Advanced Through-Hole Rework of Thermally Challenging Components/Assemblies: An Evolutionary Process

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Abstract
Although the vast majority of electronic equipment has made the transition to lead-free without significant issue, some market segments still utilize tin-lead solder. The European Union's RoHS legislation currently exempts server, storage array systems and network infrastructure equipment from the requirement to use lead-free solder (exemption 7b). The reliability of network infrastructure equipment in Finance, Health Care and National Security applications is critical to the health and safety of consumers, countries and the global community and the long term reliability of these end products using lead-free solder is not completely understood [1].

Figure 1 shows the projected phase out of servers, storage array systems and network infrastructure equipment for switching, signaling and transmission as well as network management for telecommunications over the next few years in the European Union.

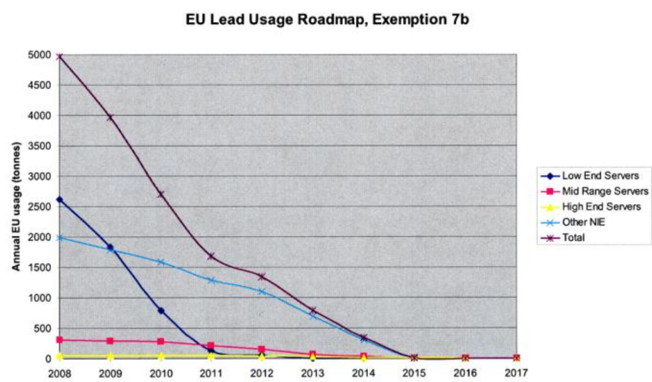

Figure 1: EU Lead Usage Roadmap, Exemption 7b [2]

In addition to Government regulations, the conversion of high end server and network applications to lead free is also being hastened by the limited availability of tin-lead components. Although the exact conversion date is unclear, the requirement to ultimately convert these complex products to lead-free is absolutely clear.

The successful transition of low end and mid-range server applications to lead-free has come largely through wave solder process optimization and the use of alternate lead-free alloys for mini-pot rework.

Copper dissolution has become an industry buzzword and numerous studies have concluded that the current industry standard procedure of using the mini-pot for PTH Rework will not provide the capability to rework extremely large, high thermal mass network/server PCB's even when SAC305 is replaced with alternate lead-free alloys such as SN0.7Cu0.05Ni (SN100C) with lower copper dissolution properties. These new rework challenges are reviewed in detail along with potential alternatives to mini-pot rework for these high end applications.

Introduction

A logical question to ask before reading this paper is why are we even concerned about Plated Through-Hole (PTH Technology), after all isn't it being replaced by Surface Mount Technology? The short answer is that even though we have been in high volume SMT production for over two decades, PTH technology still exists and is not expected to go away for a long time to come [3]. As long as we humans have to touch it, switches, connectors and other mechanical devices are better attached to the circuit board with through-hole connections. This is also true for devices which may encounter high forces such as military, aerospace and automotive applications [4].

iNEMI's (International Electronics Manufacturing Initiative) strategic methodology provides an overview of how and why technology changes. Two major factors include "Government" and "Disruptive Technology" [5]. Certainly, these two factors combined to create an industry upheaval during the transition from tin-lead to lead-free beginning in 2000.

PTH rework was extremely straightforward prior to the transition to lead-free. The solder fountain or "mini-pot" was the technology of choice and "copper dissolution" was a largely irrelevant technical term. Mini-pot operators simply flowed solder against the component lead pattern for as long as was required to remove or replace a component. In extreme cases, a high thermal mass assembly was preheated in an oven prior to rework to reduce thermal shock and to minimize solder contact time. Today if you google "copper dissolution during lead-free PTH rework", you will find page after page of information and technical studies involving the once obscure mini-pot.

Objectives

The main objectives of this paper are as follows:

1) To outline the reasons why the mini-pot is receiving so much attention and technical analysis in regard to lead-free PTH rework.
2) To outline the evolution of the mini-pot including what lead-free PTH rework it is capable of doing as well as identifying its technical limitations.
3) To communicate the gaps and challenges identified in the PTH Rework and Repair section of the 2013 iNEMI Technology Roadmap and to discuss efforts-to-date to resolve these gaps including an assessment of alternative rework technologies, an overview of a next generation mini-pot system and a lead-free PTH rework study.

Figure 2: Mini-Pot

The Solder Fountain and Lead-Free Solder

Although "solder fountain" and "mini-pot" are generic terms, they most often refer to one particular machine, which is the machine we will be referring to throughout this paper (Figure 2). The solder pot and pump housing on this machine are both cast iron which is resistant to the corrosive nature of lead-free solders. However, two changes to the mini-pot were required to provide lead-free capability. First, all pump components such as the impeller, screws and solder baffle were changed from stainless steel to titanium and second, the flow wells which direct the solder flow were changed from plated steel to titanium (Figure 3). No coatings of any kind are used due to user concerns regarding coating wear/scratching and contamination.

Figure 3: Solder Wave on Mini-Pot

The main issue with lead-free PTH rework on the solder fountain is easily described in two words: copper dissolution. Copper dissolution is a two stage process whereby copper on the PTH knee, barrel and annular ring is dissolved by tin and forms an intermetallic compound which in turn is dissolved in solder.

Copper dissolution is often a hidden defect (Figure 4). Multiple studies have shown that copper at the PTH knee erodes at a much faster rate than either the annular ring or barrel. Therefore it is possible to have pads that appear to be perfectly acceptable while the knee, which is hidden from view, can have significant or even complete dissolution.

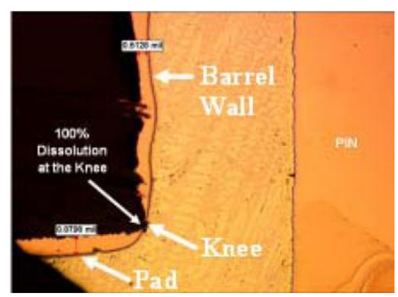

Figure 4: Hidden Defect [6]

There are two reasons why copper dissolution, which was a non-issue for tin-lead rework, is now a significant issue for lead-free PTH rework. First, the higher tin content in lead-free solder significantly increases the dissolution rate as shown in Figure 5. Second, the higher melt temperature of lead-free solder requires increased contact time and/or increased solder temperature to reflow the component, both of which lead to increased dissolution.

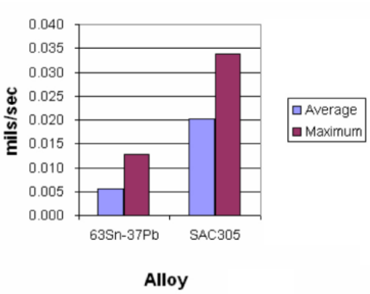

Figure 5: Dissolution Rates by Alloy [7]

The higher dissolution rate of lead free solder combined with higher solder melt temperature significantly reduces the rework process window on the mini-pot.

The extremely narrow PTH rework process window that SAC305 provides is being addressed today largely through the use of alternate solder alloys such as SN-0.7Cu-0.05 Ni which contain a small amount of nickel that retards dissolution.

However even the use of lower dissolution solder in the mini-pot rework process is not the end-all solution for successful lead-free PTH Rework, especially for mid-range applications where significant (45+ seconds) total solder contact time is required to remove and replace a component. A previous study of copper dissolution on the PTH knee using a mid-range server board which required 45 seconds total contact time to remove and replace the component yielded the following results regarding copper dissolution [8].

Alloy	Process	Cu Dissolution
SAC305	Wave Solder Process	2-6 microns (4.0 Avg)
SAC305	Mini-Pot Process	15-22 microns (18.5 Avg)
SN100C	Mini-Pot Process	7-12 microns (9.5 Avg)

IPC Standard 6012-B specifies an "as received" copper minimum thickness average of 20 microns for Class 1 and 2 PCB's[9]. In addition, previous studies on copper dissolution and solder joint reliability have demonstrated that when copper at the PTH knee falls below 12.7 microns, cracks may form during reliability testing [10]. As a result, 12.7 microns has become the industry minimum acceptable copper thickness standard.

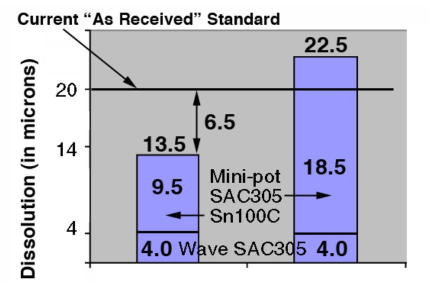

Figure 6. "As Received" Cu Minimum Thickness Standard (20μm)

Figure 6 shows the importance that the "as received" copper thickness plays in regards to having acceptable copper thickness levels remaining after the wave and mini-pot processes. Although a mini-pot rework process using low dissolution solder would reduce dissolution almost 50% on average (9.5 vs 18.5 microns), the remaining copper thickness after wave solder and rework would be 6.5 microns if the "as received" thickness was 20 microns (minimum "as received" thickness standard). This value of 6.5 microns is approximately 50% below the current post-rework minimum standard thickness of 12.7 microns.

Rather than hope that the actual "as received" copper thickness exceeds the 20 micron minimum standard, one possible solution is to increase the standard itself. In fact, iNEMI is now proposing that the "as received" standard be increased from the current 20 microns to 33 microns. A SAC305 wave solder process followed by a SN100C mini-pot rework process would yield successful results with a new "as received" standard of 33 microns as shown in Figure 7. If the "as received" copper thickness was 33 microns and the total wave and mini-pot dissolution was 13.5 microns, the post-rework thickness would be 19.5 microns which is well above the 12.7 micron minimum.

Regardless of whether the "as received" copper thickness standard is increased or not, every possible effort should be explored and if practical, implemented to expand the mini-pot rework process window.

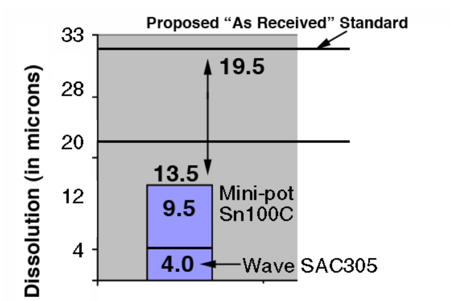

Figure 7. Proposed "As Received" Standard (33 μm)

Expanding the Mini-Pot Process Window

Virtually every mini-pot study uses a remote oven to preheat the PCB prior to mini-pot rework. Although the concept of preheating the PCB to minimize solder contact time is valid, the unintegrated approach results in significant heat loss prior to solder contact. Alternatively, a mini-pot configuration with a integrated top and bottom IR Preheater provides rapid transfer of the PCB from the preheater to the solder wave with virtually no heat loss (Figure 8). In addition, several studies preheat the board to relatively low levels (100-125C) remotely due to concerns regarding temperature sensitive component on the board. In one previous study where the board was preheated remotely to 125C, the board temperature during actual rework had dropped 35 degrees to 90C. Maximizing the board preheat temperature will minimize the required solder contact time which is critical for minimizing copper dissolution. Current studies have shown that bottom-side preheating of high thermal mass assemblies allow the topside board temperature to reach 150°C while topside temperature-sensitive components such as electrolytic capacitors reach only 85-105C.

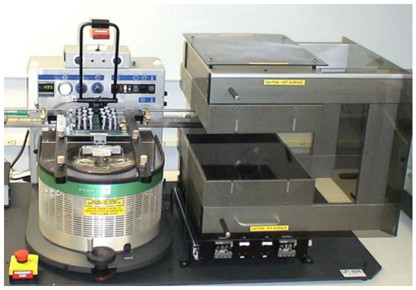

Figure 8: Mini-Pot With IR Preheater

Another way to further increase the process window for lead-free PTH Rework is to remove the component using a combination of convective and IR heating.

In 2009, the New England Lead-Free Consortium conducted an extensive long term reliability study of lead-free and halogen-free electronic assemblies. Of particular interest was a rework process that compared initial installation, removal and replacement of a 200 pin lead-free connector on a high thermal mass PCB using a large solder fountain system compared to a process where the large solder fountain system was used for initial connector installation and replacement, however a DRS25 BGA Rework System with topside convective heating and bottom side IR heating was used to remove the connector (Figure 9). The consortium found that the convective removal process reduced copper dissolution by 43% (11). The only downside to the convective removal process on a BGA Rework System is that it is not integrated with the mini-pot and therefore requires two separate pieces of equipment to be used. In addition, the capability to remove and replace a component in a single cycle which is desired by many users due to its timesaving nature is impractical with a separate convective removal process.

Figure 9: BGA Rework Station

Summary of Recommendations for Increasing the Process Window for Lead-Free PTH Rework on Low to Mid-Level Complexity PCB's

1) Use SN-0.7Cu-0.05 Ni solder as the nickel acts to retard copper dissolution.
2) Add an integrated top and bottom IR preheater to the mini-pot to maximize the core temperature of the PCB during rework and to minimize solder contact time.
3) If #1 and #2 do not provide the process window required for a particular application, use a BGA rework machine with combined convective/IR heating for component removal.

Lead-Free PTH Rework of High Thermal Mass Components on Large, High Thermal Mass PCB's

Discussions in the previous sections focused on optimizing the capability of the mini-pot to provide the ability to rework lead-free PTH components on low to mid-complexity assemblies.

However, the current "lead in solder" exemption for servers, storage array systems and network infrastructure equipment is scheduled to expire in July, 2014. The Rework and Repair section of the 2013 iNEMI Technology Roadmap has identified several challenges and gaps related to lead-free PTH rework of high thermal mass components on very large, high thermal mass PCB's including meeting IPC standards for copper dissolution and barrel fill, addressing the significant challenge of reworking PTH connectors with body temperature ratings of only 240°C, increasing the process window to allow removal and replacement of a PTH component in a single step, selecting a common industry lead-free solder alloy for PTH rework and determining the impact of mixing different lead-free solder alloys during wave soldering and rework. Contamination of the mini-pot is also a concern as well as the use of fluxes that are electrically reliable even if not sufficiently heated (12).

Due to the fact that mini-pot optimization is required to provide the capability to rework lead free PTH components on low to mid-complexity assemblies, previous studies have concluded that alternative solutions are required for reworking high thermal mass, lead-free PTH components on very large, high complexity PCB's for server, network and storage applications. These assemblies will typically exceed 0.120 inches in thickness, have fourteen or more layers, seven or more ground layers and ten ounces or more of copper (13). iNEMI mentions convection, IR, laser and vapor phase technologies as possible alternative solutions to the mini-pot for lead free PTH rework of high complexity assemblies (14).

Convection has been proven to be a viable technology for lead-free PTH component removal and barrel cleaning although issues related to board discoloration and resin recession exist. Vapor phase is in use for removing large, high thermal mass surface mount connectors on high complexity assemblies. (15) It would seem logical to assume that vapor phase could also effectively remove high thermal mass lead-free PTH components on high complexity assemblies. However, vapor phase subjects the entire assembly to an additional reflow cycle and the cost of Galden, which is the liquid that is boiled to transfer energy through the heat of condensation, is extremely expensive. In addition, neither convection nor vapor phase offer practical solutions for replacing lead-free PTH components as both methods involve the use of solder paste and solder performs or screen printing which add complexity and significantly increase cycle times. Some IR rework systems designed primarily for BGA rework claim to have PTH component rework capability, however these systems appear to lack the capability to handle high thermal mass PTH components on high complexity assemblies and also lack the ability to effectively clean the barrels and replace the component. Information on laser technology typically focuses on SMT Rework and Selective Soldering.

Figure 10: PCBRM 100

Continued Evolution of the Mini-Pot

None of the alternative technologies discussed above appears to be well suited as a mini-pot replacement for lead-free PTH rework of high thermal mass components on large, high complexity assemblies. The reason for this lies in the fact that none of these technologies were designed with this objective in mind. At best, we are trying to utilize existing technology that was designed for other purposes as a solution for a significant industry issue.

Rather than try to force-fit an existing technology as a possible solution, what is needed is the "clean sheet of paper" design approach. "What is really needed is an alternative rework system for through-hole that does not exist today. Anyone who can come up with a rework system that can reflow and remove through-hole components quickly without causing internal barrel or trace cracking can truly claim an advantage. Does such a system exist today in the market place? No. Can such a system be developed? Yes, but it requires engineering and financial resources of users and equipment suppliers". [16]

As the mini-pot has been the technology of choice for tin-lead rework for over 20 years and is able to provide rework capability for lead-free PTH components on low-to-mid complexity assemblies, it would seem logical to develop a system that utilizes the strengths of the mini-pot and to address its weaknesses to best address the challenges of reworking complex server, storage and network infrastructure applications. In fact, this concept has already been in development and beta site testing for over three years. The PCBRM100 is next generation mini-pot technology designed specifically for rework of lead-free PTH components on large, high thermal mass assemblies. The 100 is a large machine compared to the mini-pot with a footprint measuring 3050mm long by 1320mm wide by 1955mm high (120x52x77") (Figure 10).

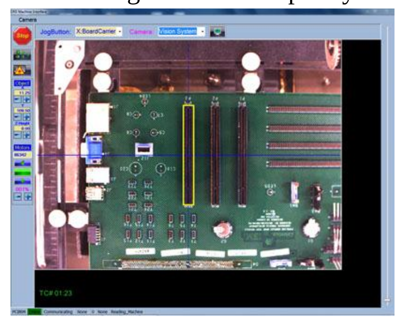

Figure 11: EZ-Line Alignment System

The 610x660mm (24x26") board carrier includes a pull-out feature to provide ergonomic loading/unloading of heavy boards and a tilt frame to allow operator access to the bottom of the board for fluxing and positioning bottom side supports. The carrier is programmable in the "x" and "z" axes and uses linear encoders for accuracy and repeatability. Spring-loaded carrier arms allow for thermal expansion of the board during rework.

Figure 12: Solder Pot with Titanium Solder Stack

The EZ-Line alignment system features a down-looking digital camera with zoom lens mounted on a programmable "y" axis that superimposes the image of the solder stack over the top of the board. X/Y joystick-based controls are used to quickly and accurately align the component with the solder stack (Figure 11)

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A 711x711mm (28x28") quartz composite top and bottom IR preheater (16Kw) with 25 watts per square inch heating density and independent temperature control provides rapid, uniform preheating of even the largest, most thermally challenging PCB's. The preheater panels have an extremely high radiant efficiency and do not depend on external reflectors. The top preheater panel has a programmable "z" axis which allows the preheater to "sandwich" the PCB based on its topside topography, thereby creating a high-efficiency oven-like preheating effect. A thermocouple attached to the PCB provides temperature-based preheating control for process repeatability.

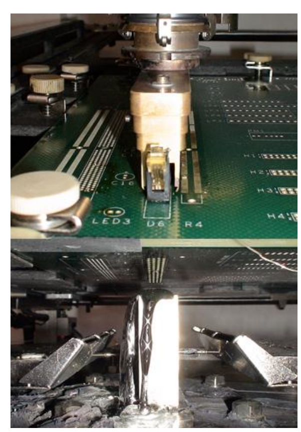

Figure 13: Focused Convective Heating

The heart of the 100 is a cast iron solder pot with titanium pump components. No coatings of any kind are used to handle the aggressive nature of lead free solder alloys. The pot has a solder capacity of 90 pounds and is nitrogen inerted. An internal chambering system along with a servo-motor driven pump creates a laminar solder flow with extreme thermal uniformity across the wave (+/- 2°C). Quick change titanium solder stacks direct a flow of solder against the lead pattern of the component to be reworked (Figure 12). The solder pot is programmable in the "y" axis and has quick electrical disconnects so that the existing pot can be removed and replaced by a spare pot with a different solder alloy.

What makes the 100 truly unique is the integrated Focused Convective top and bottom Heating systems (FCH). After the entire board is preheated, the PCB is moved to a position just above solder contact position. The programmable hot gas head brings the nozzle down and over the topside of the component to be reworked. The nozzle is fed by a 2Kw heater so it has the power needed to heat virtually any component regardless of size or thermal mass. Two (2) seven inch convective heating blades focus heat on the bottom side leads. Each blade is fed by a 3.5Kw heating element and has a quick slide baffle that allows the heat from the blades to be sized to match the size of the lead pattern (Figure 13). Other key features include a laser distance sensor which provides automatic squaring of the convective heating nozzle and eight (8) traveling TC's which provide on-machine profiling capability.

A typical removal process would be to preheat the entire board to 150°C followed by a Focused Convective Heating (FCH) stage until all joints reach approximately 200°C (as per the thermal profile) at which time the bottom side pins are immersed in solder for 10-20 seconds depending on the thermal mass of the component and PCB. Top and bottom side focused convective heating continues during solder immersion. Solder contact combined with Focused Convective Heating provides the maximum thermal transfer in the shortest possible time. The nozzle lifts automatically and the operator removes the component. This hybrid heating approach eliminates the requirement for 100% convective/IR heating as is done on BGA rework machines which reduces potential issues such as exceeding the maximum package temperature specifications, resin recession and board discoloration.

The PTH barrels can be cleaned immediately after the component is removed and the solder flow stops. The PCB remains in place over the solder stack with the bottom convective heating blades on. The component nozzle is replaced by the barrel cleaning nozzle which provides heat and vacuum to remove the solder in the barrels. The vacuum tip is made of a high temperature composite to prevent any abrasion of the pads or laminate. A precision force sensor controls the initial touch off of the vacuum tip on the board. A vacuum sensor automatically and continuously adjusts the tip height providing non-contact barrel cleaning. Dual digital cameras provide the operator with multiple viewing angles during the cleaning process. The operator uses the x/y/z joystick to move the vacuum tip as desired (Figure 14).

The replacement process typically duplicates the removal process where FCH occurs until the joints reach 200°C at which time the bottom side leads are immersed in solder. However, instead of the nozzle lifting and the operator removing the component, the nozzle remains in place over the component while it is soldered in place. Using FCH in this fashion eliminates the solder contact time typically required to bring the component through an extended soak stage during both the removal and replacement processes. The reduction in solder contact time results in reduced copper dissolution. In addition, topside FCH during the replacement process improves barrel fill by providing a heated upward path for the solder to follow.

Rework Study

A Rework Study was conducted on the PCBRM100 to assess its capability to effectively rework challenging PTH components on high thermal mass assemblies. The test vehicle (TV) was a 180x200mm (7.1x7.9"), 3.3mm (.130") thick twelve layer board with thirteen ounces of copper and an OSP finish. PTH components on the TV include electrolytic caps, headers and two (2) 140mm (5.5") DIMM connectors (Figure 15). The DIMM connectors were chosen for the rework study due to their size, thermal mass, number of pins and known issues regarding connector body temperature.

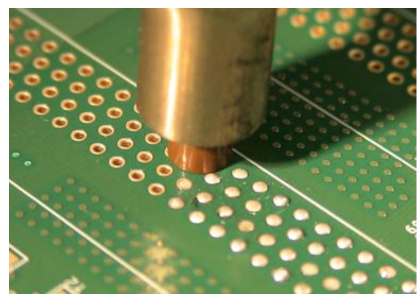

Figure 14: Barrel Cleaning

Figure 15. Test Vehicle

SN100C solder was used due to its previously documented lower copper dissolution rate during mini-pot rework compared to SAC305. SN100C has a melting temperature of 227C which is ten degrees higher than SAC305 (217C). The solder pot temperature used in the study was 272°C which is 45 degrees above the melting temperature. Kester RF771 tacky flux was used as its formulation is designed specifically for rework. The solder contact time during PTH rework is multiple times longer than the contact time during wave soldering, therefore the fluxes typically used for wave soldering are not designed to withstand the rework process.

Multiple thermocouples were attached to the bottom side and top side DIMM joints as well as to the DIMM body. A baseline thermal profile and an alternate thermal profile were developed. The baseline profile preheated the entire board to 150C. The instrumented DIMM was then immersed in solder until all top side joints reached 240C which took forty-five (45) seconds.

During the alternative profile, the board was preheated to 150C just like the baseline process. However a three (3) minute Focused Convective Heating (FCH) stage took place prior to immersion in solder. During the FCH stage, top side heating from the nozzle and bottom side heating from the universal heating blades increased the top and bottom side joint temperatures by approximately 55C. The FCH stage acts like an extended soak stage where the DIMM temperature is increased and stabilized and where the core temperature of the board near the DIMM is maintained.

Immersion in solder occured after the FCH process was complete, however the required contact time to achieve 240C top side joint temperature was significantly shorter, in this case twenty (20) seconds versus forty-five (45) seconds for the baseline process (Figure 16).

Figure 16: Thermal Profiles

		Contact Time	
	Entry Temp	**20 Sec**	**45 Sec**
• Board			
○ Baseline	145	-	138
○ Alternate (FCH)	138	138	-
• DIMM Body			
○ Baseline	101	-	185
○ Alternate (FCH)	214	236	-
• Top Side Joints (Avg)			
○ Baseline	122	-	241
○ Alternate (FCH)	185	247	-
• Bottom Side Joints (Avg)			
○ Baseline	122	-	237
○ Alternate (FCH)	190	245	-

Initial assembly of the test vehicles was done on a standard wave soldering system using SAC305. Kapton tape was used to protect twenty (20) bottom side "joints" on one end of each DIMM site from wave soldering. These unsoldered joints represented the "as received" copper thickness for each DIMM site. An additional twenty (20) joints were protected from the rework processes. These joints represented the "post-wave" copper thickness for each DIMM site.

A total of twenty-six (26) DIMM sites were subject to a complete rework cycle that included removal, barrel cleaning and replacement using either the baseline or alternate process. Reworked TV's were sent to an independent laboratory for cross section analysis. Twelve (12) cross section measurements of the bottom side knee were taken in the "as received", "post wave" and "post rework" sections on each DIMM site (Table 1. "x" represents ten data points)

Table 1 : Copper Dissolution Results
(Baseline vs Alternate Process)

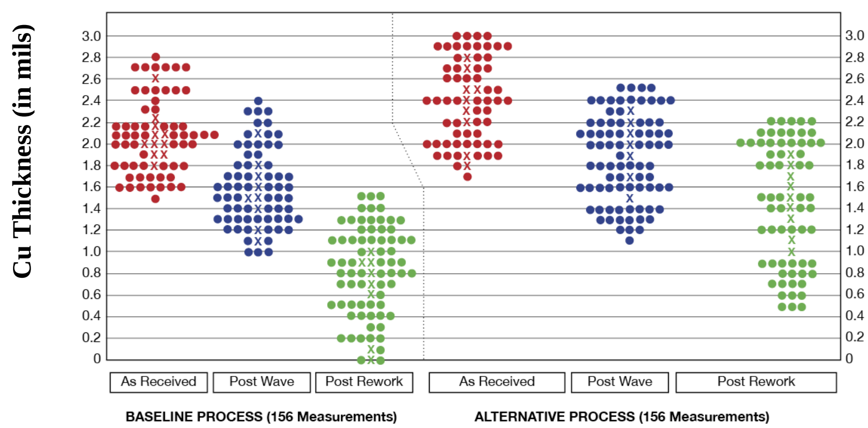

Table 1 shows that the as "received" copper thickness varied widely from a low of 1.6 mils to a high of 3.0 mils which in turn resulted in a wide variation of both the "post wave" and "post rework" copper thicknesses.

Table 2 is a summary of the average copper thickness and average dissolution based on the data points in Table 1. The key point in Table 2 is that the average "post rework" copper dissolution for the alternate (FCH) process was 0.5 mils compared to 0.9 mils for the baseline process. Convectively heating the DIMM prior to solder immersion resulted in a 45% (0.5 vs 0.9 mils) reduction in copper dissolution. Table 2 also shows that the average "post rework" copper thickness for the alternate (FCH) process was 1.5 mils which is significantly above the minimum standard of 0.5 mils (12.7 microns). Comparatively, the average "post rework" copper thickness for the baseline process was only 0.7 mils which is just above the minimum standard. In addition, 22% of the baseline copper thickness measurements taken fell below the 0.5 mil minimum standard while none of the alternate (FCH) process copper thickness measurements fell below 0.5 mils. Tables 1 and 2 clearly show that the alternate (FCH) rework process significantly increases the lead-free PTH rework process window for high complexity assemblies.

Figure 17 shows one of the worst case results from the baseline process where 100% dissolution occurred at the knee and significant dissolution occurred at the pad and in the barrel. In contrast, Figure 18 shows the typical copper thickness after the alternate (FCH) process where minimal copper dissolution has occurred at the knee as well as in the barrel and on the pad.

Table 2: Copper Dissolution Summary
(Baseline vs Alternate Process)
In mils

	Baseline	**Alternative**
As Received Cu Thickness - **Average**	**2.1**	**2.4**
Post Wave Cu Thickness - **Average**	**1.6**	**2.0**
Post Rework Cu Thickness - **Average** - **Minimum Standard**	**0.7** **0.5**	**1.5** **0.5**
Average Cu Dissolution - **Post Wave** - **Post Rework**	**0.5** **0.9**	**0.4** **0.5 (45%)**

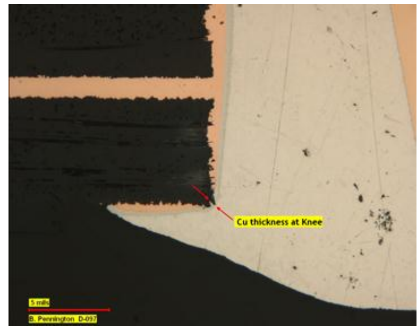

Figure 17. Baseline Process
(100% Cu Dissolution at Knee)

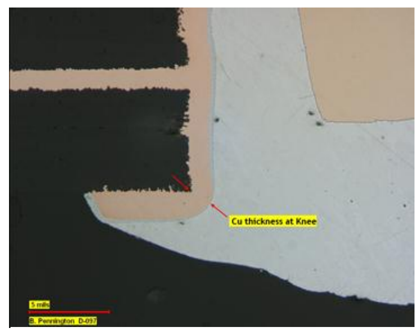

Figure 18. Alternate Process
(Minimal Cu Dissolution at Knee)

In addition to copper dissolution, iNEMI also cited barrel fill as a key concern for lead free PTH rework on Class 3 assemblies. Laboratory analysis of barrel fill on “post wave” solder joints varied widely from a low of 44% to a high of 100% with an average barrel fill of 76%. In addition, 31% of the “post wave” joints did not create a complete fillet where solder climbs the pin (Figure 19). It is important to note that the pin protrusion on the TV’s was virtually zero which is perhaps a worst-case scenario for barrel fill and fillet formation. However, despite this fact, the “post rework” barrel fill and fillet results were excellent. 100% barrel fill was measured on all but four of the one hundred and fifty-six measurements taken. In addition, a positive fillet was formed on every “post rework” joint that was analyzed (Figure 20).

Figure 19: Negative Fillet from
Wave Soldering

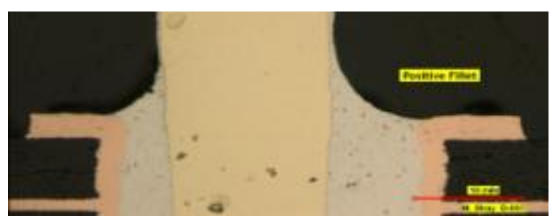

Figure 20: Positive Fillet from
Rework Process

100% barrel fill was a key objective of the alternate (FCH) process. It was expected that Focused Convective top side Heating (FCH) of the component would significantly improve barrel fill by creating a heated upward path for the solder to follow. However 100% barrel fill was also achieved in the baseline process where no FCH was used. It was surmised that there were two reasons for the significant improvement in barrel fill during PCBRM100 rework compared to wave soldering. First, the solder contact time during rework is multiple times longer than in the wave soldering process. Second, flux was applied to the bottom side of the board, the top side of the board and onto the replacement component pins during the rework process compared to just the bottom of the board during wave soldering.

A “post rework” void analysis was also performed on the one hundred and fifty-six (156) joints that were analyzed. 42% of the joints analyzed had zero voiding, 44% has a worst case void diameter of 10% or less and 14% had a worst case void diameter of over 10%.

Unfortunately, the DIMM connector on the TV did not lend itself well to the “single cycle” rework approach as the three (3) DIMM locating holes had annular rings which collected solder. This caused the locating pins to remain behind during component removal which prevented any attempt to immediately re-insert a replacement component. A future design recommendation is for DIMM locating holes to not have annular rings.

Summary and Conclusions

The solder fountain or “mini pot” has been the industry standard for tin-lead PTH rework as well as lead-free rework of PTH components on low and mid-complexity assemblies. The solder fountain process has been optimized for lead free rework by the use of lower dissolution solder alloys and by the addition of integrated preheating systems. In addition, BGA rework systems with convective and IR heating systems have been successfully used to remove lead free PTH components for applications where the optimized solder fountain process does not meet the rework objectives.

The current “lead in solder” exemption for Class 3 applications including server, storage and network infrastructure equipment is set to expire in 2014. Alternative rework solutions, including convection, IR, vapor phase and laser have been proposed, however none of the existing technologies was designed with lead-free rework of PTH components on large, high thermal mass assemblies in mind.

The PCBRM100 is a “clean sheet of paper” design approach to solving copper dissolution and barrel fill issues on Class 3 assemblies. In design and beta testing for over three years, initial production shipments will begin in the first quarter of 2013. The key to the 100 is the top and bottom focused convective heating (FCH) system which significantly reduces the required solder contact time which in turn significantly reduces copper dissolution. A two phased DIMM connector rework study on the 100 demonstrated that 100% of DIMM connectors reworked with the FCH process showed excellent results in regard to “post rework” copper thickness, barrel fill and fillet formation. Void analysis showed excellent results on 86% of the joints analyzed, however some large, random voiding did occur. The combined phase one and phase two processes were based on the complete rework (i.e. removal, barrel cleaning and replacement) of twenty-six (26) DIMM connectors with fifty-two (52) cross sections, nine hundred and thirty-six (936) copper thickness measurements taken and one hundred and fifty-six (156) barrel fill and voiding calculations made and fillet formations assessed.

Acknowledgements

I would like to thank the following individuals:

- Chuck Richardson (iNEMI) for use of the iNEMI 2013 Technology Roadmap
- Gordon O’Hara and Larry Yanaros (Flextronics)for test vehicle access and wave solder assembly
- Craig Hamilton (Celestica) and Alan Donaldson (Intel) for key reference articles on lead-free PTH Rework
- Brett Pennington (Endicott Interconnect Technologies) for performing all of the laboratory analysis for the rework study
- Mike Berry (Celestica) for providing initial test vehicles, lab analysis and machine design input
- Bob Farrell (Benchmark) for machine design input
- Yogesh Patel, Tan Tran and Himanshu Deo (Flextronics) for beta site testing and machine design input
- All of my co-workers at Air-Vac Engineering who helped me on this project.

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