Alternatives to Toxic, VOC, Ozone Depleting and Global Warming Energized Electrical Equipment Cleaners

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EXECUTIVE SUMMARY

For many years, halogenated solvents have been used for cleaning electrical equipment. The solvents, which are referred to as contact cleaners, have been used to clean energized electrical equipment which is equipment that has current running through it during cleaning and non-energized electrical equipment. The solvents have been sold in aerosol form and in larger quantities which are applied with a spray bottle, a wipe cloth or a high pressure spray device. The advantage of using these materials for this type of cleaning is that they do not have flash points and they are not conductive.

The major cleaners used for many years were two halogenated solvents that contributed to stratospheric ozone depletion, 1,1,1-trichloroethane (TCA) and CFC-113. Production of these solvents was banned in 1996. The industry converted to another material, HCFC-141b, which has been used for the last several years. Production of this solvent has been banned because it also contributes to ozone depletion. Until recently, there have still been stocks of HCFC-141b but it is likely to be completely exhausted in the near future.

Other halogenated solvents are now being used for cleaning electrical equipment. Table E-1 lists some of these solvents and provides information on their health and environmental problems. Trichloroethylene (TCE) and perchloroethylene (PERC) are both carcinogens and TCE is classified as a VOC. n-Propyl bromide (nPB) is a reproductive toxin, it causes nerve damage and it is a VOC. HCFC-225, like HCFC-141b, contributes to ozone depletion and its production is scheduled to be phased out in 2015 for that reason. Various hydrofluorocarbons (HFCs) and hydrofluoroethers (HFEs) are also combined with 1,2-trans dichloroethylene (DCE) and used for cleaning. HFCs and HFEs contribute to global warming and are likely to be restricted in the future and DCE is a VOC.

Table E-1
Health/Environmental Characteristics of Solvents Used for Cleaning Electrical Equipment

Solvent/Solvent Type	Issue(s)	Status
TCA	ozone depletion, global warming	production banned
CFC-113	ozone depletion, global warming	production banned
HCFC-141b	ozone depletion, global warming	production banned
nPB	reproductive toxin, nerve damage, VOC	may be regulated
PERC	carcinogen	toxic air contaminant
TCE	carcinogen, VOC	toxic air contaminant
HCFC-225	ozone depletion, global warming	phaseout in 2015
HFCs	global warming	may be regulated
HFEs	global warming	may be regulated
DCE	VOC	regulated as VOC

Because virtually all of the solvents that have been used for cleaning electrical equipment have health and environmental problems, there is a need to identify and test safer alternatives that can be used in their place. This project involved identifying, developing, testing and demonstrating alternative chemicals and methods that can be used for energized and non-energized electrical equipment cleaning where halogenated solvents have been used traditionally. The Institute for Research and Technical Assistance (IRTA), a technical nonprofit organization that develops and demonstrates safer alternatives, performed the project which was sponsored by U.S. EPA. IRTA focused on low-VOC, low toxicity alternatives because the project was performed in California which has stringent VOC regulations. The results are appropriate for California and they are also transferable to other parts of the country.

The alternatives that were identified, tested and demonstrated are shown in Table E-2. For non-energized electrical equipment, any process or non-halogenated materials can be used for cleaning since low conductivity and no flash point are not required. IRTA demonstrated that water-based cleaners, soy based cleaners and acetone formulations were viable cleaners for these applications. Acetone is not classified as a VOC and it is lower in toxicity than nearly all other organic solvents. Other VOC solvents could be used but IRTA tested only low-VOC alternatives.

Table E-2
Alternative Options for Cleaning Electrical Equipment

Type of Operation	Method(s)
Non-Energized Electrical Equipment	water-based cleaners, soy based cleaners, acetone cleaners
Mechanism Cabinets	water-based cleaners, acetone cleaners, carbon dioxide Sno-Gun
Control Panels	carbon dioxide Sno-Gun
Insulators and Other Energized Equipment	deionized water, media blasting, carbon dioxide pellet blasting

For cleaning mechanism cabinets with a small residual current, water-based and acetone cleaners can be used as long as workers clean carefully. Cleaning with carbon dioxide snow using the Sno-Gun was effective for removing dust contaminants from the mechanism cabinets. For cleaning energized control panels with only dust contamination, the Sno-Gun cleaned well.

Insulators and other energized electrical equipment can be cleaned in a variety of ways. High pressure deionized water does not conduct and it can be used effectively. Media blasting operations that rely on corn cobs or limestone are suitable for cleaning light and heavy contamination. Carbon dioxide pellet blasting was also proven effective for this type of cleaning.

The alternatives that were identified, developed and demonstrated during this project are much safer from a health and environmental standpoint than the halogenated solvents.

The results of the project demonstrated that low-VOC, low toxicity chemicals and methods are effective for cleaning both energized and non-energized electrical equipment.

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I. INTRODUCTION

Aerosol and non-aerosol contact cleaners have been used extensively for cleaning of various types. The ideal contact cleaner is one that will clean oil, grease, particulates and finger prints from surfaces and evaporate completely, leaving a clean and dry substrate. Although aerosol contact cleaners are popular because of convenience, the cleaners are also purchased in liquid form in large quantities and applied with spray bottles and/or wipe cloths.

One of the major uses of contact cleaners is cleaning of electrical devices and related equipment. These devices include printed circuit boards, generators, motors, transformers, transmission lines, insulators and capacitors. In some cases, the cleaners are used for cleaning devices that do not have electricity running through them. In other cases, electricity is running through the devices and they are referred to as energized electrical equipment.

It has become acceptable to clean energized electrical equipment only with cleaners that have no flashpoint and cleaners that are not conductive. Only certain classes of solvents do not have flashpoints and these are solvents that contain halogens like fluorine, chlorine and bromine. Nearly all halogenated solvents pose health and/or environmental problems and their use is being increasingly restricted by government agencies. Water does not have a flash point but water-based cleaners often contain surfactants that may be conductive. Even tap water can contain salts which are conductive. Although many users have traditionally cleaned non-energized electrical equipment with cleaners without flash points and low conductivity, all types of cleaners can be used for these cleaning tasks. Water-based cleaners and solvents with flash points can be used for cleaning non-energized electrical equipment.

This project involved identifying, developing, testing and demonstrating safer alternatives to halogenated solvents for cleaning energized electrical equipment and non-energized electrical equipment that has been typically cleaned with these solvents . These cleaners are generally used by electrical utilities and large companies with their own generating capability. Alternatives that were found to be viable include deionized water, water-based cleaners, carbon dioxide snow cleaning, carbon dioxide pellet blasting, corn cob blasting and acetone based cleaners. Some of these cleaners have flash points and are conductive and the project demonstrated that users can use these cleaners for cleaning certain types of energized electrical equipment if they are trained properly or if the equipment can be de-energized during cleaning. All the chemical cleaners tested have low VOC content and the results are particularly important in California and other locations where there are stringent VOC regulations.

Section II of this report provides information on the history of halogenated solvent use for cleaning energized electrical equipment and the types of equipment cleaning requirements. It also discusses the approach to the project and the alternatives that were candidates for testing. Section III describes the alternatives that were tested and the applications where they were tested and/or are suitable. This section also presents cost analysis and comparison of the alternatives with the cleaners used currently. Finally, section IV summarizes the results of the project.

II. BACKGROUND ON CONTACT CLEANING

HALOGENATED SOLVENTS

Historically CFC-113 and 1,1,1-trichloroethane (TCA) were used extensively for cleaning electrical devices of all types. In 1996, production of the two solvents was banned because they contribute to stratospheric ozone depletion. Supplies of the solvents lasted a few more years and users continued to use them during that time. The advantage of the solvents is that they have no flash point and they are low in conductivity. Moreover, the solvents are not classified as VOCs which is an advantage, particularly in California, where there are stringent VOC regulations.

Alternatives to CFC-113 and TCA emerged once their production was banned. One alternative, a hydrochlorofluorocarbon, HCFC-141b, began to be used widely for cleaning electronics devices. Another HCFC, HCFC-225, was also used in similar applications but it was much more expensive. Both of these chemicals also contribute to ozone depletion but were not included in the initial ban. Production of HCFC-141b was banned later but there is still a very small supply available today. HCFC-225 is scheduled to be banned in 2015; it can still be used but its expense deters more widespread use. The HCFCs, like CFCs, are not classified as VOCs.

An MSDS for HCFC-141b, called Ecolink 2005, is shown in Appendix A. The chemical could be purchased in drums, five gallon pails, one gallon packages and aerosol cans. It can still be purchased today but is becoming scarce as the supply declines. An MSDS for an HCFC-225 formulation containing a small amount of acetone to boost its cleaning capability is also shown in Appendix A; it is called Ecolink 3005 (A).

Other alternatives, including hydrofluorocarbons (HFCs) and hydrofluoroethers (HFEs) were developed. Because they do not contain chlorine or bromine, they do not contribute to ozone depletion. Like the CFCs and HCFCs, they have long atmospheric lifetimes and are not classified as VOCs. They are, however, global warming gases which are coming under increased scrutiny. The HFCs and HFEs have a technical limitation in that they are very poor cleaners. They must be combined with other materials to provide even a small amount of cleaning capability. Generally, they are combined with 1,2-trans-dichloroethylene (DCE) and sometimes also alcohols for cleaning electronic and electrical devices. DCE is an aggressive cleaner but is classified as a VOC. Alcohols are also classified as VOCs. The HFCs and HFEs are very expensive. The blends that are used for cleaning have no flash point.

There are several other materials that are marketed for electrical and electronic device cleaning that have no flash point. One of these solvents is n-propyl bromide (nPB). nPB is classified as a VOC, it is a reproductive toxin and it causes nerve damage. An MSDS for nPB, called Ensolv-GCS Degreaser and offered by Midsun Group, is shown in Appendix A. Perchloroethylene (PERC) and trichloroethylene (TCE) are also used for this type of cleaning. Both chemicals are carcinogens and TCE is classified as a VOC.

An MSDS for PERC, which is offered by Midsun Group for cleaning electrical devices, is shown in Appendix A.

The halogenated solvents have been widely used in a variety of forms, depending on the cleaning applications. Suppliers provide the solvents in aerosol cans and in larger quantities in liquid form. Companies that purchase the solvent may apply it by hand using spray bottles and wipe cloths or they may apply it using a high pressure spray wand.

Virtually all of the halogenated cleaners that have no flash point and low conductivity have health or environmental problems. The major material used most recently for energized and non-energized electrical cleaning is HCFC-141b. Over the last few years, HCFC-141b has become scarce and companies must find alternatives for cleaning. For cleaning non-energized electrical equipment where users have conventionally cleaned with contact cleaners, a wide variety of alternatives with flash points or higher conductivity can be used. Some of the cleaners that were tested for cleaning non-energized electrical equipment are discussed later. For cleaning energized electrical equipment, there are several approaches which are described in later sections of this report.

<u>TYPES OF CLEANING OPERATIONS</u>

The project testing was performed in California but is likely to be transferable to other locations in the U.S. Whether or not cleaning is needed and the type of cleaning that is needed depends on the location of the electrical devices. In many cases, even in the Southern California area, there may be a large variation in the need to clean just based on the location.

California has much more stringent VOC regulations than the rest of the country. The chemical alternatives that were developed and tested during this project are very low in VOC content and they are likely to be acceptable alternatives throughout the country.

During the project, IRTA worked with two electric utilities and two private companies to test alternative cleaners. IRTA also worked with an electric utility and spot power generating company to test alternatives in an earlier project sponsored by the South Coast Air Quality Management District (IRTA, 2003). The work with all of these facilities is discussed in this report.

In some locations, electrical equipment at utilities, spot power generators and other private companies can become soiled. In desert locations, for example, the equipment might become soiled with dust. In locations near the beach, a salt residue may be the soil that attaches to the device. In inner city locations, the devices may become soiled with dust, dirt and oil residue. In some locations where there is a great deal of precipitation and the air is clear, the devices may not become soiled at all. The types of contaminants that need to be removed influence the choice of the cleaning method.

Another factor that can affect the choice of cleaning method is the nature of the electrical device and its maintenance procedures. In some cases, for instance, insulators are sealed with a silicon grease that prevents contamination of the outer casing with water and other substances that would cause it to flash over. Cleaning insulators without grease is much easier than cleaning insulators with grease because the grease and the other soils must both be removed.

One approach to cleaning is to de-energize the equipment prior to cleaning. In this case, water-based cleaners or solvents with flash points that are conductive can be used for the cleaning. The devices must be fully dried before they are re-energized. While this may be acceptable for certain companies and certain types of operations, the disadvantage of this method is that power outages must be scheduled. Most power outages that are scheduled are on weekends or evenings and the labor cost of overtime work will be higher. Some companies or utilities have difficulty scheduling outages because it might interrupt power flow to their customers or they may operate several shifts.

Another approach is to simply not clean at all. Some utilities and companies have adopted this approach because they can no longer get a supply of HCFC-141b. This can be dangerous in certain locations where soiling is heavy. The soils, if they are not removed, can cause a high voltage arc which is often called flash over or tracking or arc blasting which can develop along contaminated or wet surfaces. Tracking eventually will lead to a dielectric breakdown and a short circuit will occur, generally causing permanent damage that must be isolated and repaired before electricity can be restored. In some cases, the damage may be so extensive that parts or equipment will need to be replaced.

COMPONENTS REQUIRING CLEANING

Several types of electrical or electronic components at utilities and large industrial facilities may require routine cleaning in areas where they become soiled. Transmission lines with voltages ranging from 66 kilovolts (kV) to 500 kV must be cleaned. Insulators and bushings made of porcelain or composites which are energized to about 66 kV require cleaning. Mechanism cabinets for circuit breakers and contact switches in circuit breakers or interrupters should also be cleaned. Industrial facilities may have various types of components that require cleaning. Examples include telephone switching equipment, high speed textile looms and control panels on various types of equipment.

CALIFORNIA REGULATIONS

The regulations in California are generally more stringent than the regulations in other parts of the country. The local air districts in California regulate the VOC content of cleaning operations performed at stationary sources. The California Air Resources Board (CARB) regulates the VOC content of consumer products which generally includes aerosol products.

The South Coast Air Quality Management District (SCAQMD) has jurisdiction over about half the sources in the state. SCAQMD Rule 1171 “Solvent Cleaning Operations” regulates various types of cleaning operations. The VOC limit in the rule for general repair and maintenance cleaning is 25 grams per liter. The limit for electrical apparatus components & electronic components under repair and maintenance cleaning is higher, at 100 grams per liter. Utilities and other large companies with generating capability would be subject to these limits. Rule 1171 also prohibits the use of PERC and methylene chloride.

SCAQMD also has a limit in Rule 1171 on the amount of aerosol cleaner that can be used at a stationary source. These sources can use 160 fluid ounces (about 10 aerosols) of high VOC cleaner per day. If they use more than that, the cleaners must have a VOC content of 25 grams per liter or 100 grams per liter if it is being used to clean electrical apparatus components & electronic components.

For aerosol products regulated by CARB, the VOC limit for a variety of automotive aerosol cleaners which might be used by utilities for general purpose cleaning, is 20 percent and it is scheduled to decline to 10 percent in the future. The VOC content for electrical cleaners is 45 percent. An electrical cleaner is a product labeled to remove heavy soils such as grease, grime or oil from electrical equipment. The VOC limit for electronic cleaners is higher, at 75 percent. An electronic cleaner is a product labeled for the removal of dirt, moisture, dust, flux or oxides from the internal components of electronic or precision devices. There is no VOC content limit for energized electrical cleaners which is defined as a product for cleaning when electrical current exists or when there is a residual electric potential from a component. Energized electrical cleaners must be labeled "Energized Equipment use only. Not to be used for motorized vehicle maintenance, or their parts."

SAFER ALTERNATIVES CONSIDERED AND ANALYZED

During this project, IRTA examined a number of alternative cleaning methods and tested them for cleaning certain types of energized components. Deionized water was considered for transmission line cleaning and cleaning of bushings and insulators. Carbon dioxide cleaning was tested for cleaning control panels, telephone switchgear, insulators and mechanism cabinets. Cleaning with corn cob blasting was tested for cleaning insulators. Water-based cleaners and solvent blends were tested for cleaning mechanism cabinets with a residual current.

IRTA also examined safer alternatives for cleaning certain types of equipment that was de-energized. The alternative cleaners included water-based cleaners, solvents with flash points that have low VOC content and low toxicity for cleaning contact switches in circuit breakers or interrupters. The reason IRTA tested these alternatives in de-energized equipment is because the halogenated solvents have been routinely used for this type of cleaning as well as for energized equipment. In an earlier project, IRTA also tested halogenated solvent alternatives that are now under increased scrutiny because they are global warming chemicals.

All of the cleaners that were tested by IRTA during this project had very low VOC content even though the SCAQMD and CARB regulations may allow the use of higher VOC products. IRTA tries to find alternatives with low VOC content wherever it is technically feasible.

III. APPROACHES TO CLEANING AND CLEANING ALTERNATIVES

NON-ENERGIZED AND ENERGIZED CLEANING ALTERNATIVES IN EARLIER PROJECT

Burbank Water & Power

In an earlier project, sponsored by SCAQMD, IRTA worked with a small municipal utility to test alternatives for cleaning surfaces of generators and transformers that are not energized and various types of energized components. In the same project, IRTA also worked with a spot energy producer to test alternatives for cleaning non-energized generators. In both cases, halogenated solvents had been historically used for the cleaning.

In the past, Burbank Water & Power had used halogenated solvents for their maintenance cleaning of the non-energized and energized components. The utility converted to a water-based cleaner for cleaning the surfaces of generators and transformers which are not energized when TCA and CFC-113 production was banned. The utility used HCFC-141b in place of the two other solvents for cleaning energized components after the production ban.

The utility cleaned their non-energized electrical equipment with TCA and CFC-113 until the solvents were no longer available. At that stage, the company converted to an alkaline water-based cleaner containing 10 percent of a glycol ether. The cleaner was used at full strength or at 50 percent concentration. The VOC content of the cleaner when used at full strength was 120 grams per liter. IRTA tested three other water-based cleaners with no solvent additives with the utility. IRTA provided five gallons of the alternative cleaner that worked most effectively and the personnel indicated that it cleaned as well as their current cleaner. This cleaner has less than 25 grams per liter VOC. The cost of using the alternative cleaner, assuming the same amount of usage, was estimated to be somewhat higher than the cost of using the currently used cleaner. Many other water-based cleaners with no solvent additives would also be appropriate for non-energized electrical cleaning of this type.

The utility also used CFC-113 and TCA in aerosol form for cleaning energized equipment but converted to HCFC-141b in aerosol form when the solvent supply ran out. Production of HCFC-141b has been banned and there is now very little supply left. IRTA tested three alternatives with the utility. These included HCFC-225, a blend of HFC-245fa and DCE and a blend of HFEs and DCE. The HCFC-225 is less aggressive than HCFC-141b and the personnel did not think it cleaned adequately. Both of the other cleaners worked well and the personnel indicated they worked as effectively as HCFC-141b. The cleaners have very high VOC because they contain DCE. The HFEs and the HFC also contribute to global warming and they are likely to be restricted in the future for that reason. IRTA's cost analysis for the two alternatives indicated that the cost of using the HFC based cleaner was comparable to the cost of using the current cleaner; the cost of using the HFE based cleaner was higher than the cost of using the current cleaner.

Covanta Energy

During the earlier project, IRTA also worked with Covanta Energy which had a generating facility in Sun Valley, California. The company provided power to Southern California Edison. Covanta maintained their generators in the field on a regular basis and the generators were not energized when they were cleaned. The company historically used mineral spirits to clean the generators. Covanta converted to TCE and used it exclusively in both aerosol and bulk form with high pressure sprayers to clean the generators for many years.

IRTA tested alternatives with the company on a generator that was taken off-line for the testing. The alternative that worked most effectively was a soy based cleaner in a blend of water with a rust inhibitor added. The cleaner contained 25 percent soy, 70 percent water and five percent rust inhibitor and it was applied with a high pressure spray wand. IRTA's cost analysis indicated that the cost of using the soy based cleaner was more than 30 times less costly than using the TCE aerosol and non-aerosol cleaners.

For the non-energized electrical equipment cleaning performed at Burbank Water & Power and Covanta, alternatives are readily available. Water-based cleaners and soy based cleaners proved to be effective cleaners. For the energized electrical equipment cleaning, the alternatives that were tested are not viable because they are blends of global warming gases which will be more heavily restricted in the future. Other alternatives, discussed below, are preferable.

NON-ENERGIZED VACUUM BREAKER CLEANING AT SOUTHERN CALIFORNIA EDISON

Southern California Edison has historically used denatured alcohol for cleaning the high voltage compartment of vacuum breakers and gas filled breakers. A picture of a gas filled circuit breaker is shown in Figure 3-1. The breakers are de-energized and the compartments are opened up periodically for cleaning. Current regulations require a lower VOC cleaner. IRTA tested two alternatives with Edison on various parts that had the same soils encountered in the compartments. The alternatives were also tested on various parts that require general purpose cleaning. One of the parts that was cleaned with the alternative cleaners is shown in Figure 3-2.

The alternative formulations that were tested were a blend of 97.5 percent acetone and 2.5 percent DPM, a glycol ether, and a blend of 97.5 percent acetone and 2.5 percent VM&P. MSDSs for acetone, DPM and VM&P are shown in Appendix B. Personnel who routinely conduct the cleaning indicated that both cleaners performed as well as the denatured alcohol that is used currently. Mitsubishi manufactures the equipment for Edison and must approve the alternative cleaners. Edison is currently seeking approval for the two cleaners.

Figure 3-1. Gas Filled Circuit Breaker

Figure 3-2. Parts Cleaned with Low-VOC Alternative Cleaners

ENERGIZED TRANSMISSION LINE CLEANING AT SOUTHERN CALIFORNIA EDISON AND RIVERSIDE

Southern California Edison and Riverside Electric Utility use high pressure deionized water spray systems to clean the energized transmission lines. At Riverside, the system involves using a truck with a 400 gallon storage tank filled with deionized water to clean the lines and all the conductors up to the transformers at all the substations. The deionized water is sprayed at 400 to 600 pounds per square inch pressure. Two people spray at the same time from opposite directions. The purpose is to make sure that the soil removed and pushed to the backside by one of the people is removed by the second person. If the soil is just pushed around, it could conduct at a later time and cause a flashover.

A picture of a typical substation is shown in Figure 3-3. A picture of the tank containing the deionized water is shown in Figure 3-4. Two views of the spraying operation are shown in Figures 3-5 and 3-6. Note that in each case, two people perform the spraying at the same time.

Figure 3-3. Typical Substation

Figure 3-4. Tank Containing Deionized Water

Figure 3-5. View of Spraying Operation


3-6. Another View of Spraying Operation

Some small utilities share a truck for cleaning with the deionized water. Other utilities do not clean at all because of the expense. If the utility is located in an area where the lines and conductors become soiled, the routine cleaning is necessary. If the soil is allowed to build up, it could conduct and cause a flash over that could require equipment replacement.

ENERGIZED CONTROL PANEL AND CABINET CLEANING AT BRITHINEE ELECTRIC AND SOUTHERN CALIFORNIA EDISON

Brithinee Electric

IRTA tested a carbon dioxide snow device for cleaning dust from control panels at Brithinee Electric. The Sno-Gun, made by Va-Tran Systems Inc., located in Chula Vista, California, is an effective method for removing particle and light hydrocarbon contamination from electrical and electronic devices. It has been used for cleaning hybrid circuits, fiber optics, mirrors, silicon wafers, disc drive assemblies medical instruments and a variety of other components that require precision cleaning. The carbon dioxide snow is not conductive and the tests were conducted on control panels at Brithinee that were energized during cleaning.

The Sno-Gun can clean both plastic and metal substrates. It does not damage bonding wires during cleaning. The Sno-Gun is available in hand held and automatic configurations. The hand held device was used for the testing. The hand applicator is connected to a tank of high purity liquid carbon dioxide.

The snow device was tested on a nine volt telephone panel which was energized during the cleaning and a smaller 460 volt machine control panel that was also energized during the cleaning. Pictures of the Sno-Gun cleaning the telephone switching control panel are shown in Figures 3-7 and 3-8. Pictures of the device cleaning the automatic head cutting saw control panel are shown in Figures 3-9 and 3-10. Both the telephone control panel and the saw control panel were heavily contaminated with dust and dirt. The Sno-Gun effectively cleaned the dust and dirt from the components, leaving a clean surface.


Figure 3-7. Sno-Gun Cleaning Telephone Switching Control Panel

Brithinee Electric does not currently use cleaners for cleaning the control panels. The company rebuilds electric motors and installs them in the field. The company expressed interest in being able to clean during and after installation of the electric motors as part of the service they offer. The demonstrations showed that the device is very effective in removing the types of dust and dirt they would encounter in the field in a desert location.

Figure 3-8. Another View of Sno-Gun Cleaning Telephone Control Panel

Figure 3-9. Sno-Gun Cleaning Saw Control Panel

Figure 3-10. Another View of Sno-Gun Cleaning Saw Control Panel

Southern California Edison

IRTA also tested the Sno-Gun at a Southern California Edison facility in Alhambra for cleaning circuit breaker mechanism cabinet components. As discussed above, some of the components, like the heater and battery voltage for the circuit breaker, are isolated and turned off during the cleaning. There is a residual current, however, during cleaning and the personnel must exercise caution while cleaning and must know the proper procedures. The dry ice, because it does not conduct, is a viable cleaning method in this case. The inside of typical low voltage mechanism cabinets is shown in Figure 3-11, 3-12 and 3-13.

A picture of the Sno-Gun device being tested in the mechanism cabinets at Alhambra is shown in Figure 3-14. A picture of the dry ice cylinder that feeds the Sno-Gun is also shown in Figure 3-15. The Sno-Gun was effective for cleaning components that were contaminated only with dust or dirt but was not effective for cleaning components that had oil based contamination. The testing at Brithinee Electric involved removing dust and dirt because the company is located near the desert. Most of the components at the Alhambra location, which is more of an inner city environment, had heavier oil based contamination. The Sno-Gun did not remove this contamination well.

IRTA tested additional cleaners at the Alhambra location for removing the heavier oil based contamination. The other alternatives that were tested included several water-based cleaners and two acetone cleaners. These cleaners are conductive and must be used carefully along with isolating certain of the components. Tests of the alternative cleaners are shown in Figure 3-16 and Figure 3-17.

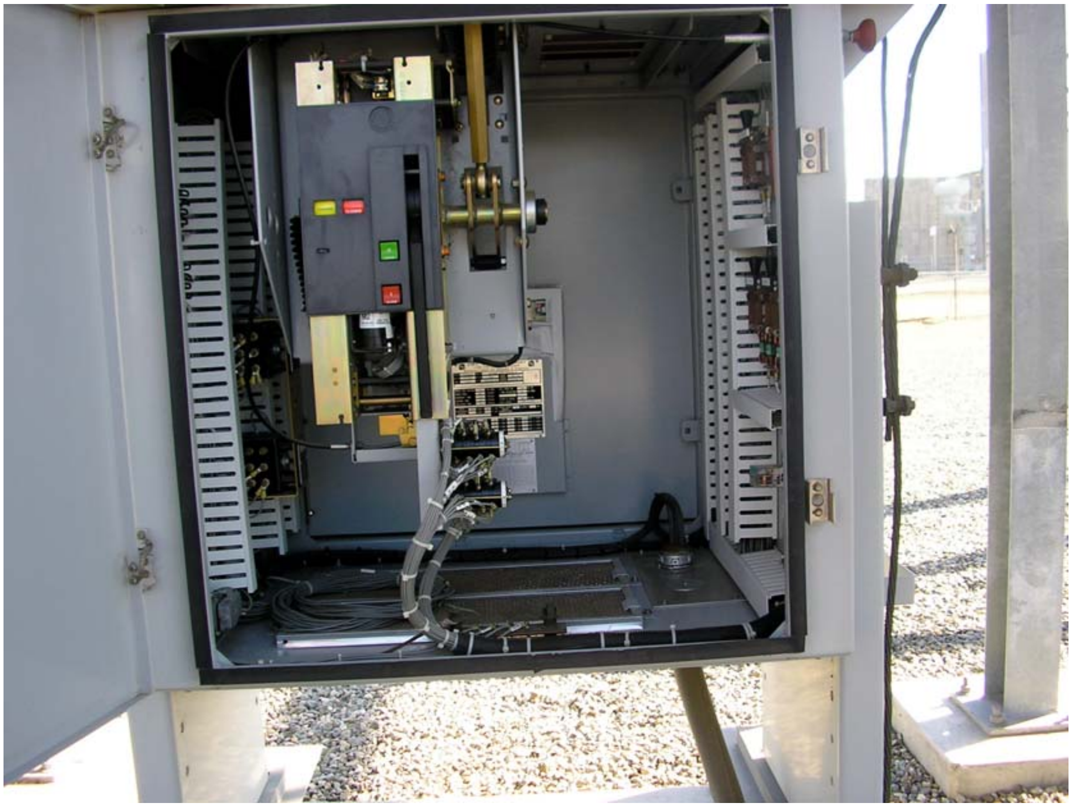

Figure 3-11. Circuit Breaker Mechanism Cabinet

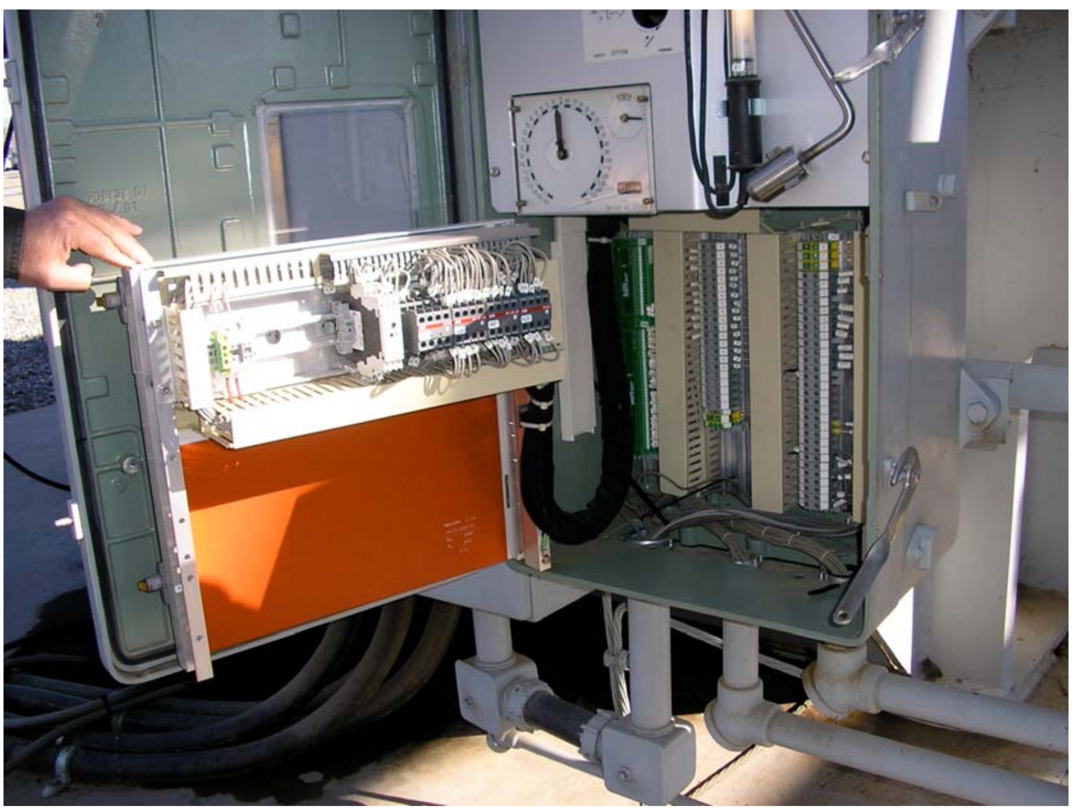

Figure 3-12. Door and Inside of Mechanism Cabinet

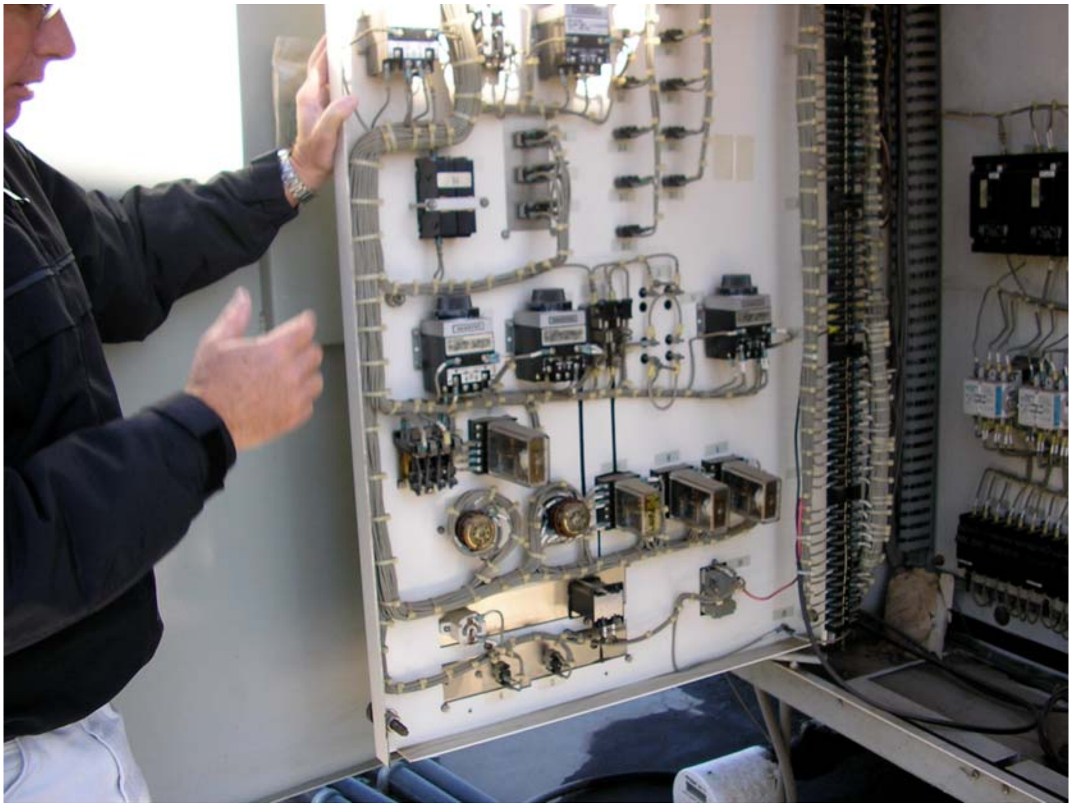

Figure 3-13. Details of Mechanism Cabinet

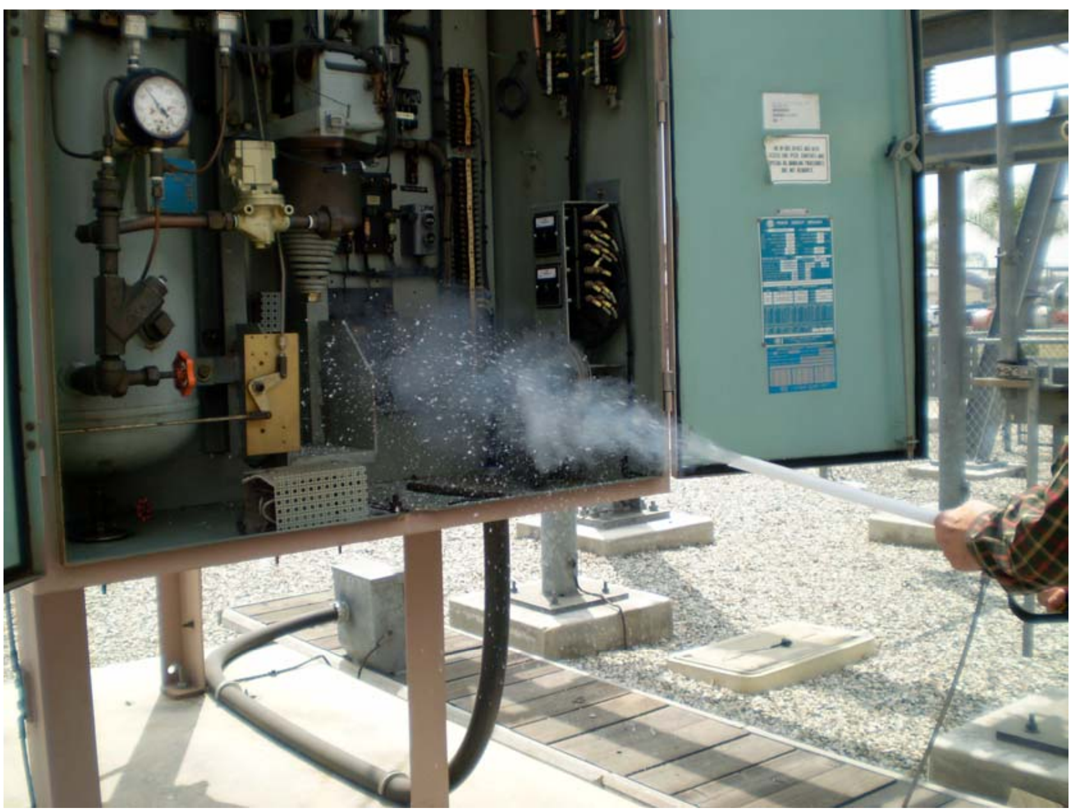

Figure 3-14. Sno-Gun Cleaning Mechanism Cabinet

Figure 3-15. Sno-Gun Dry Ice Cylinder

Figure 3-16. Testing Water-Based and Acetone Cleaners for Mechanism Cabinet Cleaning


Figure 3-17. Testing Water-Based Aerosol Cleaner for Mechanism Cabinet Cleaning

One cleaner that worked well was a water-based aerosol cleaner called Kyzen Aerosol Degreaser 11 (Aerosol CAN). An MSDS for this cleaner is shown in Appendix B. Three other water-based cleaners were tested at 50 percent concentration. MSDSs for these cleaners are also shown in Appendix B. They include PWF-10, Power Kleen: Super Scrub and Mirachem Pressroom Cleaner. The personnel liked the Kyzen cleaner best, probably because it was packaged in an aerosol can, but also indicated that the three other water-based cleaners worked well. A higher concentration of the three water-based cleaners, full strength or 75 percent, may have performed even better.

One acetone based aerosol cleaner was also tested at Alhambra and the personnel indicated that it worked well. An MSDSs for the cleaner, called Kyzen Aerosol Degreaser #3, is shown in Appendix B. The cleaner is a blend of 90 percent acetone and 10 percent VM&P with a carbon dioxide propellant. Another cleaner, a non-aerosol blend of 97.5 percent acetone and 2.5 percent of a propylene glycol ether, was also tested. An MSDS for this cleaner, Called Kyzen Aerosol Degreaser #2, is also shown in Appendix B. The personnel indicated that these cleaners also performed very well.

IRTA also conducted testing with the personnel at the Mira Loma Edison substation. Alternatives were tested for general purpose cleaning and cleaning mechanism cabinets. The company was using a high VOC aerosol cleaner and a water-based cleaner with solvent additives. IRTA tested three aerosol cleaning alternatives. The first was a blend of 75 percent acetone and 25 percent soy called Kyzen Aerosol Degreaser #1. An MSDS for the cleaner is shown in Appendix B. The second cleaner is the blend of 90 percent acetone and 10 percent of VM&P called Kyzen Degreaser #3. The third is the blend of 97.5 percent acetone and 2.5 percent of a glycol ether called Kyzen Degreaser #2.

IRTA also tested three water-based cleaners. Two of the cleaners, 90 percent PWF-10 and 10 percent water and 90 percent Power Kleen: Super Scrub and 10 percent water performed very well. The Kyzen Aerosol Degreaser 11 water-based cleaner also performed well.

ENERGIZED INSULATOR, VAULT ROOM AND SWITCHGEAR CLEANING

All utilities and large companies that have their own generating capability have insulators that are made of porcelain or other composite material. A picture of three insulators that are not in service are shown in Figure 3-18. Many utilities and companies de-energize the insulators that are in service and wipe them clean by hand with a wipe cloth and perhaps some deionized water. This is very labor intensive and it also requires the system to be down while the cleaning is being conducted. In some areas where there is substantial contamination, a silicon grease is used on the insulators to protect them from the environment. When these are maintained, they cannot be wiped clean and deionized water will not remove or solubilize the grease.

Figure 3-18. Typical Insulators

There are three alternatives for cleaning the insulators when they are energized. First, the high pressure deionized water spray using a truck can be used for insulators that are not heavily soiled and do not contain silicon grease. Second, dry ice blasting using carbon dioxide pellets is a more aggressive method that can be used for more heavily soiled insulators. Third, corn cob or other harder media blasting can be used for heavily soiled insulators and/or insulators with a greased surface. The other media that can be used include baking soda, crushed limestone and walnut shells. Limestone is less aggressive, corncob is harder and more aggressive and walnut shells are even harder and the most aggressive media.

Southern California Edison

IRTA tested a carbon dioxide pellet blasting technology at one Edison substation. Dry ice is made by liquefying carbon dioxide under pressure and then allowing it to expand rapidly. Part of the carbon dioxide evaporates and cools the remaining gas so that it freezes and creates carbon dioxide snow. Dry ice pellets with a diameter of 3 millimeter are obtained by pressing the carbon dioxide snow through an appropriate die. The dry ice pellets are used as the blasting medium which vaporizes or sublimates immediately upon impact with the surface being cleaned and returns to the atmosphere as carbon dioxide gas. There is no residue, apart from the contaminants that are removed, from the operation.

Dry ice systems typically do not come with a compressed air source but rely on the addition of an air compressor in the 50 to 75 horsepower range. Typical consumption rates are between 50 to 250 pounds per hour. Dry ice units have a hopper to store and feed the dry ice into the system. The system meters the dry ice into the hose which delivers the product through a trigger gun. A picture of the dry ice blasting unit that was used is shown in Figure 3-19. The blasting unit and the container with the dry ice is shown in Figure 3-20. The dry ice pellet blasting system cleans much more aggressively with higher pressure than the Sno-Gun discussed earlier.

The dry ice blasting system was used to clean soiled insulators at one of Edison's substations. A picture of the wand directed to insulators is shown in Figure 3-21. A closer view of the insulator cleaning is shown in Figure 3-22. According to the Edison personnel, the insulators were cleaned effectively.

Southern California Edison also uses corn cob blasting for insulator cleaning. The corn cob media is delivered with compressed air. Corn cob is a biodegradable, organic blasting media that is obtained from the hard woody ring of the cob. It is resistant to breakdown and can be used multiple times in the blasting process. Corn cob is available in a variety of grit size. An MSDS for the media is shown in Appendix B. The corn cob blasting operation is virtually dust free with no sparking and it leaves a clean, dry surface.

Figure 3-19. Dry Ice Blasting System Used for Testing


Figure 3-20. Blasting System Dry Ice Container

Figure 3-21. Dry Ice Blasting Wand Directed to Insulators

Figure 3-22. Closer View of Insulation Dry Ice Blasting

Other Utilities

Several electric utilities have also used the dry ice blasting system for major components of their overhead and underground systems, including vault rooms and switchgear. Two Canadian utilities, Oakville Hydro and Milton Hydro, had problems with energized equipment dielectric breakdown because of dust mixed with road salt and condensation deposited on live and grounded parts. The methods the utilities used for cleaning were hand wiping and high pressure water cleaning and both required de-energizing the equipment.

The utilities adopted the dry ice blasting method for cleaning the energized equipment. They were able to realize cost savings of at least 50 percent per switchgear unit by using the dry ice method in place of the conventional water wash method. The utilities are now using the method on other applications than switchgear including both dead and live front transformers, transformer rooms, electrical terminations on submersible equipment and elbows on dead-front switching units. Other utilities, including Ontario Hydro and Manitoba Hydro, have used the dry ice blasting method to clean generator windings and associated equipment.

NOT CLEANING AT ALL

IRTA contacted several utilities and large industrial operations with their own generating capacity in the course of this project. Many of the utility and company representatives had used HCFC-141b either in aerosol or bulk form for cleaning their energized electrical equipment. Most were no longer able to get the HCFC-141b so they had stopped cleaning altogether. The problem with this approach is that, if the equipment does contain contaminants, they could eventually conduct and cause an arc or flash over and the equipment will fail. In some cases, the equipment might require replacement. This is a very expensive proposition. A better approach would be to clean the equipment regularly with one of the options described earlier like deionized water, corn cob blasting or dry ice blasting or to de-energize the equipment and clean it regularly with a water-based, soy based or acetone based low-VOC cleaner.

COST ANALYSIS/COMPARISON FOR INSULATOR CLEANING

Four approaches to cleaning insulators were evaluated. First, utilities can use their own workers to hand clean the insulators with deionized water when they become soiled. Second, utilities can use halogenated aerosol or liquid cleaners to clean insulators. In this case, the workers use wipe cloths and the solvents to perform the cleaning. Third, utilities can hire a contractor who provides the service and uses media blasting to clean the insulators. Fourth, the utility can purchase a dry ice blasting system and conduct the cleaning with their own workers. The cost of performing the cleaning in these four ways was evaluated for an electric substation with 60 115 kV insulators. The insulators contain light to medium soiling.

For the deionized water hand cleaning option, it was assumed that four electricians would be required to clean the insulators in an eight hour day. The electricians would use rags wet with water to clean the soils from the insulators and then dry them by hand with a dry wipe cloth. Assuming a loaded labor rate for the workers of $75 per hour, the cost of cleaning the insulators would amount to $2,400.

For the solvent hand cleaning option, it was assumed that only three electricians would be needed to clean the insulators in an eight hour day. Use of the solvents instead of plain deionized water would allow faster cleaning because the solvent is more aggressive and would not require drying. For the case of cleaning with aerosols, it was assumed that one aerosol can would be required for each insulator. Thus 60 aerosol cans would be used for the cleaning. When HCFC-141b was widely available, the cost of an aerosol can amounted to $10. At this stage, if the solvent is available, the aerosols would be much more costly. Aerosol cans containing nPB, another solvent that is a reproductive toxin, can also be used. The nPB aerosols are priced at $15 per can. The cleaning operation could also be performed with a blend of HCFC-225, which causes ozone depletion and global warming. The cost of an aerosol can containing HCFC-225 and acetone is $25. Assuming an average cost of $20 per can, the cost of the solvent for the job would amount to $1,200. Assuming a labor rate for the electricians of $75 per hour, the labor cost for the cleaning operation would be $1,800. The total cost of the cleaning would be $3,000.

IRTA obtained a cost estimate from a company that provides the service of cleaning insulators with blasting media for utilities. Two people would be required for an eight hour day to perform the cleaning. The company would charge about $2,500 for the service.

The capital cost of a dry ice blasting system a utility would purchase is $22,000. The unit requires a compressor and the utility would also purchase this equipment. The capital cost of the compressor is estimated at $22,500. The total capital cost of the equipment is $44,500. Assuming a life for the system of 10 years and a cost of capital of four percent, the annualized capital cost is $4,628. The periodic maintenance and parts cost for the system is estimated at $2,000 per year. It will be assumed that the utility will use the system for 10 large cleaning jobs per year (one per month) and that the capital and maintenance cost can be spread over these 10 jobs. This indicates that, for cleaning the 60 115 kV insulators, the capital and maintenance cost would amount to $384 and $167 respectively.

Cleaning the 60 insulators would require three workers over an eight hour day. Two workers would perform the cleaning and one worker would make sure the hopper contained dry ice that was feeding steadily. Again, assuming a labor rate for the workers of $75, the labor cost would be $1,800. The dry ice consumption rate is 66 to 220 pounds per hour. Assuming an average consumption rate of 120 pounds per hour, an operating time for the unit of seven hours and a cost for the dry ice of 40 cents per pound, the cost of the dry ice for the job is $336. Taking these figures into account, the total cost of performing the one-day cleaning amounts to $2,687.

Table 3-1 summarizes and compares the cost of the four options. The cost of the solvent cleaning option for the 115 kV insulators is higher than the other three options which do not rely on solvents for the cleaning. Aerosol packaging of solvents is very expensive. The solvent cleaning operation could be performed with less labor by using a high pressure spray wand to apply the solvent. The solvent is very expensive, however, and much more would be used this way. In addition, the solvents pose toxicity problems to the workers and are global warming and/or ozone depleting.

Table 3-1
Annualized Cost of Cleaning 60 115kV Insulators

Method	Capital Cost	Labor Cost	Cleaner/Dry Ice Cost	Service/Maint-enance Cost	Total Cost
Water/Cloth	-	$2,400	-	-	$2,400
Solvent/Cloth	-	$1,800	$1,200	-	$3,000
Media Blasting	-	-	-	$2,500	$2,500
Dry Ice Blasting	$384	$1,800	$336	$167	$2,687

The other three options are better than the solvent cleaning option from an overall health and environmental perspective. The hand cleaning with water and the media blasting alternative options are comparable in cost. The dry ice blasting operation is somewhat higher in cost. The water hand cleaning method requires de-energizing the components which is an unquantified additional cost. Use of the outside contractor for the cleaning is attractive because the workers do not need to be diverted and it offers the convenience of having the contractor deal with everything the job involves. Finally, purchasing and using a dry ice system would require workers but is convenient for scheduling when needed and appropriate. All three methods have advantages and disadvantages.

COST ANALYSIS/COMPARISON FOR CONTROL PANEL AND CABINET CLEANING

As discussed earlier, utilities and private companies clean energized control panels and cabinets with a residual current. Historically, companies used HCFC-141b in aerosol cans for this type of cleaning. Other cleaners being used today are HCFC-225 blended with a small amount of acetone and nPB aerosol cleaners. Alternatives that were successfully tested during this project included the carbon dioxide snow technology which is effective for control panels and cabinets that contain only dust and water-based cleaners and low-VOC solvent aerosols formulated by IRTA for cabinets containing heavier soils. These are the options analyzed below. For each of the options analyzed, it was assumed that the labor cost of the cleaning operation would be the same.

According to one supplier of halogenated aerosols, typical users purchase between 12 cans and 2,000 cans of aerosol cleaners per year. The analysis is conducted here for a user that purchases 100 cans per year of the aerosol cleaners. When the supply of HCFC-141b was still plentiful, the cost of an HCFC-141b aerosol cleaner amounted to $10 per can. The cost of an aerosol can containing the blend of HCFC-225 and acetone is $25 per can. The cost of an aerosol can containing nPB is about $15 per can. Again, assuming an average cost today for an aerosol can of $20, the user would spend $2,000 per year purchasing halogenated solvent aerosol cans.

The capital cost of the Sno-Gun system offered by Va-Tran Systems Inc. is $1,975. The kit contains nine different nozzles for cleaning, depending on the characteristics of the cleaning task. Assuming a cost of capital of four percent and an equipment life of 10 years, the annualized cost would amount to $205. The maintenance and parts cost is estimated at $200 per year. The carbon dioxide consumption rate for one of the nozzles, the low flow focusing nozzle, is 15 pounds per hour. Assuming a cost for the carbon dioxide of 40 cents per pound and that the device is used for 100 hours per year (about twice a week for one hour), the cost of the carbon dioxide would amount to $600 per year. The total annual cost of using the Sno-Gun for cleaning is $1,005 per year.

The water-based and acetone based aerosol cleaners tested for cabinet cleaning were developed for testing in the auto repair industry during an earlier IRTA project (Wolf and Morris, 2006). The water-based cleaner was obtained from a supplier and IRTA had it packaged in aerosol form. IRTA developed the two acetone cleaners and also had them packaged. Since these products are not commercial, they do not have a purchase price. In the earlier study, IRTA based the cost analysis on the raw materials price of the cleaners. The raw materials cost of the water-based cleaner was estimated at 54 cents and the raw materials cost of the two acetone cleaners was 52 cents per pound. Competitive products sold for auto aerosol cleaning had roughly the same raw materials cost. These auto aerosol cleaners were sold to dealerships for $1.80 per can. For this analysis, a higher price of $2.50 per can for purchasing individual cans was assumed to be conservative. One hundred cans per year of the halogenated aerosols are purchased for the cleaning tasks. Assuming the same number of cans of the water-based cleaners and the acetone cleaners would be required leads to a total cost for this option of $250 per year.

Table 3-2 summarizes the costs for using halogenated aerosols, the Sno-Gun and the water-based and acetone based aerosol cleaners for cleaning cabinets. The cost of using the water-based and acetone cleaners is much lower than the cost of using the other two cleaning methods. The cost of cleaning with the Sno-Gun which can clean panels is substantially lower than the cost of using the halogenated aerosols.

Table 3-2
Annualized Cost of Cleaning Cabinets

Method	Capital Cost	Maintenance/ Parts Cost	Cleaner Cost	Total Cost
Halogenated Aerosols	-	-	$2,000	$2,000
Sno-Gun	$205	$200	$600	$1,005
Water-Based/Acetone Aerosols	-	-	$250	$250

The options compared here have limitations. The halogenated solvent aerosol cans can be used for cleaning cabinets and for cleaning control panels. The solvents have health and environmental disadvantages, however, and may be restricted in the future. The Sno-Gun is suitable only for cleaning dust but can be used for both control panels and cabinets. The water-based and acetone cleaners can be used for cabinet cleaning if the workers exercise care but probably should not be used for cleaning highly energized control panels.

IV. RESULTS AND CONCLUSIONS

Halogenated solvents have been used for many years for cleaning energized and non-energized electrical equipment. These solvents have no flashpoint and they have low conductivity. Historically, TCA and CFC-113 were extensively used for cleaning. When their production was banned in 1996 because they contributed to stratospheric ozone depletion, the market converted to HCFC-141b. This chemical also contributes to ozone depletion and production was banned. At this stage, there may be some HCFC-141b remaining in stockpiles but other chemicals are now being used in its place. The market has partitioned to a range of different cleaners. These include HCFC-225 which causes ozone depletion and global warming and various HFCs and HFEs which cause global warming and are likely to be restricted in the future. Other solvents like nPB, which is a reproductive toxin, PERC and TCE, which are carcinogens, are also being used. Table 4-1 summarizes the issues with all of these materials.

Table 4-1
Problems With Solvents Used for Cleaning Electrical Equipment

Solvent/Solvent Type	Issue(s)	Status
TCA	ozone depletion, global warming	production banned
CFC-113	ozone depletion, global warming	production banned
HCFC-141b	ozone depletion, global warming	production banned
HCFC-225	ozone depletion, global warming	phaseout in 2015
HFCs	global warming	may be regulated
HFEs	global warming	may be regulated
nPB	reproductive toxin, nerve damage, VOC	may be regulated
PERC	carcinogen	toxic air contaminant
TCE	carcinogen, VOC	toxic air contaminant

Virtually all of the halogenated solvents pose a health and/or environmental problem. Many of them have already been banned or regulated and the others are likely to be regulated or banned in the future. It is important to identify suitable alternatives for these materials for cleaning electrical equipment.

This project focused on identifying, developing and testing alternatives to the halogenated solvents for cleaning electrical equipment. IRTA primarily focused on alternatives for cleaning energized electrical equipment but also addressed some non-energized electrical cleaning applications where halogenated solvents have historically been and are still being used. Alternatives were identified for all applications and they included alternative technologies and alternative cleaners. California has very stringent VOC regulations and, since the project was performed in the state, the alternative cleaners that were identified have very low VOC content and low toxicity. The results of the project are appropriate for California and they are also transferable to the rest of the country.

The results of the cleaning tests are summarized in Table 4-2. For non-energized electrical equipment cleaning, any process or non-halogenated cleaner can be used. IRTA demonstrated that water-based cleaners, a soy based cleaner and low-VOC acetone cleaners are appropriate for these tasks. Acetone is not classified as a VOC and it is lower in toxicity than nearly all other organic solvents. Although other solvents with high VOC content could be used in these cases, IRTA tested only low-VOC materials. For the aerosol products, the VOC content was about 10 percent; for the non-aerosol alternatives, the VOC content was 100 grams per liter or less.

Table 4-2
Safer Options for Cleaning Electrical Equipment

Type of Operation	Method(s)
Non-Energized Electrical Equipment	water-based cleaners, soy based cleaners, acetone cleaners
Mechanism Cabinets	water-based cleaners, acetone cleaners, carbon dioxide Sno-Gun
Control Panels	carbon dioxide Sno-Gun
Insulators and Other Energized Equipment	deionized water, media blasting, carbon dioxide pellet blasting

For cleaning mechanism cabinets with a small residual current, water-based and acetone based cleaners are suitable as long as the workers perform the cleaning carefully. For mechanism cabinets containing only dust contamination, the carbon dioxide Sno-Gun proved acceptable. For cleaning energized control panels containing extensive dust contamination, the Sno-Gun was a very good option.

For cleaning a variety of energized equipment including insulators, there are a number of options. High pressure deionized water can be used. Media blasting operations with corn cobs or limestone is a good option. Carbon dioxide pellet blasting also proved to be effective.

Halogenated solvents have been and are used widely for cleaning electrical equipment. Their advantage is that they are easy to use and very forgiving. The results of this project demonstrate that low-VOC, low toxicity alternatives are available for both energized and non-energized electrical equipment cleaning. Use of these alternatives will lead to better protection of health and the environment.