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Number	
2.6.7.2	
Subject	
Thermal Shock, Thermal Cycle and Continuity	
Date	Revision
3/2020	**C**
Originating Task Group	
Thermal Stress Test Methodology Subcommittee (D-32)	

IPC-TM-650
TEST METHODS MANUAL

1 Scope and Purpose

1.1 Scope This method subjects unpopulated test specimens (samples) to sudden, extreme changes in temperature in order to evaluate the quality of interconnects formed during the manufacturing processes.

1.2 Purpose This method **shall** be used to simulate the thermodynamic effects of extreme temperature variations. The use of this method is intended to be able to capture ''infant mortality'' types of manufacturing defects.

1.2.1 This method may provide for qualification, quality conformance testing and lot acceptance.

2 Applicable Documents

IPC-T-50 Terms and Definitions

IPC-2221 Generic Standard on Printed Board Design

IPC-A-600 Acceptability of Printed Boards

IPC-1601 Standard for Printed Board Handling and Storage

IPC-4101 Specification for Base Materials for Rigid and Multilayer Printed Boards

IPC-4103 Specification for Base Materials for High Speed/High Frequency Applications

IPC-6012 Qualification and Performance Specification for Rigid Printed Boards

IPC-6013 Qualification and Performance Specification for Flexible Printed Boards

IPC-6018 Qualification and Performance Specification for High Frequency (Microwave) Printed Boards

IPC-9241 Guidelines for Microsection Preparation

IPC-TM-650 Test Methods Manual[1]

2.1.1 Microsectioning - Microsectioning, Manual and Semi or Automatic Method

2.6.27 Assembly Simulation - Thermal Stress, Convection Reflow Assembly Simulation

3 Terms and Definitions

3.1 Thermal Shock (Unpopulated Printed Board) A temperature cycle with a change rate of 1 °C or more per second as measured on the surface of the test specimen, for at least the center 60% of each transition, during the heating and cooling portions.

3.2 Thermal Cycle (Unpopulated Printed Board) A temperature cycle that has a sample change rate of less than 1 °C per second as measured on the surface of the test specimen, for at least the center 60% of each transition, during the heating and cooling portions. While no minimum temperature change rate is specified, a change rate of at least 10 °C per minute is expected for qualification testing.

4 Test Specimen

4.1 Design/Construction Criteria

4.1.1 The test specimen **shall** be the D coupon in accordance with the requirements of IPC-2221 Appendix A, or alternate coupon(s) AABUS.

4.1.2 The test specimen(s) **shall** be constructed with holes contained in the printed board it represents as follows:

- Through holes: D coupons **shall** be constructed with both the largest plated-through holes (PTHs) and the smallest plated-through vias.
- Propagated structures: D coupons **shall** be constructed with and represent all applicable blind, buried, or filled through hole (propagated) via structures as defined in IPC-2221 Appendix A. D coupons contain two nets (structures). Multiple D coupons are used for designs with more than two structures.

4.1.2.1 The test specimen(s) **shall** contain the representative ground and power planes of the printed board design.

4.1.3 The test specimen(s) **shall** allow for microsection evaluation of all the applicable, representative PTHs and vias defined in 4.1.2 after exposure to the conditions of this Test Method. IPC-9241 provides guidance on the proper preparation of a metallographic sample (microsection) of a printed board.

4.1.4 Deviations to the test specimen design/construction or use of an alternate test specimen **shall** be AABUS.

5 Apparatus

5.1 Drying Oven The oven **shall** be capable of maintaining a uniform set temperature within the 105 to 125 °C range.

5.2 Environmental Test Chamber

5.2.1 Dual Chamber Option An automatically controlled dual temperature environmental test chamber or other apparatus capable of maintaining the upper and lower temperatures.

5.2.2 Single Chamber Option An automatically controlled environmental test chamber or other apparatus capable of maintaining the upper and lower temperatures.

5.2.3 The system **shall** have adequate environmental controls to maintain the tolerance range and limits listed in 6.5.1.3.

5.2.4 The system should accommodate verifiable calibration compliance. See note 7.1 for additional considerations.

5.2.5 Deviations to the equipment requirements and acceptability of the alternative methods **shall** be AABUS.

5.3 Microscope The magnification used for defect recognition **shall** be in agreement with the inspection requirements/capabilities defined in the applicable performance specification (e.g., IPC-6012, IPC-6013, IPC-6018, etc.) and the IPC-A-600 visual workmanship standard.

5.4 Resistance Measurements

5.4.1 The resistance measurement **shall** have enough precision to clearly determine the resistance percent change as required by the user for the resistance level of each test specimen's nets.

5.4.2 The total system uncertainty from resistance, temperature and time/cycle variations **shall** be less than 10% of the failure criteria required by the user. For example, if the required failure criteria is 5% then the total system uncertainty **shall** be no greater than 0.50%.

5.4.3 The resistance measurement system **shall** be capable of recording resistances at least once per cycle, at or near the end of the peak temperature dwell, after the coupon has reached temperature stabilization.

5.5 Temperature Measurements

5.5.1 The temperature measurement system should be capable of recording temperatures at least once per second throughout a complete cycle for both a representative test specimen and the heating/cooling medium. The system **shall** be capable of demonstrating the change rate defined in 3.1 and 3.2 and documenting a representative cycle.

6 Procedure

6.1 Conditioning

6.1.1 The test specimen(s) **shall** be conditioned by drying in an oven to remove moisture for a minimum of six (6) hours at 105 to 125 °C. This conditioning process is mandatory if this method is used for qualification purposes.

This method **shall** replicate the assembly process. The requirement for conditioning (bake/drying) **shall** be in accordance with product/process lot Quality Conformance criteria. If conditioning of the printed board is not part of the normal assembly process, and this method is being used for quality conformance testing, then conditioning is not a requirement.

6.1.2 Test specimens that are thicker or more complex may require longer baking times to achieve acceptable moisture levels. Record the bake times and temperature if different than those stated in 6.1.1. See IPC-1602 for additional guidance on baking to achieve acceptable moisture levels.

6.1.3 Deviations to the conditioning requirements in 6.1.1 such as when used for quality conformance criteria and/or any changes to the time and temperature **shall** be AABUS.

6.2 Reflow Simulation

6.2.1 The test specimen(s) **shall** be subjected to six (6) reflow simulation cycles in accordance with IPC-TM-650, Method 2.6.27 prior to Thermal Shock or Thermal Cycling.

6.2.2 The reflow profile **shall** be in accordance with IPC-TM-650, Method 2.6.27, as specified.

6.2.3 Other profiles or reflow simulation testing for other than 6 cycles are AABUS.

6.3 Interconnect Resistance Measurements Interconnect resistance measurements **shall** be taken at the following times:

• Prior to the test (initial ambient after reflow simulation).

- During the initial cycle after the high temperature dwell. Peak resistance during this cycle **shall** be the reference resistance.
- At or near the end of the peak temperature dwell, after the coupon has reached temperature stabilization, peak resistance during the cycle **shall** be recorded.

6.4 Qualification (also see 6.6 and Table 6-2) For qualification testing, the product environment and life expectancy should be taken into consideration to determine the temperature extremes and number of cycles. Qualification testing parameters **shall** be AABUS.

6.4.1 Historical Examples Historical examples as described in Table 6-1 were not product focused.

Table 6-1 Historical Qualification Temperature Extremes

Cycles	Temperature Range °C	Test Condition[1]	Previous Use
100	-40 to +85	B	Generic for IPC-4103, RT/duroid® materials
100	-55 to +105	C	Generic for IPC-4101, G10 materials
100	-55 to +125	D	Generic for IPC-4101, Epoxy materials
100	-65 to +150	E	Generic for IPC-4101, FR-5 materials
100	-65 to +170	F	Generic for IPC-4101, Polyimide materials

Note 1. Test Conditions B through F are from the previous revision to this test method.

6.4.2 Cycles The test specimen(s) **shall** be subjected to the specified number of cycles between the specified temperature extremes.

6.4.2.1 Tolerances The tolerance associated with the hot cycle is +/-5 °C. The tolerance associated with the cold cycle is +/-5 °C.

6.4.3 Dwell Time at Extremes During each cycle, the test specimen(s) **shall** be subjected to each temperature extreme for the time required for stabilization and resistance measurement (15 minutes when a dual chamber is used).

6.4.4 Temperature Change Rate The rate of change between temperature extremes, both high to low and low to high, **shall** be as high as possible. The temperature change **shall** be at least 10 °C per minute for at least the center 60% of each transition period, hot to cold and cold to hot.

6.4.5 Temperature Documentation

6.4.5.1 The temperature of a representative test specimen **shall** be recorded at the end of the dwell at each temperature extreme, for every cycle.

6.4.5.2 A temperature profile from at least one complete cycle **shall** be recorded during each test in accordance with 5.5.1 and 6.4.2.1 and included in the test report. This **shall** include the temperatures of a representative test specimen and the hot/cold media. Recording data every second for this purpose is recommended.

6.4.6 Dual Chamber Systems For dual chamber systems:

- The transfer time between chambers **shall** be less than two (2) minutes.
- The thermal capacity of each chamber **shall** be such that the ambient temperature **shall** reach the specified temperature within two (2) minutes after the test specimens have been transferred to the appropriate chamber.

6.5 Quality Conformance (see also 6.6 and Table 6-2)

6.5.1 Temperature Cycling The test specimen(s) **shall** be subjected to one hundred (100) cycles of temperature cycling to the extremes defined below:

6.5.1.1 The high temperature extreme **shall** be the **least** of the following:

- Material T_g[1] – 10 °C (lowest T_g of the materials used in the specimen, but not lower than 125 °C)
- Reflow peak temperature – 25 °C
- 210 °C

Note 1. The originating subcommittee for this Test Method was not able to obtain industry consensus on a default method for determining T_g. Therefore, methods to determine T_g (as specified in the procurement documentation or AABUS) may include:

- Lowest T_g listed on the Material Data Sheet
- T_g (from TMA) listed on the Specification Slash sheet
- Actual T_g of the material, determined after reflow simulation

6.5.1.2 The low temperature extreme **shall** be one of the following:

- -40 °C
- -55 °C (default)
- -65 °C

6.5.1.3 Tolerances The tolerance associated with the hot cycle is +/-5 °C. The tolerance associated with the cold cycle is +/-5 °C.

6.5.1.4 Dwell Time at Extremes During each cycle, the test specimen(s) **shall** be subjected to each temperature extreme for the time required for stabilization plus time required to record all measurements (up to 15 minutes when a dual chamber is used).

6.5.2 Temperature Change Rate The rate of change between temperature extremes, both high to low and low to high, **shall** be as high as possible. The temperature change **shall** be at least 1 °C per second for at least the center 60% of each transition period, hot to cold and cold to hot. Note that for thicker coupons greater than 2.5 mm [0.100 in], this change rate may not be achievable.

6.5.2.1 Temperature Documentation

6.5.2.1.1 The temperature of a representative test specimen **shall** be recorded at the end of the dwell at each temperature extreme, for every cycle.

6.5.2.1.2 A temperature profile from at least one complete cycle **shall** be recorded during each test and included in the test report. This **shall** include the temperatures of a representative test specimen and the hot/cold media. The temperatures **shall** be taken at sufficient frequency to show compliance to 5.5.1 and 6.5.1.3. Recording data every second for this purpose is recommended.

6.6 Testing Summary

A summary of Qualification and Quality Conformance testing is listed below in Table 6-2.

6.7 Evaluation

6.7.1 Resistance Change The change in resistance between the first and each succeeding temperature cycle **shall** be determined. The maximum allowable percent change in resistance between the first and any subsequent cycle **shall** be 5% unless otherwise specified.

6.7.2 Results Test results including cycles to failure, corresponding percent change of the failure, and the percent change of the final cycle **shall** be documented.

6.8 Deviations Deviations to the stated requirements or additional requirements defined here **shall** be AABUS.

Table 6-2 Comparison of Qualification and Quality Conformance Testing

Item	Qualification	Quality Conformance / Acceptance Testing[1]	
Conditioning	6 hours minimum, 105 - 125 °C		
Reflow Simulation	6 cycles, 230, 245 or 260 °C profile		
Temperature Min	AABUS	-40 °C, -55 °C (default), -65 °C	
Temperature Max	AABUS	min. of:	T_g-10 °C
			Reflow peak -25 °C
			210 °C
Sample Change Rate	> 10 °C/min for both hot and cold	> 1 °C/sec for both hot and cold	
Number of Cycles	AABUS	100	
Failure Threshold	AABUS	5%	
Resistance Data	1 reading/cycle near the end of the high temperature dwell		
Temperature Data	1 reading/cycle near the end of the high and low temperature dwells (sample) 1 reading/sec through 1 complete cycle (sample and media)		

Note 1. Acceptance testing and quality conformance testing as described in IPC-6010 series printed board performance specifications.

7 Notes

7.1 The design of the thermal cycling system must be flexible enough to allow for an extremely high rate of temperature change and for the rate of temperature change to be determined. Some issues to consider are as follows:

- Thermal mass compensation capability (energy vs. time)
- Environmental control capability (heating and cooling)
- Reproducibility of parameters
- Transfer speed (if applicable)
- Heating ramp rate
- Cool down rate
- Programming capability
- Profile memory

7.2 Suggested Drawing Note As this method addresses assembly issues with printed boards, it is recommended that the user of the printed board establish a drawing note in the procurement documentation to provide the printed board fabricators with guidance relative to the intended reflow process of the printed board. An example of such a drawing note is provided as follows:

XX. IPC D COUPON TESTING

A. COUPONS SHALL INCLUDE COMPONENT (A), VIA (B) AND ALL PROPAGATED B STRUCTURES IAW IPC-2221B APPENDIX A. **2** OF EACH COUPON DESIGN **SHALL** BE TESTED PER MANUFACTURING PANEL.

B. THE IPC D COUPONS **SHALL** BE SUBJECTED TO 6 REFLOW SIMULATIONS IAW IPC-TM-650, METHOD 2.6.27 USING THE [**230 °C, OR 245 °C, OR 260 °C**] PROFILE. ACCEPTANCE CRITERIA **SHALL** BE < 5% CHANGE IN RESISTANCE.

C. AFTER REFLOW SIMULATION TESTING, THE IPC D COUPONS **SHALL** BE SUBJECTED TO 100 THERMAL SHOCKS IAW IPC-TM-650, METHOD 2.6.7.2 FROM -55C TO [MINIMUM OF (**LAMINATE T_G – 10 °C**), OR (**REFLOW PEAK TEMPERATURE – 25 °C**), OR **210 °C**]. ACCEPTANCE CRITERIA **SHALL** BE < 5% CHANGE IN RESISTANCE.

Note: *Parameters in **bold** should be tailored to each application.*