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Are You Ready for Lead-free?

NEW REFLOW PROFILES AND OVEN CONFIGURATIONS MUST BE EXPLORED TO MEET THE NEEDS OF LEAD-FREE SOLDER PASTE.

COVER STORY

By Marc Peo and Don DeAngelo

Various international market trends drive electronics manufacturers and their materials and equipment suppliers to develop new assembly techniques to reduce the industry's environmental impact. Two primary forces in this drive are the movements to lead-free assembly and ISO 14000 certification. In response to these factors, reflow technology advances are enabling manufacturers to meet or anticipate the new environmental mandates.

In some cases, the mandates take the form of legislation, such as the European Community directives that will restrict the sale of lead-bearing electronic products in Europe after January 1, 2004. In Japan, a voluntary program of lead elimination has gathered momentum among major manufacturers, including Sony, Matsushita (Panasonic), Hitachi and Toshiba.

Concurrently, many of these same companies and other industry leaders are implementing international ISO 14000 certification programs that support more environmentally friendly manufacturing techniques. In addition to eliminating the use of lead and halides, certified companies must minimize the quantity of effluents being released into the atmosphere. In both cases, electronics manufacturers have turned to vendors to provide materials and equipment that meet the new "green" standards.

Solder Pastes

In terms of materials, a number of new lead-free solder pastes are being released to the market; because none of them are exact drop-in replacements for tin/lead solder, all require some process adjustments. The primary difference between most of the new formulations and traditional solder is a higher melting point. Instead of reaching liquidus at 183°C, as tin/lead solder does, the lead-free pastes melt at anywhere from 195° to 227°C, depending on the formulation.

Profiling

Higher melting points shrink the process window dramatically. Eutectic tin/lead solder has a melting point of 183°C with a full liquidus temperature of 205° to 215°C and a maximum printed circuit board (PCB) temperature of 230° to 240°C. A true process window of 15° to 35°C exists. However, the melting point of the more popular lead-free formulations is in the range of 216° to 220°C, and the full liquidus temperature is 225° to 235°C.

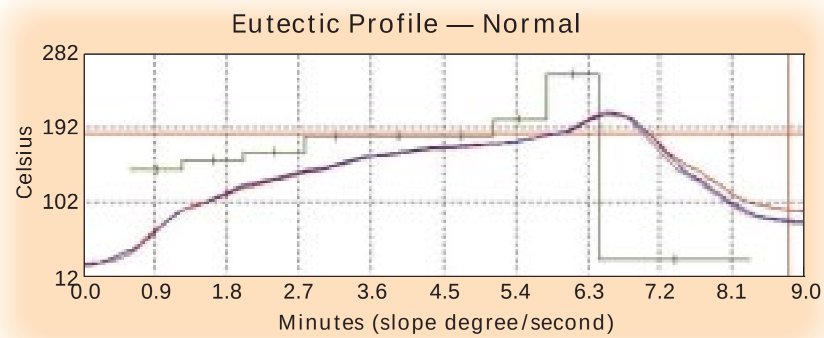

Figure 1. In a typical reflow profile of 40 to 60 seconds for lead-bearing solder, the temperature rises to a relatively short peak and then drops off.

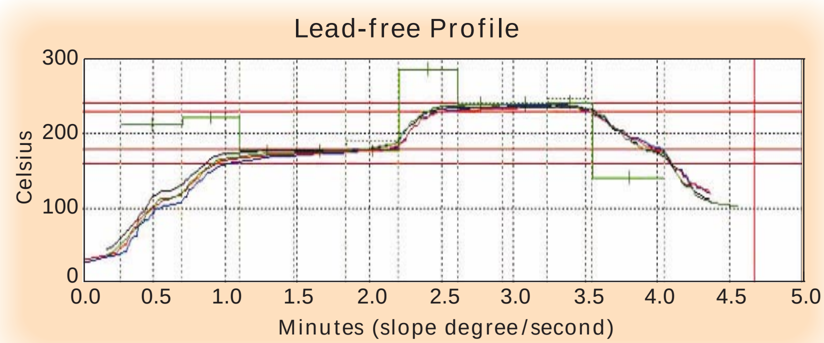

Figure 2. A reflow profile using lead-free solder usually lasts 60 to 90 seconds. The heat rises to a higher level than for lead-bearing solder and remains at that plateau for a longer period of time.

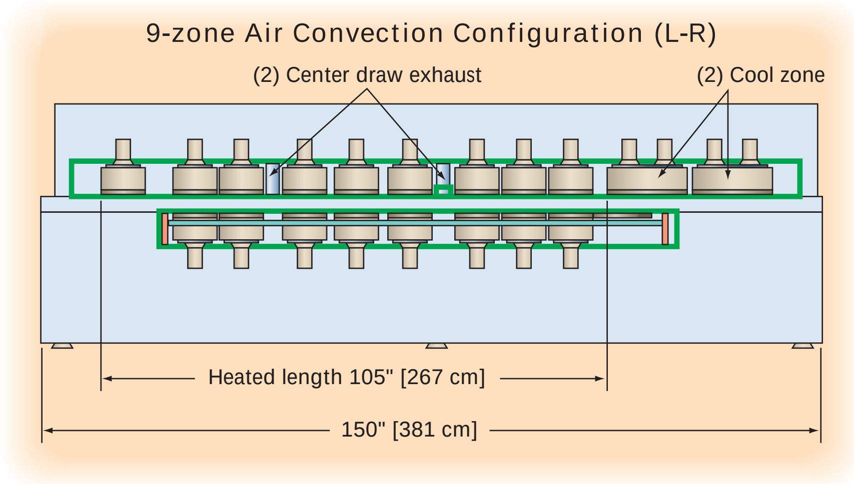

Figure 3. This reflow oven design for lead-free processing features nine zones.

Because maximum temperature on the PCB remains the same, the process window shrinks to as little as 5° to 15°C. This narrower process window requires the oven to perform with greater levels of repeatability and accuracy as well as very tight on-board ΔTs. For example, if the process window is 10°C and the ΔT on the PCB is 10°C, the process would be running with a zero margin of error.

In addition to higher temperatures, most lead-free solder pastes require an extended period of time at liquidus — usually 60 to 90 seconds — rather than the traditional 40 to 60 seconds. As a result, the profile for lead-free reflow tends to differ from the typical tin/lead profile (Figures 1 and 2). Instead of rising to a relatively sharp peak and then dropping off, the heat rises to a higher level and remains at that plateau for a longer period of time.

Reflow Ovens

Taking into account material and process differences, the data point to forced-convection reflow oven use for these lead-free assemblies to maintain control at higher process temperatures. Nitrogen, which has the effect of widening the process window, is also recommended (but not required) by many lead-free paste suppliers.

Process benefits of nitrogen include the use of lower melting point paste formulations (195°C) and improved solder flow and wetting angles. Nitrogen also may reduce discoloration caused by the higher temperatures and longer reflow times for lead-free pastes. Additionally, because lead-free joints tend to be duller than tin/lead joints, nitrogen can improve their appearance. However, in some markets, the cost of nitrogen generation steers manufacturers away from these formulations.

While newer forced-convection ovens have been (and may continue to be) used for lead-free reflow development, the latest advances in oven design can enhance lead-free assembly implementation. These oven innovations include increased reflow zones, a change in zone configuration, a reduction in overall oven length and new center board-support options. Other developments in reflow technology, such as flux separation and collection systems, are responding to environmental requirements to minimize the oven's effluent discharge.

In an oven designed for lead-free processing, the number of reflow zones has increased, while the size of each individual zone has decreased (Figure 3). The new configuration provides greater process control while maintaining higher temperatures more consistently at the same throughput rate.

This configuration, including warm-up, reflow and cool-down sections, can be contained within a 150" oven length, providing throughput similar to a conventional 183" reflow oven.

Redesigning the center board supports responds to the impact higher processing temperatures have on PCB materials. When temperatures rise above 150°C, the PCB enters a glass-transition phase that causes it to sag in the center. The higher the temperature, the greater the sag and the greater the possibility that the board may not recover its flat, rigid form. This is critically important for the first pass of a double-sided board, because second-pass screen printing on a warped board is regarded as a prescription for disaster.

The newest design concept in center board support involves using the mechanism only in those areas of the oven where it is required — reflow and cooling. Typically, the supports that run the length of an oven require large, bulky rails that can block air flow to the PCB and increase the board's ΔT. Additionally, the support mechanism can lower the overall board temperature, requiring different profiles for boards with or without the center support.

Because boards do not sag appreciably when they are below the glass-transition temperature (150°C), reducing the length of the center support and eliminating it from the preheat section of the oven provides support only where the board needs it. The resulting shorter support rail also can be thinner than traditional rails, making it transparent to the PCB (Figure 4). Testing has shown that the ΔT across a PCB remains unchanged, and the overall board temperatures repeat to within 0.5°C, with or without the center board support installed.

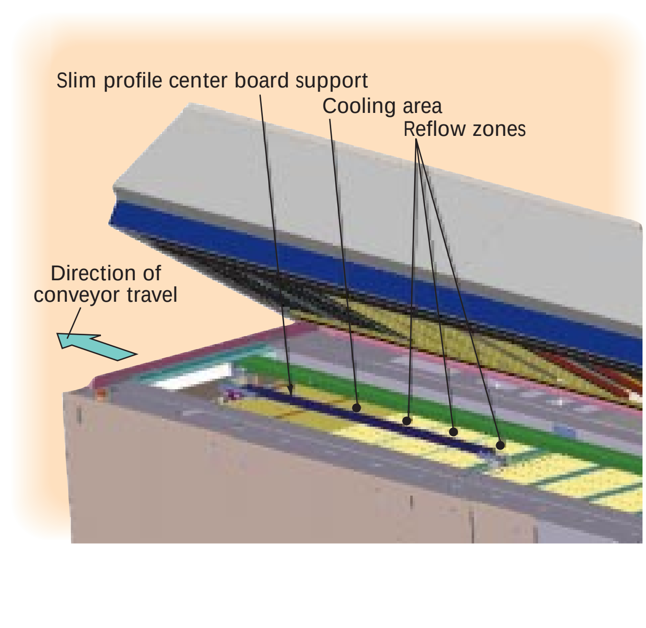

Figure 4. Reducing the length and width of the center board support and removing it from the oven's preheat section eliminates the need to develop different profiles for boards processed with or without the support mechanism.

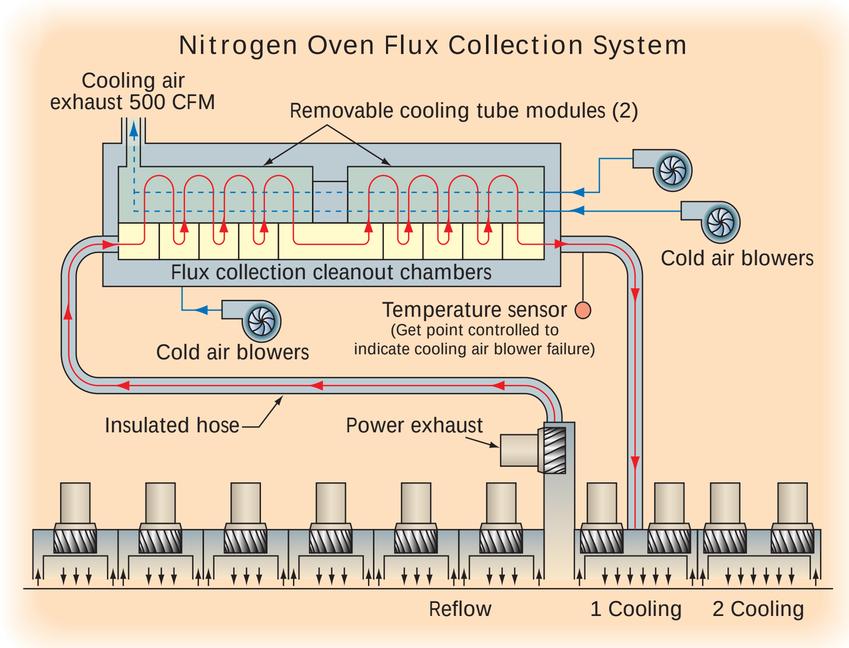

Figure 5. A closed-loop flux separation system passes nitrogen through a separation module and returns it to the cooling zone, where it can be recirculated.

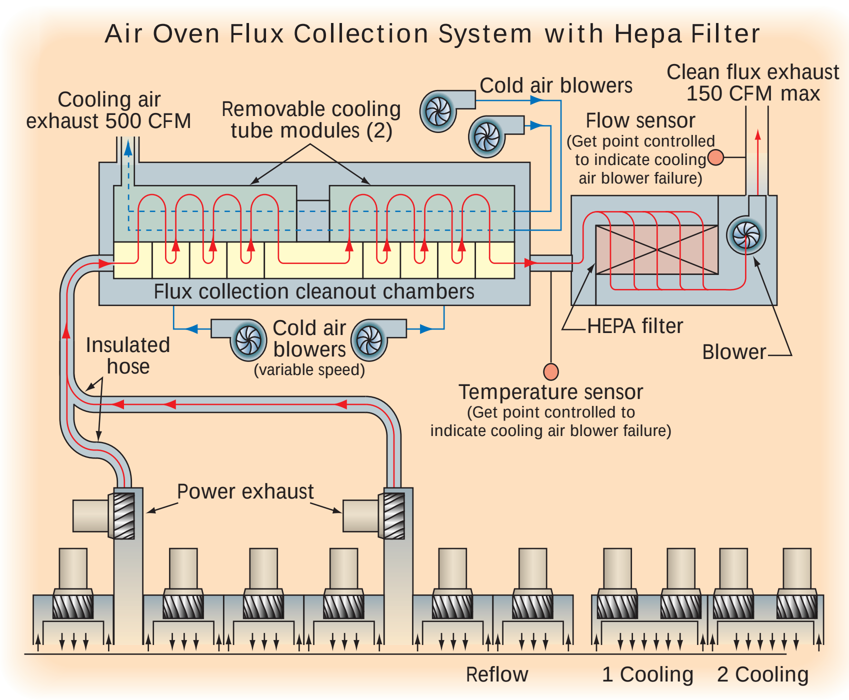

Figure 6. On a reflow oven using air, the addition of a Hepa filter minimizes the amount of particulates released into the building's exhaust system and the environment.

Separating and collecting flux for removal from the reflow oven has always been required for nitrogen processing. With the implementation of ISO 14000 regulations, many companies require a similar system for air reflow to prevent the release of volatiles into the atmosphere. An automatic flux-removal system also serves to preserve the oven's internal cleanliness, minimizing production interruption for maintenance purposes.

Some flux separation and collection systems can remove 95 percent of flux residues from the oven interior, with extended maintenance intervals of 30 to 90 days in high-volume operations. These systems employ a combination of internal cooling techniques, mechanically activated flux agitation, and increased surface area for flux residue and particulate capture.

For inert reflow, closed-loop systems can pass the nitrogen through a separation module and return it to the cooling zone (Figure 5). The "cleaned" gas can be recirculated, reducing the cost of nitrogen usage. Some systems have provisions for the addition of a Hepa filter to comply with local EPA or ISO guidelines, minimizing the amount of particulates released into the building's exhaust system and the environment (Figure 6).

Conclusion

The long-term impact lead-free assembly and ISO 14000 certification will have on the electronics industry is as yet undefined. However, initial implementation stages are developing rapidly. Lead-free paste alternatives are available and some companies have incorporated them successfully in major production lines.

While the installed base of modern forced-convection reflow systems is capable of handling many new lead-free solder pastes, the newest oven configurations enable manufacturers to optimize reflow for the entire range of pastes and profiles. In anticipation of manufacturers' needs to adapt their installed bases, oven suppliers have made innovations such as flux separation systems and center board supports that are retrofittable for existing equipment.

Through a combination of adaptation and expansion, today's reflow systems can be prepared for lead-free reflow and ISO 14000 certification. Such systems are already in use by numerous major assembly companies and are available to all manufacturers.

Any implementation program begins with gathering information from various sources, including both materials and equipment vendors, as well as industry sources such as the IPC Web site (www.ipc.org) and the ITRI Web site (www.lead-free.org). Armed with an understanding of the issues involved, a manufacturer can take the steps required to maintain a competitive position in the worldwide electronics marketplace. SMT

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