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Maximizing Reflow Yield with Advanced No-clean Ovens and Real-time Thermal Managers

In today's competitive market, SMT assemblers and manufacturers must make every effort to maximize reflow throughput and increase yield. Success depends upon two critical factors: minimizing oven downtime; and the ability to precisely define and monitor the thermal process in real-time. Two complementary tools designed specifically to help SMT assemblers achieve these goals are the no-clean oven and the real-time thermal manager.

Flux Deposit Removal and Oven Downtime

One of the major causes of production downtime for reflow oven users is oven maintenance. For a high volume production facility, the reflow oven must be shut down to remove flux deposits every two to six weeks. In a facility running a 24-hour operation, it is not uncommon for the oven to be cleaned weekly.

Reflow oven flux buildup is primarily due to three factors: the use of low solids pastes, nitrogen recirculation, and refrigerated board cooling. If flux deposits are not removed from the oven's heater cavity, these waste deposits can drip onto circuit boards at the most critical point in the reflow process. Furthermore, flux clogged convection jets or nozzles can destabilize heat-transfer profiles. Flux can also contaminate conveyor positioning shafts, making width adjustment difficult and board-support problems likely.

Conventional reflow ovens utilize a variety of methods to remove flux from the oven. These methods include burning off flux residues at extremely high temperatures (upwards of 450°C), or condensing flux in a heat exchanger that contains removable fins for cleaning. Lower maintenance designs use condensation plates or trays external to the cooling zone to reduce flux build up. The problem with these cleaning processes is that they inevitably cause oven performance problems which in turn lead to further downtime. Disassembling flux contaminated nitrogen heater cavities breaks cover seals, and broken seals lead to increased nitrogen consumption. In addition, scraping hardened flux deposits from the heater cavity has the potential to damage convection gas supply nozzles. It is extremely difficult to restore an oven to its original factory condition after the seals and gas nozzles have been damaged.

These practices are so common that manufacturers have mistakenly come to view frequent flux removal as a routine cost of doing business. The widespread notion that weekly oven cleaning and maintenance are part of a 24-hour reflow operation prevents many plant managers from realizing just how much production time they're losing.

The No-clean Reflow Oven

The optimal solution to the problem of production downtime as a result of frequent oven cleaning is the no-clean oven. The no-clean oven has been specifically designed to automatically prevent heater cavity flux buildup and eliminate downtime due to flux removal.

The no-clean oven keeps its heater chambers clean by using a cavity design that keeps reflow process gas above flux condensation temperature at all times. The no-clean cavity design produces a cascading gas effect which maintains positive gas pressure in the reflow zone. This prevents flux particles suspended in the reflow gas from solidifying in the oven cavity. Instead of allowing flux to accumulate in the heater cavity, the recirculated gas is purged into the preheat zone and the exit exhaust, and flux accumulates on a condensation plate located beneath the cooling section.

The design of the no-clean oven offers minimal maintenance downtime. Once the machine is placed in the line, users have the ability to run boards on a 24/7 basis. The result is higher yields and a greater profitability on the SMT line.

Real-time Thermal Manager

The real-time thermal manager is a tool capable of continuously monitoring process temperature in the reflow oven. Thirty thermocouples embedded in two slim stainless steel probes are permanently mounted just above or below the conveyor. The probe thermocouples continuously monitor the process temperatures, taking readings as frequently as every five seconds. These temperatures are graphically displayed as "Process Profiles" on the user's PC screen. All data is recorded permanently to the hard drive, giving users the ability to review process data from any previous production date. The real-time thermal manager reveals critical temperature variations that may be hidden from the oven control thermocouples, making any temperature drift during production and its location immediately visible on the PC screen.

The real-time thermal manager provides a product profile for every board processed by creating a mathematical correlation between product profile, as measured by a pass-through profiler, and process temperature, as measured by the real-time thermal manager thermocouple probes. This "Virtual" product profile is calculated every 30 seconds, and Virtual Profile statistics, such as peak temperature are also calculated and continuously updated. The instant the Virtual Profile falls outside the defined process window, an alarm will sound. This feature can also turn on an alarm light or even shut down the oven feed conveyor. The real-time thermal manager is an excellent tool for zero defect production because it eliminates the potential for product defects due to thermal variations.

The real-time thermal manager is also available with an automated prediction tool, which allows users to predict how changes to belt speed and oven setpoints will affect a product profile. In the automated mode, the thermal manager will create and evaluate thousands of potential product profiles, automatically selecting the profile that best fits the process window. The automated prediction tool is also capable of finding common recipes for lines that run multiple dissimilar products.

When Virtual Profiling is combined with the Real-time Thermal Manager's ability to continuously store process temperature data and bar code reader, users have the capability to record a permanent record of the thermal profile of every board produced. As the process temperatures are measured, they can also be fed to an external SPC package for real-time process control. ISO 9000 process documentation and production tracking can also be achieved with virtually no manual input.

The No-Clean Oven with Real-time Thermal Manager in Production at Lucent's Columbus Plant

An additional benefit of the real-time thermal manager is that you never have to run periodic verification profiles with a pass-through profiler. This is because the Virtual Profile is verifying the process continuously. This continuous process verification complements the reliability and low downtime of the no-clean oven. Few process engineers are going to be willing to believe that the no-clean oven is capable of running 24/7 for up to a year (depending on the process, paste, etc.) without preventive maintenance, but with the real-time thermal monitor to confirm that the process is within the acceptable window, there's no reason not to run the oven full-time. The real-time thermal manager confirms that the no-clean oven is running within process parameters and allows users to get the maximum benefit from the oven's low maintenance requirements and high Mean Time Between Failures.

Melissa Roe, Senior Process Engineer at Lucent Technologies Columbus Works, is responsible for several lines on which no-clean ovens and real-time thermal managers were installed two years ago. She explained why she feels the need for a real-time thermal manager: *"The way the ovens are built, the thermocouples that are installed by the oven vendor are right up against the heater panel, and these don't give you a true reading of the air temperature inside the oven. The real-time thermal manager, with the thermocouples installed at the belt, does give an accurate reading of the atmosphere inside the oven."*

The real-time thermal manager has proved valuable to Lucent in a number of ways:

- Preventing defects: Alarms have prevented defects on several occasions. In one situation, a heater was not responding correctly and the temperature in the reflow zone was dropping below the alarm limit. The real-time thermal manager identified this failure and prevented a potentially serious cold solder problem.
- Process setup: This plant runs a large variety of products, from very thin Teflon boards to heavy plated boards which have a regular FR4 PWB bonded with adhesive to a 1\4"thick aluminum plate. Oven performance for the whole range of products has been analyzed with the real-time thermal manager to determine how well the heaters perform with a given type of load. This analysis is used to determine the maximum oven loading for a given product.
- Eliminated Weekly Profiling: Prior to obtaining the real-time thermal manager, a pass-through profile was run weekly to confirm that the ovens were within spec. This requirement has been eliminated.

The No-Clean oven has also provided superior performance. The previous ovens required cleaning every month, and the no-clean oven has proven capable of running nine months without cleaning. Lucent is currently using the real-time thermal monitor to determine the necessary intervals for preventive cleaning. Melissa estimates that the preventive maintenance interval will be between three to six times longer than the previous interval, depending on the line and the product being run.

Conclusion

In a market that gets increasingly competitive day by day, SMT assemblers need every productivity advantage they can get. Yield is the bottom line, and yield can be increased by using the no-clean reflow ovens in combination with the real-time thermal manager.

