empfasis

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The EMPF is a U.S. Navy-sponsored National Electronics Manufacturing Center of Excellence focused on the development, application, and transfer of new electronics manufacturing technology by partnering with industry, academia, and government centers and laboratories in the U.S.

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In This Issue

Design, Manufacturing, and Packaging in Sustainment

According to the Defense Systems Management College (DSMC), Program Sustainment is defined as an activity to meet the operational and support requirements of a program in a cost effective manner. Program Sustainment emphasizes system availability, maintenance, and system upgrades, but in the case of the AN/ARS-6 (V) being re-designed at the EMPF, this includes increases in functional capabilities, manufaturability, and packaging as well.

The AN/ARS-6 (V) Personnel Locator System (PLS) is the airborne radio that communicates with the PRC-112 and other handheld survival radios during CSAR (Combat Search And Rescue) operations. They are used in CSAR systems for the US Army (standard), Navy, Air Force, National Guard, and NATO providing directional and range information to the rescue aircrew, locating downed pilots or other survivors. Compatibility with multiple platforms and aircraft, power and communications bus systems, in addition to the new functionality, is required.

Upgrade/Sustainment of the AN/ARS-6 (V) PLS (as shown in Figure 1-1) was initiated by the program stakeholder, the US Army Communications Electronics Command (CECOM) - Logistics and Readiness Center - Fort Monmouth, New Jersey.

This unique sustainment project's goal is to upgrade the functionality while sustaining the service life of the AN/ARS-6 (V) Receiver/Transmitter Unit, Control Display Unit, and Remote Display Unit. The three upgraded components of the AN/ARS-6A (V) must be compatible with the current system's form, fit, and function in the rescue vehicle, typically the Blackhawk A and L model helicopters, or fixed wing aircraft such as the Air Force A-10.

In addition to functionality improvements, manufacturability is being improved by the application of DFM (Design for Manufacture) principles to the assembly. The AN/ARS-6A (V) will maintain the equivalent fit as the original

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Figure 1-1 – AN/ARS-6 (V) System used in DoD and NATO rotorcraft

NAVY MANTECH manufacturing technology program

Design, Manufacturing, and Packaging in Sustainment

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in existing applications through the use of a mounting bracket. But for ease of assembly and repair, and new smaller form applications (such as Blackhawk M and UAVs) will be streamlined and miniaturized. (See Figure 1-2) These techniques are based on use of COTS components and current electronics packaging systems such as compact PCI bus architecture and standard interconnect hardware.

Figure 1-2 – AN/ARS-6 (V) system (left) with newer redesigned AN/ARS-6A (V) (right)

A critical sustainment project milestone is passing the Airworthiness Requirements defined by the program stakeholder.

Functional Testing

The upgraded AN/ARS-6A (V) must pass a series of environmental and Electromagnetic Interference (EMI) tests while in operation. These functional requirements were specified by the Army's Aviation Engineering Directorate (AED) and include the newly designed-in functionality. To pass functional testing, compatibility with the GPS (Global Positioning System) and SARSAT (Civilian Satellite based search and rescue) waveforms, in addition to the DME waveform used in the current system, is required.

Failure to pass these functional tests indicates the system is not acceptable for flight operations. For example, the AN/ARS-6A (V) display units will have to be compatible with night vision goggles used by rescue aircrews. The COTS software defined radio used must be able to be programmed with the legacy DME as well as the GPS and SARSAT waveforms. Compatibility with the new CSEL survival handheld radio will be attained using a Communications Interface Module (CIM) separately contracted with the CSEL vendor.

Environmental Stress Screening and Electromagnetic Interference Testing

These procedures expose the hardware to the environmental conditions it will experience during its service life. Conditions of shock, vibration, salt spray, among others need to be tailored to fit the many potential service environments

Electromagnetic Interference (EMI) test procedures are provided in MIL-STD-461E; Department of Defense Interface Standard This standard identifies the verification requirements for the control of electromagnetic interference within systems and subsystems. This EMI requirement must be met for all of the rescue vehicles in which the system might be deployed, whether it is a (typically legacy) aircraft with no internal EMI shielded bus structure, 1553 Ethernet or ARINC signaling bus as on more current aircraft, or other signaling or different power bus structures. For example, ACI engineers recently addressed such EMI issues on a helicopter borne intercom system in a similar sustainment/redesign effort. Through use of selective filtering connectors and other mitigation techniques, good EMI performance was attained.

Functional Tests will be performed during the specific environmental and electromagnetic tests required to obtain the Airworthiness Certification

Conclusion

The re-design/sustainment of the AN/ARS-6 (V) PLS has presented design, packaging, and manufacturing issues.

The new AN/ARS-6A (V) re-designed system will be collaboration between the CECOM program stakeholder and the ACI system developer. The program stakeholder, CECOM, defined the system functional and sustainment issues. This strategy for developing and fielding the new, more functional, and more manufacturable, AN/ARS-6A (V) PLS to meet its mission, Airworthiness Certification, and program sustainment requirements is currently being implemented at the EMPF.

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IPC/WHMA-A-620

The EMPF offers operator proficiency training for IPC/WHMA-A-620. This specification describes the accept and reject criteria for producing crimped, mechanically secured or soldered interconnections as well as the lacing and restraining criteria related to cable and wire harness assemblies.

The duration of the training program can range from 1 to 3 days, depending on the modules selected. Proficiency is determined through a series of written, standardized exams developed by the IPC/WHMA. Operators will be tested on each module in which they are trained and will receive a portable certification (valid for 2 years) in the areas where proficiency is demonstrated. Following is a brief description of each of the modules available.

Modules 1 and 2 (prerequisites for modules 3 - 18)
Modules 1 and 2 cover the purpose and scope of the document, general criteria, and related applicable industry specifications. Students will learn how to properly interpret the acceptability requirements, understand the differences between the classes of electronics, and become familiar with commonly used terminology. Companies can select additional training for the various other cable and wire assembly acceptance requirements.

Module 3 - Preparations
Module 3 covers the allowable amount of conductor strand damage, wire separation, and insulation damage.

Module 4 - Solder Terminations
Module 4 covers the requirements for tinning and gold removal of wires, cleanliness, insulation, flexible sleeve insulation, wire separation, wire attachment, and solder requirements for wires attached to common terminals.

Module 5 - Crimp Terminations
Module 5 covers the requirements and allowable deformation for stamped/formed contacts and machined crimp contacts.

Module 6 - Insulation Displacement Connections (IDC)
Module 6 covers the acceptance criteria for mass termination, flat cable, and discreet wire terminations.

Module 7 - Ultrasonic Welding
Module 7 covers insulation clearance and weld nugget criteria.

Module 8 - Splices
Module 8 covers soldered splices, crimped splices, and ultrasonic welded splices.

Module 9 - Connectorization
Module 9 covers acceptance criteria for hardware mounting, strain relief, sleeving, boots, and allowable amount of connector damage.

Module 10 - Molding Potting
Module 10 covers the requirements for molding and potting of cables and wires.

Module 11 - Cable Assembly and Wires
Module 11 covers the identification of reference designators and surfaces and how to properly measure wire lengths.

Module 12 - Marking and Legibility
Module 12 covers the requirements for marking content, legibility, permanency, location, functionality, and marker sleeves.

Module 13 - Coaxial and Twinaxial Assemblies
Module 13 covers the requirements for stripping, center conductor terminations, solder ferrule pins, coaxial connectors, terminal covers, shield terminations, center pin position, semi-rigid coax, swage-type connector, and soldering and stripping of biaxial or twin axial wires.

Module 14 - Wire Bundle Securing
Module 14 covers the proper tie wrap and lacing application, requirements for wire breakouts, and wire bundles.

Module 15 - Shielding
Module 15 covers the requirements for electrical shielding. Operators will learn requirements for braided shielding, shield termination, proper tape wrapping, conduit shielding, conductive coating, and shrink tubing.

Module 16 - Cable and Wire Harness Protective Coverings
Module 16 covers protective coverings used for cable and wire harness assemblies. Subjects include braid, taping, sleeving, and spiral plastic wrap.

Module 17 - Installation
Module 17 covers the requirements for installation of hardware and wire harness installation. Operators will learn the proper assembly sequence for hardware and the stress relief required for wires.

Module 18 - Solderless Wrap
Module 18 covers the acceptance requirements for solderless wrap connections. Topics include number of turns, turn spacing, end tails, insulation wrap, raised turns, connection position, wire dress, wire slack, plating, and damage.

Employees who attend a regimented training program will be better equipped to recognize acceptable products from defective ones. For further information, please contact the EMPF registrar at (610) 362-1295 or registrar@empf.org.

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Analysis and Restoration of Storm Damaged Boards

In a world of aging circuitry and components, many companies often try to maintain electronic systems as long as possible. Most companies have developed plans to retrofit systems and update circuitry. Through-hole devices will be replaced by surface mount technology, discrete ICs will be eliminated with system on chip technology, and multiple circuit cards will be replaced with only one printed wiring assembly. Their goal is modernization and reduction in scale. But what can a company do when nature suddenly wrecks an electronic system just prior to this transition to this updated technology?

Hurricane Katrina subjected many large, and hard to replace, circuit card assemblies to severely adverse conditions. For one particular company, thousands of boards were submerged in standing water with heavy contaminants. Even though this company had plans in place to ultimately replace the aging systems, the newer units were still in the design phase at the time of the disaster, and not ready to be implemented as replacements. The company quickly decided to salvage and repair the existing systems, and it was determined that the EMPF's facilities would be ideal for the task

A process flow diagram (Figure 2-1) was developed to determine what cleaning process would be applied to a given piece of hardware, depending on the type of board and components, and the level of contamination.

The boards were unpacked from their boxes and anti-static bags and placed in trays on a multitude of racks. The bags and desiccant were discarded due to contamination. New antistatic bags were ordered that would accommodate the boards even if larger than necessary. New desiccant was also acquired to be used within each new bag. Re-packaging procedures were basically the same as if the products were new, and not salvage material.

All boards were then inspected by an electronics manufacturing technician for levels of particulate matter, process compatibility, and to assess whether or not the boards were recoverable. Additionally, the history of each board's storage

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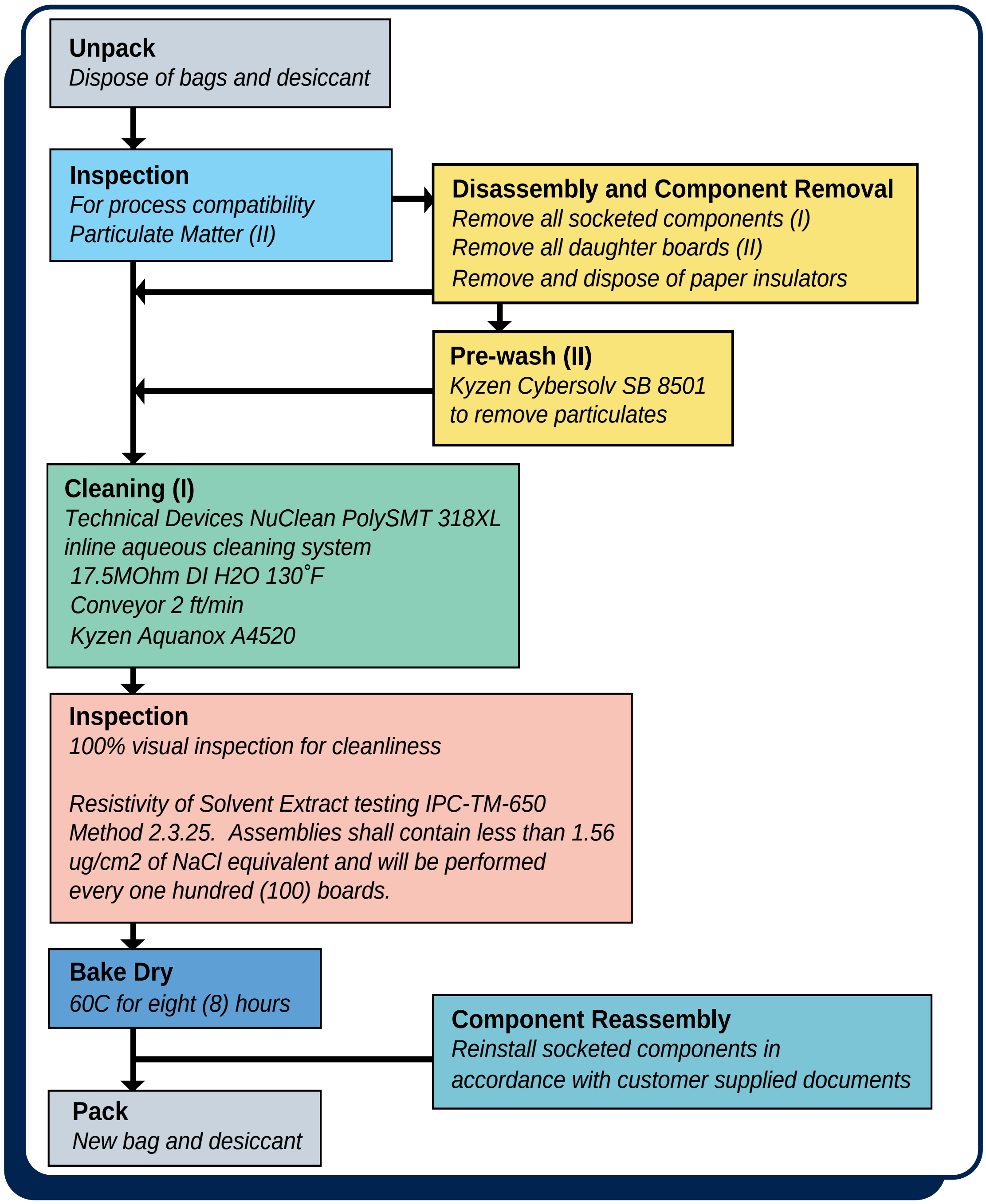

Figure 2-1 – Cleaning Process Flow Diagram

Ask the EMPF Helpline!

A customer called the EMPF helpline requesting that printed circuit boards be analyzed to determine the reliability of two different lead-free surface finishes, electroless nickel immersion gold (ENIG) and immersion silver (ImAg).

Over the past few years, the EMPF Helpline has been helping OEM's and contract manufacturers convert from leaded to lead-free products. One common request is to evaluate a set of first run or prototype assemblies. These first run assemblies are usually the first experience an assembler has with lead-free solders, components, and boards. Often the assembler will experiment with variables such as profile, alloys, or surface finishes, to determine what parameters produce the best set of boards. The customer supplied assembled boards for thermal cycling, vibration testing, and cross-section analysis. The boards were soldered with a tin-nickel-copper solder paste (SNC). The EMPF staff then examined the lead-free finishes by assessing the boards at different stages during thermal cycling and after vibration testing.

Test methods

Thermal cycling was performed in accordance with IPC-SM-785 class 2 recommendations. The temperature alternated between 0ºC and 100ºC with a 10 minute dwell time at each temperature extreme. Each board endured 1000 thermal cycles. Samples were removed at intervals of 250, 750, and 1000 cycles, and continuity testing was performed on all samples at these thermal cycling intervals. Next, z-axis vibration testing was performed on samples that had endured 1000 thermal cycles. Vibration frequencies ranged from 20Hz to 2000Hz. Finally, optical imaging, cross-sectioning, and scanning electron microscopy were performed on random locations of the printed circuit boards.

Results

250 Thermal Cycles

No fractures or separations were observed in either of the lead-free finishes after 250 cycles. As expected, the different lead-free finishes produced different intermetallic layers.

The number of voids observed in ball grid arrays (BGAs) was dependent on the type of lead-free finish. Specifically, boards finished with Immersion Silver (ImAg) showed significantly more voids than those finished with Electroless Nickel Immersion Gold (ENIG). Many of these voids were observed at the solder-component interface. Still, the number of voids did not exceed the IPC recommended limit of 25 %. Voids are displayed in the figure below (Figure 3-1).

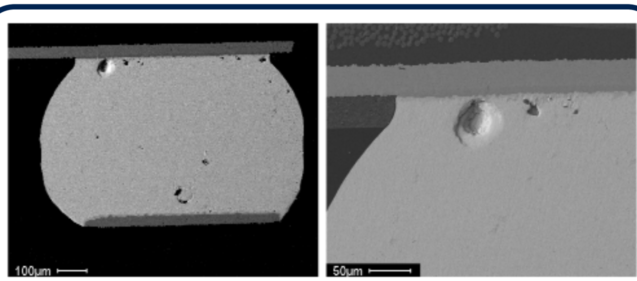

Figure 3-1: BGA after 250 thermal cycles

750 Thermal Cycles

A fatigue crack was observed at the component interface of one of the boards after 750 cycles. No other fractures or cracks were observed in the 750 thermal cycle surface mount solder joints. Intermetallic layers grew non-uniformly into the solder on boards with both lead-free finishes. Small voids were observed in the solder adjacent to the intermetallic layers, as shown in Figure 3-2.

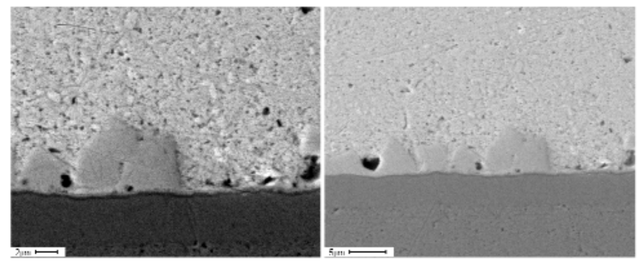

Figure 3-2: BGA intermetallic layers after 750 cycles

Large voids observed at the component-solder interface of the BGA components likely resulted from trapped flux gasses caused by improper solder reflow. Smaller voids observed along the intermetallic layers at the interfaces possibly resulted from the Kirkendall effect, which is voiding caused by differences in diffusion rates.

1000 Thermal Cycles and Vibration Testing

After 1000 thermal cycles, small cracks were observed at the component-solder interface on the corner BGAs for boards containing both lead-free finishes. The crack sizes ranged from 10 micrometers to 20 micrometers.

Boards were examined after vibration testing. Again, the number of voids depended on the type lead-free finish on the board since the ENIG finish yielded smaller and fewer voids than the ImAg finish.

Conclusions

Both boards containing different lead-free finishes passed environmental testing. Nevertheless, for tests conducted on this customer's sample, the ENIG lead-free finish displayed significantly less voiding and greater solderability than the ImAg finish. Also, for this customer's sample, fewer and smaller voids were observed at the component-solder interface for boards containing the ENIG finish.

For more information, please contact the EMPF helpline at (610)362-1200 or via email at helpline@empf.org.

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Analysis and Restoration of Storm Damaged Boards
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and exposure conditions were evaluated, with a focus on original date of manufacture and time in storage. Severity of exposure, storage location (e.g., in crates at the floor level, shelved above the water line, etc.), and any processing or recovery operations performed after exposure to the conditions created by the storm were also examined. Figure 2-2 is an example of the condition of one of the boards at its initial examination.

Figure 2-2 – Storm damaged board before cleaning

Most small boards immediately went to Cleaning (I). These were boards that were often lightly contaminated and did not have special components. Clean DI water at 130°F in an inline aqueous cleaning system (Technical Devices NuClean PolySMT 318XL) was used with a saponifier (Kyzen Aquanox A4520).

Many boards went to a Disassembly and Component removal phase, in which all socketed components had to be removed. This is because the corrosion was severe on the leads, and to ensure that contaminants were cleaned from within the socket. All daughter boards were removed as well for the same reason. Other components were also removed and separated, including paper insulators, all ICs, all displays, and all batteries.

Boards and components that were heavily contaminated went to a Pre-wash (II) phase using Kyzen Cybersolv SB 8501 to remove particulates. Boards were soaked for several minutes, lightly brushed, and then rinsed in cleaner baths of solution. Afterwards, the boards went to Cleaning.

Boards underwent 100% visual inspection for cleanliness. Every 100th board underwent ionic cleanliness testing using Resistivity of Solvent Extract, with the requirement to have 10.06 micrograms of NaCl equivalents/square inch maximum. All boards were then baked dry at 60°C for 8 hours.

Boards then went to the Component Reassembly phase. Socketed components and daughter cards that were removed and separately cleaned were reinstalled in accordance with customer supplied documents. The boards were then packed in new bags, with fresh desiccant, and shipped back priority to the customer for further reassembly and testing on site at their facility.

In all, more than 4,450 boards were cleaned at the EMPF and then sent to another lab for testing. Figure 2-3 shows a board after having gone through the cleaning process.

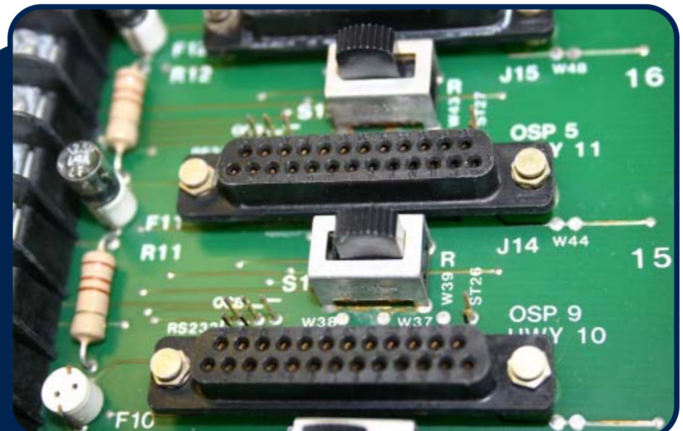

Figure 2-3 – Board cleaned of storm damage

The boards having been recovered in roughly half the time that was projected, the customer was able to reinstall this hardware and bring their systems back online sooner than expected.

The EMPF was able to assist with the salvage and repair operation for the company, effectively helping them to resume normal operations in the face of what otherwise would have been a lengthy downtime following the devastation cause by hurricane Katrina.

This is an extreme example of the kind of printed wiring assembly analysis and cleaning work that takes place at the EMPF's facilities. To find more information on the EMPF's projects and capabilities, or how the EMPF can help you resolve your electronics issues, visit the EMPF website at http://www.empf.org, or call the EMPF helpline at (610) 362-1320

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Harware Restoration

Restoring electronic hardware damaged from harsh conditions of environmental exposure is a difficult task.

Recently, the EMPF's facilities were instrumental in the recovery of several thousand circuit boards damaged following hurricane Katrina.

The following three step process outlines the EMPF development of a cleaning procedure which was effective at restoring these assemblies:

1. Understand what you are trying to remove.
2. Determine the limitations of the assembly
3. How densely populated is the assembly?

1. Understand what you are trying to remove.
The floodwaters, which these assemblies were subjected to, contained a broad spectrum of contaminants including unknown solvents, hard water residues, salt, dirt and oil. The degree of contamination, coupled with the myriad of contaminants, demanded an effective, repeatable procedure to achieve pristine levels of cleanliness.

Cleaning chemistries have changed since the Montreal Protocol banned halogenated hydrocarbons. Those early chemistries worked very well for the flux residues of the day (activated rosin) by dissolving and washing them off the surface through direct immersion, spraying or vapor degreasing. The number of options available today is less, with water as the "universal solvent".

Because of the limited solubility of many materials in water, the key to removal is a combination of time, water volume, temperature, and efficiency of agitation. Ultimately, water alone may not suffice, thus additives (surfactants) will be introduced to reduce surface tension, improve penetration, and induce one or more of the following phenomena: wetting, emulsification, solubilization, saponification, deflocculation, and sequestration.

For this endeavor, the water-soluble and semi-soluble residues required de-ionized water while the oil, grease and dirt required saponifier chemistry.

2. Determine the limitations of the assembly.
In the case of most assemblies there will be parts (ICs, any ceramic components, capacitors, etc.) that should not be subjected to vibration which will preclude ultrasonic pre or post cleaning. In this particular case there were some assemblies with significant debris that required some pre-cleaning. Temperature was a factor for some of the older assemblies, as IPC J-STD-033 recommends baking some moisture sensitive surface mount components at 125ºC, while some older dip packages are rated for baking at a maximum temperature of 60ºC. Obviously care needs to be taken in this regard, as using current recommendations on this older technology would most likely lead to component failure.

3. How densely populated is the assembly?
The edge connectors on some of the assemblies will tend to collect material along with the Dual In-line Packages (DIPs) and Small Outline Integrated Circuits (SOICs). The more densely populated the board, the more areas there are going to be for particulate mater to collect

The obvious objective was to remove the dirt and debris. The end use for these assemblies required a level of cleanliness that assured long term reliability. As a result, the level of ionic contamination also needed to be determined. Given the number of assemblies involved, a combination of IPC-A-610D visual inspection and J-STD-001 bulk ionic testing, using an Alpha Metals 500M SMD II Ionograph, was performed for process control and to provide confirmation of cleanliness.

Based on an understanding of the conditions and requirements of the material at hand, the following steps were taken.

1. Part removal, rework steps, as needed.

2. Pre-cleaning with a brush in Kyzen Cybersolve® SB8501, deionized water solution as needed.

3. All cleaning was performed at ACI by using a Technical Devices NuClean® PolySMT 318XL in-line aqueous cleaner, operating condition:
- ♦Kyzen Aquanox® A4520/deionized water (17 Mega-Ohms) solution (17%v/v)
- ♦Rinse and wash temp: 130°F
- ♦Belt speed: 2.0 ft/min.
- ♦Air dryer temp: 170°F

4. Inspection and cleanliness testing.

5. Drying the assemblies at 60°C for eight hours.

This process significantly improved the cleanliness of the assemblies and reduced the ionic residue levels, some of which were above 50 micrograms of NaCl equivalents/square inch down to less than 2 micrograms of NaCl equivalents/square inch, which is well beyond the J-STD-001 requirement of 10.06 micrograms of NaCl equivalents/square inch maximum.

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PRC-112 Battery Upgrade

The use of portable electronic devices and equipment has become a major part of modern warfare. These portable devices require light weight, cost effective and reliable energy storage devices to power them.

The armed forces have been using a recently redesigned battery pack to power the PRC-112D survival radio. This pack uses eight non-rechargeable commercial AA batteries, and provides the Warfighter with a more cost effective alternative. Now there is a new task to improve upon this first redesign of the battery pack to increase the reliability and manufacturability, further lower the unit cost, while adding the ability to recharge the battery in the field. These new rechargeable units would also have a charge monitoring device built into the battery pack body. The charge monitoring device would ensure that the batteries are in good working order before being shipped out to the field, as well as for the user in the field to be able to monitor the charge status of the batteries.

The design and development process of the rechargeable battery pack began by taking advantage of the lessons learned during the initial battery pack redesign experience. Both Concurrent Engineering Practices and Design for Manufacturing (DFM) principles were used to produce a reliable cost effective re-usable Battery Pack for the customer.

Design

The AA design uses two molded parts to build the body of the battery pack by ultrasonically welding the parts. A lid, along with rubber gaskets, is then screwed on top of the battery case to provide a water tight seal. It is usually difficult to provide a quality water tight seal along an ultrasonic weld joint, especially with welds of a great length. So in this case the parts have very tight tolerance controls on features and dimensions that come together during the welding process to form a water tight seal. The need for tight tolerances makes the mold very expensive to make and maintain. In addition, the molding parameters need to be tightly controlled to get a consistently quality water tight weld in the ultrasonic weld process, otherwise the reject rate would be significant.

One of the goals of the redesign was therefore to eliminate the ultrasonic weld. The two piece part design is eliminated by making the housing as a single piece molded part. This eliminates the ultrasonic welding, and also reduces the cost of the piece part by first, making the mold tool simple and less expensive since the need for tighter tolerances can now be relaxed, and second, only one piece is now needed for the battery pack body instead of two.

Figure 4-1 – AA re-usable battery pack (left), new re-charchable battery pack(right)

Assembling the lid to the housing in the AA design uses three screws and three rubber gaskets to provide the water tight seal. In the new design the screw assembly has been replaced by a snap fit assembly with only one rubber gasket required to create the seal. The cost savings due to elimination of the three screw assembly process by a one step snap type assembly is significant, in addition to the cost savings due to having four fewer parts than the AA model. Furthermore, the snap fit feature eliminates the need to have a tool to open and close the lid with screws to change the battery, especially, if this is being done in the field where changing the battery in the shortest possible time can be of critical importance.

The internal battery contacts and pressures between various mating surfaces have been modified to reduce the electrical contact resistance between the parts thereby decreasing the voltage drop between the batteries and the radio.

The design of the external contacting surface and other mating parts of the sub-assemblies have been further modified in the new design to reduce the amount of wear and tear on the mating surface as a result of frequent changing of battery packs. Changes made to the design have enhanced the overall reliability of the battery pack by providing a consistently tighter connection to the radio.

These and other changes were incorporated into the new design using Solidworks 2006 as the design tool. Solidworks allows for the creation of 3D models for individual parts and assemblies which reduced the overall design time and facilitated quick checks of the parts and assemblies for assembly tolerances, expected smooth operation, and potential interferences. Additionally, 3D model-

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ing allows the designers to quickly run some of the "what if" scenarios to help make quick decisions between many available design and material options. Figure 4-2 is a rendering of the battery pack using Solidworks 2006 software.

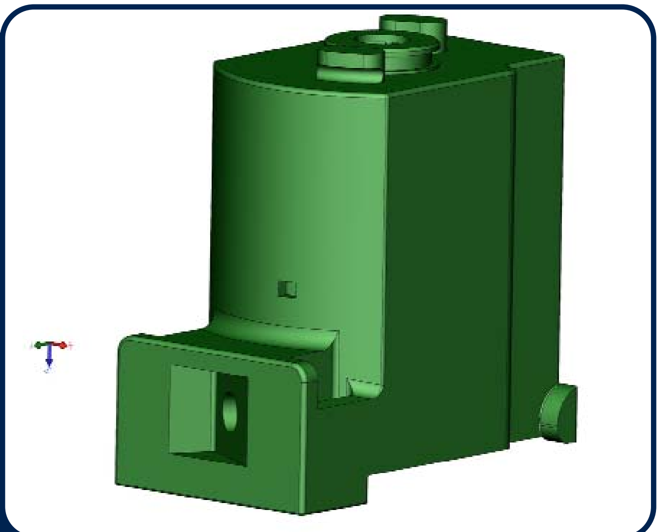

Figure 4-2 – Rendering of the new battery pack using Solidworks

Prototyping

To shorten the time from design to high level verification testing, Stereo Lithography was used to build prototype models straight from the Solidworks generated 3D models. The availability of these models helps by allowing for quick evaluation of the fit and form characteristics of the design before giving a go ahead to the mold maker and other tool makers. These prototype samples were also used to assess the manufacturability and the difficulty level for assembling the design. The stereo lithography model also allowed for early discussion of the design with the customer and to get a quick approval decision.

Testing

Preliminary drop and water submersion testing was performed on the stereo lithography models. The drop tests resulted in cracking on some areas of the housing. FEA (Finite Element Analysis) was performed using Algor V19 software (see figure 4-3) to simulate drop testing impact forces, which allows the engineer to see the dynamic interaction of these forces to create high stress concentration zones. The results of the FEA analysis provided good probable cause of failures. Based on the results and analysis of these tests, the design was modified to eliminate, wherever possible, the stress concentration zones or at least minimize their effects.

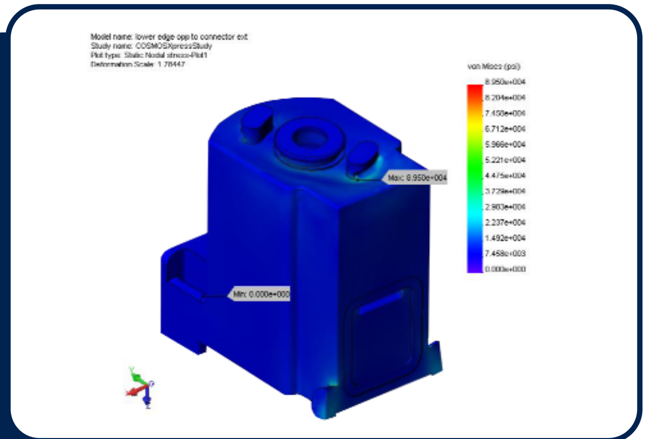

Figure 4-3 – Stress analysis of battery model in Algor

Manufacturing

One of the key decisions that needed to be made at the early design stage of the product development process was whether to assemble the product manually or using an automated process. This is important since the part design features needed for manual versus fully automated assembly could be vastly different. Automated assembly requires unique handling and orientation features on the piece parts for automated machines to be able to assemble the new battery packs without high reject rates.

Having designed the parts to suit the pre-selected manual assembly approach, the other factors that play a key role in developing a cost effective assembly line/manufacturing process are the material flow, jigs & fixtures, assembly line tools, in process and final inspection tools. The manufacturing team needs to be an integral part of the overall team to help envision the assembly techniques that could be incorporated in the design to minimize the tooling and machines needed to make the assembly cost effective.

By using some simple principles of Concurrent Engineering, Design for Manufacturing, and fast prototyping techniques, and building a partnership of suppliers, toolmakers, prototype shops and manufacturing engineers, the realization of going from "Design to Manufacturing" yielded a high quality product to the customer.

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Manufacturer's Corner
Technical Devices – Dual Process Wave Soldering

The EMPF requires both tin lead (SnPb) and lead free wave soldering capabilities to support process development, prototype manufacturing functions, and training. When addressing this need for a dual process system, the EMPF decided to convert an existing Technical Devices Nu/Era Wave Soldering System (Figure 5-1) to accommodate both solder alloys rather than purchase a new, dedicated lead free wave soldering system.

When converting to a lead free system, the following four process elements provide the most effective opportunities to incorporate economical practices:

1. Solder recovery. The greatest cost savings can be gained through the use of a solder recovery system. As much as 75 percent of the solder bath (depending on pump design) can oxidize over time to become dross, the main component of which is pure solder. Manufacturers can process their own dross and reap the financial benefits in the form of reduced solder expenditures. With every dollar counting, this money-saving procedure cannot be ignored.

2. Lead free process control. One of the major contributors to defects, such as bridging, icicling, and insufficient topside fillets, is poor heating of the printed circuit board (PCB) assembly during the preheat stage. Too much heat is just as bad as too little, a fact that is especially true in a lead free process. In fact, preheating must be more exact in lead free applications simply because of the higher temperatures involved. Some lead free solders will require melting temperatures near 700°F.

3. Preheater types. Manufacturers of wave soldering equipment use a variety of heating methods. Quartz lamps, infrared (IR) tubes, and Calrod elements all operate at high temperatures (1,330° to 2,000°F) to bring the PCB to its optimum topside board temperature of 190-240°F before entering the wave. Obviously, this high Delta T constitutes a very inefficient use of energy. Furthermore, the assembly does not absorb much of the heat emitted by such sources. Attempting to reach this relatively low temperature using such a high heat source greatly increases the possibility of burning the flux. (Tubular and quartz type preheaters randomly spray heat waves in all directions, providing as little as a 50 percent absorption rate.)

In contrast, the most energy-efficient method to heat a PCB is by using low-watt-density black-body IR heating strips. These IR units emit long IR wavelengths that are easily absorbed by the board. Hence, the Delta T between the heat source and the board is much lower than that produced by lamps, tubes, etc. Black-bodied IR radiant emitters direct heat at the PCB with absorption rates as high as 85 percent.

4. Preheater design. Most wave soldering machines offer a variety of preheater configurations. The optimum design for a preheating system should include more than one type of heater – e.g., a system that includes black-body IR heating strips on the bottom, coupled with forced-air convection from above.

Another contributing factor to heating the board evenly and gradually is the physical design of the preheater. For example, if there are gaps between the end of the preheater and the beginning of the wave, cooling will occur. Similarly, the distance between the board and the heat source as it travels on the conveyor can play a

Figure 5-1 – Technical Devices Nu/Era Wave Soldering System

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Technical Devices – Dual Process Wave Soldering
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role in how the board is heated. Ideally, the board should get closer to the heat source as it approaches the wave. In addition, because lead free solder will be at a higher temperature together with the PCB upon entering the wave bath, the most efficient preheating system should minimize defects and the cost of repair and replacement, while yielding longer production runs to meet quantity goals.

A different alloy in every pot

If some production runs require lead free solder while others do not, the most economical solution is to have separate rollout solder pots and carts for each. This eliminates the downtime required to drain one pot and refill it with another alloy, as well as avoiding cross-contamination between alloys.

Besides the financial benefits, there are other reasons for not using lead free solder exclusively. It does not wet as well as tin lead and yields a duller surface finish. This may cause a higher percentage of good boards to be rated as defective, increasing rework time using current pass/fail criteria.

Controlling parameters

With different processes and solder alloys, one must be able to adjust the wave soldering machine to different parameters. To that end, temperature controls for the preheater and solder baths are easily adjustable, as is conveyor speed. The latter parameter affects the amount of time that the PCB is in the preheat zone as well as the duration the board is in the solder wave. Conveyor height is also crucial because the thickness of the board and the size of the components will vary. Other variables include conveyor width, nitrogen control, and all fluxing controls – all easily set and monitored on wave soldering machines. For each process, an optimal set of parameters exists. These can be set and monitored best using a computer-controlled wave soldering machine with the capacity to remember an infinite number of recipes (parameter sets). Another advantage is the ability to view what is happening inside the machine via a monitor.

As new, lead free processes continue to evolve, wave soldering machines are adapting to the new parameter requirements. While economic resources are tight for most companies, wave soldering continues to be an efficient and cost-effective tool for production.

The EMPF has a Technical Devices Nu/Era Wave Soldering System with two pots on site. If you would like a demonstration of this system, please contact Robert Berta at the EMPF at (610) 362-1200, extension 253, or rberta@aciusa.org.

Point of Contact: *Robert Berta* – Bob is the Business Development Representative at ACI. Comments or questions pertaining to this article can be sent to rberta@aciusa.org.

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