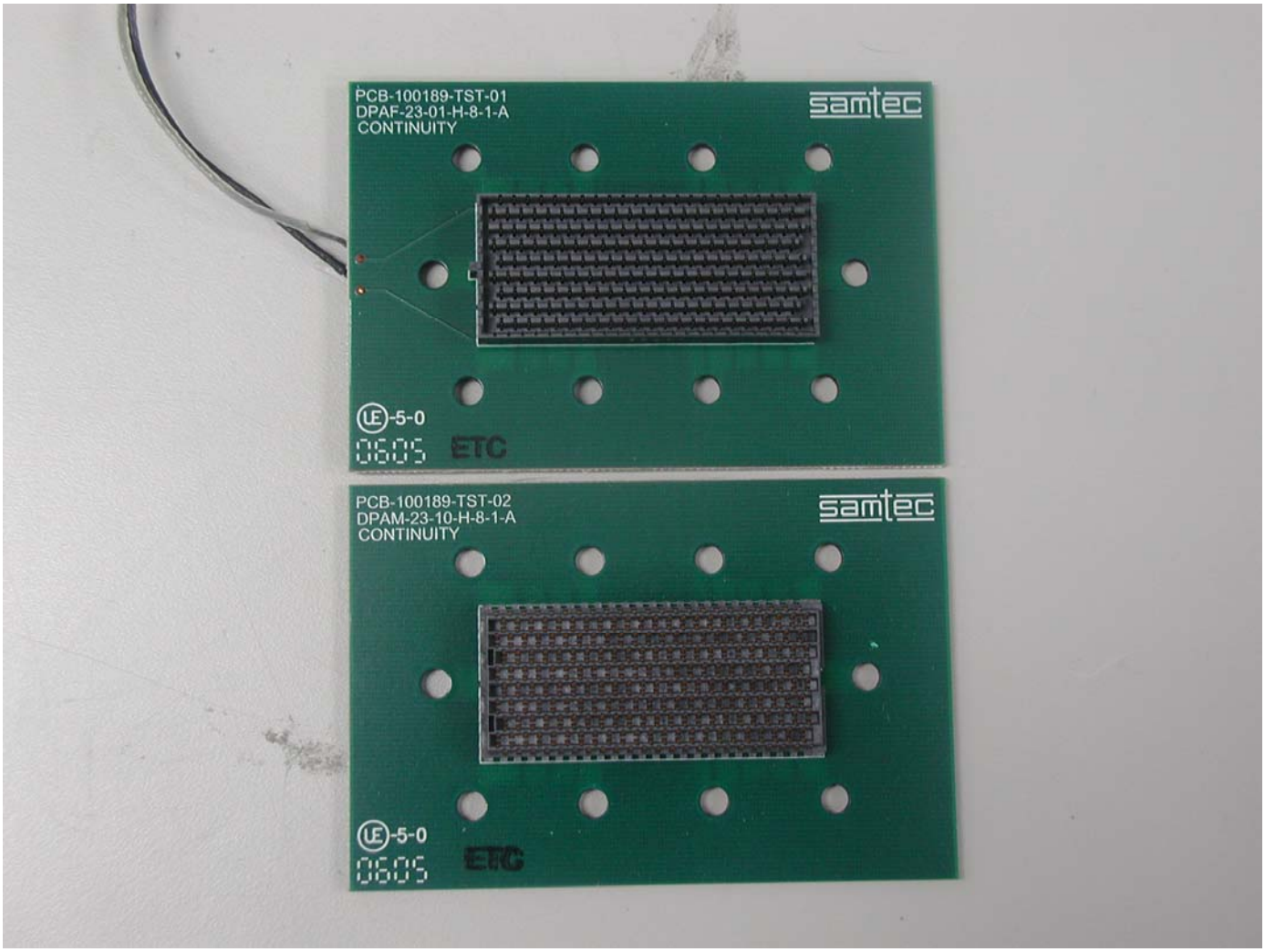
Project Number: SJR	Tracking Code: TC054-SJR-0604		
Requested by: Jeremy Wooldridge	Date: 1/21/2005	Product Rev: 4	
Part #: DPAM-23-10-H-8-1	Lot #: 12/24/04	Tech: Troy Cook	Eng: Dave Scopelliti
Part description: Differential Pair DPArray			Qty to test: 64
Test Start: 03/15/2005	Test Completed: 7/1/2006		



Solder Joint Reliability Summary Report

PART DESCRIPTION

DPAM-23-10-H-8-1 mated with
DPAF-23-01-H
CERTIFICATION

All instruments and measuring equipment were calibrated to National Institute for Standards and Technology (NIST) traceable standards according to IS0 10012-l and ANSI/NCSL 2540-1, as applicable.

SCOPE

To perform the following tests: Solder Joint Reliability and life expectancy predictions via Thermal Cycling of Tin-Silver-Copper (SAC) and Tin-Lead (SnPb).

RELIABILITY PROJECTIONS

1) Life expectancy was calculated for field service conditions of 25ºC to 45ºC cycles.
2) Field use cycles were calculated at 6 (Cycles/Day) x 365.25 (Days/Year) = 43830 Cycles/Year. If actual field use Cycles/Year is half that, then Years to %Failed will double, assuming similar dwell times at the temperature extremes.

	Condition: 25ºC to 45ºC, 6 cycles/day	
	SAC	SnPb
Years to 0.01% Failed	166 years	15.2 years
Years to 0.1% Failed	270 years	27.42 years

FIGURE 1: Summary of reliability projections under field use condition.

APPLICABLE DOCUMENTS

- Industry Standard: IPC-9701A
- Clech, J-P., "Acceleration factors and thermal cycling test efficiency for lead-free Sn-Ag-Cu assemblies", Proceedings, SMTA International Conference, Chicago, IL, Sept. 25-29, 2005, pp. 902-917.
- Clech, J-P., "An obstacle-controlled creep model for Sn-Pb and Sn-based lead-free solders", Proceedings, SMTA International Conference, Chicago, IL, September 26-28, 2004.
- Clech, J-P., “Review and Analysis of Lead-Free Solder Material Properties”, NIST report, on-line version can be viewed under NIST's Metallurgy Division web site: http://www.metallurgy.nist.gov/solder/clech/
- Clech, J-P., “Solder Reliability Solutions: a PC-based design-for-reliability tool”, Proceedings, Surface Mount International Conference, Sept. 8-12, 1996, San Jose, CA, Vol. I, pp. 136-151. Also in *Soldering and Surface Mount Technology,* Wela Publications, British Isles, Vol. 9, No. 2, July 1997, pp. 45-54.

TEST SAMPLES AND PREPARATION

Sample preparation was performed in accordance with paragraph 4.2.3.1 and 4.3.1 of IPC-9701A and the following test conditions:

1) All materials were manufactured in accordance with the applicable product specification.
2) All test samples were identified and encoded to maintain traceability throughout the test sequences.
3) All components were preconditioned prior to soldering at 125 C for 24 hours.
4) All test PCB's were preconditioned prior to soldering at 105 C for 24 hours.
5) All samples tested were preconditioned after soldering prior to testing at 100 C for 24 hours.
6) Samtec Test PCBs used: 100189-TST-XX (FR4), 0.093 inches thick, 6-layer with 70 Cu coverage on layers 2 and 4, 40% Cu coverage on layers 3 and 5.

TEST BOARD ASSEMBLY

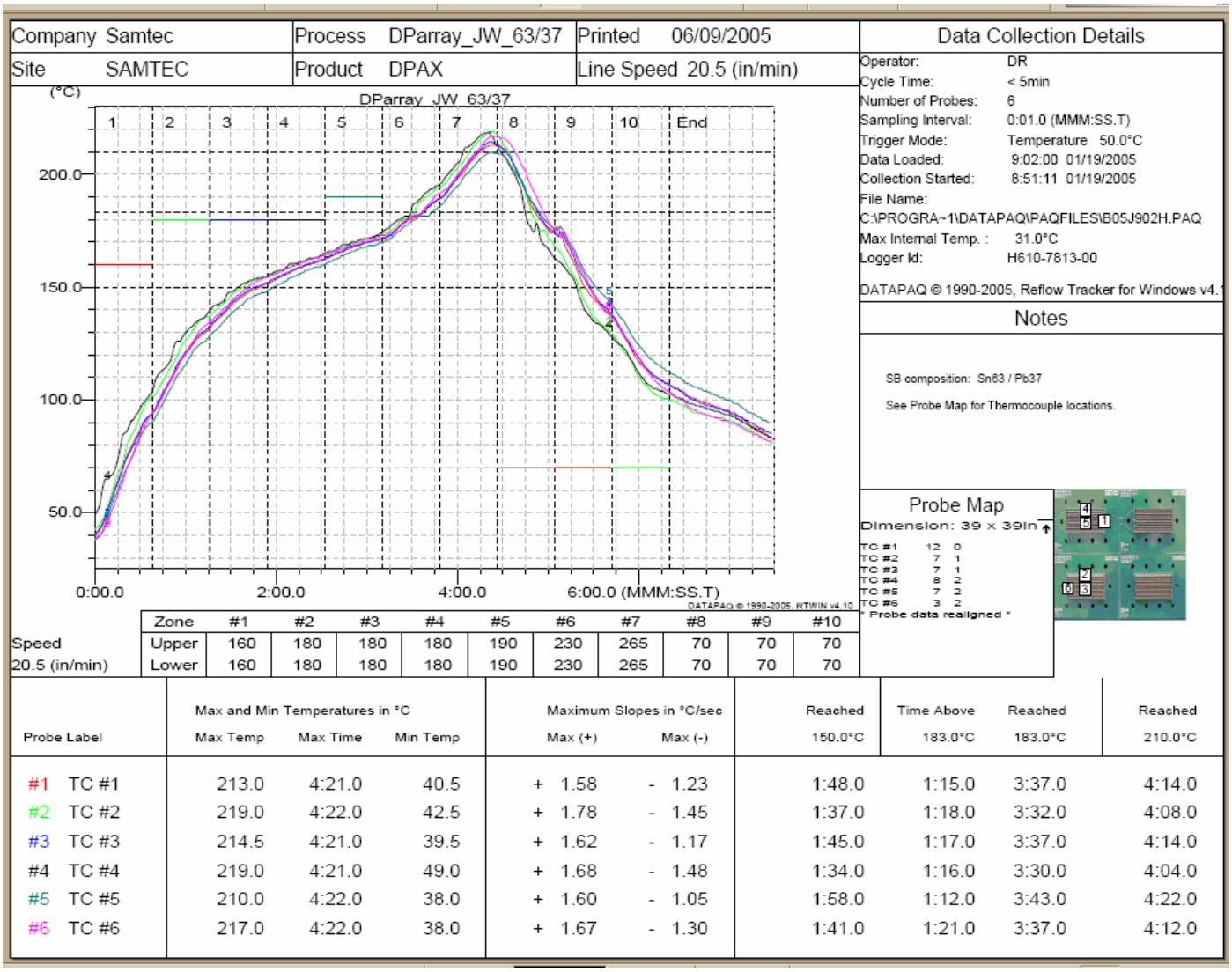


FIGURE 2: Soldering profile for SnPb samples.

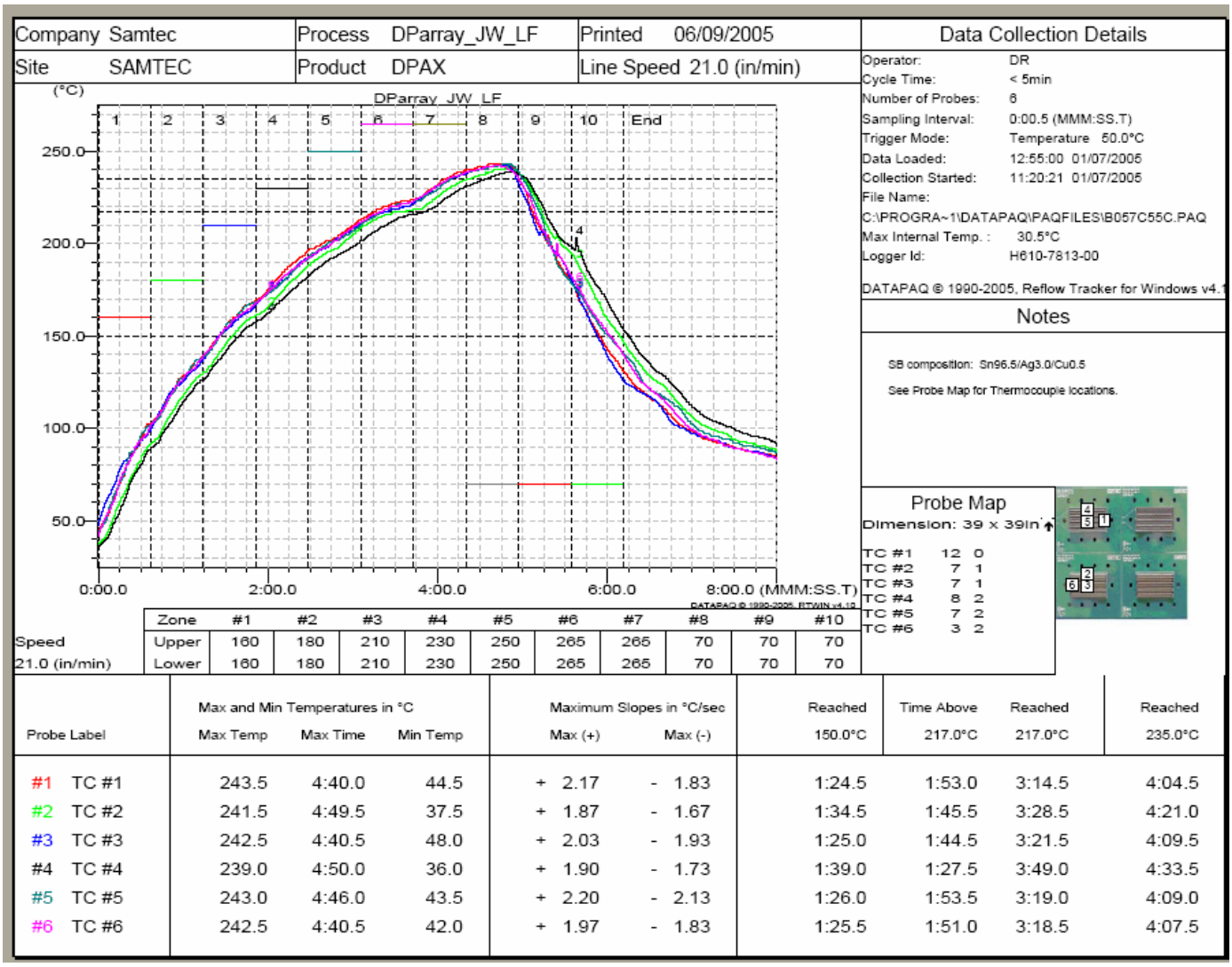


FIGURE 3: Soldering profile for SAC samples.

1) SnPb samples used Kester HM531 Type 3 Solder Paste containing Sn63 Pb37, 90% metal, 325 mesh.
2) SAC samples used Kester R520A Type 3 Solder Paste containing Sn96.5 Ag3.0 Cu0.5, 89.5% metal, 325 mesh.
3) For both SnPb and SAC, stencil thickness was 0.006 inches with aperture diameter of 0.04 inches.

THERMAL CYCLING:

Thermal Cycling was performed in accordance with Table 4-1 of IPC-9701A and the following test conditions:

1) Thermal Limits: Low Temperature = 0° C +0/- 3° C; High Temperature = 100° C + 5/- 0° C
2) Dwell Time at Thermal Limits: Fifteen (15) minutes
3) Ramp Time to Thermal Limits: Ten (10) minutes

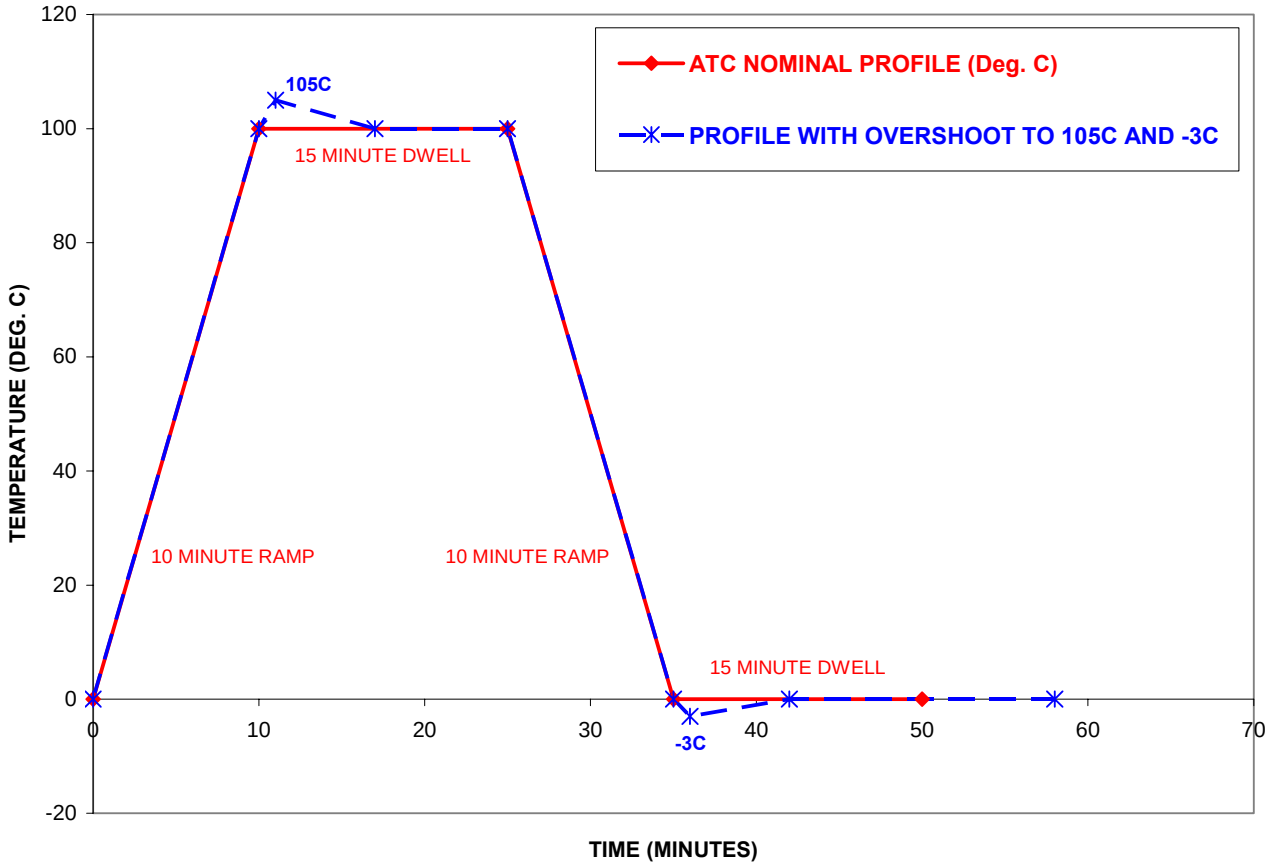


FIGURE 4: Accelerated thermal cycling profile.

CONFIGURATION

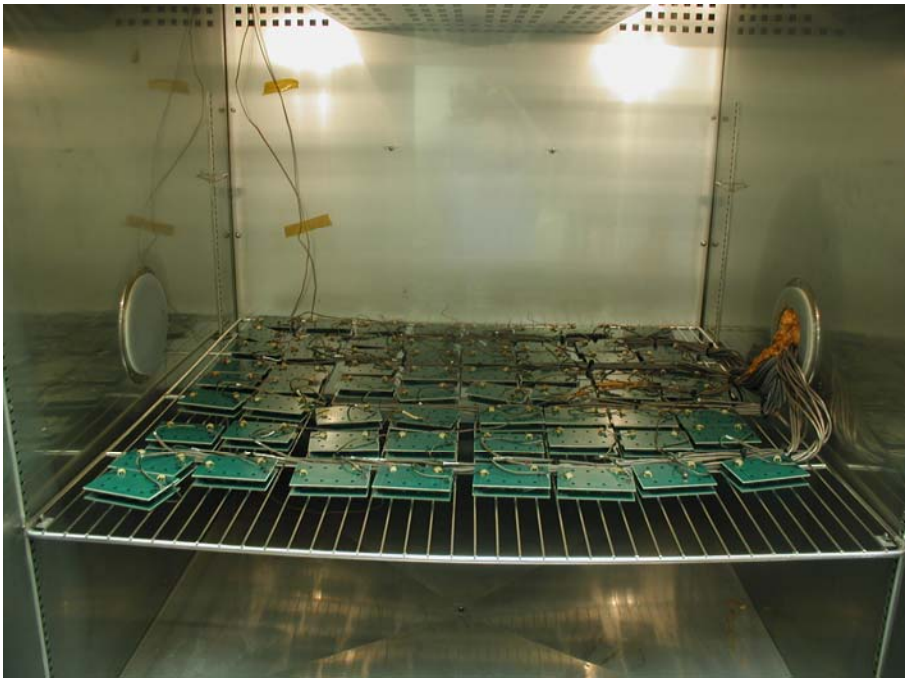


FIGURE 5: Group 1, consisting of 32 mounted mated pair samples of SAC and Group 2, consisting of 32 mounted mated pair samples of SnPb, were monitored. Signal routing was daisy-chained through all 828 positions on each sample facilitating 100% contact monitoring.

EVENT DETECTION:

1) Events were established in accordance with Paragraph 4.3.3.3 of IPC-9701A and Table 4-4.
2) An event was defined as a Signal Interruption exceeding 1000 Ω lasting for greater than 200 nanoseconds.
3) Multiple events occurring during the same cycle are counted as a single event.

FAILURE CRITERIA:

1) Failures were established in accordance with Paragraph 4.3.3.3 of IPC-9701A and Table 4-4
2) A failure was defined as 10 events within an elapsed time of 10% of the thermal cycles to the initial event. I.e. if the first event happens at cycle 1000, 9 more events need to happen by cycle 1100.
3) Thermal Cycling was terminated when ≥62% of the product fails or 6000 cycles are completed. This test was continued until 7546 cycles to collect more data.

FLOWCHART

Thermal Cycling for SJR (0 - 100 degrees C)

	32 mated assemblies	32 mated assemblies
TEST	**GROUP 1 Lead**	**GROUP 2 Lead-Free**
STEP	**IPC-9701, 32 signals**	**IPC-9701, 32 signals**
	10 Min Ramp	**10 Min Ramp**
	15 Min dwell at T-Limits	**15 Min dwell at T-Limits**
01	Component Conditioning	Component Conditioning
02	PCB Conditioning	PCB Conditioning
03	Assembly Conditioning	Assembly Conditioning
04	Event Detection	Event Detection

SJR = IPC-9701, TC1 up to 6000 cycles

a. Component Conditioning, 125 deg C for 24 hrs
b. PCB Conditioning, 105 deg C for 24 hrs
c. Assembly Conditioning, 100 deg C for 24 hrs
d. 1000 ohms at 200 nS, 10 events constitute a failure (within 10% of the time to first event).

FIGURE 6: Flowchart for SJR test.

RESULTS

SAC Solder Process:

One Failure out of 32 monitored daisy chains at 7546 test cycles

Failure Percentage for 32 SAC signal channels ----------3.125%

- **Failure#1----------6917**

The Weibull shape parameter was determined using the same β as for SnPb assembly, i.e. β = 4.736
Characteristic life was then estimated from Weibull equation:
% Fail at 1st failure = 1/32 = 1-exp[-(6917 / α)^4.736]
which gives α = 14,331 .

SnPb Solder Process:

Five failures out of 32 monitored daisy chains at 7546 test cycles

Failure Percentage for 32 PbSn signal channels----------15.625%

- **Failure#1----------5240**
- **Failure#2----------5363**
- **Failure#3----------7281**
- **Failure#4----------7416**
- **Failure#5----------7466**

Two-parameter Weibull analysis of failure cycles gives:
Characteristic life: α = Cycles to 63.2% Failures = 11270 cycles
Shape parameter (slope of Weibull distribution): β = 4.736

DETERMINING ACCELERATION FACTOR

The following acceleration factors were determined in Calculations for Solder Joint Reliability Summary Report, which is located in the same Mechanical Test Reports section as this report.

JPC Compact Strain Energy Model for SAC3807/3906	STRAIN ENERGY ΔW (MPa) ATC	 USE = 25C to 45C, 6 CYCLES/DAY	ACCELERATION FACTOR AF= ΔW (ATC) / ΔW (USE)
GLOBAL MISMATCH	3.916E+00	2.198E-02	178.160
LOCAL MISMATCH	3.056E-05	7.562E-08	na
TOTAL (LOCAL + GLOBAL)	3.916E+00	2.198E-02	178.161
% Local Strain Energy Over Total Strain Energy	0.001%	0.000%	

FIGURE 7a: SAC, 25 - 45°C

JPC Compact Strain Energy Model for Sn37Pb	STRAIN ENERGY ΔW (MPa) ATC	 USE = 25C to 45C, 6 CYCLES/DAY	ACCELERATION FACTOR AF=ΔW (ATC) / ΔW (USE)
GLOBAL MISMATCH	3.168E+00	1.533E-01	20.666
LOCAL MISMATCH	4.353E-05	6.150E-07	na
TOTAL (LOCAL + GLOBAL)	3.168E+00	1.533E-01	20.667
% Local Strain Energy Over Total Strain Energy	0.001%	0.000%	

FIGURE 7b: SnPb, 25 - 45°C

MEASURED PATH RESISTANCES OF SAMPLES

SnPb

	Path Resistances, Ω		
	Before Test	Δ Passed Samples	Δ Failed Samples
Minimum	4.7	-0.7	1.1
Maximum	6	3.4	112.3
Average	5.3	0.1	37.7
St. Dev.	0.23	0.80	44.93

SAC

	Path Resistances, Ω		
	Before Test	Δ Passed Samples	Δ Failed Samples
Minimum	4.6	-1.4	5.3
Maximum	5.7	0.4	5.3
Average	5.3	-0.2	5.3
St. Dev.	0.22	0.33	NA

FIGURE 8: Path resistances of daisy-chained samples through 18 ft. lead wires.

CROSS SECTION ANALYSIS

1. Cross sections were taken on 3 SnPb failed samples and on 1 SAC failed sample and 2 SAC passed samples (6 total). On failed samples row by row sections were taken starting at the outside rows until a complete crack was observed. On the 2 passed SAC samples each row was taken to confirm that no complete cracks existed.
2. Results of the cross section analysis concur with the event detection results. No indication of poor wettability or foreign material inclusion was observed.

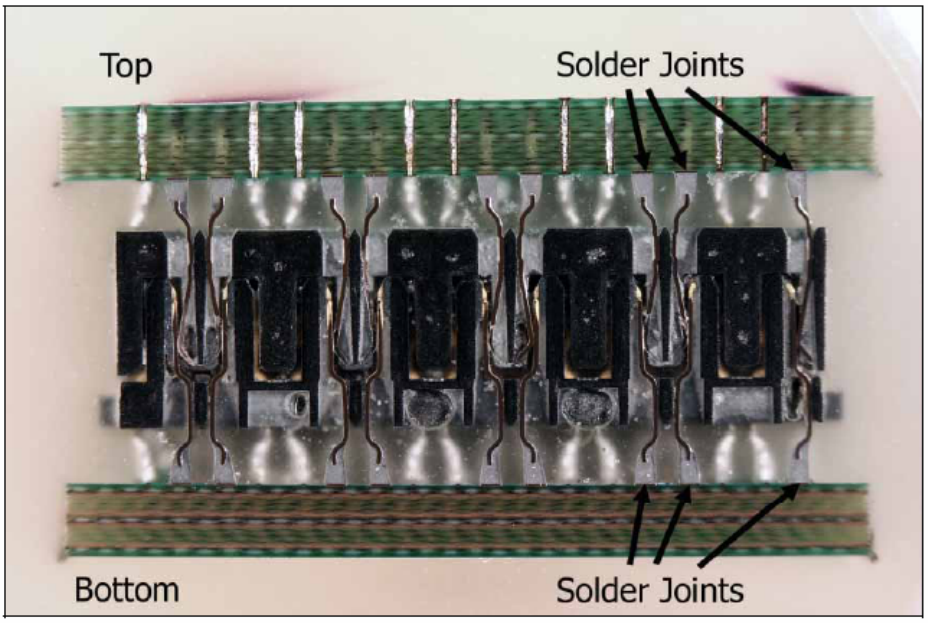


FIGURE 9: A cross section image showing the solder joint orientation. (5X)

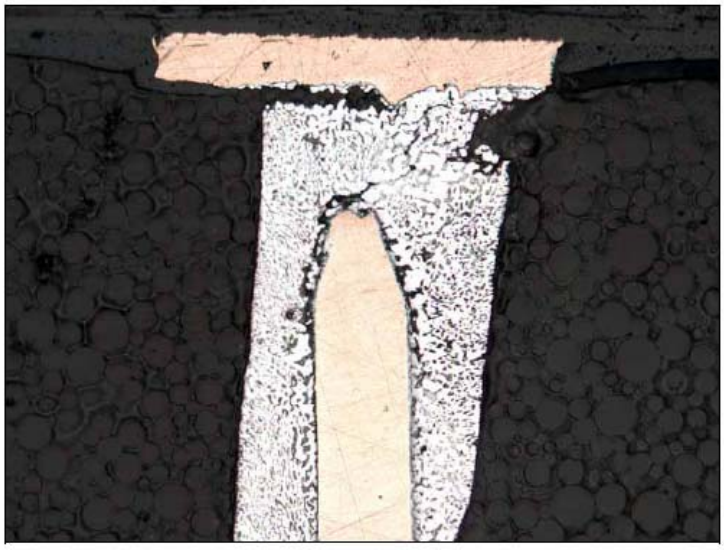


FIGURE 10: A failed solder joint on the first failed PbSn sample. (100X)

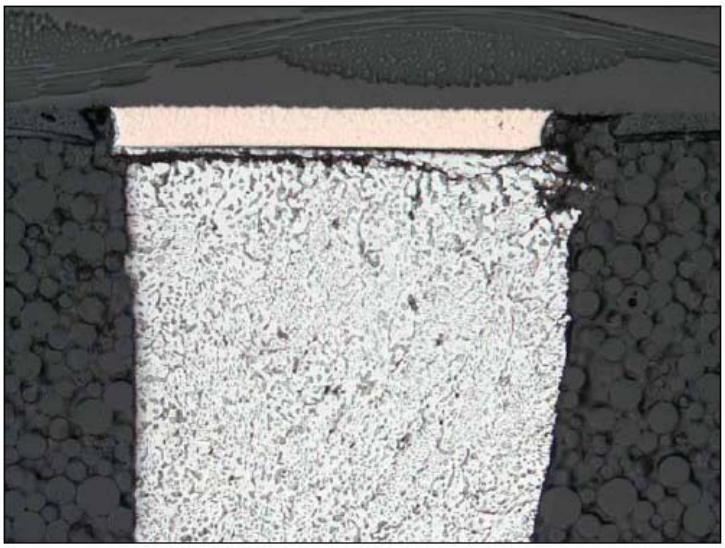


FIGURE 11: A failed solder joint on another failed PbSn sample. (100X)

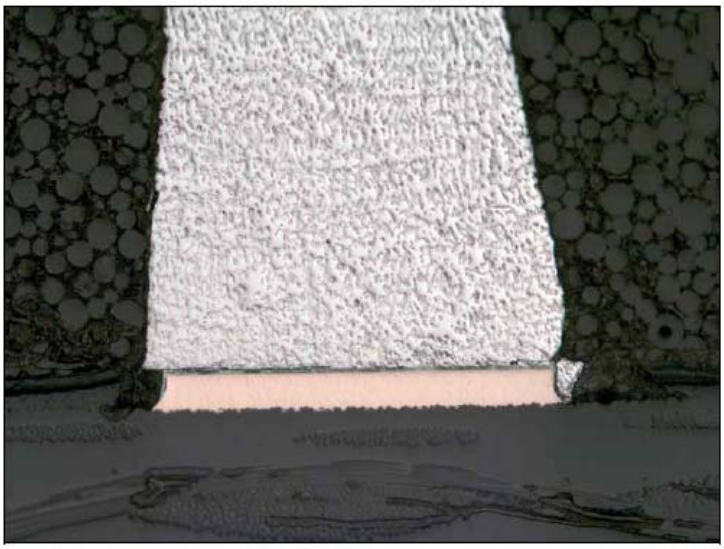


FIGURE 12: A failed solder joint on the only failed SAC sample. (100X)

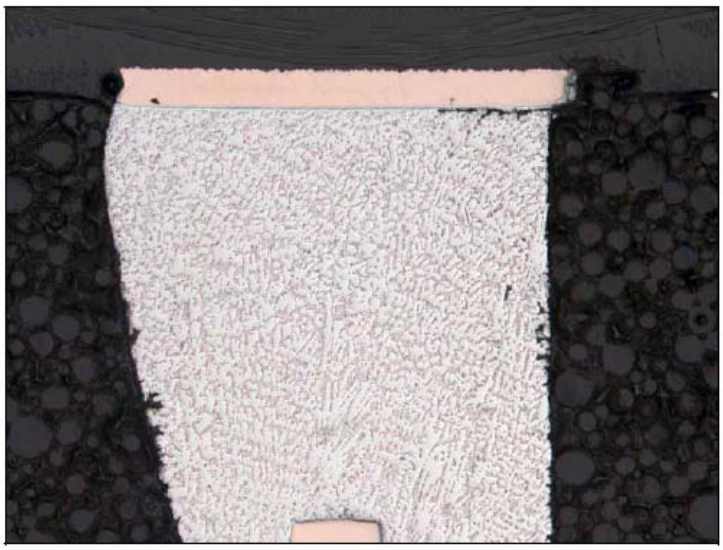


FIGURE 13: A partial crack observed on a passed SAC sample. (100X)

EQUIPMENT AND CALIBRATION SCHEDULES

Equipment #: MM-01
Description: Digital Multimeter
Manufacturer: Fluke
Model: 87 III
Serial #: 74660176
Accuracy: See Manual
… Last Cal: 05/16/06, Next Cal: 05/16/07

Equipment #: THC-02
Description: Temperature/Humidity Chamber
Manufacturer: Thermotron
Model: SE-1000-6-6
Serial #: 31808
Accuracy: See Manual
… Last Cal: 7/15/2005, Next Cal: 8/15/2006

Equipment #: ED-01
Description: STD Series Event Detector
Manufacturer: Analysis Tech
Model: 256
Serial #: 1010425
Accuracy: See manual
… Last Cal: 06/29/06, Next Cal: 06/29/07

…