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Technical Report

Round Robin Test on Steam Ager Temperature Control Stability

A report developed by the IPC Steam Aging Task Group

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Objectives

The Round Robin Solderability Steam Ager Temperature Stability Test had the following objectives:

1. Develop a test method to measure the ability of a steam ager to hold the desired test temperature across the chamber area, for the length of the test. This test was to be easy to perform and use readily available equipment.
2. Determine the required steam aging temperature tolerance to be specified in solderability specifications.
3. Measure the performance of a representative sample of steam agers currently in use, and report on lessons learned.

Introduction

Steam aging is a commonly used preconditioning procedure that is applied to components prior to the solderability test such as in ANSI/J-STD-002 (Component Solderability). The purpose of steam aging is to help identify those components which may not have adequate solderability following warehouse storage.

Most test specifications have recently begun to add requirements for the temperature inside the ager at the component level. This was a result of tests [1] which showed that ager temperature varied, and that temperature variations could cause measurable differences in the weight gain of copper and solder coupons.

The Steam Aging Task Group undertook this Round Robin Test in order to measure the magnitude of the temperature variations within the ager during the length of the conditioning. The purpose of the test was to provide data to help recommend a steam ager temperature tolerance, and provide further data on actual ager performance in the field to support other Task Group tests.

Conclusions

1. The test procedure was found to be an effective means of quantifying steam ager temperature variability.
2. On the basis of this study, most agers would be capable of controlling temperature to a $\pm 3^{\circ}\text{C}$ tolerance if properly installed, adjusted, and optimized. If non-random variability is reduced, the CP Index for 32 of the 34 tests could be improved.
3. Most of the steam agers evaluated in this study were not properly installed, adjusted, and/or optimized before the data were collected.

Of the 34 ager tests performed:

- 10 ager tests operated at the target temperature $\pm 3^{\circ}\text{C}$.
 - 9 ager tests had temperature ranges which would have operated within the tolerance window, but needed a temperature level adjustment.
 - 15 ager tests indicated that the ager would require repair or optimization before being able to control temperature within $\pm 3^{\circ}\text{C}$.
4. Steam agers tend to control temperature better at higher temperatures.
 5. Sources of temperature variation included:
 - long term ager temperature drift.
 - stabilization times of up to 4 hours.
 - temperature stratification due to external influences.
 - automatic water fill valve adjustments.
 - temperature controller adjustments.

Recommendations

1. The round robin test procedure should be submitted to the IPC-TM-650 Task Group as a Steam Ager Control Capability Test Method.
2. The task group supports the temperature tolerance of $\pm 3^{\circ}\text{C}$ during the steam aging exposure as specified in ANSI/J-STD-002 (Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires) and ANSI/J-STD-003 (Solderability Tests for Printed Boards). It limits the risk of large temperature variations, and yet is wide enough for most present agers to be able to comply.
3. The Steam Aging Task Group recommends that all steam aging equipment be tested according to this procedure upon installation and periodically thereafter.

Test Procedure

The Round Robin test procedure is shown in Appendix A. It was designed to be easy to perform, and use commonly available equipment. Calculations and data manipulation were kept to a minimum. The procedure was designed so that this test could be performed by those without an extensive statistical background. In summary, this procedure calls for approximately 10 thermocouples to be evenly distributed around the inside of an ager at the component level. The thermocouples are specified as type T copper- constantan wire, 24 AWG, premium grade, with a $\pm 0.75^{\circ}\text{F}$ accuracy. The thermocouple indicator was specified at $\pm 0.5^{\circ}\text{C}$ accuracy. No special data logging equipment was to be included, but it was specified that all thermocouples must be read within 2 minutes.

The thermocouples were then calibrated. All thermocouples were to be loosely bundled and placed into boiling water. The temperature indicated by each thermocouple was then recorded. If any one thermocouple differed from the others by more than 0.5°C , that thermocouple was to be rejected or reworked and reverified. This precaution helped to minimize measurement variability.

The thermocouples were installed in the ager. The exact number of thermocouples was to be determined by the size of the ager. The distance from each thermocouple to the water was to be the same (± 0.25 inch). Each thermocouple was to be kept at least 1 inch away from sidewalls or bulkheads.

The thermocouples were to be secured by a mechanical means that would not limit the normal circulation inside the ager.

A very important feature of the test is that the end of the thermocouple wire, including the weld bead should be oriented vertically, with the bead pointing up. This prevents water droplets from collecting. Tests indicated that water droplets collecting on the weld bead could cause an additional 2-3 degrees temperature variability.

Data logging was to begin when the usual test procedures indicated ager stabilization had been achieved. The test was to be performed at 87°C , 93°C and 97°C . The test was to continue for 8 hours, recording data every 15 minutes or as appropriate.

Data Analysis

The data were analyzed in two ways. First, X-bar and R control charts were prepared and process stability evaluated. Secondly, histograms were prepared and the CP Index was calculated for comparison to the specification requirements.

Subgroups were to consist of all thermocouples measured simultaneously at each test interval.

The purpose of using the control chart was to determine whether systematic or non-random variation was present, indicating that assignable causes were influencing ager performance. Optimal ager performance is attained when systematic variation is eliminated and only random variation remains.

For the purpose of this test, systematic or non-random variation (or process instability) was deemed to be present when one of four situation was noted:

1. one or more data point(s) beyond the control limits.
2. 2 of 3 consecutive data points near a control limit (outer 1/3).
3. a run of 8 or more points above or below the average.
4. a run of six or more points increasing or decreasing.

The individual data points, the temperatures measured by each thermocouple at each time interval, were then to be plotted on a process capability histogram. From this histogram the mean and standard deviation was estimated. The histogram should show that the distribution of temperature readings was approximately normally distributed, and fell within the specification limits (target temperature $\pm 3^{\circ}\text{C}$). Any non-symmetrical histogram pattern would indicate non-random variation.

Finally, the process capability index (C_p) was calculated. This index is the ratio of the difference in the specification limits (6 degrees $^{\circ}\text{C}$) divided by six times the process standard deviation, as estimated on the histogram. In order to be capable of performing the test: $C_p > 1$.

Test Participants

Data were received from the following companies:

- Electronic Manufacturing Productivity Facility
- Harris Semiconductor
- Naval Air Warfare Center
- Rockwell/International, Collins Avionics and Communication Group
- Texas Instruments, Austin
- Texas Instruments, Defense Systems and Electronics Group
- Texas Instruments, Semiconductor

Data were recorded on equipment manufactured by the following companies:

- Blue M
- Express Test
- General Production Devices
- Mountaingate Engineering
- Robotic Process Systems
- Beaker and Hot Plate

Test Results

In all, 34 steam ager tests were performed by seven users on agers from six manufacturers, involving a total of 13 different models.

A detailed set of graphs showing the X-bar and R data for each test is shown in Appendix B, and is summarized in Table 1.

The participants names have been encoded using the following form (user)/(manufacturer)(model). For example "A/B1" is the test by user "A" on manufacturer "B", model "1".

Of the 34 ager tests performed, 24 tests had some temperature readings on some thermocouples which were more than 3 degrees different from the user's target temperature, and thus did not comply with the test.

The control charts showed non-random or unstable variation in all tests except the 87°C and 97°C tests on B/B1. This indicates that ager performance on 32 ager tests could be improved if the assignable causes of variation could be identified and corrected.