I. INTRODUCTION AND BACKGROUND

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 1-1 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 1-1. 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 1-1
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 • Printed circuit board rework • Cleaning hybrid circuits • Cleaning general electrical components • Cleaning electric motors	100
Cleaning of Solar Cells, Lasers, Scientific Instruments & High Precision Optics	100
Repair & Maintenance Cleaning	
Electrical Apparatus Components & Electronic Components • Field cleaning of electric motors, generators, energized equipment • In-house cleaning of electric motors and other electrical equipment during rework, refurbishing, or rebuilding	100
Coating & Adhesive Application Equipment Cleaning • 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	25
Cleaning of Ink Application Equipment • Screen printing • UV printing • Specialty flexographic printing • UV lamp cleaning	100

Table 1-2 shows the companies and the electronics or high technology operation for which low-VOC cleaners were targeted. Tables 1-3 and 1-4 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 1-2
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.

COST ANALYSIS

IRTA performed cost analysis for each of the alternatives that was 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.

Table 1-3
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 1-4
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

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.

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.

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.

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 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 which is 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 is less than 20 grams per liter.

IRTA also successfully tested another soy based product, called Autowash #3 which is 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 this cleaner.

Acetone

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-dichloroethylene (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.

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 electronics and high technology 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 and makes recommendations for cleaning categories covered in Rule 1171. Appendix A provides Material Safety Data Sheets (MSDSs) for

some of the coatings used by the facilities in this project. Appendix B includes some 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.