ASSESSMENT, DEVELOPMENT AND DEMONSTRATION OF LOW-VOC CLEANING SYSTEMS FOR SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT RULE 1171

Executive Summary

Prepared for:
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DISCLAIMER

Introduction

Volatile Organic Compound (VOC) emissions from solvent cleaning operations contribute significantly to the South Coast Air Basin's emission inventory. The South Coast Air Quality Management District (SCAQMD or District) periodically adopts an Air Quality Management Plan (AQMP). This AQMP calls for significant reductions in VOC emissions from cleaning and degreasing operations by 2010 to achieve attainment status.

One of the District's rules 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." In order to help develop low- or non-VOC technologies to comply with these provisions and to satisfy the AQMP's goals, the District contracted with the Institute for Research and Technical Assistance (IRTA). Under the contract, IRTA investigated and tested low- and non-VOC alternatives in a variety of cleaning processes. The aim was to identify technologies that could be substituted for high VOC technologies used today in many types of cleaning.

Target Applications

At the beginning of the two-year project, IRTA and the District staff identified the cleaning applications in Rule 1171 where more work and development and demonstration of low-VOC technologies was needed. The areas of focus were cleaning of certain electrical equipment and high technology devices, cleaning of coating and adhesives application equipment and cleaning of various types of printing application equipment. In earlier amendments to Rule 1171, the District had established target VOC content limits for these applications. The aim of this project was to assess, develop and demonstrate low-VOC cleaning systems and determine whether they could be used in these applications to comply with the target VOC limits. Another goal of the project was to evaluate the technical feasibility and cost of the low-VOC alternatives.

Table E-1 shows the applications of interest as they are listed in Rule 1171. The table also specifies the target VOC content of the cleaning systems established in Rule 1171 for 2005. Two of the items, cleaning of spray equipment for architectural coating and cleaning of solar cells, laser hardware, scientific instruments, and high-precision optics, appear as exemptions in Rule 1171. The target VOC content for the spray equipment cleaning was 25 grams per liter and for the high technology systems, the target VOC content was 100 grams per liter.

Project Approach

IRTA and the District decided to investigate low-VOC alternatives by working with specific companies in the Basin that conduct the operations listed in Table E-1. IRTA is also conducting a project under EPA sponsorship that is focusing on some of the same areas that were addressed in the SCAQMD project. Specifically, IRTA is working with companies that need to clean coating application equipment and printing application equipment. IRTA has completed the analysis with some of the companies participating in the EPA project. The results of the analysis for these companies in the EPA project are presented here.

Table E-1
Rule 1171 Cleaning Applications and Target VOC Content

Cleaning Application	Target VOC Content (grams per liter)
Product Cleaning	
Cleaning of Electrical Apparatus Component and Electronic Component Products	100
• Printed circuit board rework	
• Cleaning hybrid circuits	
• Cleaning general electrical components	
• Cleaning electric motors	
Cleaning of Solar Cells, Lasers, Scientific Instruments & High Precision Optics	100
Repair & Maintenance Cleaning	
Electrical Apparatus Components & Electronic Components	100
• Field cleaning of electric motors, generators, energized equipment	
• In-house cleaning of electric motors and other electrical equipment during rework, refurbishing, or rebuilding	
Coating & Adhesive Application Equipment Cleaning	25
• Cleaning of spray guns (general)	
• Cleaning of spray guns used for architectural coating	
• Cleaning of electrostatic spray guns	
• Cleaning of adhesive application equipment	
• Cleaning of application equipment for satellite/radiation effect coatings	
Cleaning of Ink Application Equipment	100
• Screen printing	
• UV printing	
• Specialty flexographic printing	
• UV lamp cleaning	

Table E-2 shows the companies and the electronics or high technology operation for which low-VOC cleaners were targeted. Tables E-3 and E-4 show the same type of information for coating application equipment and printing operations. The companies IRTA is working with in the EPA project are designated in the tables.

Table E-2
Companies Participating in SCAQMD Project with Electronics or High Technology Operations

Cleaning Application	Company
Printed Circuit Board Rework	Hydro-Aire Teledyne Controls
Hybrid Circuit Manufacture	Teledyne Microelectronic Technologies
General Electrical Apparatus Manufacture	Corona Magnetics Cicoil
Electric Motor Manufacture	Sterling
Rebuilding/Refurbishing of Electric Motors	Walton
General and Field Electrical Equipment Maintenance	Burbank Water & Power Covanta Energy
Energized Field Electrical Equipment Maintenance	Burbank Water & Power
Solar Cells	Northrop Grumman (formerly TRW)
Optics	Northrop Grumman (formerly Litton Guidance & Control Systems)
Scientific Instruments	Astro Pak

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 as 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.

Table E-3
Companies Participating in SCAQMD Project with Coating or Adhesives Applications

Operation	Company
Aerospace Coatings	Hydro-Aire Gulfstream California Propeller (EPA)
Metal Coatings	American Security Products Metrex (EPA)
Wood Coatings	Oakwood Bausman & Father (EPA)
Autobody Coatings	El Dorado Holmes (EPA) Westway (EPA)
Architectural Coatings	PCM Leisure World (EPA and SCAQMD) Murphy
Adhesives	Hickory Springs VACCO

Table E-4
Companies Participating in SCAQMD Project with Printing Applications

Operation	Company
Electronics Screen Printing	Teledyne Electronics
Plastic Screen Printing (UV inks)	Owens Illinois
Banner Screen Printing (UV inks)	Southern California Screen Printing
Metal Screen Printing	Nelson Nameplate
Varied Screen Printing	City of Santa Monica Paint Shop (EPA)
Textile Screen Printing	Stith Quick Draw (EPA) Melmarc Total Enterprises
Specialty Flexographic Printing	Huhtamaki

Cost Analysis

IRTA performed cost analysis for each of the alternatives that were successfully tested at each of the facilities participating in the project. The 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

For the capital costs, IRTA generally assumed a 10 year useful life of equipment and amortized the capital cost over this period assuming a cash purchase. 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 in the full report on the results of this project. This method makes the costs transparent so that they could be calculated based on other assumptions.

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.

Water-Based Cleaners. Two water-based cleaners were tested at a variety of 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, for cleaning electrical windings on electric motors and for cleaning non-energized field electrical equipment.

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. This cleaner worked well for removing ink in certain of the screen printing applications and in the specialty flexographic printing application.

A third water-based cleaner was tested at one facility for cleaning hardened grease from tooling and the floor. This cleaner was the commercially available Formula 409. IRTA called the company that manufactures the cleaner but the company did not know the VOC content of the cleaner.

<u>Soy Based Cleaners.</u> 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 the available data and their structure, HESIS indicated that these cleaners were likely to have low toxicity. One of the soy based cleaners tested for field generator cleaning and 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 Gas Chromatograph/Mass Spectrometer (GC/MS) method (called Method 313) used in the certification program indicates that this cleaner has a VOC content of less than five grams per liter.

IRTA also successfully tested another soy product, called Soy Gold 2000, and made by the same company in screen printing applications. This product has not been certified as a Clean Air Solvent but it is based on Soy Gold 1000 and contains about three percent of a surfactant that makes it water rinseable. The SCAQMD has determined the VOC content of this product to be less than 20 grams per liter.

IRTA also successfully tested another soy based product, called Autowash #3 and made by Seibert, in screen printing. It is composed of about 85 percent soy and 15 percent surfactants. SCAQMD has not yet determined the VOC content of Autowash #3.

<u>Acetone.</u> Acetone cleaners were widely and successfully tested by IRTA during the project in electronics and high technology application cleaning, in spray gun cleaning and, in some cases, in screen printing cleanup. Acetone is exempt from VOC regulations and it is low in toxicity when compared with most organic solvents.

One of the issues that arises with the use of acetone is its low flash point. 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 fire walls or other fire department approved building improvements are installed, more of the chemical can be used and stored.

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.

Volatile Methyl Siloxanes. IRTA tested volatile methyl siloxanes (VMSs) unsuccessfully for cleaning silicone based grease in an electronics application. The VMSs are exempt from VOC regulations. One of the project participants, an electric motor rebuilder, converted to a VMS called D5 for cleaning electric motors when they come in from the field. There is recent evidence that D5 causes tumors in rodents and the company is evaluating a conversion to a water-based cleaner.

HCFC, HFEs and HFCs. IRTA evaluated HCFC-225, a blend of two HFEs with 1,2-trans-dichoroetheylene (DCE) and a blend of an HFC and DCE for cleaning energized electrical equipment. HCFC-225, the HFEs and the HFCs are exempt from VOC regulations. HCFC-225 contributes to stratospheric ozone depletion and it will eventually be banned for that reason. The HFEs and HFCs contributes to global warming. DCE is classified as a VOC and it has not been tested for chronic toxicity. Its structure indicates that it might have toxicity problems.

Preliminary Laboratory Testing

For the category of "Electronics and High Technology Applications," IRTA obtained contaminated parts from some of the participating companies and performed preliminary testing using different cleaning agents that might be suitable. In other cases, the cleaning of field electrical equipment for instance, it was not possible to perform preliminary laboratory testing.

For the category of "Coating and Adhesive Application Equipment," at the beginning of the 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 also 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 HVLP spray gun to use in the preliminary testing at the ACT test center.

IRTA obtained samples of coatings from all of the participating 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 so that additional types of coatings possibly not used by the participating companies could be tested.

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 could then be provided to the companies participating in the project for testing in the field. IRTA used the spray gun cleaner and the spray gun provided by Graco to test the alternatives. IRTA tested several different water-based cleaners, soy and a soy blended with water and acetone on all of the coatings. If none of the options worked well, IRTA modified the alternatives to find one that did work effectively.

For the category of "Ink Application Equipment," IRTA obtained samples of inks from all of the participating 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 ink suppliers' facilities on several typical inks used in the screen printing industry so additional inks could be tested. Finally the Screen Printing and Graphic Imaging Association (SGIA) and 3M also provided a variety of inks for screening tests.

Again, 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. 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 ink. For UV curable inks, the soy based cleaners also worked well. Acetone worked well for many inks including the difficult to remove solventborne inks.

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 some cases, the participating companies decided to convert to the alternative and, in other cases, they did not convert. In some instances, companies are continuing to test alternatives.

Results of the Testing and Analysis

Table E-5 summarizes the applications and companies that participated in the project. It also specifies the alternatives that were tested and cleaned the contaminant(s).

Table E-5
Rule 1171 Operations

Category	Company	Operation	Contaminants	VOC Limit			Tested Alternatives	VOC Content	Description
				Before 12/2001	Current	After 7/2005			
Product Cleaning and Surface Preparation -- Electronics									
Printed Circuit Boards	Teledyne Controls	Rework	Water soluble flux	900g/L//33 mm Hg	500g/L	100g/L	D.I water Acetone / IPA / D.I. water blend Water-based cleaner	0 0 NAV	Converted to D.I water, acetone / IPA / D.I water blend
	Hydro-Aire	Rework	Rosin flux	900g/L//33 mm Hg	500g/L	100g/L	Acetone/IPA blend Acetone Water-based cleaner	100g/l 0 <50g/l	
Hybrid Circuit Manufacture	Teledyne Microelectric Technologies	Various	Rosin flux, particles	900g/L//33 mm Hg	500g/L	100g/L	Not cleaning Water-based cleaner	NAP <50g/l	Eliminated cleaning step
Transformer Component Manufacture	Corona Magnetics	Various	Rosin flux, particles, fingerprints	900g/L//33 mm Hg	500g/L	100g/L	Acetone Acetone/IPA blend	0 100g/l	
Flexible and Cast Cable Manufacture	Cicoil Corp.	Various	Rosin flux, silicone grease	900g/L//33 mm Hg	500g/L	100g/L	Water-based cleaner Acetone Acetone/IPA blend Volatile methyl siloxane	NAV 0 395g/l 0	Converted to acetone / IPA blend
Optics Manufacture	Northrop Grumman (formerly Litton Guidance & Control Systems)	Precision cleaning of Optics	Wax, pitch, lapping compounds, epoxy	exempt	exempt	exempt	Material change Physical barrier Hot water Acetone Water-based cleaners	NAP NAP 0 0 <50g/l	Converted to alternatives
Solar Cell Manufacture	Northrop Grumman (formerly TRW)	Precision Cleaning	Particles	exempt	exempt	exempt	Acetone Acetone / IPA blend	0 100g/l	Conducting wipe extraction testing
Gauge Manufacture	Astro Pak	Precision Cleaning	Particles, oils	exempt	exempt	exempt	Acetone / IPA blend Acetone	100g/l 0	Customer did not approve conversion

Note: NAP is Not Applicable; NAV is Not Available

Table E-5 Continued
Rule 1171 Operations

Category	Company	Operation	Contaminants	VOC Limit			Tested Alternatives	VOC Content	Description
				Before 12/2001	Current	After 7/2005			
Repair and Maintenance Cleaning -- Electronics									
Electric Motors	Walton	Rebuilding	Oil, grease, carbon deposits, dirt	900g/L//20 mm Hg	900g/L	100g/L	D5 Water-based cleaner	0 0	Converted to D5
Field Generators	Covanta Energy	Non-energized equipment maintenance	Oil, grease, dirt	900g/L//20 mm Hg	900g/L	100g/L	25% soy / 75% water blend	<5g/L	
Field Transformers	Burbank Water & Power	Non-energized equipment maintenance	Oil, grease, dirt	900g/L//20 mm Hg	900g/L	100g/L	Water-based cleaners	<25g/L	Uses water-based cleaner
		Energized equipment maintenance	Oil, grease, dirt	900g/L//20 mm Hg	900g/L	100g/L	HCFC-225 HFC245fa / DCE blend HFC / DCE blend	0 857g/L 1104g/L	Uses HCFC - 141b
Cleaning of Coating and Adhesive Application Equipment									
Aerospace Coatings	Hydro-Aire	Spray gun cleaning	Epoxy primers and polyurethane topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	Converted
	Gulfstream	Spray gun cleaning	Epoxy primers and polyurethane topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	
	California Propeller	Spray gun cleaning	Epoxy primers and polyurethane topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	Converted
Metal Coatings	American Security Products	Spray gun cleaning	Solventborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	Converted
		Spray gun cleaning	Waterborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Water	0	Uses water
	Metrex	Spray gun cleaning	Marine solventborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	Converted

Note: NAP is Not Applicable; NAV is Not Available

Table E-5 Continued
Rule 1171 Operations

Category	Company	Operation	Contaminants	VOC Limit			Tested Alternatives	VOC Content	Description
				Before 12/2001	Current	After 7/2005			
Cleaning of Coating and Adhesive Application Equipment Continued									
Wood Coatings	Oakwood	Automated spray equipment cleaning	Solventborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Water-based cleaner Acetone	0 0	
		Spray gun cleaning	Waterborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Water	0 0	Converted
	Bausman & Father	Spray gun cleaning	Solvent and waterborne coatings	950g/L//35 mm Hg	550g/L	25g/L	Acetone Water-based cleaner	0 0	Converted
Autobody Coatings	El Dorado	Spray gun cleaning	Solventborne primers, basecoats and topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone Acetone / methyl acetate blend	0 0	
	Holmes Body Shop	Spray gun cleaning	Solventborne primers, basecoats and topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone Acetone / methyl acetate blend	0 0	
	Westway Industries, Inc.	Spray gun cleaning	Solventborne primers, basecoats and topcoats	950g/L//35 mm Hg	550g/L	25g/L	Acetone	0	
Architectural Coatings	PCM Leisure World	Spray equipment cleaning	Latex coatings	950g/L//35 mm Hg	550g/L	25g/L	Water	0	Uses water
			Enamel coating	950g/L//35 mm Hg	550g/L	25g/L	Soy cleaner Acetone	<5g/L 0	
	Murphy Industrial Coatings, Inc.	Spray equipment cleaning	Industrial Maintenance Coatings	950g/L//35 mm Hg	550g/L	25g/L	Acetone Acetone / surfactant blend	0 <2.5g/L	
Adhesives	Hickory Springs	Spray gun cleaning	Solventborne foam fabrication adhesives	950g/L//35 mm Hg	550g/L	25g/L	Acetone Soy / water blend	0	
	Vacco	Spray gun cleaning	Solventborne thin film laminating adhesives	950g/L//35 mm Hg	550g/L	25g/L	Acetone Water-based cleaner	0 0	Alternatives ineffective

Note: NAP is Not Applicable; NAV is Not Available

Table E-5 Continued
Rule 1171 Operations

Category	Company	Operation	Contaminants	VOC Limit			Tested Alternatives	VOC Content	Description
				Before 12/2001	Current	After 7/2005			
Cleaning of Ink Application Equipment -- Screen Printing									
Screen Printing Ink	Teledyne Microelectronic Technologies	Screen Cleaning	Solventborne dielectric ink	1070g/L//5 mm Hg	750g/L	100g/L	Acetone	0	
	Owens Illinois	Screen Cleaning	UV curable ink for plastics	1070g/L//5 mm Hg	750g/L	100g/L	Soy cleaner	<20g/L	
	Southern California Screen Printing	Screen Cleaning	UV curable ink for banners	1070g/L//5 mm Hg	750g/L	100g/L	Soy cleaner	NAV	
	Nelson Nameplate	Screen Cleaning	UV curable ink for metal Solventborne ink for metal	1070g/L//5 mm Hg 1070g/L//5 mm Hg	750g/L 750g/L	100g/L 100g/L	Water Acetone / glycol ether blend Acetone Acetone / glycol ether blend	0 100g/L 0 100g/L	
	City of Santa Monica Print Shop	Screen Cleaning	Solventborne metal and plastic sign ink	1070g/L//5 mm Hg	750g/L	100g/L	Acetone Acetone / glycol ether blend Soy cleaner	0 100g/L <20g/L	Converted to acetone
	Stith	Screen Cleaning	Plastisol textile ink	1070g/L//5 mm Hg	750g/L	100g/L	Water-based cleaner Soy cleaner	25g/L <20g/L	
	Quick Draw	Screen Cleaning	Plastisol textile ink	1070g/L//5 mm Hg	750g/L	100g/L	Water-based cleaner Soy cleaner	25g/L <20g/L	
	Melmarc	Screen Cleaning	Plastisol textile ink	1070g/L//5 mm Hg	750g/L	100g/L	Water-based cleaner Soy cleaner	60g/L <20g/L	Scaled up testing not completed
	Total Enterprises	Screen Cleaning	Plastisol textile ink	1070g/L//5 mm Hg	750g/L	100g/L	Water-based cleaner Soy cleaner	25g/L <20g/L	Scaled up testing not completed
Cleaning of Ink Application Equipment -- Specialty Flexographic Printing									
Specialty Flexographic Ink	Huhtamaki	Flexographic ink cleaning		810g/L//21 mm Hg	600g/L	100g/L	Water-based cleaners	<75g/L	Uses water-based cleaner

Note: NAP is Not Applicable; NAV is Not Available

Under the first category "Product Cleaning and Surface Preparation—Electronics," IRTA worked with a number of companies that have operations that require flux removal. For flux removal operations, plain D.I. water, water-based saponifiers, acetone, acetone/IPA blends and D.I. water/acetone/IPA blends are good cleaners, depending on the characteristics of the operation.

Teledyne Controls and Hydro-Aire both conduct printed circuit board rework operations. Teledyne uses a water soluble flux and a number of alternatives including plain water worked effectively for removing the flux. The company converted to a blend of D.I. water containing small amounts of acetone and IPA. In some cases, the operators clean the reworked boards in Teledyne's water cleaning equipment with D.I. water. At Hydro-Aire, the company uses rosin flux. An acetone/IPA blend effectively removed the flux. The blend is being tested for compatibility with the component materials. Hydro-Aire has water cleaning equipment that uses a saponifier with low VOC; the operators can clean the reworked boards in this equipment but it would require more time.

For hybrid circuit manufacture, Teledyne Microelectronic Technologies was able to eliminate one of their cleaning operations altogether. In the manufacturing process, Teledyne is primarily cleaning flux from the assemblies. Although Teledyne delayed work on the project, they did test a number of water cleaning alternatives successfully.

In the case of Corona Magnetics and Cicoil Corp., flux removal is also a major cleaning task. Corona Magnetics can use acetone or an acetone/IPA blend to remove the flux in place of plain IPA and a vapor degreaser. The Cicoil flux could not be removed with a formulation with 100 grams per liter VOC or less. The company must use a blend of 50 percent IPA/50 percent acetone because the assemblies are also contaminated with silicone grease. Companies using silicone grease might be able to identify an alternative mold release agent but IRTA did not pursue this change in this case.

Northrop Grumman (formerly Litton Guidance & Control Systems) has been cleaning optics used in laser applications without VOC solvents for several years. IRTA worked with the company in an earlier project and has included the information in this document to demonstrate that optics companies can find alternatives.

Northrop Grumman (formerly TRW) uses IPA to clean solar cells. IRTA tested acetone based alternatives which worked effectively. Northrop Grumman is conducting testing to determine whether the acetone leaches components from the wipes and contaminates the solar cells in the cleaning; the results should be available this year. IRTA has suggested that the company try cleaning with an acetone/D.I. water blend during this testing. Diluting the acetone makes it much less aggressive; the removal of particles should still be adequate but the D.I. water may prevent the acetone from leaching components.

Astro Pak cleans a variety of scientific instruments and IRTA worked with the company on testing alternatives for cleaning aerospace gauges. Using non-volatile residue (NVR) analysis, acetone was found to perform better than IPA, the currently used VOC solvent.

Table E-5 also summarizes the results for the category “Repair and Maintenance Cleaning—Electronics.” There are a number of electric motor rebuilders in the SCAQMD jurisdiction. IRTA worked with one electric motor rebuilder in the past, Brithinee Electric. That company uses water-based cleaners exclusively. During this project, IRTA worked with Walton, a company that performs most cleaning with water-based cleaners. The company has one operation where an exempt solvent is now used. IRTA tested a water-based cleaner for this operation that was effective.

For field electrical equipment, IRTA worked with two companies, Burbank Water & Power and Covanta Energy. For cleaning non-energized equipment, IRTA tested water-based cleaners and a soy/water blend that cleaned effectively. Burbank Water & Power has been using a water-based cleaner for cleaning non-energized equipment for many years. For cleaning energized electrical equipment, most companies, including Burbank Water & Power, are using aerosol formulations containing HCFC-141b, an exempt chemical. IRTA tested a few alternatives that contained exempt chemicals or exempt chemical/VOC blends; the VOC blends have a reported VOC content greater than 800 grams per liter. Although the exempt chemical/VOC blends worked well, it is not clear whether they are recommended by the manufacturers for cleaning energized electrical equipment.

For the category of Cleaning of Coating and Adhesive Application Equipment,” in the case of Vacco, none of the alternatives tested by IRTA were able to clean the adhesive residue. IRTA discussed the issue with 3M, the adhesive supplier and suggested that a low VOC alternative could be found if 3M would reformulate the adhesive from tetrahydrofuran (THF) to tetrahydrofurfural alcohol. 3M refused to consider reformulation. IRTA did not test blends of acetone and THF but this approach could be successful at some concentration of acetone.

For all the other companies in the coating and adhesive application equipment cleaning category listed in Table E-5, 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 are widely applicable. In some cases, plain acetone cannot clean effectively and other components like methyl acetate or a special surfactant formulated to clean high solids coatings were designed to perform the cleaning.

In the case of Murphy Industrial Coatings, Inc., the architectural industrial maintenance coatings, additional testing using the acetone/surfactant blend should be conducted to evaluate the performance and refine the costs.

IRTA did not work with any facilities that used electrostatic spray equipment. IRTA has held discussions with one supplier of electrostatic spray equipment. According to a Graco representative, companies can use low-VOC, low toxicity alternatives if they have the proper electrostatic spray equipment. Specifically, the company has designed electrostatic spray equipment with the proper grounding to use waterborne coatings. This spray equipment, since it is designed to use water, can be cleaned with plain water. The company has also designed spray equipment for use with acetone coatings and this spray equipment can be cleaned with acetone. The important point is that the proper cleanup solvent must be used with the specific equipment designed for that purpose.

IRTA did not test plain water for cleaning waterborne coatings and adhesives during the project. Several of the companies that participated in the project, including American Security Products, Oakwood, Bausman & Father and PCM Leisure World, either use waterborne coatings today or used the coatings in the past; all of these companies used plain water for cleanup of the spray equipment. Many other companies have used waterborne coatings for many years and have used plain water for cleanup. None of the companies IRTA worked with flushed their spray equipment with solvent after cleaning with plain water.

Table E-5 summarizes the types of inks that were the focus of the testing, the companies that used these inks and the alternatives that performed successfully for the category of "Printing Application Equipment." In a few cases, the alternatives performed at least as well as the cleaner the companies were using. At Teledyne, for instance, the acetone worked more effectively in cleaning the ink than IPA.

At Owens Illinois, the soy cleaner worked very effectively and the workers liked it better than their current solvent.

IRTA tested a soy based cleaner called Autowash #3 at Southern California Screen Printing. It did not perform as well as their current cleaner and it required more labor. The company is now in the process of converting to a water-based cleaner that they identified and they believe it performs better than their current high VOC cleaner.

At Nelson Nameplate, the acetone/glycol ether blend worked well but more would be used than the current cleaner on the solventborne ink because of the high vapor pressure of acetone. The high acetone content of the cleaner removed Nelson's emulsion. IRTA identified and tested an alternative emulsion with Nelson and the new emulsion remained intact during cleaning with the acetone blend. This cleaner as well as plain water worked effectively on Nelson's UV curable 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 cleaner, the City must remove the ink quickly so the stencil is not damaged.

In the plastisol ink category, two of the textile printers, Melmarc and Total Enterprises, dropped out of the testing program before the testing and analysis could be completed. Preliminary results at these facilities indicated that water-based cleaners and soy based cleaners were effective at cleaning the ink. At Stith, water-based cleaners could not really be tested because the company's emulsion was water soluble. The soy based cleaner that was tested was effective in cleaning the ink but it added a rinsing step to the process. 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 cleaned the ink effectively. Again, the soy based cleaner required an additional rinse step. Since two of the participants dropped out of the testing program, IRTA believes additional work with textile printers should be done to further refine the performance and cost of the alternatives.

Huhtamaki has been using a water-based cleaner for several years; IRTA tested an alternative water-based cleaner that performed as well as that cleaner for removing specialty flexographic ink.

Recommendations

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

- electronics and high technology cleaning applications
- coating and adhesive spray equipment cleaning
- screen and specialty flexographic ink cleanup

Table E-1 provided the target VOC content limits that IRTA attempted to meet in the testing. In the first category in the table, "Product Cleaning," IRTA was able to find low-VOC alternatives that were cost effective in every case except Teledyne Microelectronic Technologies and Cicoil. Teledyne was willing to perform only limited testing. In Teledyne's application, the cleaning is primarily flux removal which can be accomplished by a wide range of low-VOC alternatives. The results of the testing in this category indicate that the 100 gram per liter VOC limit can be met. In the case of Cicoil, IRTA tested a number of alternatives and the only low-VOC formulation that worked for the application of cleaning the silicone grease was a blend of acetone and IPA with a VOC content of about 400 grams per liter. For Cicoil's other cleaning applications, the 100 gram per liter VOC limit can be met.

In the second category shown in Table E-1, "Cleaning of Solar Cells, Lasers, Scientific Instruments and High Precision Optics," IRTA also identified low-VOC alternatives that performed well and were cost effective. Northrop Grumman (formerly TRW) is conducting leaching tests on the solar cells with acetone which should be completed within the next year. The results of the testing in this category indicate that the 100 gram per liter VOC limit can be met.

In the third category in Table E-1, "Repair and Maintenance Cleaning of Electrical Apparatus Components and Electronic Components," IRTA identified low-VOC alternatives that were cost effective except in the case of cleaners for energized electrical equipment. Companies have traditionally used exempt solvents like TCA, CFC-113 and HCFC-141b in aerosol packages for energized electrical equipment contact cleaning. TCA and CFC-113 production have been banned and, more recently, the production of HCFC-141b has also been banned. The alternatives that will be available for this application are HFCs or HFEs which are exempt chemicals blended with DCE which is a

VOC. These formulations have a much higher VOC content than 100 grams per liter. The VOC content of two of the cleaners that were tested is 857 and 1104 grams per liter.

In SCAQMD Rule 1171, the District provides an exemption from VOC limits for aerosol products if 160 fluid ounces or less of the aerosol product are used per day. The data provided by Burbank Water & Power indicates that the company used far less than 160 fluid ounces of aerosol products per day. It is unlikely that other companies would use more than 160 fluid ounces of the aerosol products in a day. This suggests that companies that are performing energized electrical cleaning with aerosol products already meet the requirements of Rule 1171. Thus, IRTA believes that setting a VOC limit of 100 grams per liter for the entire third category is reasonable.

In the fourth category of Table E-1, “Coating and Adhesive Application Equipment Cleaning,” IRTA identified low-VOC alternatives that were cost effective for every company except VACCO. IRTA did not test cleaning agents for cleaning equipment used to spray every possible adhesive or coating but the results of the testing indicate that it is reasonable to expect that a limit of 25 grams per liter could be met. This is based on the wide range of coatings and substrates successfully tested during this project. Only two companies, VACCO and one other company, use the high VOC thin metal laminating adhesive in the Basin. The District could provide an exemption for cleaning application equipment that has been used to apply this specific adhesive.

In the fifth category in Table E-1, “Cleaning of Ink Application Equipment,” IRTA identified low-VOC cost effective cleaners for all the companies that participated in the project. In one of the subcategories, textile printing, IRTA was not able to gather implementation data. For this subcategory, IRTA suggests that more performance and cost information be obtained before the lower VOC limit for cleaners of 100 grams per liter goes into effect. For the other subcategories, IRTA believes the 100 gram per liter VOC limit can be achieved. IRTA worked with several companies that used UV curable screen ink and the results indicate that the 100 gram per liter limit can be achieved for UV printing operations. IRTA worked with one company that has been using a low-VOC cleaner for cleaning specialty flexographic ink. This indicates that the 100 gram per liter VOC limit can be achieved for this type of printing. IRTA did not work with any companies that clean UV lamps because input from industry prior to the project initiation indicated that the 100 gram per liter VOC limit for this application can be achieved easily.

In summary, then, IRTA tested a variety of alternatives for cleaning in electronics and high technology applications, coating and adhesive application equipment and printing application equipment. IRTA tried to cover all of the categories of cleaning in the application areas and worked with a number of companies on their processes. The project did not involve testing cleaning alternatives for all contaminants, coatings, adhesives or inks but it did focus on many different widely used types of these materials. IRTA believes it is reasonable to expect that a VOC limit of 100 grams per liter could be met.