II. ALTERNATIVES IN ELECTRONICS AND HIGH TECHNOLOGY EQUIPMENT CLEANING

SCAQMD Rule 1171 regulates solvent cleaning activities and, as part of that, it establishes limits for cleaners that can be used to clean electronic devices and other high technology systems. During this project, IRTA focused on cleaners used in three of the categories. First, in the product cleaning during manufacturing category for electrical apparatus components and electronic components, the VOC content of the cleaners is currently 500 grams per liter. In July, 2005, the VOC content declines to 100 grams per liter. Second, in the repair and maintenance cleaning category for electrical apparatus components and electronic components, the VOC content of the cleaners is currently 900 grams per liter. In July, 2005, the VOC content declines to 100 grams per liter. Third, in the category of solar cells, lasers, scientific instruments and high precision optics, there is currently no VOC limit for these cleaners. The target VOC limit for this category is 100 grams per liter.

2.1 Preliminary Laboratory Testing

Table 1-2 showed the list of companies IRTA worked with 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. In other cases, the cleaning of field electrical equipment for instance, it was not possible to perform preliminary laboratory testing.

Table 2-1
Electronics and High Technology Cleaning Applications

Company	Application
Teledyne Controls	Rework of printed circuit boards
Hydro-Aire	Rework of printed circuit boards
Teledyne Microelectronic Technologies	Manufacture of hybrid circuits
Corona Magnetics	Manufacture of transformers
Cicoil	Manufacture of flexible cables
Sterling	Manufacture of electric motors
Walton Motors & Controls, Inc.	Rework/rebuilding of electric motors
Burbank Water & Power	Maintenance of general field electrical equipment
	Maintenance of energized field electrical equipment
Covanta Energy	Maintenance of general field electrical equipment
Northrop Grumman (formerly TRW)	Manufacture of solar cells
Northrop Grumman (formerly Litton (Guidance & Control Systems)	Manufacture of optics
Astro Pak	Cleaning of gauges

2.2 Field Testing

For each of the companies participating in the SCAQMD 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 one case, the company decided to convert to the alternative and, in other cases, they did not convert. In some instances, companies are continuing to test alternatives.

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 for the companies participation in the study for the cost estimates. For instance, some companies indicated that their acetone use would increase and others did not. In the case where the company did convert to an alternative, a stand alone case study that describes the conversion is presented in Appendix B.

2.2.1 Teledyne Controls

Teledyne Controls is located in West Los Angeles, California. The company builds data acquisition equipment and supporting ground data processing stations for airlines and airports. Teledyne also manufactures a wireless ground link system. The systems must have high reliability.

Teledyne has their circuit boards assembled on the outside. The company does a small amount of additional assembly on the boards when they arrive in-house. A few of the boards fail quality control and they are reworked and cleaned by hand. In addition, the customer repair department does a large amount of rework. The boards are assembled using a water soluble flux. The company has a water-based cleaning system with D.I. water. This system is used in a few cases for the cleaning the flux after rework. In other cases, the company used plain isopropyl alcohol (IPA) for some of the cleaning and a blend of 50 percent IPA and 50 percent D.I. water in an aerosol package for the rest of the cleaning.

IRTA and Teledyne tested a variety of low-VOC alternatives for the IPA and the IPA/D.I. water blend. These included plain D.I. water, acetone, a saponifier and different blends of acetone, D.I. water and IPA. All of the cleaners provided visually clean boards but the worker that was performing the testing did not like the high acetone content cleaners or the saponifier because the worker determined it left a residue. The remaining three cleaners, a material called Ionox, plain D.I. water and a blend of 85 percent D.I./five percent IPA and 10 percent acetone, were further tested to determine the ionic contamination left on the boards after cleaning. All three cleaners resulted in low ionic contamination levels. Teledyne decided to adopt the blend of D.I. water, acetone and IPA which has less than 100 grams per liter VOC.

Teledyne used about 12 gallons per year of IPA for rework. At a cost for electronics grade IPA of $12.25 per gallon, the annual IPA cost amounted to $147. Teledyne also used 18 aerosol cans per year of the 50 percent IPA/50 percent D.I. water blend. At a cost of $8 per can, the cost of this cleaning agent was $144 per year. The total cost of cleaning with these materials was $291 annually.

For the alternative (85 percent D.I.; five percent IPA; and 10 percent acetone), it was assumed that usage would be the same, 12 gallons plus 96 ounces or 12.75 gallons. According to Teledyne, for the new solution, the cost of acetone would be $25 per gallon and the cost of IPA would be $15 per gallon. On this basis, the total annual cost for purchasing the low-VOC blend is $41.

Table 2-2 shows the cost comparison of the IPA and the aerosol cleaner and the blend that Teledyne adopted. The values show that Teledyne Controls reduced their costs by more than seven times through the conversion.

Table 2-2
Annual Cost Comparison for Teledyne Controls for Rework Cleaning

	IPA and Aerosol	Low-VOC Blend
Cleaner Cost	$291	$41
Total Cost	$291	$41

A stand alone case study for Teledyne Controls is presented in Appendix B.

2.2.2 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.

As part of their operations, Hydro-Aire assembles printed circuit boards. In some cases, the boards do not pass quality control and they need to be reworked. The rework process is done by hand and isopropyl alcohol (IPA) is used to clean the flux from the boards after the components have been soldered to them. Hydro-Aire uses a rosin based flux because the company has existing aerospace contracts that require it.

Two alternatives were considered for the rework operation. The reworking takes place in the same room as the main assembly operations. For assembly, the boards are cleaned in a high pressure spray system with a water-based saponifier. One option for Hydro-Aire is to clean the boards that have been reworked in this machine. The machine cycle is about 20 minutes long and the workers that clean with IPA do the cleaning in a few minutes. Although cleaning with the water-based cleaning system is an alternative, IRTA did not analyze the costs.

The second alternative tested was blends of IPA and acetone. Hydro-Aire tested a blend of 92 percent acetone and eight percent IPA, a blend IRTA devised to meet about 100 grams per liter VOC. The company used the blend for a period of time and it seemed to work well for removing the flux. Hydro-Aire is currently conducting compatibility tests to determine if the alternative cleaner is compatible with all the materials in the boards. The tests should be completed this year.

Hydro-Aire currently uses 55 gallons per month of IPA for the rework operation. The company pays $5.01 per gallon for IPA so the annual cost of purchasing the IPA amounts to about $3,307. If Hydro-Aire converted to the 92 percent acetone/eight percent IPA blend, the cost of the blend would be $4.31 per gallon, assuming a cost for acetone of $4.25 per gallon. Assuming the same amount of cleaner would be required, the annual cost of purchasing the blend would be about $2,845.

Hydro-Aire pays emission fees for the IPA. Assuming a density for IPA of seven pounds per gallon and that the cost of one ton of VOC emissions is $345, the annual emission fees amount to $797. For the new blend, which still contains some IPA, the annual emission fee would be $64.

Table 2-3 shows the cost comparison for the IPA and the IPA/acetone blend. The cost of using the IPA/acetone blend is 29 percent lower than the cost of using plain IPA.

Table 2-3
Annual Cost Comparison for Hydro-Aire for Rework

	IPA	IPA/Acetone
Cleaner Cost	$3,307	$2,845
Emission Fees	$797	$64
Total Cost	$4,104	$2,909

2.2.3 Teledyne Microelectronic Technologies

Teledyne Microelectronic Technologies is located in Marina del Rey, California. The company manufactures several different types of hybrids. In the solid state relay assembly procedure, the company employs many different cleaning processes including vapor degreasing with a cyclohexane and IPA mixture and batch loaded cold cleaning and handwiping with a range of VOC solvents.

IRTA worked with Teledyne to identify and test alternative low-VOC, low toxicity cleaners for one of the hybrid processes. The focus was to be on removing flux after soldering operations and finding alternatives for the VOC solvents used in batch loaded cold cleaning.

In one operation, the non-solid state hybrids were flushed with a spray system using IPA prior to cover sealing the assemblies. IRTA suggested that Teledyne test acetone and not cleaning at all. The not cleaning at all option worked well and Teledyne discontinued the spray cleaning operations throughout the facility.

IRTA began work with Teledyne on the flux removal operation. The company used rosin flux and removed it with a vapor degreaser that used a VOC solvent. IRTA and Teledyne decided to pursue converting to water soluble flux and testing alternative water-based saponifiers for removing the rosin flux. Although some testing was conducted, Teledyne continued to pursue testing without the support of IRTA and is currently cleaning some solid state parts with water and a saponifier. The SCAQMD extended an exemption for VOC solvents used in small vapor degreasers and batch loaded cold cleaners so the company no longer had an imminent deadline to meet.

2.2.4 Corona Magnetics

Corona Magnetics is located in Corona, California. The company manufactures electromagnetic components used in transformers and other equipment for military and medical applications.

The magnet wire used by Corona Magnetics is generally solid copper wire coated with enamel and it is hand soldered to a terminal in a printed circuit board or a copper or nickel pin. During the soldering process, the enamel is burned off. As a result, the soldering is done at high temperature, more than 700 degrees F.

In the cleaning process, the flux from the soldering operation and various other contaminants need to be cleaned. Corona Magnetics currently uses two types of cleaning processes for removing the flux. First, most of the parts are cleaned in a vapor degreaser which contains a blend of HCFC-225 and alcohol called AK-225-AES-L. Previously, Corona Magnetics used a different blend called AK-225-AES and began using AK-225-AES-L in 2003 because of VOC restrictions in SCAQMD Rule 1122. The AK-225-AES-L has a VOC content less than 50 grams per liter because it contains less alcohol than AK-225-AES. The engineer at Corona Magnetics indicates that the company is not happy with the AK-225-AES-L because it requires more handwipe cleaning.

Second, the very small and very large parts were cleaned with isopropyl alcohol (IPA) by hand. More recently, because the regulation required cleaners to have a lower VOC content, the company converted to a blend of 60 percent acetone and 40 percent IPA. In some cases, if there is a residue left after the vapor degreaser cleaning step, the cleaning is again done by hand.

Corona Magnetics currently uses a rosin based flux on the parts. IRTA and Corona Magnetics tested a water soluble flux but it was not suitable for the high temperatures required for the soldering. Rosin flux can be cleaned with a water-based cleaner and a saponifier. The company did not want to use a water-based cleaner, however, because of the uncertainty in knowing whether the part was completely dry.

IRTA and Corona Magnetics tested three alternatives including acetone, a blend of 92 percent acetone and eight percent IPA and a blend of 92 percent acetone and eight percent d-limonene, a terpene. The terpene blend did not work at all. The plain acetone and the acetone/IPA blend worked as well as the current process.

IRTA analyzed the costs of replacing the vapor degreaser and the hand cleaning with IPA with hand cleaning with either acetone or the 92 percent acetone/eight percent IPA blend. To convert to the acetone or the acetone/IPA blend, Corona Magnetics indicates they will have to install six lab hoods at $500 each. The company would also have to spend about $3,000 on additional ventilation. The total capital cost would amount to $6,000. Assuming the system would last 10 years leads to an annual cost of $600.

Corona Magnetics used about five gallons of IPA per week for the hand cleaning. The company paid $12.25 per gallon for electronics grade IPA. The cost of the 60 percent acetone/40 percent IPA blend is higher, at $20 per gallon. The annual cost of using the IPA was $3,185. The annual cost of using the 60 percent acetone/40 percent IPA blend is $5,200. Conversion to the 92 percent acetone/eight percent IPA would require 10 percent more solvent because of the higher vapor pressure of acetone. Assuming the same cost as for the acetone/IPA blend used currently, the cost of purchasing the high acetone content blend would be $5,720. The cost of acetone is about the same as the cost of IPA. Assuming that 10 percent more acetone would be used, the cost of purchasing plain acetone would amount to $3,504 annually.

The HCFC-225 blend used in the vapor degreaser costs of $140 per gallon. Corona Magnetics uses about five gallons per month. The annual cost of purchasing the HCFC-225 blend is $8,400. If acetone in a handwipe process were substituted for the HCFC-225 vapor degreasing process, more would be required. Assuming that the usage would increase to five gallons per week, the annual cost of purchasing the acetone would be $3,185. Assuming the same usage of the 92 percent acetone/eight percent IPA blend, the annual cost would amount to $5,200.

The total annual cost of purchasing the solvents for the vapor degreaser and the IPA handwipe solvent amounts to $11,585. The annual cost of purchasing the solvents for the vapor degreaser and the 60 percent acetone/40 percent IPA (the current situation) is $13,600. The annual cost of purchasing plain acetone in handwipe as a substitute for the vapor degreaser and the IPA handwipe is $6,689. The annual cost of purchasing the 92 percent acetone/eight percent IPA blend in handwipe as a substitute for the vapor degreaser and the IPA handwipe is $10,920.

The vapor degreaser uses approximately 6 kWh of electricity. Assuming it operates half the time to maintain temperature, it will use 6,240 kWh of electricity annually. At 12 cents per kWh, the annual electricity cost amounts to $749. The ventilation hoods that need to be installed for using the acetone and acetone/IPA blends would likely have one-fourth horse power blowers and they would be operated for four hours per day. Each hood would use 0.2 kW or 208 kWh annually. The six hoods would use 1,248 kWh per year. Again assuming a cost of 12 cents per kWh, the annual electricity cost of the ventilation hoods would be $150.

Corona Magnetics indicated that there is no disposal cost for the vapor degreaser. The handwipe solvents would evaporate so they would not require disposal.

Table 2-4 shows the cost comparison for Corona Magnetics. The lowest cost option is to convert the operation to plain acetone handwipe. This option is about half the cost of the cleaning currently (use of the vapor degreaser and the 60 percent acetone/40 percent IPA blend). The next lowest cost option is use of the 92 percent acetone/eight percent IPA blend in a handwipe operation. This option is about 22 percent less costly than the current option.

Table 2-4
Annual Cost Comparison for Corona Magnetics for Electromagnetic Assembly Cleaning

	Vapor Degreaser/ IPA	Vapor Degreaser/ 60/40 Acetone Blend	Acetone	92/8Ace-tone Blend
Capital Cost	-	$600	$600	$600
Cleaner Cost	$11,585	$13,600	$6,689	$10,920
Electricity Cost	$749	$749	$150	$150
Total Cost	$12,334	$14,949	$7,439	$11,670

2.2.5 Cicoil Corporation

Cicoil is a small company with 75 employees located in Valencia, California. The company manufactures flexible and cast cables that are used in aerospace, military and process automation. Cicoil assembles about 40 parts per day and they use solvent in various parts of the process. The primary cleaning agent used by the company historically was isopropyl alcohol (IPA).

IPA was used to clean the tools used in the assembly process. Some of the tools are aluminum and some are plexiglass. IPA was also used to clean flux from the cables after they were soldered. Finally, IPA was used to remove a silicone based mold release agent that was left on the assemblies from a potting operation. All of the cleaning is done in handwipe operations.

IRTA worked with Cicoil for several months and tested a variety of alternatives. The company cannot use water-based cleaners on the cables because the water can travel up the teflon insulation and into the wires when they are in the field and cause failure. Cicoil can use water-based cleaners, however, for cleaning their tooling. Some of the alternatives that were tested included water-based cleaners, various blends of acetone and IPA, d-limonene which is a terpene and a siloxane solvent.

For cleaning the aluminum tools, Cicoil converted from IPA to acetone and found that acetone worked better than IPA. The company converted to a commercial water-based product, Formula 409, for cleaning the plexiglass tooling and for removing the mold release agent from the floors. Cicoil then decided to convert to Formula 409 for cleaning the aluminum tooling as well. This cleaner worked as well as IPA. For the flux removal from assemblies that also contain some silicone grease, the only alternative that worked well was a blend of 50 percent acetone/50 percent IPA. Blends with lower concentrations of IPA simply could not remove the silicone grease. Although the siloxane solvent did remove the grease, it was incompatible with the materials of construction of the electronic assemblies.

Cicoil was using 55 gallons per month of IPA. Of the 55 gallons about three gallons were used for cleaning the tooling and 52 gallons were used for flux and silicone grease removal. Cicoil pays $6.23 per gallon for IPA. The annual cost for purchasing IPA for cleaning the tooling was about $224; the annual cost for purchasing IPA for flux and grease removal was $3,888. Cicoil is paying $7.07 per gallon for acetone. Assuming that Cicoil uses the same amount of the 50 percent acetone/50 percent IPA blend, the cost of purchasing the cleaner for flux and grease removal is now $4,150. Cicoil pays $12.61 per gallon for Formula 409. Assuming three gallons per month usage, the cost of purchasing the Formula 409 amounts to $454 per year.

Table 2-5 shows the cost comparison for Cicoil. Cicoil's cost increased by about 12 percent when the company converted to the acetone/IPA blend and the Formula 409.

Table 2-5
Annual Cost Comparison for Cicoil for Cleaning Electronic Assemblies

	IPA	Acetone/IPA and Formula 409
Cleaner Cost	$4,112	$4,604
Total Cost	$4,112	$4,604

2.2.6 Sterling Electric, Inc.

Sterling Electric, Inc. is an electric motor manufacturer located in Irvine, California. The company has been operating since 1927 and manufactures 50 motors per day. Many of the electric motors manufactured by Sterling are used in food processing equipment.

The electric motors are made of cast iron and aluminum. Sterling paints the electric motors after they have been assembled. In the past, prior to the coating process, the company used a brush and a mineral spirits VOC solvent to handwipe the motors to remove finger prints and other contaminants.

IRTA tested two alternatives for cleaning prior to painting. IRTA brought Sterling a parts cleaner containing a neutral water-based cleaner. Even though the cleaner contained a rust inhibitor, the company believed the parts were beginning to rust just after cleaning. IRTA also tested acetone for handwiping the parts. Acetone seemed to clean well and the company has recently converted to this alternative.

Sterling used about one gallon per day of VOC solvent for cleaning the electric motors. The cost of the solvent was $3 per gallon and the total annual cost for purchasing the solvent was $780. IRTA estimates that the company uses 10 percent more acetone because acetone's vapor pressure is higher than the vapor pressure of the mineral spirits. Assuming a cost of acetone of $5.17 per gallon, the total annual cost of using the acetone amounts to $1,479.

Table 2-6 shows the cost comparison for Sterling. The values show that the cost of using acetone is almost double the cost of using mineral spirits.

Table 2-6
Annual Cost Comparison for Sterling for Electric Motor Manufacture

	Mineral Spirits	Acetone
Cleaner Cost	$780	$1,479
Total Cost	$780	$1,479

2.2.7 Walton Motors & Controls, Inc.

Walton Motors & Controls, Inc. is a small company with 17 employees located in South El Monte. The company rebuilds electric motors that have been in the field, sometimes for many years. Motors are received at the facility and they are disassembled. It the windings on the electric motors are still good, they clean them without removing the protective varnish. The metal parts are cleaned in a spray cabinet that uses a water-based cleaner.

Walton historically cleaned the windings in a mineral spirits parts cleaner. IRTA tested two alternatives with Walton. IRTA provided the company with a water-based parts cleaner. The water-based cleaner is an alkaline cleaner with virtually no VOC. It performed effectively on the cleaning but Walton was reluctant to use it because oven baking would be necessary for the parts cleaned in the water-based cleaner. IRTA also tested a soy based cleaner which did not perform well on the parts. A service provider brought Walton a parts cleaner with a distillation unit that relied on a volatile methyl siloxane called D5 which is exempt from VOC regulations. Walton decided to adopt the D5 system.

IRTA analyzed and compared the costs of the mineral spirits used by the company originally, the D5 used currently and the water-based cleaning alternative.

If Walton were to use the water-based cleaner, a heated parts cleaner would be required. The cost of the unit is about $1,500. Assuming a useful life for the parts cleaner of 10 years, the annual cost would be $150.

Walton leased a mineral spirits parts cleaner from a service provider who supplied the cleaning unit and the mineral spirits and provided maintenance and disposal services. The annual cost of the service was $1,300. Walton also leases the D5 unit and the service includes maintenance and disposal costs but the company purchases the D5 separately. The cost of the D5 service is $1,188 annually.

The cost of the D5 is $35 per gallon. Walton uses the distillation unit to recycle the solvent so the company purchases five gallons every six months. The total annual cost of the D5 is $350. The cost of the water-based cleaner is $10 per gallon. If a 30 percent concentration of the cleaner were required for the 30 gallon parts cleaner, then the cost of replacing the bath would amount to $90. The cleaner would require replacement every three months. The annual cost for purchasing the water-based cleaner would be $360.

The mineral spirits parts cleaner had a one-fourth horse power pump which ran four hours per day. The annual electricity cost was $42. The D5 unit has the same pump but also has a still that is run at the end of the day. The still uses 5 kW of electricity and runs for a two hour cycle. Assuming an electricity cost of 12 cents per kWh and that the still operates for 260 days per year, the electricity cost for the D5 unit is $354 annually. The water-based parts cleaner has the same pump as the other two units and it has a 2 kW heater that cycles on and off. Assuming the parts cleaner is used four hours per day, that it cycles on half the time, that it is used for 260 days per year and that the electricity cost is 12 cents per kWh, the annual electricity cost of the water-based cleaner is $167.

If Walton were to adopt a water-based cleaner, most of the parts would be air dried. The oven the company already owns would be used to dry the electrical windings. There would be no extra cost for drying the windings because they could be put through the oven with other parts that have been coated.

The disposal costs for the mineral spirits and the D5 are included in the servicing cost. For the water-based cleaner, it was assumed that the disposal cost would amount to $2 per gallon. The disposal of the 120 gallons annually would cost $240.

Table 2-7 shows the cost comparison for Walton. The cost of using the D5 is 41 percent higher than the cost of using the mineral spirits. The cost of using the water-based cleaner is lower than the cost of using either of the solvents.

Table 2-7
Annual Cost Comparison for Walton for Electric Motors

	Mineral Spirits	D5	Water-Based Cleaner
Capital Cost	-	-	$150
Servicing Cost	$1,300	$1,188	-
Cleaner Cost	-	$350	$360
Electricity Cost	$42	$354	$167
Disposal Cost	-	-	$240
Total Cost	$1,342	$1,892	$917

2.2.8 Burbank Water & Power

Burbank Water & Power, located in Burbank, provides power to the city of Burbank. The company must maintain their equipment in the field and part of that maintenance involves cleaning surfaces of generators and transformers that are not energized and various types of equipment while it is energized which means that electricity is running through it.

Burbank Water & Power cleans their non-energized field equipment with a water-based cleaner. This water-based cleaner contains less than 10 percent of a glycol ether. Assuming the glycol ether accounts for 10 percent, the cleaner would have a VOC content of about 120 grams per liter. The company uses the cleaner sometimes at full strength and sometimes at 50 percent concentration.

IRTA provided three water-based alternative cleaners that do not have any solvent additives for testing. These include Spray Clean 12, Spray Clean 14 and AX-IT. One of the cleaners, Spray Clean 12, performed as well as the current cleaner and it has zero VOC. IRTA provided five gallons of the cleaner to the facility and the personnel indicated it cleaned well.

Burbank Water & Power currently uses 85 gallons per year of their water-based cleaner to maintain their non-energized equipment. The cost of the water-based cleaner is $9.09 per gallon. The total annual cost of purchasing the cleaner is $773. The cost of the alternative cleaner is about $10 per gallon. Assuming the same level of use, the annual cost of purchasing the lower VOC water-based cleaner would be $850.

Table 2-8 shows the cost comparison for the water-based cleaners for the non-energized electrical equipment cleaning. The cost of using the lower VOC cleaner is slightly higher than the cost of using the current cleaner.

Table 2-8
Annual Cost Comparison for Burbank Water & Power for Non-Energized Electrical Equipment Cleaning

	Current Water-Based Cleaner	Alternative Water-Based Cleaner
Cleaner Cost	$773	$850
Total Cost	$773	$850

Cleaning of energized electrical equipment is generally done with a so-called contact cleaner. The cleaner cannot be water-based because most water-based materials have low dielectric strength and they conduct electricity which would be dangerous to the workers. The cleaner generally cannot have a flash point because these cleaners also generally have low dielectric strength as well. Historically, the industry used 1,1,1-trichloroethane and CFC-113 for cleaning energized electrical equipment. When production of these two chemicals was banned, the industry began using cleaners based on HCFC-141b. HCFC-141b is a fairly significant ozone depleter and its production has now been banned. Because companies that perform energized electrical cleaning still have an inventory of the chemical, it will be used for a period of time until there is no more inventory. HCFC-141b has a dielectric strength of 53 kV while the cutoff for cleaners that can be used on energized equipment is generally 30 kV.

Burbank Water & Power, like other companies that maintain energized electrical equipment, uses an HCFC-141b aerosol cleaner. IRTA tested three alternatives with the company that could be replacements for the HCFC-141b. The first of these was based on another HCFC, HCFC-225 which is an exempt chemical. This HCFC is not as aggressive a cleaner as HCFC-141b and employees of Burbank Water & Power did not think it performed well. IRTA provided two other cleaners. One of these was a combination of hydrofluoroethers (HFEs) and 1,2-trans-dichloroethylene (DCE). The other is based on a hydrofluorocarbon, HFC-245fa, and DCE. Both of these cleaners worked well, and the employee indicated they worked as well as the HCFC-141b. The HFEs and the HFC do contribute to global warming; DCE has not been tested for chronic toxicity and it's structure indicates that it could possibly be a carcinogen. According to the MSDSs, the HFC blend has a listed VOC content of 857 grams per liter and the HFE blend has a listed VOC content of 1,104 grams per liter.

Burbank Water & Power currently uses 247 16-ounce cans of the HCFC-141b aerosol cleaner at a cost of $14 per can. The total annual cost of using this cleaner is $3,458. The cost of the HFE/DCE cleaner is $25.98 for a 12-ounce can. This translates to $34.64 for a 16-ounce can. Assuming the same usage, the annual cost of purchasing the HFE/DCE blend is $8,556. The cost of the HFC/DCE blend is $16.16 per 16-ounce can. Again, assuming the same usage, the annual cost of purchasing the HFC/DCE blend amounts to $3,992.

The employee who supervises and performs the cleaning indicated that the alternative cleaners worked well but he was concerned that the workers that do the cleaning might have to spend more time if the cleaners failed to work as well in some instances. For this scenario, IRTA assumed the cleaning labor would increase by 30 percent. Currently, six people spend two hours per week performing this type of cleaning. Assuming a labor rate of $30 per hour, the labor costs for energized electrical equipment cleaning are $18,720. If the labor cost increased by 30 percent through adoption of one of the alternatives, the labor hours would amount to 811 per year and the labor cost would total $24,336.

Table 2-9 shows the cost comparison for the energized electrical equipment cleaning. The cost of using the HFE/DCE blend if labor remains the same is 23 percent higher than the cost of cleaning with the HCFC-141b. The cost of using the HFC/DCE blend if labor remains the same is comparable to the current cost of using HCFC-141b. If the labor cost increases, the cost of using both of the alternatives is much higher than using HCFC-141b.

Table 2-9
Annual Cost Comparison for Burbank Water & Power for Energized Electrical Equipment Cleaning

	Current Cleaner	HFE/DCE (same labor)	HFC/DCE (same labor)	HFE/DCE (more labor)	HFC/DCE (more labor)
Labor Cost	$18,720	$18,720	$18,720	$24,336	$24,335
Cleaner Cost	$3,458	$8,556	$3,992	$8,556	$3,992
Total Cost	$22,178	$27,276	$22,712	$32,892	$28,327

2.2.9 Covanta Energy

Covanta has a generating facility in Sun Valley, California. The company provides electrical power to Southern California Edison. Covanta maintains their generators in the field on a regular basis. The generators are not energized when the cleaning occurs.

Covanta historically used mineral spirits to clean the generators. The company currently uses trichloroethylene (TCE) both in bulk quantities and in aerosol cans to perform the generator cleaning. Covanta provided a discarded generator so IRTA could test alternatives. A high pressure spray system that was used for spraying the mineral spirits was used for testing alternatives. IRTA and Covanta tested a soy based cleaner in various dilutions with water containing a rust inhibitor. A blend of 70 percent water, 25 percent soy and five percent rust inhibitor performed well in cleaning the generator and did not rust the parts.

Covanta uses 32 gallons of TCE at their two locations including the Sun Valley plant. About 80 percent of the TCE volume or 25.6 gallons is used in aerosol cans. Assuming there are 13 cans in a gallon, the company uses 333 cans per year. The price of the TCE is $6.94 per can. The annual cost for purchasing the aerosol cans is $2,311. The remaining 6.4 gallons of TCE is used in a blend of 80 percent TCE and another component. The price of the blend is $47. Thus the annual cost of the non-aerosol TCE blend is $376. The total annual cost of purchasing the TCE products is $2,687.

IRTA estimates that if Covanta converted to the soy material, they would have to use about 10 percent more product to obtain equivalent cleaning. Covanta uses 32 gallons of TCE based products currently so 35.2 gallons of the soy blend would be required annually. The blend is made up of about nine gallons of soy, about two gallons of rust inhibitor and the remainder is water. The cost of soy and the rust inhibitor are about $6 and $10 per gallon respectively. The annual cost of the blend would be $74.

Covanta currently pays SCAQMD toxics fees for the emissions of TCE. The cost of the emissions is 11 cents per pound. Assuming a density of 12.13 pounds per gallon for the 32 gallons of TCE used per year, the toxics fees paid by Covanta amount to $43 annually.

Table 2-10 summarizes the cost comparison for Covanta. The cost of using the soy based blend is 37 times lower than the cost of using the TCE.

Table 2-10
Annual Cost Comparison for Covanta for Generator Cleaning

	TCE	Soy Based Cleaner
Cleaner Cost	$2,687	$74
Emission Fees	$43	-
Total Cost	$2,730	$74

2.2.10 Northrop Grumman (Formerly TRW Space & Technology Division)

Northrop Grumman, located in Redondo Beach, California, manufactures solar arrays for satellites. As part of the manufacturing process, the solar cells are assembled in an array and cleaned with isopropyl alcohol (IPA) and acetone. The contaminants that are being removed are primarily particles and fingerprints.

IRTA worked with Northrop Grumman to identify and test alternative handwipe solvents for the solar cells. The company provided IRTA with a solar array with several cells to perform initial testing. In the initial testing, IRTA used IPA as the baseline. The alternatives that were tested included plain deionized (D.I.) water, plain acetone, a blend of 50 percent acetone and 50 percent D.I., a blend of 90 percent acetone and 10 percent IPA and a water-based cleaner followed by a D.I. rinse. The Northrop Grumman engineer indicated that the acetone and the acetone/IPA blend appeared to work best.

The company and IRTA performed scaled up testing on the solar cells. The technician indicated that she had used acetone in the past and it worked well. The tests indicated that acetone did perform well.

One issue that arises with the use of acetone concerns the wipe cloths used by Northrop Grumman for cleaning the solar cells. Acetone extracts certain components from the cloths. The company has a concern that the materials that are extracted from the wipe cloths will end up contaminating the solar cells if acetone is used as a final wipe. At this stage, Northrop Grumman is planning to perform tests on the wipe cloths and to determine the levels of extraction and if there could be other wipe cloths that would not result in as much extraction. IRTA also suggested that the company include blends of acetone with D.I. to see if the extraction could be minimized.

Currently, Northrop Grumman can use acetone for cleaning the solar cells but must use either IPA or ethyl alcohol for the final wipe. The results of the wipe cloth research may determine a way for the company to convert to acetone for even the final wipe.

Northrop currently pays $5.75 per gallon of semiconductor grade IPA and $5.85 per gallon for semiconductor grade acetone. The company currently uses 20 gallons of IPA and six gallons of acetone. The annual cost of purchasing the cleaners amounts to $150. If Northrop Grumman were to convert to acetone exclusively, assuming the cleaner usage would be the same, the annual cost of purchasing acetone would be $152.

Table 2-11 shows the cost comparison for converting the operation from IPA to acetone. The cost of using IPA and acetone is about the same as the cost of using acetone alone.

Table 2-11
Annual Cost Comparison for Northrop Grumman for Solar Cell Manufacture

	IPA/Acetone	Acetone
Cleaner Cost	$150	$152
Total Cost	$150	$152

2.2.11 Northrop Grumman (formerly Litton Guidance & Control Systems)

Northrop Grumman manufactures laser guidance systems for commercial and military aerospace applications including spacecraft and aircraft missiles. The high precision parts are lapped and polished and blocking materials are used to hold the parts in place during these operations. The parts are cleaned in several steps of the process to remove the lapping, polishing and blocking compounds.

In the past, Northrop Grumman relied heavily on CFC-113 and TCA for cleaning the parts. Several years ago, Northrop Grumman initiated projects to find alternatives. They converted primarily to VOC solvents and some water-based cleaning processes. At that stage, the company's operations were classified as Batch Loaded Cold Cleaners (BLCCs) using VOC solvents and were covered by Rule 1122. Northrop Grumman did not have to make a conversion away from the VOC solvents in 1999 because they qualified for an exemption, (k)(1)(c), that extended the deadline until 2003. Even so, the company decided they wanted to convert away from the VOC solvents in 1998 and they again began working on non-VOC alternatives. By January, 1999, Northrop Grumman reduced their use and emissions of VOC solvents by 16,000 pounds or eight tons annually.

In the frame manufacturing operation, Northrop Grumman used n-methyl pyrollidone (NMP) to clean wax which was used to plug the frame bores to prevent lapping compound from intruding. The company eliminated this cleaning step by using plugs with O-rings to block the frame bores acting as a physical barrier to the lapping compound. In another step, epoxy was used to bond the frames to holding fixtures during lapping and polishing. NMP was used to remove the epoxy. Hot air at a temperature of 200 degrees F is now used to separate the frame from the fixture. The thermal expansion differences between the glass frame, metal fixture and epoxy causes the debonding.

In another operation, the substrate operation, pitch was used to hold the mirror substrates to mounting blocks during lapping and polishing. NMP, Bioact 280, a terpene-based solvent and small amounts of methanol and methylene chloride were used for deblocking and cleaning. Litton has substituted a thermoplastic for the pitch in the bonding operation. Acetone is currently used to dissolve most of the thermoplastic; this cleaning step is followed by a soak in an Armakleen detergent that is a certified Clean Air Solvent. Acetone was also used in the past for the cleaning.

In the prism operation, wax is used to bond the prisms to mounting blocks for lapping and polishing. A terpene product called Opticlear was used to dissolve the wax and clean the parts. This product has been replaced by Daraclean 121, a water-based cleaner.

Northrop Grumman used 10 drums of NMP per year in their process in the past. The cost of the NMP was $450 per drum. The total annual cost of the NMP was $4,500. Fourteen drums of Bioact 280 were used each year at a cost of $550 per drum. The total cost of using the Bioact was $7,700 per year. Fourteen drums of Opticlear were also used each year at a cost of $1,695 per drum. The total cost of using the Opticlear was $23,730 annually. The cost of the methylene chloride and the methanol amounted to $200 per year. The total yearly cost for purchasing the VOC solvents was $36,130.

The new operations involve the use of Daraclean 121 and an Armakleen cleaning agent. Northrop Grumman estimates that three drums of Daraclean 121 at a cost of $850 per drum will be required. Two drums of the Armakleen detergent at $105 per drum will also be required. The total cost of the two water-based cleaners amounts to $2,760 annually.

Northrop Grumman substituted thermoplastic for pitch in the bonding operation. The thermoplastic, at a cost of $12000 annually, is much more expensive than the pitch which carried a cost of about $2,000 annually.

Disposal costs for the Bioact 280 were $1,890 per year. Disposal costs of the Opticlear was also $1,890 per year. The disposal cost for the NMP was $1,350 per year. The total disposal cost for the solvents amounted to $5,130 annually.

The disposal cost for the Daraclean 121 is $405 per year. The Armakleen detergent does not have a disposal cost. Northrop Grumman is exploring whether the thermoplastic can be recycled.

Northrop Grumman estimates that the electrical cost and the labor cost remain the same with the old and new operations.

Table 2-12 shows the cost comparison for the VOC solvents and the water-based cleaners. By making the conversions to not cleaning and to water-based cleaning, Northrop Grumman reduced their emissions by about eight tons per year. They also reduced their costs by about 65 percent.

Table 2-12
Annual Cost Comparison for Northrop Grumman for Optics Cleaning

	VOC Solvents	Water-Based Cleaning
Cleaner Cost	$36,130	$2,760
Materials Cost (Thermoplastic and Pitch)	$2,000	$12,000
Disposal Cost	$5,130	$405
Total Cost	$43,260	$15,165

A stand alone case study of Northrop Grumman's conversion is provided in Appendix B.

2.2.12 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 2-13 shows the cost comparison for IPA and acetone. The cost of using acetone is somewhat higher than the cost of using IPA. It is important to note, however, that the acetone cleaned better than the IPA.

Table 2-13
Annual Cost Comparison for Astro Pak for Scientific Instruments

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