Can Existing Tools Survive Pb-Free Soldering?

By Jasbir Bath

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Most machines pass the test, but some key changes are ahead.

LEAD-FREE WATCH
12 months
Countdown to July 1, 2006

In the transition to lead-free soldering, an area of concern in assembly operations is what equipment changes, if any, will be needed for lead-free electronics assembly processes. SnAgCu (or SAC), the most common lead-free solder alloy, has a higher melting point than SnPb solder, which increases the thermal demands on certain processing equipment. There are also concerns about mixing SnPb and Pb-free soldering operations and whether dedicated equipment is necessary to avoid contamination.

Screen printers. Equipment currently used for paste printing can also be used for Pb-free printing. Older Pb-free solder paste formulations often required the use of slower printer speeds with higher print pressures because of the non-optimized flow characteristics of the pastes. However, improvements in Pb-free solders have optimized the metal content and paste viscosity, so printer settings for Pb-free pastes are now very similar to those for SnPb. Stencil cleaning may need to be monitored, at least initially, and there should be dedicated and clearly labeled squeegee blades, stencils, support pins and blocks to avoid any contamination with SnPb paste.

Placement. The concern with placement machines has been whether Pb-free components (Sn-based passives, QFP, BGA, etc.) may require different component recognition and lighting adjustment than standard SnPb-coated parts. In general, such differences have not been found when existing placement equipment is used for Pb-free components. Previous iNEMI lead-free projects have not reported placement issues for SnPb or Pb-free components.

Reflow ovens. The SAC alloy melting point is 34°C higher than SnPb (217°C compared to 183°C). The higher temperatures affect the thermal performance of boards and components. Perhaps the most effective way to protect boards and components is to reduce the D_T between solder joint and component body.

For Pb-free soldering, 10-zone convection ovens are often preferred over six-, seven- and eight-zone ovens, especially for large server-type boards. The additional zones permit sufficient time in reflow to achieve the desired preheat and soldering temperatures while reducing the D_T between solder joint and component top and across components on the board. It also permits sufficient soak time and temperature prior to reflow without rapid temperature changes required in adjacent zones.

Note that the largest, thickest boards do not always have the greatest D_T between solder joint and component top. In a 2002 paper[1], the greatest D_T across the board for Pb-free soldering for a wide array of board types (disk drive, laptop, server) was found on smaller, thinner, double-sided paste-in-hole laptop boards that used a closed reflow fixture.

Table 1. Equipment Use Recommendations

Can Use Existing Equipment	Consider Dedicated (Product Dependent)	Dedicated Equipment Recommended
• Screen printer • Component placement equipment • Test equipment (ICT/x-ray/AOI/flying probe) • Cleaning equipment	• BGA/CSP rework tools and area	• Spatulas, stencils, squeegee blades • Surface mount pallets • Wave solder machine • Wave pallets • Hand-soldering iron/tips and desolder station • Mini-pot machine • Any other contact type of equipment • Soldering materials storage • Component storage • Solder disposal

When deciding whether to invest in 10-zone convection ovens, manufacturers need to consider the types of boards they are building. For thinner boards, such as those used in cellphones, eight-zone reflow ovens should still be sufficient for Pb-free soldering. For laptop boards with a thickness around 0.063", a 10-zone reflow oven should be considered. A 10-zone reflow oven is recommended for thicker (>0.090" thick) boards.

Debate continues over the use of nitrogen versus air in reflow assembly. The iNEMI Pb-free Assembly and Rework Project found that nitrogen is better in terms of aesthetic appearance of Pb-free solder joints, but not necessary to ensure joint integrity. Again, manufacturers need to consider the types of boards they are building when deciding whether to use nitrogen.

Nitrogen use may be more appropriate to preserve solderability of certain board surface finishes such as OSP (organic solderability protectant). This is especially true for boards passing through multiple thermal excursions, such as when using both surface-mount and wave soldering as is typical in boards when board thickness is 0.063" or more. Nitrogen may also help to improve ICT pin probeability of no-clean solder paste flux residues, which may be harder during higher temperature Pb-free processing in air atmosphere.

Wave soldering. Dedicated wave machines for Pb-free soldering are recommended. The typical 1600 lb. solder pot makes changeover from SnPb to Pb-free wave soldering difficult and time-consuming, and lead contamination remains a risk. The high-tin content of SAC solders increases erosion on certain stainless steel parts, especially those in contact with the wave, and they must be replaced more often than when using Sn63Pb37 solder. Some wave-solder equipment suppliers once provided nitride-coated parts, but titanium parts appear to be better. Titanium parts are scratch-resistant (during maintenance) and should have longer manufacturing service life. Wave-soldering equipment suppliers are aware of these issues and can provide assistance as needed. Given the increased solder pot temperatures required for SAC solder, manufacturers should also consider the use of nitrogen over the molten wave for no-clean VOC-free fluxes to help improve process windows (typically much narrower for Pb-free soldering).

Rework. Despite efforts to reduce defects, rework remains an essential part of production. For Pb-free soldering, at least while process experience is being gained, rework may increase. The various rework equipment to consider includes area-array rework machines for BGAs and CSPs; hand soldering; and mini-pot/solder fountain for connector/pin-through-hole rework.

Area-array rework tools. BGA and CSP rework may require a dedicated rework machine and area. Increased board heat is needed for Pb-free rework to reduce the D_T between the solder joint and component top, especially for larger, thicker boards. This D_T difference is typically worse for BGA/CSP rework equipment than for first-pass reflow ovens. The uniformity of heat into the board is also important to reduce hot spots on the board as well as to reduce D_T.

Recent iNEMI studies found that Pb-free server boards approximately 0.135" thick required higher temperatures and were more difficult to rework. Thermal heat shrouds can be used over the board to reduce the amount of heat into boards from the bottom heaters and top nozzle. The ability of current rework tools to maintain acceptable temperature profiles has not been widely investigated. Nozzles and heaters also need further development.

Areas to consider and control for BGA/CSP rework include:

Minimize adjacent and bottom-side temperatures.
Better thermal controls.
Use top-side thermal heat shrouds to reduce amount of bottom-side heat needed.
Better bottom-side heat distribution.
New rework nozzle designs.
Tighter tolerances and more repeatable rework systems.

Hand soldering. Pb-free soldering may require increased tip temperatures, but these increases should not be significant. Hand soldering requires greater care with time and temperature applied to the soldered part and better thermal controls to avoid component or board damage. There may be more erosion of tips with Pb-free solder because of its higher tin content. Dedicated hand soldering equipment should be used to avoid lead contamination.

Mini-pot/solder fountain connector/PTH rework. Mini-pot rework equipment needs further development. It is more challenging to obtain good hole-fill for SAC solders. Board preheat prior to solder fountain rework helps to produce better hole-fill and should be used for improving Pb-free mini-pot rework. With its higher tin content, SAC solder may also increase erosion of copper barrel PTH boards and should be monitored.

Test and inspection. Some test and inspection methods will also have to be tweaked for optimum Pb-free performance.

X-ray. Generally, x-ray images of Pb-free soldered joints are similar to SnPb, although grayscales may be slightly different for SAC solder because of the absence of lead. Some reprogramming of automated x-ray machines may be required but is expected to be relatively minor. Previous iNEMI projects found little issue analyzing Pb-free soldered joints using x-ray equipment.

AOI. Visual appearance of Pb-free soldered joints may be duller or there may be a mixture of dull and shiny joints. AOI equipment may need to be reprogrammed to adjust to the variations in visual appearance but typically these adjustments are minor.

Visual inspection. As mentioned for AOI, visual appearance for Pb-free soldered joints will likely show a mixture of dull and shiny joints. Inspection criteria should be adjusted and operators trained so that duller Pb-free joints are not classified as cold joints and reworked unnecessarily. The recently released IPC-A-610D standard will help educate inspectors. It provides pictures of Pb-free soldered joints side-by-side with SnPb soldered joints.

ICT. The initial set of SAC no-clean solder pastes, along with higher soldering temperatures, will likely produce harder solder flux residues, which may cause more false calls during ICT. The increased hardness of SAC compared with SnPb solder may also wear out probe tips more frequently and should be monitored. Nonetheless, manufacturers should be able to use existing ICT equipment.

Flying probe. Flying probe equipment has the same issues as ICT. Limited work has been done on flying probe evaluations. With the reduced process windows for Pb-free soldering, especially wave soldering with thicker boards, companies may evaluate VOC containing no-clean fluxes. This change could increase solder flux residue and cause probing issues, which should be monitored.

Cleaning equipment. Existing cleaning equipment and solvents can be used to clean SAC no-clean solder pastes from stencil apertures and misprinted boards. More work is needed to verify newly emerging SAC materials.

Lead detection equipment. Handheld and desktop XRF equipment is being considered for detecting lead contamination on Pb-free soldered boards. Accuracy and repeatability of the equipment is subject to many factors. In general, the handheld XRF equipment is more convenient to use on the production floor but less accurate than desktop models.

Other considerations. Dedicated wave/SMT pallets and dedicated carrier trays will help avoid mixing SnPb and Pb-free processes, thus reducing contamination effects. Highly visible labeling of Pb-free equipment, supplies and tools will also help. Surface mount assembly (print, place, reflow) does not need to be dedicated, but Pb-free wave and rework should be for initial assembly and to deal with field returns for rework. n

Reference

1. M. Kelly, D. Colnago, V. Sirtori, J. Bath, S.K. Tan, L.H. Teo, C. Grosskopf, K. Lyjak, C. Ravenelle and E. Kobeda, “Component Temperature Study on Tin-lead and Lead-free Assemblies,” SMTA International *Proceedings*, September 2002.

Jasbir Bath is an advisory process engineer for Solectron Corp. (**solectron.com**); **jasbirbath@ca.slr.com**. He has led various iNEMI lead-free programs. He is currently organizing a new iNEMI initiative in Pb-free rework optimization.

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