bureau of Sanitation and Cal/EPA's Department of Toxic Substances Control with EPA Region IX funding. The facility cleans the screens by hand at this stage and IRTA is testing additional cleaners at the facility.

The description of the testing and the cost analysis of the alternatives for each of the facilities involved in the EPA project is described below. IRTA generally attempted to include all the costs a company would incur in the cost comparison of the alternatives with the cleaning system that is currently used. In the two instances where companies did convert to an alternative, stand alone case studies that describe the conversion are presented in Appendix B.

4.3.1. City of Santa Monica Print Shop

The City of Santa Monica Print Shop provides support to the city for various printing activities. One of their operations involves printing on envelopes and stationery with a small lithographic printing press. The press is used twice a month and it is cleaned after each print session.

In the past, the city used two high VOC cleaners, one for cleaning the rollers and the other for cleaning the cylinder plate. The city used one gallon of the roller cleaner each year. At a cost of $40 per gallon, the total cost of purchasing the roller cleaner was $40 per year. The city used one quart of the cylinder cleaner each year. At a cost of $15 per gallon, the total cost of purchasing the cylinder cleaner was about $4 annually. Cleanup mats are used to collect the ink when the solvent is applied to the rollers. The city used 120 cleanup mats per year. At a cost of 28 cents per cleanup mat, the total annual cost was $34. The cost of purchasing cleaning materials was about $78 annually.

IRTA worked with the city to test alternatives. After testing several formulations, the city decided to convert to a soy based cleaner called Soy Gold 2000 for roller cleaning and a water-based cleaner called Mirachem Pressroom Cleaner for the cylinder cleaning. Both the soy cleaner and the water-based cleaner are lower in toxicity than the VOC cleanup solvents used by the city previously. About one gallon per year of the soy cleaner is required. At a price of $8 per gallon, the annual cost of purchasing the roller cleaner is now $8. For cleaning the cylinder, the city uses one quart per year of the water-based cleaner. At a cost of $10 per gallon, the annual cost of the formulation is $3. The city uses more cleanup mats with the new cleaner because the soy cleaner needs to be rinsed with water so it does not leave a residue; about nine cleanup mats per job or 216 cleanup mats per year are required. The annual cost of the cleanup mats is now about $60. The yearly total cost of cleaning materials is now $71.

The labor cost for cleaning has increased. When the city used the VOC cleaners, it took about one-half hour to clean the press twice a month. At a labor rate of $17.50 per hour, the annual labor cost for cleaning amounted to $210. The cleanup now takes one hour twice a month. The labor cost is twice what it was in the past, at $420.

The annualized cost comparison of the VOC solvents and the low VOC cleaners is shown in Table 4-2.

Table 4-2
Annualized Cost Comparison for Cleaning Lithographic Press at City of Santa Monica

	VOC solvents	Soy and Water-Based Cleaner
Cleaner and Cleanup Mat Cost	$78	$71
Labor Cost	$210	$420
Total Cost	$288	$491

The values of Table 4-2 show that the cost for cleaning at the city increased by 70% when the city substitute the low VOC alternatives.

4.3.2 Huhtamaki

Huhtamaki prints on consumer packaging like ice cream cartons. The company has a web press with seven stations which includes six colors and a clear coating. Huhtamaki uses electron beam (EB) curable ink, which requires an electron beam system for curing. Figure 4-1 shows an example of the ice cream cartons printed by Huhtamaki and Figure 4-2 shows a picture of the press.

In the past, Huhtamaki used a glycol ether cleaning agent for the blanket and roller wash and the off-press cleaning. To meet the current 800 gram per liter VOC content requirement of SCAQMD Rule 1171, the vendor reformulated the cleaner. IRTA began working with Huhtamaki as part of an EPA project and a project sponsored by Cal/EPA's Department of Toxic Substances Control. The aim of the projects was to identify and test alternative off-press cleaners that met the SCAQMD Rule 1171 current requirement of 25 grams per liter VOC and the future VOC requirement of 100 grams per liter for the on-press cleaning.

Figure 4-1. Ice Cream Carton Printing at Huhtamaki

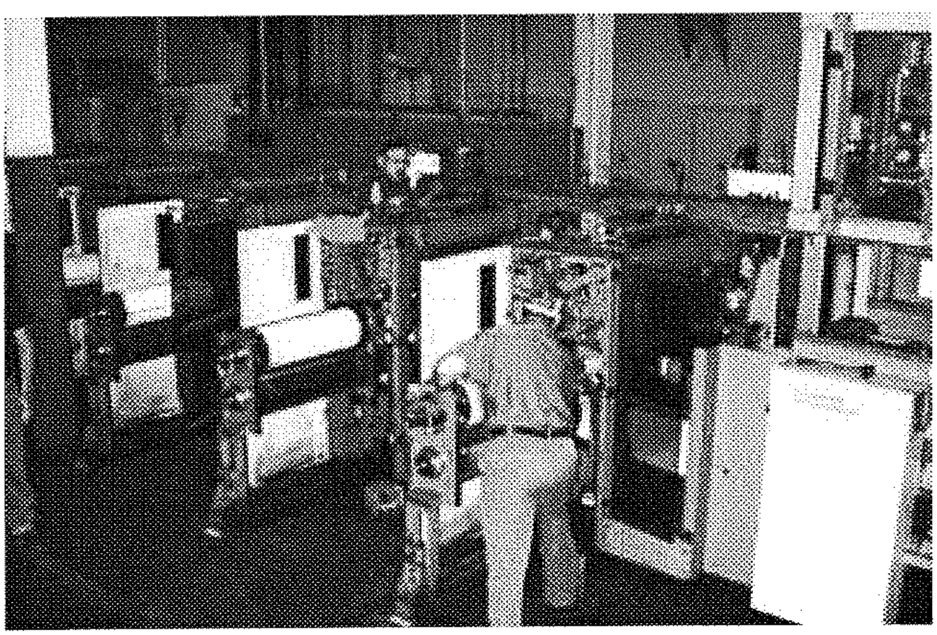

Figure 4-2. Huhtamaki Six Color Press

In the preliminary testing with Huhtamaki's ink, IRTA found a water-based cleaner that cleaned the ink fairly well. Soy based cleaners also cleaned the ink well. Finally, acetone cleaned the ink very effectively. Huhtamaki uses a material called EPDM for their blankets and their rollers. Soy has been determined to be incompatible with EPDM so, even though the soy cleaners cleaned the ink effectively, they could not be used for the on-press cleaning because they might have adversely affected the rollers and blankets. The soy cleaners could be used for off-press cleaning but the company decided not to have soy in the pressroom at all.

IRTA tested a number of different cleaners for off-press cleaning. The cleaner that Huhtamaki liked best, based on the employee judgement of effective cleaning, was a blend of 50 percent of a water-based cleaner called Brulin 815GD and 50 percent acetone. The VOC content of the Brulin cleaner is 15 grams per liter. The VOC content of the blend is 7.5 grams per liter since acetone is exempt from VOC regulations. IRTA identified a company that would blend and supply the cleaner to Huhtamaki. Huhtamaki has been using the cleaner for a short time.

The testing also indicated that the 50/50 blend would work well as a blanket wash for the on-press cleaning. IRTA tested a different water-based cleaner, called UV Magic Wash, for cleaning the rollers. It was a little slower at cleaning than the current cleaner but it cleaned the ink effectively. The cleaner has a VOC content of 90 grams per liter.

In the past, Huhtamaki normally purchased two 55 gallon drums per month of the glycol ether for on-press and off-press cleaning. A full drum was used for the off-press cleaning, three-fourths of a drum is used for blanket cleaning and one-fourth of a drum is used for roller cleaning. The cost of the cleaner is $9.09 per gallon. The annual cost of cleaner amounted to $12,000. The annual cost of the cleaner for off-press cleaning was $6,000.

The cost of the Brulin/acetone blend is $7.80 per gallon. Assuming Huhtamaki uses the same amount of this cleaner for off-press cleaning as the high VOC cleaner, the cost of off-press cleaning using the alternative is $5,148.

The labor cost for the off-press cleaning will remain the same with the alternative as with the current cleaner. The off-press cleaning is conducted about every three weeks when the press is not running so it was assumed that there would be no change in the labor.

Huhtamaki currently pays an emissions fee to the SCAQMD for the VOC cleaner. In 2003, the company paid an emissions fee of $356. Since half the use of the high VOC cleaner was for off-press cleaning, the emissions fee for off-press cleaning amounts to $178. Huhtamaki will pay no emissions fee for the alternative cleaner since the emissions fee only applies to emissions of four tons per year or more.

Table 4-3 shows the annualized cost comparison for the current and alternative cleaners for Huhtamaki for off-press cleaning. The cost of the off-press cleaning is 17 percent less with the alternative low-VOC cleaner than with the glycol ether cleaner.

Table 4-3
Annualized Cost Comparison for Huhtamaki's Lithographic Printing Process Off-Press Cleaning

	Glycol Ether Cleaner	Acetone/Brulin Cleaner
Cleaner Cost	$6,000	$5,148
Emissions Fee	$178	-
Total Cost	$6,178	$5,148

Huhtamaki has not yet tested the alternative blanket wash and the alternative roller wash for a longer period. It is necessary to test the alternatives for at least a week to determine if the cleaners are effective and how the characteristics of the cleaning process might change. IRTA did not perform a detailed cost analysis of the alternative blanket and roller cleaners because there is not currently enough information to draw firm conclusions. Huhtamaki intends to conduct scaled-up testing for a week in the near future.

Four factors could influence the cost of the alternative blanket and roller cleaners. First, the price of the current and alternative cleaners will factor into the cost. Second, the labor used during the cleaning process could change with the alternatives. Third, compatibility of the cleaners with roller and blanket material can influence how often rollers and blankets are replaced. Fourth, Huhtamaki might avoid some record keeping requirements if the company adopted the alternatives.

As mentioned earlier, the cost of the cleaner Huhtamaki currently uses for blanket and roller cleaning is $9.09 per gallon. The cost of the alternative blanket wash, the blend of 50 percent Brulin and 50 percent acetone, is lower, at $7.80 per gallon. The cost of the alternative roller wash, called Magic UV Wash, is much higher, at $20 per gallon. During the testing, the alternative blanket wash seemed to clean the blankets as effectively as the current blanket wash. The testing also indicated that more of the alternative roller wash would probably have to be used to get the same level of cleaning currently achieved.

IRTA is working with other formulators to identify an effective water-based roller cleaner that is lower in price than Magic UV Wash. The cost of the Magic UV Wash is $20 per gallon, which is very high for a water-based cleaner. Water-based cleaners are generally priced in the range of $9 to $15 per gallon. If the formulators could develop a cleaner that was priced lower, the cost of cleaning with the alternative roller wash would be lower.

Huhtamaki indicates that three of the seven roller stations and all seven of the blankets are cleaned 30 times during the three shifts each day when the ink color is changed.

Because the alternative blanket cleaner appeared to clean effectively, no additional labor would likely be required for blanket cleaning. The alternative roller cleaner, because it is a water-based material, would require rinsing if it were substituted for roller cleaning. Thus, use of the alternative roller cleaner would require more labor than is required with the current cleaner.

As mentioned earlier, compatibility of cleaners with roller and blanket materials is an important issue for lithographic printers. For instance, at Huhtamaki, blankets are changed out every three weeks or 17 times per year, at a cost of $65 per blanket. There are seven blankets on Huhtamaki's press so the annual changeout cost amounts to $7,735. There are 70 rollers on the press that come into contact with the ink and cleaners and the annual changeout cost for the rollers is estimated at $15,000. The total cost of the roller and blanket changeout is $22,735 per year.

Huhtamaki's current roller supplier tested the roller material for compatibility with the Magic UV Wash, the roller cleaner that was tested and the Brulin cleaner tested as a blanket wash. The findings indicated there was a 3.2 percent shrinkage after a 24 hour immersion in the Magic UV Wash at room temperature. They also indicated a change in hardness of one unit after immersion for the Magic UV Wash. As a rule of thumb, some roller manufacturers find cleaners acceptable if they cause no more than a 10 percent swelling when immersed at room temperature for 24 hours. They also find cleaners acceptable if they cause no more than three units of change in hardness. The cleaner will require rinsing and this indicates that the test results may overestimate the impact of the cleaner on the rollers. On this basis, the water-based roller cleaner was judged acceptable. The Brulin cleaner showed even less damage in the compatibility tests.

The roller supplier also tested the glycol ether roller and blanket cleaner, the cleaner that is used currently for on-press cleaning. The findings indicated that the glycol ether has more of an effect on the rollers than the Magic UV Wash or the Brulin. Acetone is known to have very little effect on EPDM, the material the rollers are made of.

The compatibility data suggest that the roller and blanket changeout could be less frequent with the alternative cleaners than with the current cleaner. The labor for less frequent changeout of blankets and rollers could also be reduced.

Huhtamaki could avoid some of the record keeping that is currently required by the SCAQMD when high VOC solvents are used. If the cleaner used by a company contains 25 grams per liter VOC or less, then record keeping is not required. The Brulin/acetone blend used for off-press and blanket cleaning contains less than 25 grams per liter VOC. On this basis, the record keeping requirements for the printing operation could be reduced by two-thirds. Although this measure might not reduce the costs appreciably, it is a convenience and benefit of using the alternatives.

4.3.3. Accurate Dial & Nameplate, Inc.

Accurate Dial manufactures custom nameplates, dials, panels, keyboard overlays and other commercial and industrial products. The company uses a screen printing operation to print on the metal and plastic substrates. Ink is applied to the screen and is forced through the stencil. The ink is then cleaned by hand with a rag using a high VOC solvent. The screen is generally stored for future use. When Accurate Dial is finished with the screens, they are reclaimed by removing the emulsion with a high pressure water spray.

IRTA began testing alternative ink cleaners with the company. IRTA obtained a sample of the ink and performed screening tests. An MSDS for the ink used by the company is provided in Appendix B. Water-based and soy based cleaners were ineffective in cleaning the ink. Acetone, which is not a VOC and is lower in toxicity than the solvent used currently, cleaned the ink well but it evaporated too fast. This caused a so-called freezing effect where the ink becomes frozen on the screen and is even more difficult to remove. At that stage, IRTA decided to add a lower vapor pressure solvent, a propylene glycol ether, to the acetone to slow down the evaporation. Because of the SCAQMD regulation requiring cleaners to have no more than 100 grams per liter VOC in 2005, the blend could only contain about eight percent of the glycol ether and the balance, 92 percent, was acetone.

IRTA tested the new blend with Accurate Dial and it did clean the ink effectively. More of the cleaner was required, however, because it evaporated more quickly than the solvent used currently. In addition, the worker at Accurate Dial that performs the screen cleaning did not like the odor of the new cleaner.

Because of the odor problem, adoption of the alternative cleaner would require installation of three ventilation hoods. IRTA assumed a capital cost of $500 for each system which includes a hood and a blower. The total capital cost for the three systems was $1,500. Assuming an effective life for the system of 10 years, the annualized cost of the ventilation system would amount to $153.

Accurate Dial currently uses about 75 gallons per year of solvent. At a cost of $12 per gallon, the annual cost for purchasing the solvent amounts to $900. IRTA estimates the cost of the alternative cleaner, the acetone blend, at $5 per gallon. Accurate Dial estimates that use of the new cleaner would be 2.5 times the use of the current cleaner because the new cleaner evaporates more readily. On this basis, use of the new cleaner would total 188 gallons per year. The cost of purchasing the new cleaner would be $940 annually.

The labor cost would increase if the company adopted the new cleaner because the worker would spend more time applying the quickly evaporating blend. Currently, one employee spends one hour per day cleaning screens. At a labor rate of $11 per hour and assuming a work schedule of five days per week and fifty-two hours per year, the annual labor cost for cleaning amounts to $2,860. Accurate Dial estimates that there would be a labor increase of 40 percent with the new cleaner which leads to an annual labor cost of $4,004.

There is currently no electricity cost for cleaning. Conversion to the new cleaner would require a ventilation system. This system would have a one-fourth horse power or 0.2 kW blower which is operated for 1.4 hours per day. Assuming an electricity cost of 12 cents per kWh, the total electricity cost would amount to $9 annually.

The cost comparison for the current and new low VOC cleaner is shown in Table 4-4.

Table 4-4
Annualized Cost Comparison for Accurate Dial for Screen Printing Cleanup

	VOC Solvent	Acetone Blend Cleaner
Capital Cost	-	$153
Cleaner Cost	$900	$940
Labor Cost	$2,860	$4,004
Electricity Cost	-	$9
Total Cost	$3,760	$5,106

The values of Table 4-4 show that the total cost of using the alternative is about 36 percent higher than the cost of using the current cleaner.

4.3.4. City of Santa Monica Paint Shop

The City of Santa Monica Paint Shop provides painting and screen printing services for the City of Santa Monica. The shop prints on paper, cardboard, plastics and metals. The City uses an enamel air dry ink on metal signs. For some of the traffic signs, the City uses several other inks including a translucent reflective traffic sign ink.

IRTA began work with the City of Santa Monica on a project sponsored by EPA. The City uses a commercial cleaning agent for removing the inks and sometimes follows with MEK. The cleaner is applied to the screens by hand. IRTA performed preliminary laboratory testing and found that one water-based cleaner called Mirachem Pressroom Cleaner, a soy based cleaner called Soy Gold 2000, acetone and a blend of 92 percent acetone and eight percent glycol ether removed the enamel ink but that only acetone based cleaners removed the other inks. IRTA performed scaled-up testing with the company and found the same results.

Over the last several months, the City has been using plain acetone for cleaning the non-enamel inks. One problem with the acetone is that it tends to remove the stencil the shop uses for these types of inks. If the acetone is removed immediately, however, the stencil is not damaged.

The City has not had any enamel ink applications over the last few months but has a choice of acetone or soy based products for removing these inks.

IRTA analyzed the costs to the City for using the current cleaner and acetone on the non-enamel ink. The City purchases eight gallons per year of cleaning solvent at a cost of $14 per gallon. The total annual cost of the cleaner amounts to $112. The use of acetone is estimated to be the same. Assuming a cost of acetone of $7 per gallon, the annual cost of using the acetone cleaner would be $56.

Table 4-5 shows the cost comparison for the City. The cost of using acetone for removing the inks is half the cost of using the current cleaner.

Table 4-5
Annualized Cost Comparison for City of Santa Monica for Screen Printing

	Current Cleaner	Acetone
Cleaner Cost	$112	$56
Total Cost	$112	$56

4.3.5. Quickdraw

Quickdraw is located in West Los Angeles, California. The company is a textile printer and most of their work involves printing on T-shirts. Quickdraw removes the ink from the screens after printing. The company uses a VOC solvent for cleaning the screens currently.

IRTA tested two alternative cleaners with Quickdraw. IRTA provided the company with a heated parts cleaner containing a water-based cleaner called Mirachem Pressroom Cleaner at about a one-third concentration. An MSDS for this cleaner is shown in Appendix C. The company used the Mirachem for several months and found it satisfactory. IRTA also tested a soy based cleaner called Soy Gold 2000 in a parts cleaner with Quickdraw. The MSDS for this cleaner is shown in Appendix C. Again the company found this alternative satisfactory.

To use the Mirachem alternative, Quickdraw would need to purchase a heated water-based parts cleaner. Assuming the parts cleaner would cost $1,500 and a ten year useful life for the equipment, the annualized equipment cost would be $153. The company has a cleaning system with a pump and a brush currently. The soy could be used in this equipment. Thus for a conversion to soy, the company would not have to make a capital investment.

Quickdraw currently spends about four hours per day cleaning screens. Assuming a labor rate of $10 per hour and 260 hours per year of operation, the annual labor cost is $10,400. Quickdraw estimates that the labor cost with use of the Mirachem cleaner would increase by 10 percent because it does not remove the ink as easily as the current solvent. Thus the labor cost with the Mirachem alternative would amount to $11,440. Quickdraw estimates that an extra hour of labor would be required each day for the soy because the screens would require rinsing. Assuming five hours per day for cleaning, the labor cost for soy would be $13,000 annually.

Quickdraw currently uses seven gallons of solvent in six months. The cost of the cleaner is $11.40 per gallon and the annual cost of the cleaner is $160. The parts cleaner used with Mirachem would require changeout every six months. Assuming a parts cleaner capacity of 30 gallons, the use of the liquid would amount to 60 gallons. The Mirachem is used at a concentration of 30 percent which means that 20 gallons of Mirachem would be used each year. Assuming a cost of Mirachem of $10 per gallon, the annual cost of purchasing Mirachem would be $200. The soy cleaner is as efficient at removing the ink as the current solvent. Quickdraw would likely use the same amount of soy as the current cleaner. Assuming a cost of $6 per gallon for the soy, the annual cost of purchasing soy is $84.

The cleaning unit with the pump at Quickdraw has a one-fourth horsepower or 0.2 kW pump. The unit operates four hours per day with the current cleaner. Thus the electricity use is 0.8 kWh per day or 208 kWh per year. Assuming an electricity cost of 12 cents per kWh, the annual electricity cost with the current solvent is $25. The soy cleaner could be used in the same unit with the same annual electricity cost. The parts washer for the Mirachem cleaner is heated and the heater uses 1.5 kW; the pump uses 0.2 kW. Assuming the parts cleaner operates 4.4 hours per day (10 percent longer than the current cleaner) and that the electricity cost is 12 cents per kWh, the annual electricity use would amount to $233 with the Mirachem.

Table 4-6 shows the cost comparison for the current solvent, the Mirachem and the soy. The figures show that the cost of using the Mirachem is 14 percent higher than the cost of using the current cleaner. The cost of using the soy is 24 percent higher than the cost of using the current cleaner.

Table 4-6
Annualized Cost Comparison for Quickdraw for Screen Printing

	Current Cleaner	Mirachem	Soy Cleaner
Capital Cost	-	$153	-
Labor Cost	$10,400	$11,440	$13,000
Cleaner Cost	$160	$200	$84
Electricity Cost	$25	$233	$25
Total Cost	$10,585	$12,026	$13,109

V. RESULTS OF THE ANALYSIS

5.1. Aerospace Handwipe Cleaning

Table 5-1 summarizes the applications and companies that participated in the project in testing alternatives. It also specifies the alternatives that were tested and were effective.

Table 5-1
Aerospace Handwipe Cleaning Alternatives

Type of Application and Companies	Alternative(s)
Manufacture and Repair of Electronic Components	
Hydro-Aire	water-based cleaner, acetone
Manufacture and Repair of Fluid Systems	
Fortner Engineering	water-based cleaners, acetone
Manufacture of gauges	
Astro Pak	acetone, acetone/IPA blends

Hydro-Aire adopted a water-based cleaning alternative for cleaning electronic connectors. Acetone is also used in the process. Fortner Engineering converted to water-based cleaners in nearly all of their processes. In a few cases, acetone is used for handwipe cleaning. Finally, acetone was an effective alternative for the NVR verification cleaning performed by Astro Pak. Indeed, it was more effective than IPA in the process. Blends of acetone and IPA also performed well in the process.

5.2. Coating and Adhesive Application Equipment Cleaning

Table 5-2 summarizes the types of coatings and adhesives that were cleaned during the project, the companies that used these coatings and adhesives and the alternatives that were tested and were effective.

For all the categories and companies listed in Table 5-2, IRTA identified and tested alternatives that worked successfully. IRTA obviously did not test every coating or adhesive that is used and there may be coatings or adhesives that could not be cleaned with the alternatives tested here. In a few cases, water-based cleaners work effectively. For the most part, acetone based cleaners seem to be widely applicable. In some cases, plain acetone cannot clean effectively and other components like methyl acetate were needed to make the cleaning effective.

Aerospace coatings like epoxy primers and polyurethane topcoats can be effectively cleaned with plain acetone. Both Hydro-Aire and California Propeller have adopted the alternative. Acetone also worked well for cleaning the metal coating used by Metrex and the company adopted the alternative. A water-based cleaner worked effectively to clean both waterborne and solventborne wood

Table 5-2
Coating and Adhesive Application Equipment Cleaning Alternatives

Type of Coating/Adhesive and Companies	Alternative(s)
Aerospace epoxy primers and polyurethane topcoats Hydro-Aire California Propeller	acetone
Metal solventborne coating Metrex	acetone
Wood solventborne coatings Bausman & Father	water-based cleaner, acetone
Autobody primers, basecoats and topcoats Holmes Body Shop Westway Industries, Inc.	acetone, acetone/methyl acetate
Architectural enamel and industrial maintenance coatings PCM Leisure World	acetone, soy based cleaner
Adhesives Sanitop	water-based cleaner, acetone
Waterborne Coatings Bausman & Father PCM Leisure World	water

coatings and Bausman & Father converted to the water-based cleaning alternative. Acetone or a blend of acetone and methyl acetate worked well in cleaning autobody coatings. Acetone also worked well for cleaning an enamel coating applied by an architectural coating firm. Water-based cleaners and acetone effectively cleaned the adhesive application equipment at Sanitop. For latex architectural coatings, plain water is effective in cleaning the application equipment.

IRTA did not test plain water for cleaning waterborne coatings and adhesives during the project. Two of the companies that participated in the project, including Bausman & Father and PCM Leisure World, use waterborne coatings today; these companies use plain water for cleanup of the spray equipment when cleaning waterborne coatings. Many other companies have used waterborne coatings for many years and they also use plain water for cleanup.

5.3. Printing Application Equipment Cleaning

Table 5-3 summarizes the types of inks that were the focus of the testing, the companies that used these inks and the alternatives that performed successfully.

Table 5-3
Printing Application Equipment Cleaning Alternatives

Type of Ink and Companies	Alternative(s)
Soy based lithographic printing ink City of Santa Monica Print Shop	water-based cleaner, soy
Electron beam curable ink Huhtamaki	water-based cleaners, acetone
Solventborne metal and plastic sign ink City of Santa Monica Paint Shop	acetone, acetone/glycol ether blend, soy
Solventborne metal ink Accurate Dial & Nameplate	acetone/glycol ether blend
Plastisol textile ink Quickdraw	water-based cleaners, soy cleaner

The City of Santa Monica Print Shop uses a soy based ink. The City has adopted a soy cleaner and a water-based cleaner as alternatives to the high VOC solvent used previously.

Huhtamaki uses electron beam curable ink to print on ice cream cartons. IRTA identified and tested a blend of a water-based cleaner and acetone for off-press and blanket on-press cleaning. The company converted to this alternative for off-press cleaning. IRTA also tested a different water-based cleaner for cleaning the rollers on Huhtamaki's press. This water-based cleaner takes longer to clean because it requires a rinse but it did effectively clean the ink.

The alternative cleaners that were tested at City of Santa Monica Paint Shop worked as well as the cleaner that was being used. When using the acetone/glycol ether blend or plain acetone, the City must remove the ink immediately so the stencil is not damaged. The City decided to convert to acetone and is using it exclusively.

Accurate Dial uses a solventborne ink that must be very resistant to the elements. IRTA identified an alternative, a blend of acetone and a glycol ether, that worked effectively. More of the cleaner was required, however, because it had a higher vapor pressure than the cleaner used currently.

In the plastisol ink category, at Quick Draw, both a water-based cleaner and a soy based cleaner were tested for several months. This company used an emulsion and blockout that were solvent and water resistant. Both the soy and the water-based cleaner cleaned the ink effectively. The soy based cleaner requires an additional rinse step.

5.4. Summary of Results

In the course of this project, IRTA focused on finding alternatives in three categories including:

- aerospace handwipe cleaning
- coating and adhesive spray equipment cleaning
- lithographic and screen printing application equipment cleaning

Table 5-4 shows the information contained in Table 1-1 in the introduction and background section for reference.

Table 5-4
Cleaning Applications and SCAQMD VOC Rule Limits

Cleaning Application	VOC Content (grams per liter) Current	2005
Product Cleaning		
Electrical Apparatus Components & Electronic Component	500	100
Repair & Maintenance Cleaning		
Electrical Apparatus Components & Electronic Components	900	100
Cleaning of Coatings or Adhesives Application Equipment	550	25
Cleaning of Ink Application Equipment	750	100
Screen printing		
Lithographic or Letter Press Printing		
--roller wash step 1	600	100
--roller wash step 2, blanket wash & on-press components	800	100
--removable press components	25	25
Aerospace Cleaning Solvents	200 g/L or 45 mm Hg composite partial pressure	
Batch Loaded Cold Cleaning of Fluid Systems under certain conditions	no limit	25

Hydro-Aire performs cleaning of connectors as they are being manufactured and as part of a repair and maintenance operation. The company converted to alternatives that easily meet the 100 gram per liter VOC limit specified for 2005.
Fortner Engineering performs cleaning of fluid systems. The company has adopted alternatives that meet the 2005 VOC limit of 25 grams per liter.

Although Astro Pak's cleaning operation is not shown in the table, the acetone and acetone/IPA alternatives that were tested easily met a limit of 100 grams per liter VOC.

IRTA worked with eight companies to identify, test and demonstrate alternatives that met the 25 gram per liter 2005 limit for cleaning coating and adhesive application equipment. These eight companies represented a good cross section of the companies using diverse types of coatings. Several of the companies converted to the low-VOC low toxicity alternatives in the course of the project.

IRTA worked with two lithographic printers and identified and tested alternatives for off- and on-press cleaning. All of the alternatives tested met the 100 gram per liter VOC limit in 2005 of 100 grams per liter for on-press cleaners and the 25 gram per liter VOC limit for off-press cleaners. One company converted to the alternatives and the other company converted to the off-press cleaning alternative.

IRTA worked with three screen printers and tested alternatives that met the 100 gram per liter VOC limit specified for 2005. One of the companies converted to an alternative and IRTA is continuing work with another one of the companies.

In summary, then, IRTA tested a variety of alternatives for aerospace handwipe cleaning, coating and adhesive application equipment cleaning and printing application equipment cleaning. Historically most companies used CFC-113 or TCA for the cleaning operations that were the focus of this work. When the two ozone depleting solvents' production was banned, companies found alternatives that were VOCs and often toxic. This work demonstrates that low-VOC, low toxicity alternatives are available for three difficult areas of cleaning. Use of many of the alternatives that were tested in this project were shown to be less costly than use of the higher VOC high toxicity cleaners. The results of this analysis should be useful for companies all over the country with similar operations who would like to find low-VOC, low toxicity alternatives.