The Greening of the Reflow Process

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The Greening of the Reflow Process, Through Partnership

by Atsushi Kikuchi

After years of concentration on resolving productivity-related concerns such as increasing speed, consistency and throughput while reducing costs, many of the world's leading electronics manufacturers have added a new mandate to their agendas. They are seeking to minimize the environmental impacts of their assembly processes and final products without sacrificing the high levels of productivity and quality that have been achieved through decades of effort.

Among the most active companies in this movement is the Kohda Division of the electronics giant Sony. Kohda manufactures the Vaio laptop computer as well as Sony's camcorders, digital cameras and the PlayStation 2. The circuit boards for these products are assembled on a total of 62 lines, in three shifts that run seven days a week. In the first quarter of 2000 alone, a million PlayStations were produced on these lines, along with Kohda's other products.

Demanding technology is involved in Sony's assembly process. The double-sided boards are densely populated and range in size from the motherboard for the laptop computer down to the circuit board that powers the Sony camcorder, which contains 1500 components on a substrate approximately the size of a playing card.

In the course of developing such products and becoming a leading force in the worldwide consumer electronics marketplace, Sony has developed a high level of awareness of consumer trends. Within the past few years, the trend to favor companies with "green" manufacturing policies has gained increasing importance. Green manufacturing operations follow environmentally friendly practices that minimize adverse impacts such as emissions or landfill contamination.

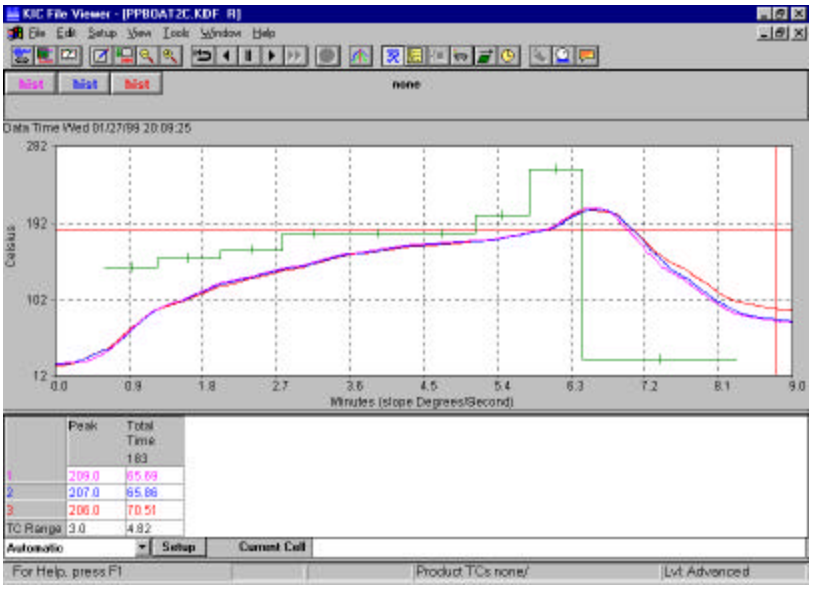
The most widely recognized international standard for green manufacturing is ISO 14000. The guidelines for ISO compliance incorporate a broad range of measures, including lead-free assembly and flux-free emissions. Achieving ISO 14000 certification thus became a major goal for Kohda and Sony as early as 1997, well in advance of initia-

tives such as the voluntary decision of the Japanese Electronics Industries Association and the current draft directives of the European Union.

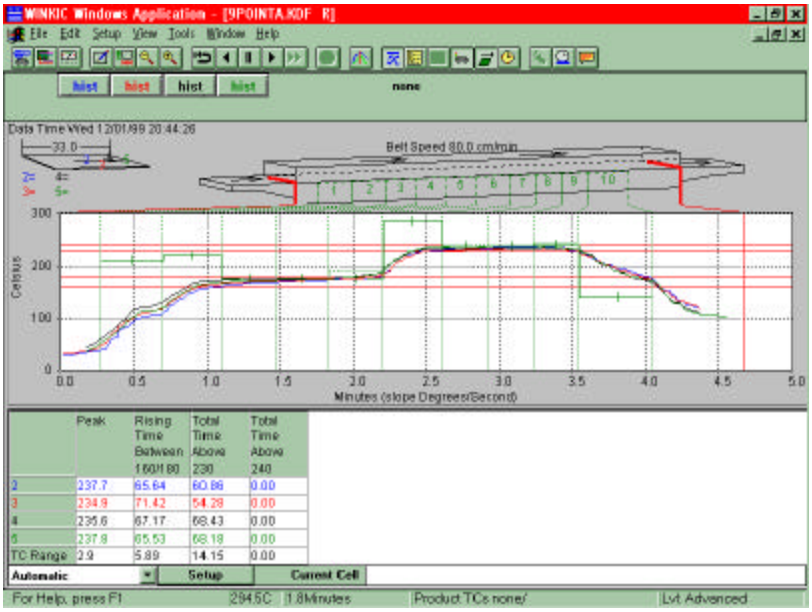
In order to minimize environmental impacts and remove lead from the assembly process, Sony undertook a massive, multi-faceted research program. Among other activities, a new, lead-free solder paste and reflow profile were developed. The primary differences between the new process and a traditional process using lead-based solder are the higher melting point of the paste and the demanding thermal profile required to process it effectively.

Lead-based eutectic solder melts at 183°C and achieves full liquidus at 210°C, where effective intermetallic transfer and a good solder result occurs. This leaves a generous 30°C process window before the substrate and components are adversely affected, at a temperature of 240°C.

Sony's new lead-free paste, on the other hand, has a melt range of 216-200°C and reaches full liquidus at a range of 230-235°C — a mere 5°C below the maximum allowable temperature of 240°C. Maintaining such a small ΔT when processing any boards, and particularly laptop motherboards with Pentium BGA components, presents a significant reflow challenge. In addition, the paste requires a demanding thermal profile with a rapid ramp-up from the 160-180°C plateau to 235°C.



A typical reflow profile for eutectic tin-lead solder



The no-lead solder paste profile preferred by Japanese manufacturers

As these new process elements were being developed, it became apparent that Sony's existing eight-year-old reflow ovens were no longer capable of satisfying either the rigorous demands of the lead-free profile or the environmental requirements of flux-free emissions. These factors prompted Kohda to undertake a worldwide search, not only for advanced reflow equipment, but also for a supplier with the capability to develop technology that did not yet exist, in order to satisfy the company's new requirements.

Over the course of a year, a Kohda evaluation team visited numerous reflow oven manufacturers in Japan, Europe and the United States, spending several days at each location. The same tests — a load test, a ΔT test to track temperature changes, a repeatability test and a test of the profile change over time — were performed on all ovens. These tests were used to establish a baseline for comparison and to determine the potential of each supplier to meet Kohda's selection criteria.

These criteria included tight temperature control with a very low ΔT, the ability to meet the challenge of the lead-free profile, flux-free and filter-free operation with minimal maintenance and, finally, as short a machine footprint as possible. There was a specific reason for each criterion: the short footprint, for example, was necessary to conserve floor space in Kohda's heavily-utilized manufacturing facilities.

Removing flux from oven emissions was required to ensure environmentally friendly operation. Capturing the flux in filters, as had been done previously, was not considered effective, since putting flux-laden filters into landfills would not provide a satisfactory solution. Additionally, the maintenance involved in filter replacement required more production downtime than Sony was willing to allow. What was sought was a new concept in automatic flux elimination.

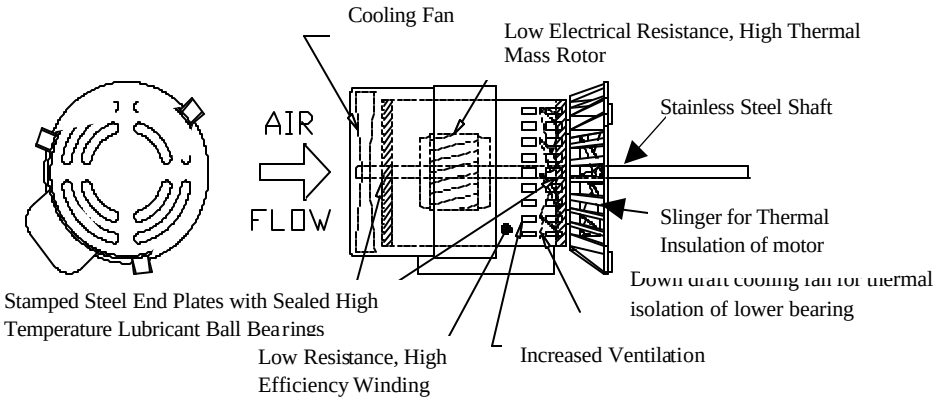
Tight temperature control with a low ΔT was, of course, the primary requirement needed to manage the very limited process window and produce Sony's new, lead-free reflow profile. Since the thermal technology to accomplish this task did not exist at the time of the company's search, it was necessary for the team to evaluate both current technology and each supplier's potential to develop new, one-of-a-kind engineering concepts.

Following the initial evaluation, four finalists were selected and a "bake-off" was conducted, using the same tests as in the initial evaluation, to determine each supplier's current and potential capabilities. The supplier that Kohda selected, Heller Industries of Florham Park, New Jersey, was chosen for several reasons: its existing reflow technology was highly innovative and incorporated numerous advanced engineering features. In addition, Heller personnel proved flexible to work with and were willing to enter into partnership with Sony to develop the breakthrough designs required to achieve Kohda's goals for lead-free, environmentally friendly operation.

From late 1998 through delivery of the first new oven in October 1999, engineers from the two companies worked closely together to develop, evaluate and refine a number of revolutionary new designs that led to the successful implementation of Sony's lead-free, flux-free assembly process. Among these new technologies were two proprietary systems: one for tight gas flow circulation management and another for filterless flux removal with a self-cleaning mode. Other innovations included a high-temperature blower motor assembly, a shorter Center Board Support and a reduction in overall machine length.

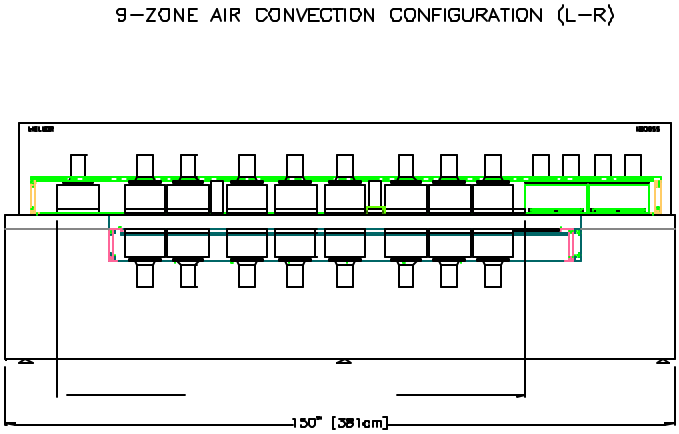
The high-temperature blower motor assembly features a ball bearing motor with a stainless steel shaft and heavy-duty steel impeller wheel. It functions in conjunction with the gas flow circulation management system to maintain the very low ΔT that ensures full

liquidus of the paste at 235°C without reaching the board danger zone of 240°C. Additionally, the ability to manage gas flow circulation was the critical factor in achieving the challenging lead-free profile.



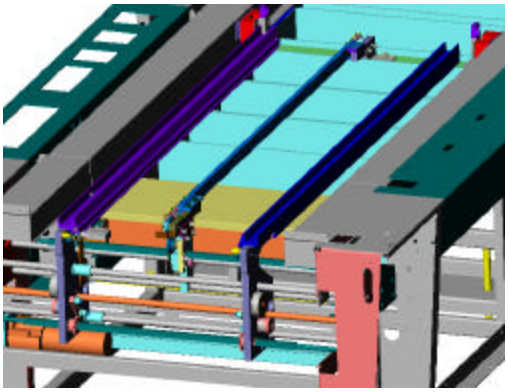
A high-efficiency ball bearing motor designed for a maximum operating temperature of 450°C helps maintain the very low ΔT required for lead-free reflow.

Because Sony's lead-free profile requires a rapid ramp-up from the 160-180°C plateau to the 235°C plateau, it became necessary for boards to move from a 180°C soak zone to a 290°C ramp-up zone and then into a 235°C reflow zone. In a forced convection oven, characterized by continuous air movement, maintaining separate zones at different temperatures in close proximity to each other poses a significant engineering challenge. The breakthrough technology that was developed to manage the air flow made it possible for Sony's lead-free profile to be maintained with consistency.



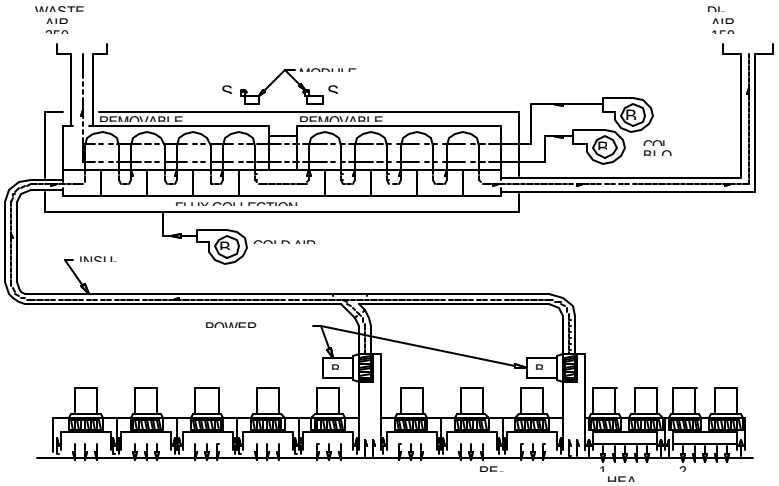
A nine-zone configuration within the reflow oven ensures the tight gas flow circulation management needed to maintain a consistent lead-free profile.

Another key breakthrough in maintaining tight temperature control was the development of a shorter Center Board Support (CBS) to eliminate thermal interference and prevent board warpage. In typical ovens, the CBS can block the air flow and affect the ΔT on the board, requiring a special profile to accommodate its use. By reducing the length of the CBS to only those high-temperature zones where boards are most likely to warp, and to the cooling zones, it became possible to maintain the low ΔT without requiring a special profile.



A Center Board Support that spans only high-temperature zones eliminates the need for a special profile to prevent board warpage.

Innovative thinking also led to a new approach to flux removal that eliminated the need for filters. The new system uses a condensation/precipitation methodology to remove flux from the oven tunnel before it reaches the cooling area, where it tends to accumulate in conventional ovens. The flux is trapped in a series of trays and concentrated into a molasses-like substance through a self-cleaning cycle that operates automatically during production. It is completely transparent to the user and requires no downtime.



An innovative flux collection system for air reflow includes dual internal and external exhausts.

After 30 days of processing using 56.0 kg of solder paste, the condenser tubes in the flux collection system show significant flux accumulation.

Following a 20-minute automatic self-cleaning cycle that does not interrupt production, the re-liquified flux is captured in collector trays that require replacement only once a year.

The trays have a capacity of approximately a year's worth of flux, at a production rate of two kilos per day of paste usage. When the trays fill up, they can be removed and replaced or removed, cleaned and returned to the oven. The replacement process can be completed in ten minutes, once a year, as opposed to the several-hour-long monthly procedure required for filter exchange. Several of Sony's new reflow ovens have been run-

ning continuously since their installation in October 1999 and, as of late August 2000, none had required downtime for flux cleaning.

To meet Sony's final requirement of a reduced footprint, the ovens were reconfigured to contain a larger number of smaller zones within a 150-inch length, yet still equal the throughput of a conventional 183-inch oven. The result was a 20% increase in throughput per linear foot, an important space-saving consideration. An added bonus was the translation of all oven software into Japanese, for greater ease of use by operators and engineers alike.

The process of developing new reflow technology for Sony required months of close partnership between supplier and manufacturer, but has resulted in benefits for both parties. The Kohda division of Sony has achieved its goal of implementing a green manufacturing operation with lead-free soldering and flux-free emissions, while maintaining or enhancing throughput. The oven supplier has developed engineering advances in reflow technology that may be extended throughout the industry as more electronics manufacturers realize the market value of instituting more environmentally friendly assembly processes.

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