

Profiling High-reliability Assembly

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Paramit Corp. provides focused electronic manufacturing and test solutions to leading OEMs in various high technology industries. It has designed an infrastructure dedicated to “simplifying business complexity” via a business model that raises several process issues. For example, many assemblies feature components having special (nonstandard) solder-reflow needs. In the past, companies have had to verify their processes by running extensive design of experiments (DOE) to prove a solder-reflow oven’s repeatability, an activity that drains engineering resources. Another issue: companies certified to manufacture medical devices require product traceability that documents all rework, including by whom performed and where it was done on the board.

The current emphasis is on a process that builds in rather than inspecting in quality. This calls for an automated management system that can continuously monitor the reflow oven and indicate if the process is drifting out of control before it actually does so. Prompting such a concern is the fact that an increased number of customers want to be assured that statistical process control (SPC) has been implemented.

ARM: the System

Automated reflow management (ARM) systems that combine continuous SPC charting, line balancing, documentation and production traceability into an integrated software package have recently been introduced. These systems automatically feed real-time process data to engineers and managers, permitting them to make critical decisions affecting production costs and quality. The systems can provide and record real-time thermal process data for every product vs. the conventional practice of only periodically checking oven performance. One is then automatically assisted in catching potential defects before they happen rather than exposing them during “inspection.”

The basic functionality of an ARM system is to accurately and automatically monitor and collect data on products passing through the reflow oven, a process that provides four significant benefits:

1. Eliminates the need for process verification profiles.
2. Provides real-time feedback and alarms for zero-defect production.
3. Automates reflow process-data collection.
4. Provides automated SPC charting of the reflow process and alerts to variances in process capability (Cpk).

Key features of an automated-reflow management system are product traceability and process documentation. The means: continuous and automatic thermal process monitoring.

Virtual Profile

As the means for verifying the profile of every board produced, the *virtual profile* is established by running a baseline profile of the product with a real-time profiler while simultaneously collecting real-time data from thermocouple probes in the oven. The mathematical correlation between the temperatures at product level and those on the product itself permits the software to simulate changes in the product profile accurately. Once a virtual profile has been established,

the system goes into monitoring mode with a real-time simulation of how the product profile is changing, based on probe readings. Process temperature or airflow cannot change without affecting the product temperature, and the software’s algorithms accurately extrapolate changes in process temperature to changes in the product profile (Figure 1).

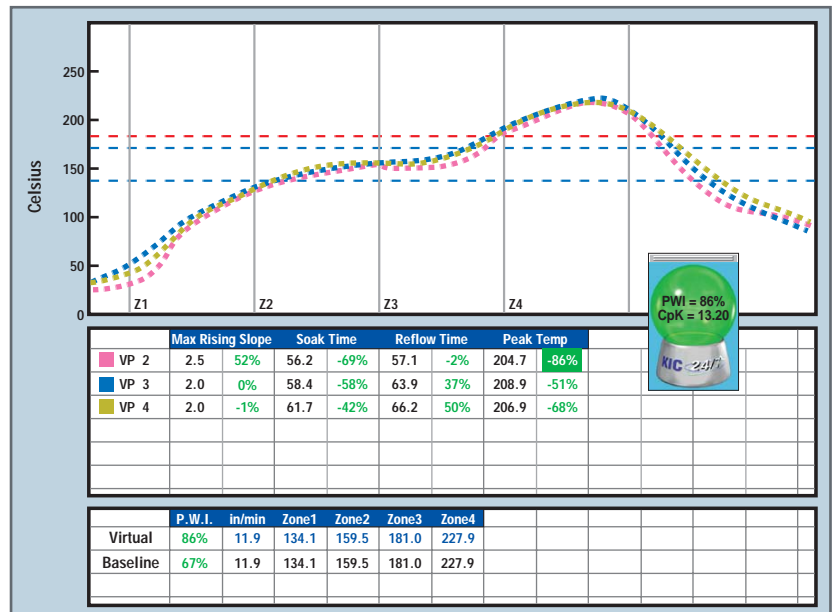


Figure 1. The virtual profile. Software algorithms extrapolate changes in process temperature to changes in the profile.

Once a profile has been established within a user-defined process window, an ARM system monitors production for that product. In the monitoring mode, the system produces a real-time profile chart and a table of data selected on the basis of the process window. Other screens display SPC control charts for each statistic as well as a control chart for the product’s overall *process window index* (PWI). Data are updated and saved for each board as it exits the oven. The PWI, a statistical method

for ranking process performance, measures how well a process fits within user-defined limits. Figure 2 illustrates how the PWI is calculated.

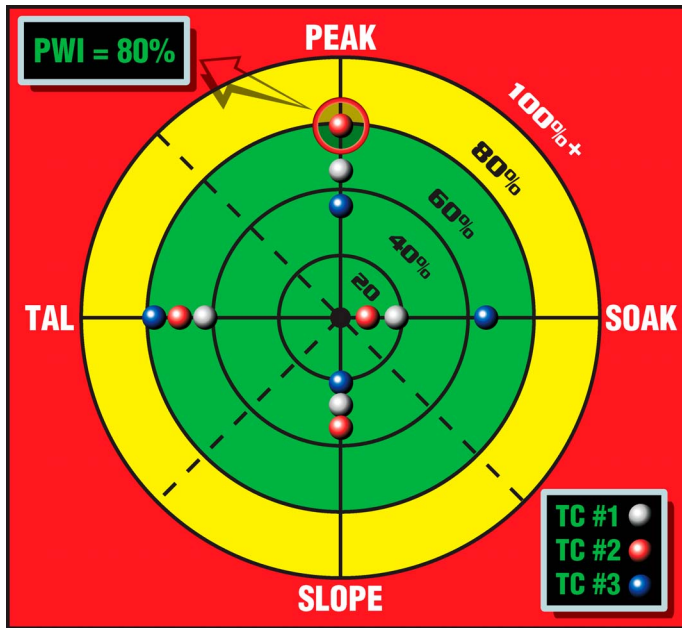


Figure 2. A statistical method for ranking process performance, the PWI measures how well an assembly process fits within a manufacturer's limits.

Automated Real-time SPC

Once the virtual profile has been established, the system will automatically begin to generate SPC data. When a board exits the oven, the data set is plotted on frequency histograms. Process data are charted for all critical process specs: peak temperature, soak time, time above liquidus, etc. The data are plotted on real-time control charts and Cpk is calculated for each spec. Finally, the overall PWI is charted, providing a real-time Cpk for the entire process (Figure 3). Any process drift outside control limits will bring an immediate alarm.

Data collection is automated and Windows-based. The system's profile explorer permits users to examine the profile for every board produced, thus providing valuable process documentation. The file system is product name-based, making all data, profiles, production data and alarm events accessible. All events and profiles are time- and date-stamped as well. The alarm record shows when alarms both occurred and were acknowledged, permitting supervisors to monitor operator performance. Alarms are triggered whenever the virtual profile statistics or the PWI exceed user-defined limits. The system will also alarm Cpk variations so that the situation can be corrected before the process goes out of spec. A third alarm function acts as a fail-safe and alerts to significant change in process temperatures.

Design of Experiment

Two DOEs are performed to validate the performance and accuracy of the ARM system. Both DOEs are continuously documented with screen captures and a manual log to supplement the data automatically collected.

The first DOE verifies that ARM automatically provides accurate profile data for each production board. An initial profile is run after which the profile is optimized using an oven recipe-search engine. Four additional runs are made to gauge the normal profile and process variation. Then four individual tests are run, each involving running 30 boards through the oven:

- Test 1: Run without changes to the oven.
- Test 2: Fault 1 — disconnect the power to the heater for zone 10.
- Test 3: Fault 2 — disconnect the fan for zone 10.
- Test 4: Fault 3 — partially block or turn down the exhaust flow vents.

Throughout the tests, simultaneous profiles are run with a standard profiler to verify the accuracy of the virtual profile. In Tests 2 through 4, the system alarms the induced faults several minutes before the oven control software.

The second DOE verifies the stability of the virtual profile. A total of 50 boards are run through the oven. Comparisons are made between the PWIs of the virtual profiles and the profiling runs.

The DOEs determine that the virtual profile is accurate and follows the trend of the actual profiles. When faults are induced, the accuracy of the virtual profile decreases, but before the variation between the virtual and the actual profiles, the Cpk and significant change alarms occur. The decrease in accuracy is within 3 to 4 percent of actual, which still gives a good indication of how the product profile is changing. Given this level of tolerance, the accuracy of the ARM system is well



Figure 3. SPC charts. Data are plotted on real-time control charts and Cpk is calculated for such specifications as peak temperature, soak time, etc.

within the “noise” of the process and the measuring devices. The only deterioration of accuracy comes when the process is out of control.

The DOEs establish that the system is stable, accurate and responds as it was designed to do to induced faults.

Conclusion

An automated-reflow management system offers benefits including SPC charting and real-time process information, resulting in reduced training costs, product traceability, verification profile elimination and zero-defect thermal processing.

From the DOEs, one can fine-tune this reflow process by centering it in the process window while determining that the oven is not as stable as once thought. The ARM, however, permits a process to be verified as good before it is run, to help prevent defects and to build in rather than inspect in the level of quality required.

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