Association Connecting Electronics Industries

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IPC-TM-650
TEST METHODS MANUAL

Number **2.6.27**	
Subject **Thermal Stress, Convection Reflow Assembly Simulation**	
Date **2/2020**	Revision **B**
Originating Task Group **Thermal Stress Test Methodology Subcommittee (D-32)**	

1 Scope and Purpose

1.1 Scope This method is intended to simulate exposure to the thermal conditions by convection reflow assembly.

1.2 Purpose This method **shall** be used to replicate the thermodynamic effects by assembly on the test specimen. The use of this method is intended to simulate those effects that are the result of soldering thermal excursions.

1.2.1 This method **shall** be used for qualification testing of an applicable test specimen. The evaluation of acceptability for qualification **shall** be in accordance with the requirements defined in 5.3.

1.2.2 This method may be used for lot acceptance. The evaluation for lot acceptability should be in accordance with the requirements defined in 5.3 or as agreed upon between user and supplier (AABUS).

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 Printed Board Handling and Storage Guidelines

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-9631 User's Guide for IPC-TM-650, Method 2.6.27

IPC-TM-650 Test Methods Manual[1]

2.1.1 Microsectioning – Microsectioning, Manual and Semi or Automatic Method

3 Test Specimen

3.1 Design/Construction Criteria

3.1.1 The test specimen **shall** be the A/B, AB-R, and/or the D coupon as designed in accordance with the requirements of IPC-2221 Appendix A or B. Use of alternate specimens **shall** be AABUS.

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

a. A/B, A/B-R and D coupons **shall** be constructed with both the largest plated through-holes (PTHs) and the smallest vias.

b. Propagated B and D coupons **shall** be constructed with the intended via structure. (Multiple B and D coupons are used for designs with multiple structures.)

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

3.1.2.2 The test specimen(s) **shall** contain the representative filled through vias, applicable blind and/or buried vias, including microvias, of the printed board design.

3.1.3 The test specimen(s) **shall** allow for microsection evaluation of all the applicable, representative PTHs and vias defined in 3.1.2 after exposure to the conditions of this Test Method.

Note: Special tooling may be required for potting an entire ''D'' Coupon for microsection examination.

3.1.4 Deviations to the test specimen design/construction or use of an alternate test specimen such as the printed board or a section of the printed board **shall** be AABUS.

4 Apparatus

4.1 Drying Oven

4.1.1 The oven **shall** be capable of maintaining a uniform set temperature within the 105 to 125 °C [221 to 257 °F] range.

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[1] Current and revised IPC Test Methods are available on the IPC Web site (www.ipc.org/test-methods.aspx).

4.2 Convection Reflow Oven or Simulator

4.2.1 The system used to simulate the thermodynamic effects of assembly **shall** be convection reflow.

4.2.1.1 The system **shall** have adequate environmental controls to maintain the tolerance range and limits in accordance with the reflow profile depicted in either Figure 5-1, Figure 5-2 or Figure 5-3.

4.2.1.2 The system should accommodate verifiable calibration compliance and reflow profile generation. See note 6.1 for additional considerations.

4.2.1.3 The test specimen **shall** be handled and stored in a controlled environment to minimize moisture ingression. See IPC-1601 for details on the proper handling and storage of test specimens.

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

4.3 Microscope

4.3.1 The magnification used for defect recognition must be in agreement with the inspection requirements/capabilities defined in the applicable performance specification (e.g., IPC-6012, IPC-6013, IPC-6018, etc.) and IPC-A-600.

4.4 Resistance Measurements of IPC-2221 Appendix A, D Coupons

4.4.1 When specified by performance specification or procurement documentation, resistance measurements of the IPC-2221B Appendix A, D coupons **shall** be required.

4.4.2 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 sample's nets.

4.4.3 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%.

4.4.4 The resistance data **shall** consist of at least 1 reading per sample net every second during the entire reflow cycle.

5 Procedure

5.1 Conditioning

5.1.1 The test specimen shall be conditioned by drying in an oven to remove moisture for a minimum of six (6) hours at 105 to 125 °C [221 to 257 °F].

5.1.2 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 5.1.1. See IPC-1601 for additional guidance on baking to achieve acceptable moisture levels. See note 6.2.

5.1.3 Deviations to the conditioning requirements in 5.1.1 such as when used for acceptance criteria and/or any changes to the time and temperature **shall** be AABUS. See 6.3.

5.2 Reflow Profile

5.2.1 Reflow the test specimen in accordance with Table 5-1 (default), Table 5-2 (low temperature profile) or Table 5-3.

5.2.2 The reflow profile **shall** be in accordance with either Figure 5-1, Figure 5-2 or Figure 5-3. Figure 5-1 represents the default reflow profile. Figure 5-2 represents the low temperature profile. Figure 5-3 represents a 245 °C reflow profile. The times to t1, t2 and t3 may vary based on the mass of the sample test specimen. To avoid over stressing of samples, times should be shortened for low mass samples. Times should be extended for high mass samples, such that the zone (air) temperature **shall not** be more than 25 °C above the target surface temperature at any point in the cycle.

The attachment of thermocouples to the sample test specimen **shall** be such that the reflow profile is calibrated to the surface temperature of the test specimen.

5.2.3 The test specimen **shall** be subjected to a minimum of six (6) reflow cycles.

5.2.4 The cool down rate **shall** be in accordance with Table 5-1, Table 5-2 or Table 5-3, based on the reflow profile selected in 5.2.1. The cool down is complete when the test specimen reaches 45 °C. The test specimen **shall** achieve a thermal equilibrium of 45 °C or less prior to starting the next reflow cycle. If the time it takes to achieve thermal equilibrium cannot be determined, then a five (5) minute dwell between reflow cycles **shall** be required.

5.2.5 Deviations to the reflow profile or number of cycles **shall** be AABUS.

Table 5-1 260 °C Nominal Reflow Profile Specifications (Default)*

Value	Time (Seconds)	Temperature (°C)	Description
t1	210 ± 15	–	Target preheat time
t2	270 ± 10	–	Target peak reflow time
t3	330 ± 15	–	Target cool-down start time
t3 - t1	120 ± 30	–	Target time above T1
T1	–	230	Maximum preheat temperature
T2	–	260 ± 5	Target reflow temperature
Point	**Time (Seconds)**	**Temperature (°C)**	**Description**
A	0	30	Upper specification limit values
B	100	230	
C	195	230	
D	255	265	
E	285	265	
F	345	230	
G	550	30	
H	30	30	Lower specification limit values
I	157	93	
J	225	230	
K	260	255	
L	280	255	
M	315	230	
N	383	30	
Segment	**Slope (°C / second)**		**Description**
A-B & I-J	2.0		Maximum preheat rate
H-I	0.5		Minimum preheat rate
F-G	-1.0		Minimum cool-down rate
M-N	-3.0		Maximum cool-down rate

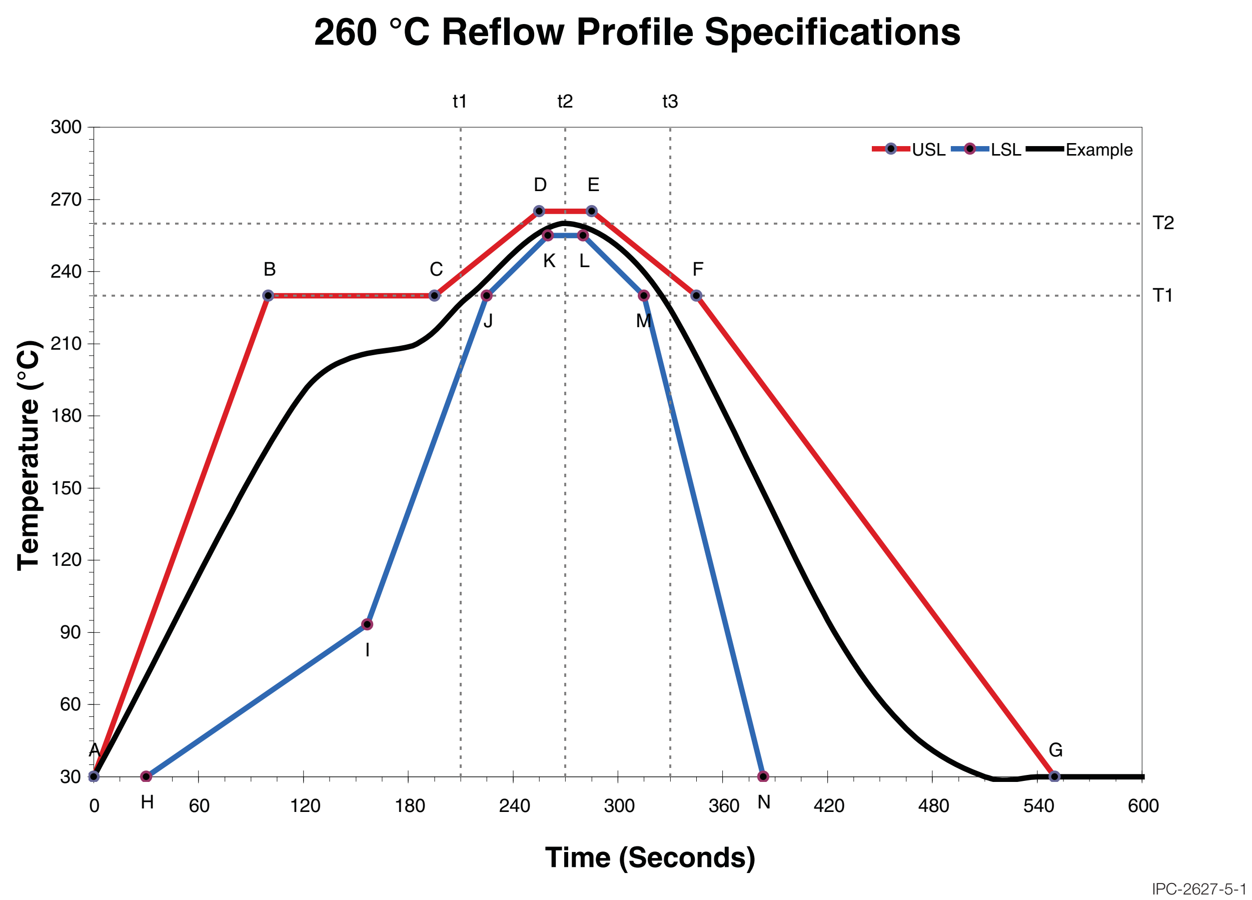

Figure 5-1 260 °C Nominal Reflow Profile Chart (Default)*

Table 5-2 230 °C Nominal Reflow Profile Specifications (Low Temperature Profile)*

Value	Time (Seconds)	Temperature (°C)	Description
t1	186 ± 15	–	Target preheat time
t2	239 ± 10	–	Target peak reflow time
t3	292 ± 15	–	Target cool-down start time
t3 - t1	106 ± 30	–	Target time above T1
T1	–	203	Maximum preheat temperature
T2	–	230 ± 5	Target reflow temperature
Point	**Time (Seconds)**	**Temperature (°C)**	**Description**
A	0	30	Upper specification limit values
B	88	203	
C	172	203	
D	226	235	
E	252	235	
F	305	203	
G	487	30	
H	30	30	Lower specification limit values
I	139	83	
J	199	203	
K	230	225	
L	248	225	
M	279	203	
N	339	30	
Segment	**Slope (°C / second)**		**Description**
A-B & I-J	2.0		Maximum preheat rate
H-I	0.5		Minimum preheat rate
F-G	-1.0		Minimum cool-down rate
M-N	-3.0		Maximum cool-down rate

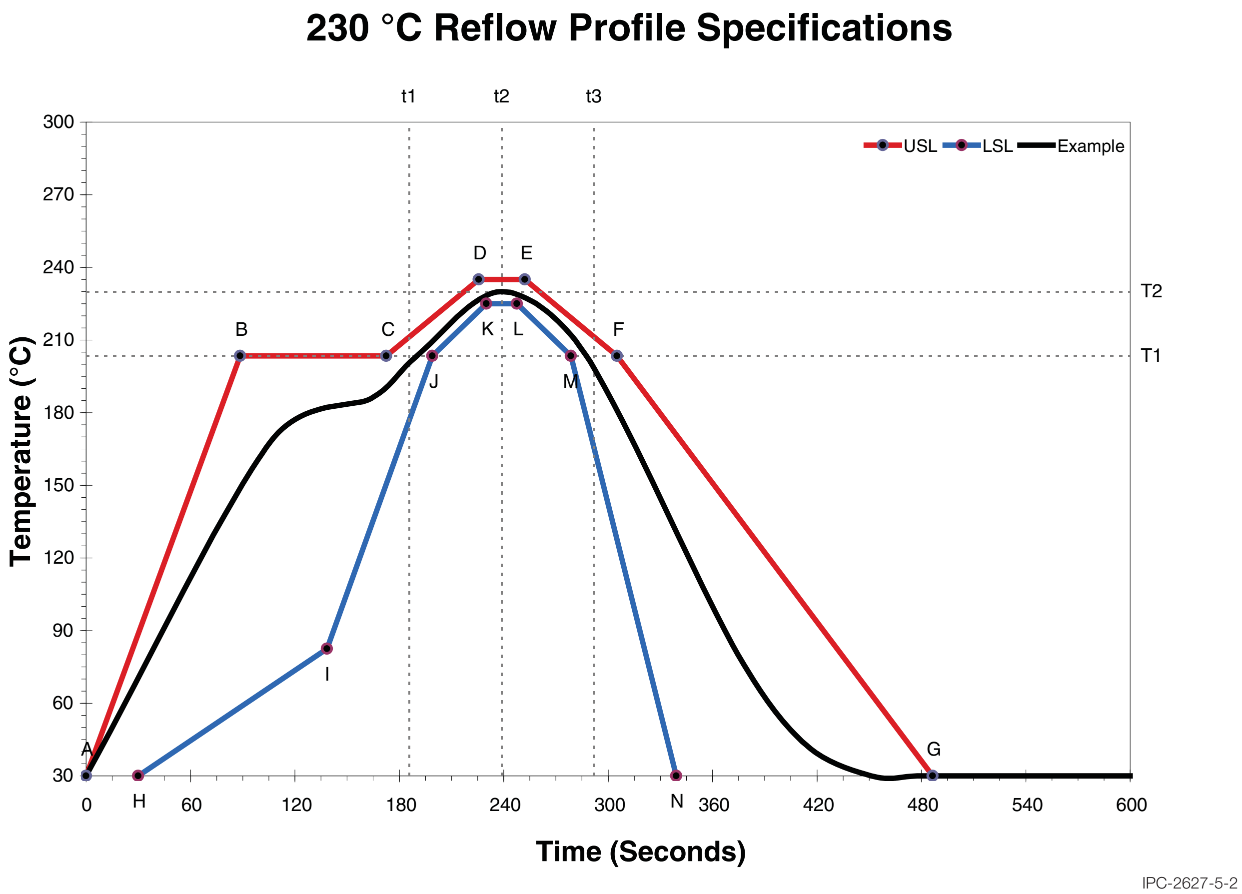

Figure 5-2 230 °C Nominal Reflow Profile Chart (Low Temperature Profile)*

Table 5-3 245 °C Nominal Reflow Profile Specifications*

Value	Time (Seconds)	Temperature (°C)	Description
t1	198 ± 15	–	Target preheat time
t2	254 ± 10	–	Target peak reflow time
t3	311 ± 15	–	Target cool-down start time
t3 - t1	113 ± 30	–	Target time above T1
T1	–	217	Maximum preheat temperature
T2	–	245 ± 5	Target reflow temperature
Point	**Time (Seconds)**	**Temperature (°C)**	**Description**
A	0	30	Upper specification limit values
B	94	217	
C	184	217	
D	240	250	
E	269	250	
F	325	217	
G	518	30	
H	30	30	Lower specification limit values
I	148	88	
J	212	217	
K	245	240	
L	264	240	
M	297	217	
N	361	30	
Segment	**Slope (°C / second)**		**Description**
A-B & I-J	2.0		Maximum preheat rate
H-I	0.5		Minimum preheat rate
F-G	-1.0		Minimum cool-down rate
M-N	-3.0		Maximum cool-down rate

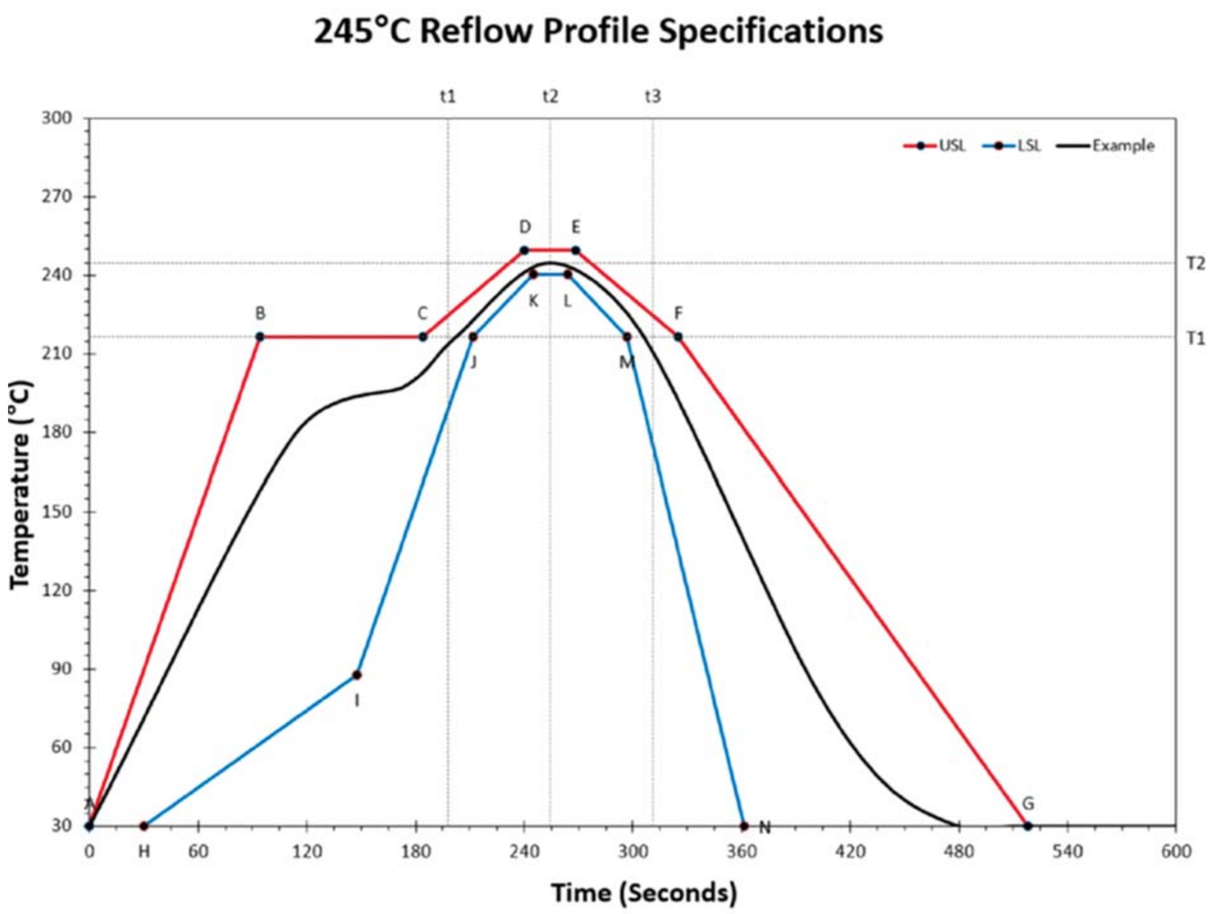

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Figure 5-3 245 °C Nominal Reflow Profile Chart*

** The times to t1, t2 and t3 may vary based on the mass of the sample test specimen.*

5.3 Evaluation

5.3.1 Microsection The test specimen **shall** be microsectioned when this test method is used for thermal stress prior to structural integrity evaluation. After the test specimen has been conditioned and reflowed in accordance with the requirements of 5.1 and 5.2, microsection the test specimen in accordance with IPC TM-650 Method 2.1.1. Inspect specimens required for microsection (e.g., A, B, A/B, AB/R, etc.) for compliance to the applicable performance specification and/or AABUS requirement.

Note: For guidelines on microsection preparation see IPC-9241.

5.3.2 Resistance Change Resistance change **shall** be used to evaluate IPC-2221 Appendix A (latest revision) D-coupons for performance-based evaluation of the samples when specified. Microsectioning of D coupons which have been evaluated by resistance change is not required.

5.3.2.1 Percent change in resistances of each sample's nets **shall** be determined using the first cycle's peak temperature resistance as the reference.

5.3.2.2 The maximum allowable percent change in resistance after the test specimen has been conditioned and reflowed in accordance with 5.1 and 5.2 **shall** be 5% maximum unless otherwise specified.

5.3.2.3 Cycles to failure, corresponding percent change of the failure, and the percent change of the final cycle **shall** be documented.

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

6 Notes

6.1 The design of the convection reflow system should be flexible enough to facilitate the creation of the reflow profiles depicted in Figure 5-1, Figure 5-2 and Figure 5-3 for all the applicable test specimen designs encountered. Some issues to consider are as follows:

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

The IPC-TM-650 website provides a non-comprehensive listing of providers of convection reflow systems suitable for meeting the reflow profiles within this test method.

6.2 Deviations to the time and temperature specified in 5.1.1 should take into consideration maintaining the solderability of the surface finish being utilized.

6.3 Example Drawing Notes 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:

A. IPC D COUPONS **SHALL** BE DESIGNED IAW IPC-2221 APPENDIX A AND **SHALL** INCLUDE COMPONENT (A), VIA (B) AND ALL PROPAGATED B STRUCTURES. X 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, 245 °C, OR 260 °C] PROFILE. ACCEPTANCE CRITERIA **SHALL** BE < 5% CHANGE IN RESISTANCE.

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