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THE SEARCH FOR CFC ALTERNATIVES IS OVER?

Tim Crawford
Electronics Manufacturing Productivity Facility
714 North Senate Avenue
Indianapolis, Indiana 46202

ABSTRACT

The Electronics Manufacturing Productivity Facility (EMPF) is a U.S. Navy Center of Excellence tasked to do research in electronics manufacturing. For the past seven years, the EMPF has performed extensive research in various cleaning materials and processes that have recently been made available to printed circuit board assemblers. This paper outlines our research and points out the positive and negative aspects that need to be considered when choosing an alternative process.

INTRODUCTION

The search to find suitable alternatives to chlorofluorocarbon-based (CFC) cleaning solvents is coming to an end. That does not mean the issues are any clearer, nor does it mean the decisions are any easier. It means that we are out of time and a decision, right or wrong, has to be made.

The Electronics Manufacturing Productivity Facility (EMPF), located in Indianapolis, Indiana, is a Navy Center of Excellence tasked to do research in electronics manufacturing. Information learned in our research is disseminated to the electronics manufacturing industry via final reports, technical articles, seminars, and workshops. Part of our charter is to give telephone consulting to those who have problems in specific areas of their assembly process. Many of the telephone inquiries that I have received lately usually begin, "I heard that CFC's are being phased out. Is this true?" Or, "My boss told me to get rid of our CFC's. What other solvent can I put in my vapor degreaser?" "I heard CFC's are being phased out, but I'm just going to have to get a waiver because I still need to clean." There was one caller who proudly stated "I don't know what all the fuss is to get rid of CFC's. I found a solvent that works just fine. Trichloroethane!" It was hard to tell him that he had jumped off a sinking ship into a life raft with a big hole in it.

For those who are still unsure of the situation, here it is in a nutshell. Scientists have claimed that CFC molecules are depleting the Earth's protective ozone layer. In 1987, the Montreal Protocol was signed, calling for a gradual global reduction of all production of CFC's by the year 2000. President Bush accelerated the reduction to include a complete phaseout in the United States by 1995. Shortly after that, the Copenhagen amendment adopted that same phaseout for the rest of the world. DuPont, the world's largest producer of CFC's, has announced it will stop all Class I CFC production by the end of 1994. In an effort to dissuade manufacturers from using CFC's, the Clean Air Act established a labeling law effective May 15, 1993 requiring products made with, or containing, Class I or Class II CFC's be labeled as such. As an added burden, annual tax increases imposed by the federal government are driving the cost of CFC's higher each year.

If you are one of many who are thinking, "No problem - I still have two years," there is more. Consider that even if you had complete control of your budget with unlimited financial resources and were able to order equipment today, you should not expect delivery for 6 to 12 months depending on how many other orders were taken that day. Add to that the acquisition of water treatment systems (both before and after the cleaning process), an air treatment system, installation, process development and training. All of a sudden two years does not seem that long.

Before any of this can happen, of course, you must select from the many cleaning chemistries and alternate fluxing/soldering processes that are available. You could call various vendors and listen to their sales pitches, or sift through junk mail and look for the advertisements with water falls, green grass, sunshine, smiling birds, orange trees and the all too familiar universal symbol for "contains no CFC's". Selecting a substitute that is right for your process is a job in itself and you can't take short-cuts by looking at your neighbor's house to see what they're using. What's right for their process may or may not be right for yours. The cleaning efficiency of a solvent will depend on variables such as flux type, board design, density, component types, throughput, cleaning machine, time, spray nozzle configurations and pressures, to name a few. In addition, environmental laws vary from state-to-state and even between localities within the same state.

CFC ALTERNATIVE TESTING

The EMPF, along with the Institute for Interconnecting and Packaging of Electronic Circuits (IPC), has tested 15 commercially available solvents to date (see table) for use with rosin-based fluxes. Although these solvents have passed a very carefully controlled test, the "best" solvent or even "possible" solvent will vary with your process. You may use this list as a starting point, select a few possibilities, and see what works best for you.

In addition to deciding what works best from a cleaning standpoint, there are other concerns that must be considered. Material compatibility examines how these cleaning materials will react to materials on your product such as part markings, solder mask, laminates and some components. Industrial hygiene and safety addresses odor, flammability, and exposure limits. From an environmental standpoint, is the waste treated as hazardous material or can the solvent be easily treated to drain, recycled or even close-looped? Finally, the cost associated with the new process needs to be considered. Equipment costs, material costs, operational costs, maintenance costs, engineering, labor and training costs. There are also costs associated with support equipment for water, air and waste management.

PHASE 2 APPROVED CFC ALTERNATIVE CLEANING MATERIALS
as of June 1, 1994

Allied Signal Genesolv 2004	Mike Ruckriegel	(201) 455-6751
Alpha Metals 2110	John Stevenson	(201) 434-6778
British Petroleum Prozone	Dave Dodgen	(214) 238-1224
Bush Boake Allen Solvent E212	Richard Lamp	(904) 783-2180
Church & Dwight Armakleen E-2000	Frank Cala	(609) 683-7068
Dr. O.K. Wack Chemi Zestron	Karsten Lessmann	011 49 841-635-0 (Germany)
DuPont Axarel 32	Rich Stewart	(919) 248-5048
DuPont Axarel 38	Rich Stewart	(919) 248-5048
ECD Emulsonator/DuPont Axarel 36	Steve Glass	(503) 659-6100
Exxon Actrel ED11 & Actrel ES	Jim Schreiner	(713) 425-2115
Envirosolv KNI-2000	Steve McCane	(904) 724-1990
Hughes RADS	Rick George	(310) 616-6085
ISP Micropure CDF	Jim Butler	(201) 628-3345
Kyzen Ionox MC	Kyle Doyel	(800) 845-5524
Petroferm Bioact EC7	Craig Hood	(904) 261-8286
Petroferm Bioact EC7R	Craig Hood	(904) 261-8286
Petroferm Bioact EC-Ultra	Craig Hood	(904) 261-8286

In addition to the solvents listed, other cleaning processes are either in process or being planned for the near future.

CLEANING WITH ULTRASONIC ENERGY

Using ultrasonic energy to satisfactorily clean tough situations or improve a less-aggressive solvent's cleaning ability may also be an option. Historically, the military has been against the use of ultrasonics because of some studies performed in the 1950's that showed ultrasonic frequencies were causing fragile wire interconnects between the die and the terminal of microelectronic devices to vibrate enough to fatigue and eventually break. The military has recently changed its stand; however, and the latest revisions to some military specifications now state:

> *"Ultrasonic cleaning is permissible on electronic assemblies with electrical components, provided the contractor has documentation available for review showing that the use of ultrasonics does not damage the mechanical or electrical performance of the product or components being cleaned."*

This change of heart by the military is due to more recent studies conducted by the EMPF and other research laboratories that have given us a better understanding of ultrasonics. At the same time, newer wire bonding techniques have provided a more robust component which is more able to withstand the harsh vibrations of ultrasonic energy. This is not to say ultrasonics is 100% safe. Under proper conditions, ultrasonics can be a useful tool, but fatigue is a part of life with ultrasonics and some components under certain applications will fail. "Test clean" a safe sample of your product in ultrasonics before you invest a large quantity of time or money.

WATER SOLUBLE FLUXES

Another option may be to eliminate rosin-based fluxes all together and use a water soluble flux (WSF). WSF can be cleaned either by using water alone, or water with a detergent/saponifier. WSFs will typically provide excellent solderability and enlarge the soldering process window. The reason they provide such good solderability is because of their corrosivity; however, these corrosive properties can cause problems if cleaning is not properly performed. If a WSF were to get trapped in an area, such as under a tightly spaced component, inside an unsealed component, or up under the insulation of a stranded wire, a failure is likely to occur. Many WSFs contain polyethylene glycols and other polyglycols which are nonionic and hygroscopic, meaning they will absorb moisture from the air and promote electrochemical migration and degradation of electrical performance in the presence of ionic contamination. Since polyglycols are nonionic, they cannot be measured in the commonly used resistivity of solvent extract cleanliness tests such as the Omegameter™ or Ionograph™. Recent revisions to military specifications are allowing the use of WSFs (except on stranded wires and unsealed components) with certain restrictions being placed on those containing polyglycols. These restrictions are currently being reviewed by the Navy.

NO-CLEAN FLUXES

If selecting a cleaning process looks tough and you're thinking about taking the easy way out by going to a "no-clean" flux, it's not that easy. No-clean does not mean you do not have to clean because there is no residue, it means you do not have to clean because the residue is small, and not detrimental to the assembly. No-clean fluxes, also known as low solids, or low residue (LR) fluxes, were formulated to leave a minimum quantity of a benign residue. This residue is not conductive or corrosive; however, it may interfere with the adhesion of the conformal coating. As in choosing a cleaning material, other issues must be considered when selecting and implementing a low residue flux. Material compatibility, environment, industrial hygiene, safety, and cost associated with the new process all need to be considered. Flux application is not as simple as it was with the good old rosin-based fluxes, and the operator must have an intimate knowledge of his soldering process. On the positive side, the military recognizes the potential for using LR fluxes for a broad range of soldering applications,

including soldering of stranded wires and unsealed components. The potential of LR fluxes is reflected in the most recent revisions to military specifications.

In contrast with the WSFs, LR fluxes are not very aggressive, therefore they create a smaller soldering process window. This window can be enlarged by using an inert atmosphere such as nitrogen to reduce oxidation of the base metals. Another process worth considering which also requires nitrogen, uses a dilute adipic acid to precondition the board. The actual soldering takes place in a sealed chamber filled with an inert atmosphere of nitrogen and formic acid. When exposed to the high temperatures associated with wave soldering, the adipic acid evaporates and the formic acid converts to carbon dioxide and water. Only a small amount of noncorrosive residue is left on the assembly.

Manufacturers who are going to LR fluxes must think no-clean ***process*** from incoming component and board cleanliness levels throughout all stages of handling, processing and shipping. Implementing a no-clean process is not as simple as changing the flux and rolling the vapor degreaser out into the back alley for the trash collector. Unfortunately, flux is not the only source of contamination. There are several very ionic, very corrosive materials that are used in the manufacturing of bare boards. An assembler must verify that the bare boards, along with components and other parts to be used on the assembly, are clean upon receiving, then maintain that level of cleanliness throughout the assembly process. Ionic and nonionic residues come from many sources and preventing this contamination from coming into contact with the assembly is hard. Even a bare board that was verified to be clean upon arrival at the assembly facility may still leach ionic materials when exposed to elevated temperatures. Parts are sometimes stored for months at a time in a clean(?) storage area awaiting subsequent operations. Boards are handled and moved from station to station for component insertion and soldering. The cleanliness level of the parts is only as clean as the people handling them, and many people do not realize that not all gloves are free of ionic residue. If the gloves are free of ionic residue, do assemblers contaminate the outside of the gloves when removing them from the bag or when putting them on? Will an assembler use the gloved hand to open a valve, turn an unclean doorknob or satisfy an itch? A no-clean process is possible, but it starts from the bare board and continues until the assembly is complete. There are big companies, with big research departments, with big dollars, that have spent years developing a reliable LR process.

CONCLUSION

Choosing and implementing a process that is right for your particular assembly house takes time, and you have no time-outs left. CFCs will be phased out by the end of 1995. Acquiring CFCs will be harder and more expensive by the end of 1994, and the labeling law is currently in effect.

- Will you use rosin-based, water soluble, or low solids flux?
- Will you solder in air or nitrogen?
- Which solvent is best?
- Which machine is best?
- Which process is best, aqueous or semi-aqueous? Batch or in-line?
- Should you use ultrasonic energy?
- Will you recycle, treat or close-loop your effluent?
- Will you clean or is no-clean the ultimate solution?

A decision has to be made because the search to find suitable alternatives to CFC-based cleaning solvents is coming to an end.

Phase 2 Approved Commercially Available CFC Alternative Cleaning Materials as of 7/94

SOLVENTS

Allied Genesolv 2004 (HCFC)	Mike Ruckriegel	(201) 455-6751
* Advanced Vapor Degreasing (AVD) with Petroferm Solvating Agent 24 & 3M PF-5070 Rinse Agent		
Petroferm Solvating Agent 24	Christine Fouts	(904) 261-8286
3M PF-5070 Rinse Agent	Wayland Holloway	(612) 737-3030

SEMI-AQUEOUS SOLVENTS

* Arakawa Pine Alpha ST-100S	Dave Ahlberg	(310) 373-0404
British Petroleum Prozone	Dave Dodgen	(214) 238-1224
Bush Boake Allen E-212	Richard Lamp	(904) 783-2180
Dr. O.K. Wack Zestron FA	Karsten Lessmann	011 49 841-635-0 (Germany)
ECD Emulsonator/DuPont Axarel 36	Pat Barrett	(503) 659-6100
Envirosolv KNI-2000	Steve McCane	(904) 724-1990
Exxon Actrel ED11 & Actrel ES	Jim Schreiner	(713) 425-2115
ISP Micropure CDF	Jim Butler	(201) 628-3345
Kyzen Ionox MC	Kyle Doyel	(800) 845-5524
Petroferm Axarel 32	Jim Scott	(904) 261-8286
Petroferm Axarel 38	Jim Scott	(904) 261-8286
Petroferm Bioact EC7	Craig Hood	(904) 261-8286
Petroferm Bioact EC7R	Craig Hood	(904) 261-8286
Petroferm Bioact EC-Ultra	Craig Hood	(904) 261-8286

AQUEOUS SOLVENTS

Alpha 2110 Saponifier	John Stevenson	(201) 434-6778
Church & Dwight Armakleen E-2001	Frank Cala	(609) 683-7068
Lonco RADS	Kevin Grossenbacher	(800) 323-9625

**** approval pending***