MEETING THE CLEANING CHALLENGES OF THE MILITARY ELECTRONICS OEM
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ABSTRACT

The use of CFC's and other halogenated solvents as cleaners in the production of electronic systems has been the standard mode of operation in U.S. industry for many years. Cleaning and degreasing processes were specifically built around the use of CFC-113 and methyl chloroform. The properties of these two materials make them ideal for use in the work place: they are non-flammable, chemically stable, and excellent solvents for a number of "soils" present in the electronics manufacturing environment. In the 1960's and 70's very little was known about the environmental threat posed by the use of these "miracle" materials. We have since come to realize that both CFC-113 and methyl chloroform are stratospheric ozone depleters.

Responding to the challenge of effectively and economically eliminating materials that are so engrained in the manufacturing process is the dilemma facing companies like Westinghouse. The fact that the products manufactured by many of these companies are sophisticated military electronics only serves to broaden the scope of the problem. At Westinghouse we have approached this problem by: 1) quantifying as accurately as possible the level of usage of ozone depleting materials, 2) creating a focal point for information dissemination regarding alternative materials and processes, 3) pooling both capital and human resources, 4) empowering engineers to solve replacement challenges in their fields of expertise, and 5) involving Corporate research and development. Specific elements of this approach as well as results of related activities are presented.

KEYWORDS: Ozone; Methyl Chloroform; CFC-113; Degreasing; Cleaning; Defluxing; Alternative Materials

1. INTRODUCTION

Westinghouse's Electronic Systems Group (ESG) designs, produces, and supports a mix
of military and commercial electronic systems. This mix is weighted heavily toward the military (approximately 80%) side of the house. Surface and airborne radar systems account for the vast majority of this product line. Because of the nature of the mission of these systems, reliability and repeatability are of paramount importance. Because both Westinghouse and our military customers believe that process control is the best guarantee of quality products, compliance to production process documentation is as tightly monitored as hardware performance. Strict adherence to military standards and specifications as well as internal Westinghouse procedures is part of doing business with the Pentagon.

A key problem facing the military electronics OEM (Original Equipment Manufacturer) is the development of hardware cleaning processes that satisfy the cognizant military specifications and/or standards while preserving stratospheric ozone. Current wording of some military specifications advocates the use of certain ozone depleting solvents/cleaners while allowing the use of alternatives only after approval by the customer. The same restrictions apply to the choice of soldering flux. This approval process is often cumbersome and lengthy because no standard protocol has been developed for this purpose. In addition, the process is accomplished on a contract by contract basis causing larger OEM’s with hundreds of contracts a nightmare of bureaucratic entanglement. This problem is exacerbated by the presence of many electronic “commodities” that make up the overall system; each requiring some type of “in process” or “final” cleaning.

The challenge to the military supplier thus becomes the development of cleaning alternatives that: 1) satisfy the customer’s current and probable future specification requirements, 2) will not compromise system performance and reliability, 3) will not deplete stratospheric ozone, and 4) will allow implementation into the manufacturing environment with minimum interruption to personnel and production.

2. ELECTRONIC COMMODITIES

As a result of the many electronic commodities comprising ESG systems, material compatibility with cleaning solvents is a fundamental issue. The constituents of these commodities include many diverse materials ranging from paper to plastic. Electronic system components such as magnetic devices, hybrid microelectronics, microwave modules, power supplies, and printed wiring assemblies (Photos 1 - 5) all are comprised of unique and sometimes exotic material combinations. Once these components are put together in the functional “black box” (transmitter, receiver, signal processor, etc.) by way of soldered connections, a defluxing/cleaning operation usually follows. The material compatibility issue is critical at this point.
CFC-113 and methyl chloroform have worked well for cleaning and defluxing these components/commodities with minimum concern for material compatibility. In addition, the use of these two solvents has greatly simplified the cleaning dilemma once faced by producers of these items. Vapor degreasing processes (Photo 6), which capitalize on the fact that these solvents are non flammable and possess very high vapor pressures, have proliferated. However; because of material compatibility concerns with potential replacement solvents, each electronic commodity may require a unique non ozone depleting alternative. The resulting proliferation of processes and materials will require additional resources of the OEM in order to assure thoroughness of testing, adequate facilities, and real time process control mechanisms.

3. **Usage Assessment**

Realizing the potential magnitude of a chlorinated solvent elimination effort, Westinghouse ESG management decided that the first step toward achieving that goal was an overall assessment of the level of usage of CFC-113 and methyl chloroform in both manufacturing and engineering operations. ESG's Office of Regulatory Control was chartered with developing a mechanism that would determine as accurately as possible these figures. A list of "users" was developed from chemical storeroom requisition logs. A questionnaire was developed that would address the following usage related issues: 1) current inventory within each department, 2) annual usage, 3) use mode (i.e. spray booth, immersion tank, vapor degreaser), 4) application (i.e. flux removal, metal cleaning), and 5) applicable military and Westinghouse documents. Information was also solicited regarding potential alternative materials and processes. Although this effort was conducted early in the chlorinated solvent elimination program, most commodity departments were aware of some developments in alternative cleaning/defluxing technology.

4. **Creating a Focal Point**

Because of the sheer size (over 10,000 employees at the time) of the Electronic Systems Group and its heavy dependence on such a myriad of electronic commodities and the corresponding military documents, centralization of the reduction/elimination effort was a must. In December of 1989 the CFC Steering Committee was formed with the mandate to "minimize to the maximum extent possible ESG's dependence on chlorinated solvents." The operational objectives of the committee would be: 1) identify why, where, how, and in what quantities chlorinated solvents are used in current operations; 2) identify short and long term substitutes; 3) evaluate substitutes for production use; 4) implement substitutions in both manufacturing and engineering; and 5) expand the effort throughout ESG and the Corporation. Committee membership includes managers and engineers from manufacturing engineering, design engineering, materials and process engineering, quality engineering, and the Office of Regulatory Control (which includes industrial hygiene
and safety, hazardous materials control and environmental resources).

One of the first tasks of the committee was the development of a test protocol for alternative materials. This protocol would assure adequacy and consistency in testing while providing documentation so that duplication of effort would be minimized. The committee would additionally have approval authority over all testing plans.

5. REDUCTION / ELIMINATION APPROACHES

As a result of ESG’s strategy of pooling resources and centralizing the chlorinated solvent elimination effort engineers were free to develop potential cleaning alternatives best suited for his particular application; but with access to information and ideas shared by the CFC Steering Committee. This prevented individual investigators from working in a vacuum. Replacement strategies began to evolve from the work of the collective group.

5.1 Alcohol. The use of alcohol as a defluxer and/or cleaner is an attractive alternative because its use is approved in all applicable military soldering specifications and standards including Mil-Std -2000, WS 6536, and Mil-Std-454. The inclusion of alcohol in these documents underlines its proven effectiveness. Although alcohol is a non ozone depleting solvent, it does possess properties that require thorough planning of implementation strategy. Chief among these properties is its classification as a VOC (Volatile Organic Compound) and its flammability. VOC emissions are regulated by the EPA and as such require appropriate SARA (Superfund Amendment Reauthorization Act) reporting mechanisms. Because alcohol is flammable appropriate precautions must be taken to reduce fire hazards in the work place.

ESG’s will make use of alcohol as an interim cleaner/defluxer at manual soldering work stations. Estimates of current methyl chloroform use for this application range from 25 - 40% of the total volume used. A blend of isopropyl, ethyl, and methyl alcohols packaged in aerosol cans with a liquid propellant has been selected to fill this need. It is important to mention here that in applications such as this where the manufacturing operator plays such an important part in the ultimate quality of the product, a thorough training program on the optimum use of the alternative process and material is essential.

Isopropyl alcohol will also replace methyl chloroform as the final cleaning solvent for one of ESG’s low volume Printed Wiring Assembly (PWA) operations. This cleaning step is performed immediately prior to the application of conformal coatings. Since this is a low volume batch operation vapor cleaning with methyl chloroform is readily replaced with pan cleaning using electronic grade isopropyl alcohol. It should be stressed that this is a final clean operation. This means that interim cleaning has previously occurred, minimizing the level of flux and other contamination present thus minimizing the need for aggressive cleaning using a vapor degreaser.
5.2 Semi-Aqueous Cleaning  Semi-aqueous cleaning may be described as a process which is accomplished in two steps. The first step is the "wash" phase which is usually a solvent immersion or spray followed by the "rinse" or aqueous phase. Water rinsing is required because the solvent used for washing, unlike most chlorinated solvents, is non-volatile and will not evaporate. Although an effective alternative, this method of cleaning does invoke concerns that are not at issue when using methyl chloroform or CFC-113. These concerns include fire safety, waste/effluent treatment and disposal, drying time, VOC emissions, and an odor that may become unpleasant to some.

Terpene/surfactant mixtures have proven excellent cleaners and defluxers in the semi-aqueous format. They are effective on both polar and non-polar contaminants which is an important requirement in military cleaning specifications. Terpenes are also a very effective cleaner for rosin based soldering fluxes and corresponding residues. The use of this class of flux is also a requirement of current military specifications. Terpene cleaning effectiveness is well documented in the literature.

One of the most thorough investigations of the effectiveness of terpene cleaning and the process associated with the cleaning scenario was conducted by the Raytheon Company between 1990 and 1991. Raytheon, a large military electronics OEM, tested several alternative cleaner/equipment combinations using ionic resistivity, organic residue, and surface insulation resistance (SIR) as measures of cleaning effectiveness. Figure 1 shows a comparison of SIR results from PWA's cleaned in a "dishwasher" using a commercially available terpene from Petroferm and PWA's cleaned in the baseline solvent: methyl chloroform. SIR results provide some indication of the degradation of electrical resistance when PWA's are subjected to heat, humidity and electrical bias. Flux residues from ineffective cleaning have been linked to poor SIR results, and as such provide a good indication of the how well alternative cleaners perform.

Petroferm's "Bioact EC-7", a d-limonene based terpene, will be used by Westinghouse ESG as a post wave solder cleaner for PWA's. The cleaning process will utilize Electronic Controls Design, Inc. (ECD) semi-aqueous and aqueous washers (Photos 7 & 8) coupled with a decanter/separator system developed by REsys, Inc. Most of the concerns related to rinse water disposal are addressed by the use of the REsys system.

Results from ionic contamination testing of ESG PWA's cleaned with EC-7 have validated the data reported by Raytheon and others. In addition, this material has undergone a testing procedure developed by a joint IPC (Institute for Interconnecting and Packaging Electronic Circuits)/EPA (Environmental Protection Agency)/DoD (Department of Defense) program. This procedure allows alternative materials to be tested against a benchmark cleanliness level achieved by using a CFC-113 based cleaner. EC-7 was judged as "better than" the benchmark. As a military contractor, not only are the favorable results important, the fact that DoD participated in this effort is also very important.
5.3 **Aqueous Cleaning** One of the cleaning/defluxing options investigated by the CFC Steering committee was the use of *aqueous* technology. This approach is attractive to the military contractor because current specifications allow the use of water and saponifier/detergent additives. These additives are required to remove the non polar rosin flux and residues after soldering. An important element of any effective aqueous cleaning system is the choice of flux and saponifier combination. One of the primary drawbacks with this approach is the high alkalinity of the saponifiers. Resulting effluents cannot be sent to drain without extensive treatment to lower alkalinity. In addition, equipment requirements are extensive.

6. **SUMMARY**

The choice of today's military electronics OEM's cleaning process is not only driven by effectiveness; but also "environmental correctness". It is no longer acceptable to use chemicals that are known to deplete the earth's ozone layer. The challenge of replacing CFC-113 and methyl chloroform is being met at Westinghouse ESG by implementing proven alternatives that will not compromise the quality of the hardware produced while satisfying our commitment to protect the environment.

These alternatives include alcohol, which is an effective cleaner/defluxer and is approved for use in military applications. Although not a cure all, alcohol is certainly capable of filling some cleaning needs; especially as an interim defluxer during manual soldering. It is important, however, to recognize and address the hazards associated with alcohol's flammability. A limited number of semi-aqueous processes employing terpenes have passed IPC/DoD/EPA testing as well as rigorous testing by many military electronics OEM's. These processes and materials are attractive because of their ability to remove both polar and non polar contaminants, which is a requirement of cleaning systems for military printed wiring assemblies.

The technology associated with alternative cleaning processes is very dynamic. The military contractor must use restraint in equipment purchasing decisions and the allocation of manpower for the evaluation of a myriad of approaches. The contractor must also nurture a relationship with his customer that allows mutual trust and respect to flourish. This atmosphere will allow cooperation between customer and contractor during critical phases of material evaluation and implementation.
REFERENCES


PHOTO 1
Typical magnetic device
(Transformer)

PHOTO 2  Hybrid microcircuit with thick & thin film technology
PHOTO

Typical magnetic device (Transformer)

PHOTO 2  Hybrid microcircuit with thick & thin film technology
PHOTO 3: Microwave module incorporating polyimide and teflon printed circuit board materials.
PHOTO 5  Fine pitch (.020 in.) surface mount printed wiring assembly

PHOTO 6  Batch vapor degreaser with automatic transport
FIGURE 1  Baseline SIR results using methy chloroform (above)
SIR results using semi-aqueous washer (Machine "D")
and terpene cleaner (below)
PHOTO 1 Batch aqueous cleaner with optional saponifier attachment

PHOTO 2 Batch semi-aqueous cleaner
CFC REPLACEMENT

CRITICAL AREA RESPONSE

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