Lead-free Reflow Oven and Rework Machine Status

Jasbir Bath, Solectron Corporation
Milpitas, CA, USA
Tel: (408) 957 2935
Email: JasbirBath@ca.slr.com

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Lead-free Reflow Temperatures on boards and components

- **One of the biggest concerns for lead-free soldering is the higher reflow temperatures used during processing which increases the temperatures that the board and components are subjected to.**
- **Today's tin-lead attachment (Sn37Pb) alloy melts at 183°C with typical peak reflow temperatures of 215-220°C.**
- **SnAgCu lead-free alloy's melting point is 217°C with peak reflow temperatures of 245-250°C.**
- **Minimum solder joint peak temperature needed for SnAgCu surface mount reflow is typically found in the range 230 to 240°C.**
- **Temperature delta across the board becomes an issue for reflow ovens as smaller components can reach up to 260°C which could lead to component damage.**

The NEMI lead-free component group conducted a study on reflow temperatures during lead-free soldering to cover the following issues:

- 1) What is the ΔT across a typical circuit board and the components
- 2) What are the typical processing tolerances for reflow ovens
- To assess the impact that reflow equipment has on ΔT, two oven manufacturers ran experiments with their 10 zone convection ovens.
- Hot air convection ovens are the standard reflow equipment used in the industry.

NEMI 10 zone reflow oven convection work (Oven A)

- Determine the maximum ΔT across a circuit board assembly for two product boards and one test board.
- Board S was 92mil thick with dimensions 18 x 12 inch and the thermal mass of the board was 1.1kg.
- Board I motherboard was 60mil thick with dimensions 12 x 8 inch and the thermal mass was 0.5kg.
- Board H (partially populated test vehicle) was 93mil thick with dimensions 12 x 18inch and 1kg thermal mass.
- The best results with reduced Delta T were obtained by :
- l) reducing the conveyor speeds,
- 2) by changing the orientation of the board so that the shorter side would be parallel to the direction of the conveyor belt

NEMI 10 zone reflow oven convection work (Oven A)

- <u>Board Tested</u> <u>Delta-T Achieved .</u>
- **Board S** **10°C (estimated value with fixture)**
  - with 20% reduction in conveyor speed compared with tin-lead profile
- **Board H Test Vehicle** **9°C**
- **Board I Motherboard** **9°C**

Min. board temp: 235°C , Max. Board temp: 245°C

NEMI 10 Zone convection oven work (Oven B)

- The impact of various lead-free reflow profiles was studied for the following:
- Board IK motherboard. The board was 60mil thick with dimensions 13 x 16 inch and thermal mass 1.25Kg.
- The delta T between large and small components on the board was 20°C for a typical lead-free profile.
- Using four zones instead of three for reflow, the delta T was reduced from 20°C to 16°C.
- By reducing conveyor speed by 22%, the delta T was reduced from 20°C to 11°C.
- By using a ramp-soak-spike profile instead of the straight ramp profile, the delta T was reduced from 20°C to 16°C.

Min. board temp: 235°C , Max. Board temp: 246°C to 255°C

Affect of Lead-free Reflow Oven Delta T on board size and thickness (IBM, Solectron, Celestica)

- Four production boards were selected to cover a large range of components and board sizes.
- The four FR4 epoxy boards selected were 36mil, 48mil, 78mil and 92 mil thick with OSP surface finish.
- The 36mil thick disk drive board was 5 x 4 inch dimensions
- The 48mil thick double sided laptop board had dimensions of 8 x 8 inch.
- The 78mil thick server board had dimensions of 20 x 15 inch with components
- The 92mil thick server board had dimensions of 10 x 6 inch

Different board thickness and size results

- 32mil thick: (6°C delta T)
- 48mil thick laptop: (19°C for lead-free bottomside (1st pass), 14°C for lead-free topside(2nd pass))
- 78mil (8°C delta T)
- 92mil thick boards (6°C delta T)
- It is not necessarily the largest and thicker boards which have the largest spread of temperatures during lead-free processing.
- The closed type of fixture required for the 48mil thick laptop board for the paste in hole process caused larger delta T across the board.

Min. board temp: 235°C , Max. Board temp: 241°C to 254°C

Affect of Lead-free Reflow Oven Delta T on different number of reflow zones (Auburn University)

- Double sided automotive controller board with dimensions 5.5 x 7.5 inch.

- 6 zone oven: Delta T of 10°C
- With additional zones, Delta T reduced from 10°C to 7°C

What are the tolerances achieved in reflow ovens (NEMI)

Temperature Tolerances in Reflow Oven Process	Typical/°C	Worst Case/°C
Furnace Repeatability	± 0.4	± 0.6
Furnace 1 To Furnace 2 (same oven model number)	± 1.5	± 2.3
Loaded (product board running) vs. No load (1st product board into unloaded oven)	± 1.4	± 1.8
Thermocouple	± 1.1	± 2.2
Total	± 4.4	± 6.9

Example of data from one oven manufacturer. Other manufacturers data may differ

Reflow Oven Tolerances: 5°C Thermocouple measurement tolerance: 2°C

Accuracy of thermocouple placement at solder joint and component are very dependent on the skill of process engineer

Reflow oven tolerances

Considering again the minimum solder joint temperature of 235°C:

Range of the temperatures across board is: 6 to 20°C ΔT {board and components temperature range}

+ 5°C {process tolerance} + 2°C {measurement error}

= 13°C to 27°C.

Thus the peak temperature for the smallest components could be between 248°C to 262°C.

Some Factors affecting reflow oven tolerances

1. Oven supplier and oven model number
2. No./type of oven zones (8 versus 10) and no. of zones used for reflow(2 vs 4)
3. Use of Surface Mount Fixture (open fixture (lower delta T) versus closed fixture (higher delta T))
4. Board size and thickness
5. Position, type and size of components on board
6. Single sided versus double sided board
7. Zone settings, zone lengths and wattage of heaters
8. Conveyor speed (slow versus fast)
9. Reflow Profile shape (Ramp-soak-spike vs straight ramp to peak)
10. Convection vs Infrared vs Mixed Convection/IR Heaters
11. Orientation of board (longer end vs short end into oven first)
12. Ability/time for process engineer to define/develop the optimal reflow profile.

Many Factors to control and consider

Comparison of Other Technologies versus Convection Oven

- **Infra-red (IR) ovens: More likely for hot spots in some areas. Larger Delta T across board**
- **Infra-red with convection: To reduce the delta T across the board, IR radiation could be used in conjunction with convection heating.**
  - Work carried out on FR4 board with thickness of 63mils and board dimension of 9 x 12 inch reduced delta T across board from 40°C to 21°C (Panasonic)
  - Ovens with this type of capability are developmental and may only be effective for certain types of boards.
- **Vapour phase: Uniform soldering temperature of 240°C across board but large installation costs, limited number of suppliers, more detailed evaluation of process and equipment needed. May have a niche for very large, thick boards.**

Reflow Oven Conclusions

- **Main reflow oven technology would likely continue to be convection reflow ovens**
- **More work needed to have tighter reflow oven tolerances which is dependent on many factors.**
- **Current J-STD-020C standard temperature classifications (245°C, 250°C, 260°C) for lead-free soldering seem to be adequate**
- **Other reflow oven technologies are being evaluated such as hot air convection with IR and vapour phase but seem to be more niche areas with more development work needed.**

Typical BGA / CSP Hot Air Rework process

TC wire is just higher than PCB pad

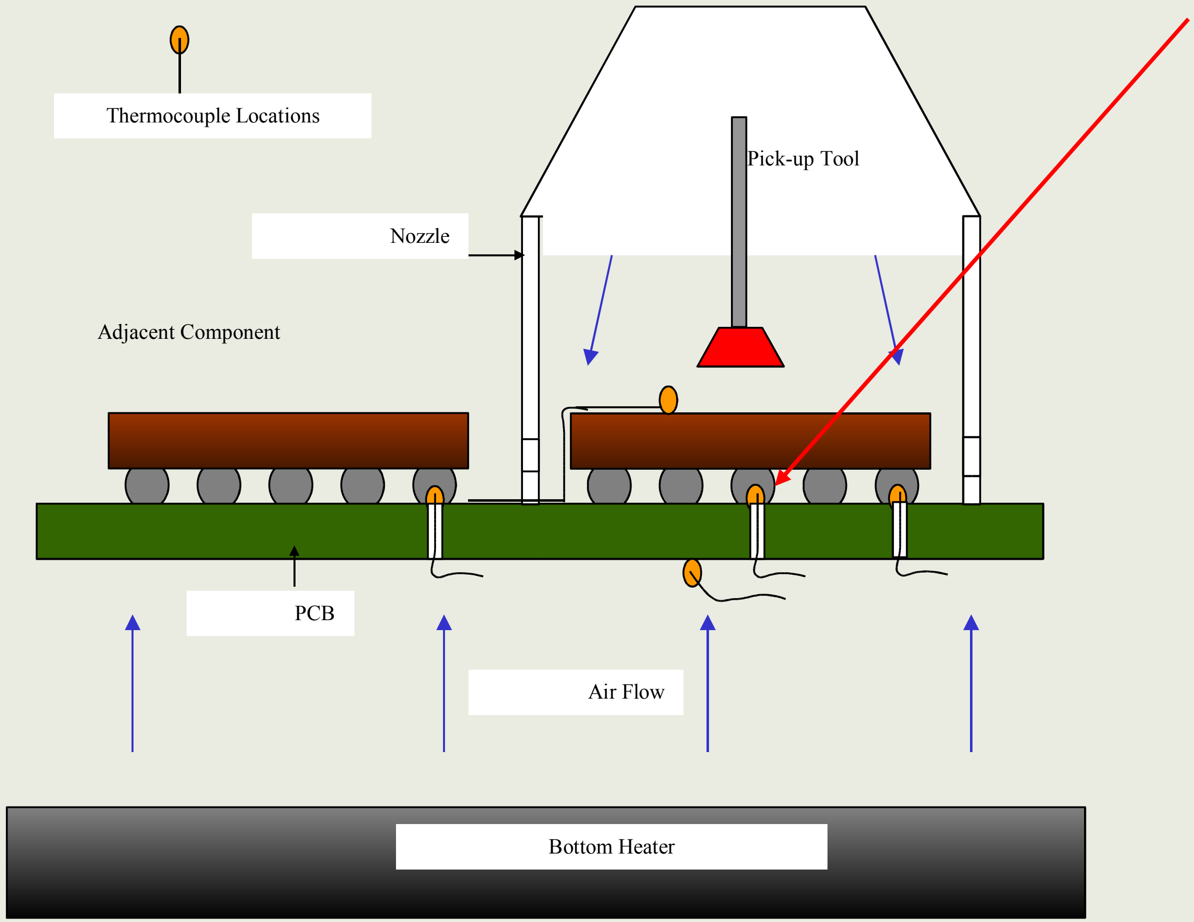


Figure 4. Thermocouple Locations

Courtesy: Gowda et al. (SUNY-Binghamton, Universal Instruments)

Example BGA/CSP profiles (1st pass versus Rework)

<u>Hot air Convection Reflow oven (1st pass Assembly)</u>

- **Delta T between solder joint and components is usually 2 to 3°C**
- **Tin-lead Solder joint peak is 205°C.**
- **Tin-lead Component top package temperature peak is 208°C**
- **Lead-free SnAgCu Solder joint peak is 235°C.**
- **Lead-free Component top package temperature peak is 238°C**

<u>Hot air Convection BGA/CSP rework machine</u>

- **Delta T between solder joint and components usually 15 to 25°C**
- **Tin-lead Solder joint peak is 200°C.**
- **Tin-lead Component top package temperature peak is 215-225°C**
- **Lead-free SnAgCu Solder joint peak is 230°C.**
- **Lead-free Component top package temperature peak is 245-255°C**

NEMI Phase 3 (Reliability Test Board rework development)

<u>NEMI Payette reliability test board</u>

93mil and 135mil thick, 7 x 17inch, High Tg FR4 (170°C), 14 copper layers

Mainly Electrolytic NiAu with some boards with Imm. Ag board finish

Standard calibrated hot air convection production rework machines and standard nozzles:

- Same model used for all UBGA and PBGA components to be reworked
- Upgraded model for CBGA rework with larger board capacity and bottom heaters

uBGA256 rework: Jabil (17mm x 17mm, 1mm pitch)

- Thickness: 1.3 mm, Volume: 376 Cumm J-STD-020C: 260°C

PBGA544 : Intel (35mm x 35mm, 1.27mm pitch)

- Thickness: 1.9mm, Volume: 2328 Cumm J-STD-020C: 245°C

CBGA933: HP (32.5mm x 32.5mm, 1mm pitch)

- Thickness: 1.6mm, Volume: 1690 Cumm J-STD-020C: 250°C

Phase 3 uBGA256 Rework Profile Results

93mil thick board

Lead-free rework profile:

Minimum Peak solder joint temperature: 230°C Component top : 245°C (15°C delta T).

Temperature at 150mils from component on board: 218°C

Tin-lead rework profile:

Minimum Peak solder joint temperature: 203°C Component top : 213°C (10°C delta T)

Temperature at 150mils from component on board: 192°C

135mil thick board

Lead-free rework profile:

Minimum Peak solder joint temperature: 229°C Component top : 245°C (16°C delta T).

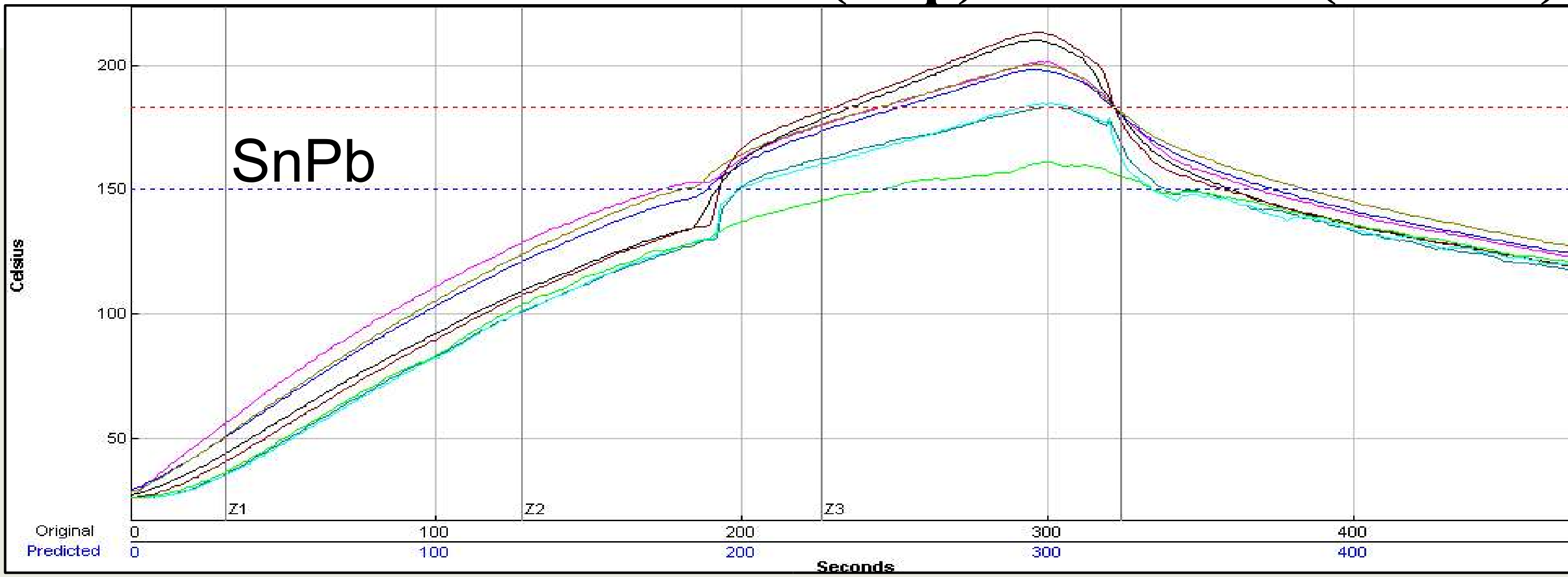
Temperature at 150mils from component on board less than 217°C: 208°C

Tin-lead rework profile:

Minimum Peak solder joint temperature: 199°C Component top: 210°C (11°C delta T)

Temperature at 150mils from component on board: 183°C

NEMI Payette 0.135” (uBGA Rework): Tin-Lead Profile(Top) / Lead-free (Bottom)



SnAgCu

Phase 3 PBGA544 Rework Profile Results

93mil thick

Lead-free:

Minimum Peak solder joint temperature: 234°C Component top: 245°C (11°C delta T)

Temperature at 150mils from component on board: 244°C

Tin-lead:

Minimum Peak solder joint temperature: 202°C Component top: 217°C (15°C delta T)

Temperature at 150mils from component on board: 217°C

135mil thick

Lead-free:

Minimum Peak solder joint temperature: 233°C Component top: 245°C (12°C delta T)

Temperature at 150mils from component on board : 248°C

Tin-lead:

Minimum Peak solder joint temperature: 201°C Component top: 217°C (16°C delta T)

Temperature at 150mils from component on board: 227°C

SnAgCu PBGA544 Rework Profile Parameters

(Package corner temperature is higher than package top center)

Same result seen for tin-lead PBGA rework

Profile Parameters	Target	Results			
		0.135” U29	0.135” U30	0.093” U29	0.093” U30
Minimum Temperature For Solder Ball	230°C	232.3°C	232.6°C	238.2°C	234.1°C
Maximum Package Temperature	245°C	Top:245°C Corner:246.7°C	Top:244°C Corner:249.7°C	Top:245°C Corner:244.5C	Top:245°C Corner:248.5°C
Maximum Temperature Delta Between Solder Ball Thermocouples (ΔT_{x-y})	10°C	6.2°C	4.7°C	4.8°C	3.7°C
Temperature Between Lowest Solder Ball & Package Top (ΔT_z)	15°C	Top:12.8°C Corner:14.4°C	Top:11.4°C Corner:17.1°C	Top:8.5°C Corner:7.9°C	Top:10.6°C Corner:14.4°C
Time Above Liquidous (TAL)	45-90sec	93.26sec	85.02sec	87.95sec	74.92sec
Heating Rate	0.5-2.5° C/sec	0.84°C/sec	0.84°C/sec	1.23°C/sec	1.13°C/sec
Cooling Rate	TBD	-0.70°C/sec	-0.79°C/sec	-1.12°C/sec	-1.13°C/sec
Soak Time (150-217°C)	TBD	108.17sec	102.92sec	91.37sec	96.86sec

Phase 3 CBGA933 Rework Profile Results

93mil thick

Lead-free:

Minimum Peak solder temperature: 239°C Component top:239°C(0°C delta T)

Temperature at 150mils from component on board: 257°C

Tin-lead:

Minimum Peak solder temperature:199°C Component top:201°C(2°C delta T)

Temperature at 150mils from component on board: 184°C

135mil thick

Lead-free:

Minimum Peak solder temperature: 235°C Component top: 238°C (3°C delta T)

Temperature at 150mils from component on board less than 217°C: 212°C

Tin-lead:

Minimum Peak solder temperature: 201°C Component top: 202°C(11°C delta T)

Temperature at 150mils from component on board: 206°C

NEMI Phase 3 Conclusions
Lead-free CBGA/PBGA/uBGA rework

- **Increasing bottom side board preheat was found effective in reducing delta T between solder joint and component body but potential risk of secondary reflow of adjacent components and bottom side components and reliability of board material**
- **Margin of error to maintain a lead-free minimum solder joint temperature of 230-235°C with maximum body temperature of 245°C-250°C (old J-STD-020B standard) is very tight (for some of the best rework development engineers in the industry).**
- **Adjacent component temperatures were being exceeded at 150mils on the board in many cases.**
- **Payette boards in Phase 3 have been assembled and reworked and are in ATC reliability testing**

Solectron SMT Reliability Lead-free Test Vehicle

93mil thick

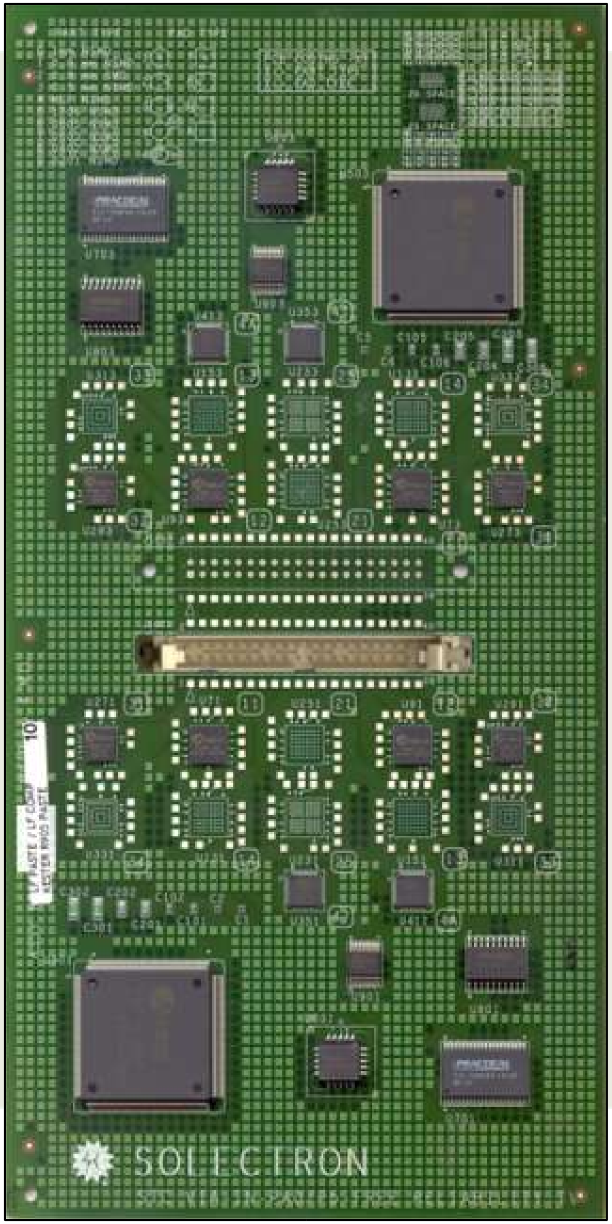
High Tg FR4
(170°C)

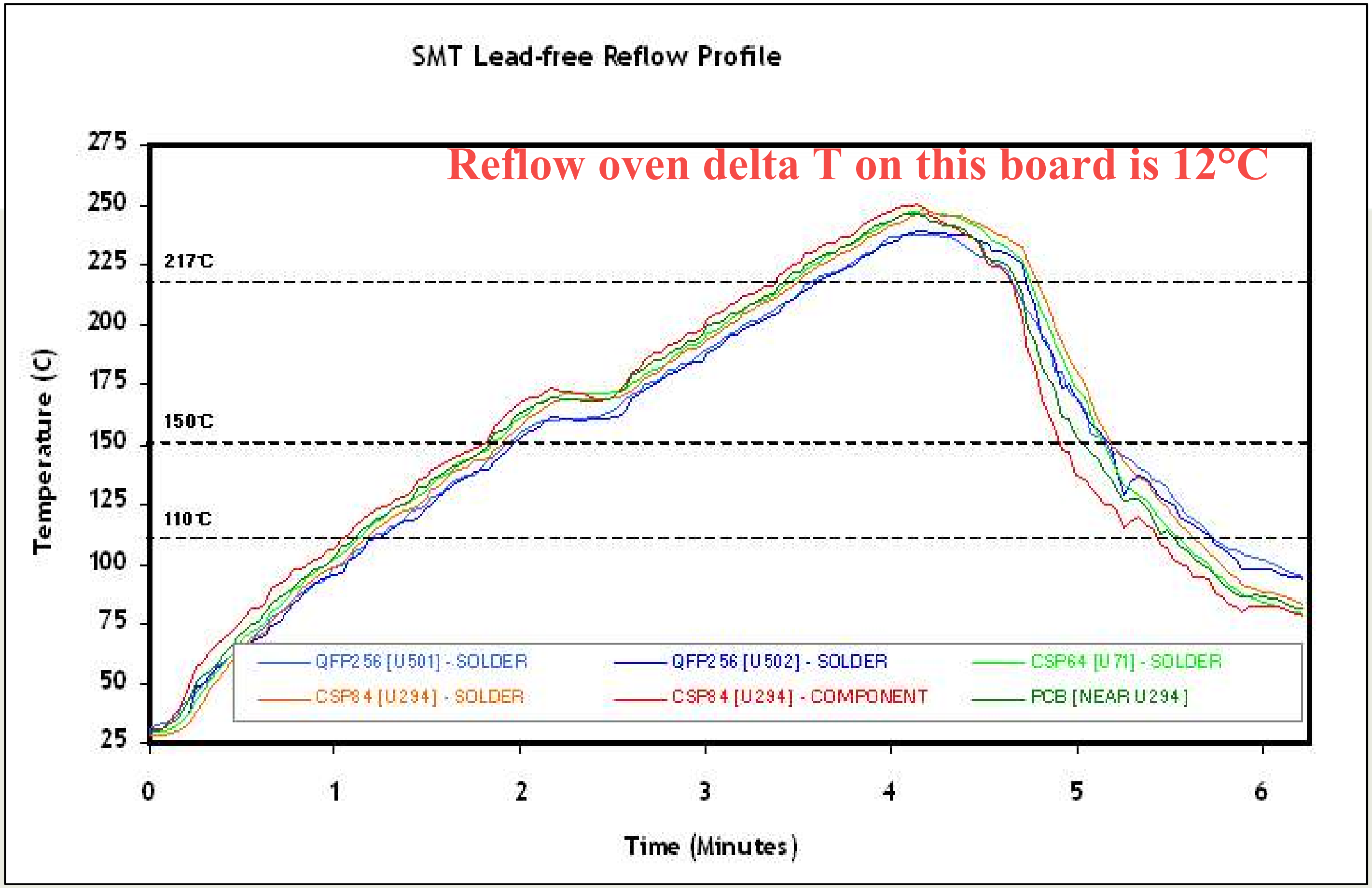
6 layers

SnAgCu CSP84: (7mm x 7mm, 0.5mm pitch),

- **Thickness: 1.3mm, Volume: 66Cumm**

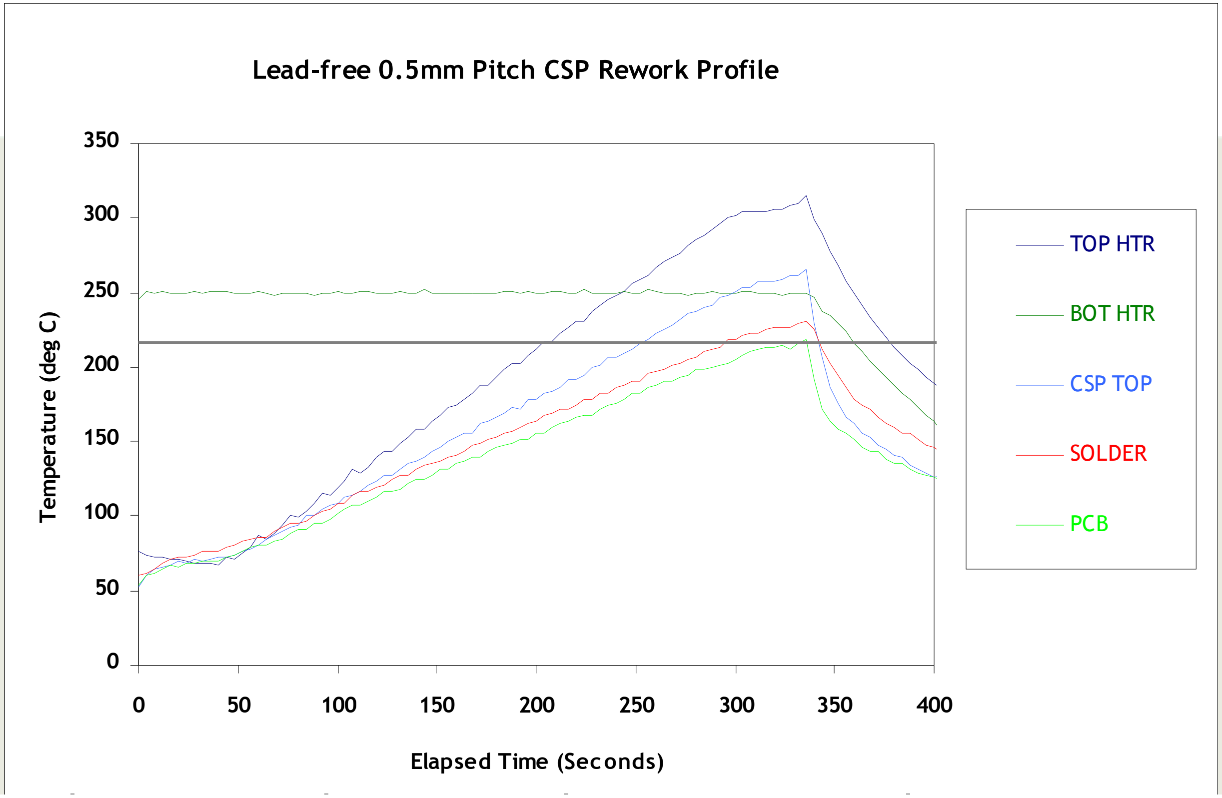
- **J-STD-020C: 260°C**





Thermocouple Location	Peak Temperature [°C]	Max Rising Slope [°C/sec]	Preheat Zone (110-150°C) [sec]	Soak Zone (150-217°C) [sec]	Time Above Liquidus (>217°C) [sec]
QFP256 [U501] - Solder	238.1	1.7	43.3	98.5	65.6
QFP256 [U502] - Solder	239.0	2.2	44.8	97.2	68.3
CSP64 [U71] - Solder	248.0	2.2	43.8	96.2	77.8
CSP84 [U294] - Solder	247.1	2.0	44.5	94.1	79.0
CSP84 [U294] - Component	250.1	2.6	46.2	94.2	76.7
PCB [Near U294]	247.3	2.1	44.5	94.2	77.2

Lead-free 0.5mm CSP Rework Profile



Thermocouple Location	Peak Temperature [˚C]	Max Rising Slope [˚C/sec]	Preheat Zone (110-217˚C) [sec]	Time Above Liquidus (>217˚C) [sec]	Max Falling Slope [˚C/sec]
Solder Joint	231.0	0.5	194	47	8.6
Component Top	265.0	0.6	-	-	6.5
PCB [5mm away]	218.0	0.5	-	-	5.8

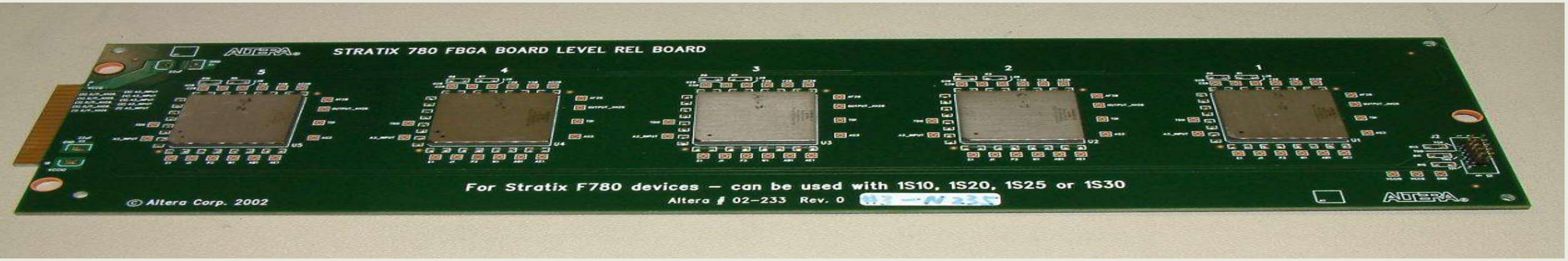
0.5mm CSP (1st Pass Reflow): Solder joint (247°C), Comp. Top (250°C)

0.5mm CSP (Rework): Solder joint (231°C), Comp. Top (265°C)

Rework machine delta T is 34°C

FCBGA 780 SMT and Rework Test vehicle (Solectron/ Altera)

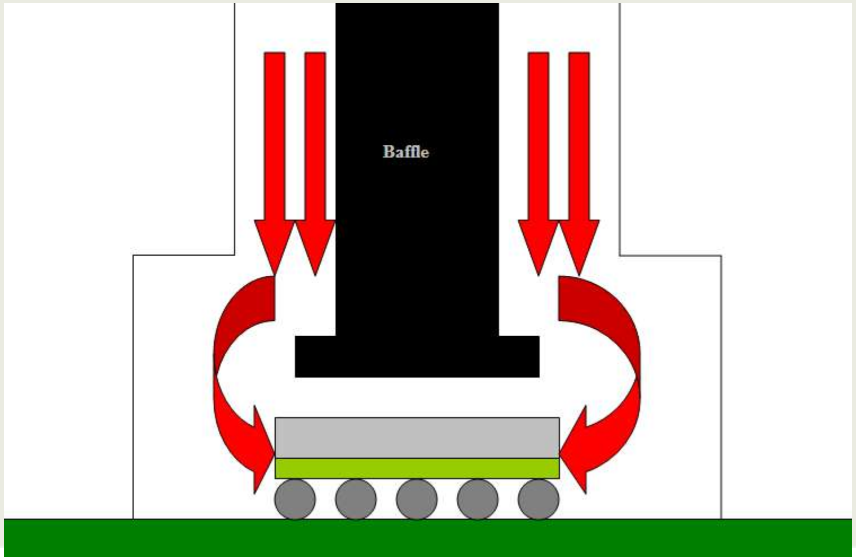
- PCB
  - 93mil thick, 8 layer board, High Tg FR4. OSP surface finish



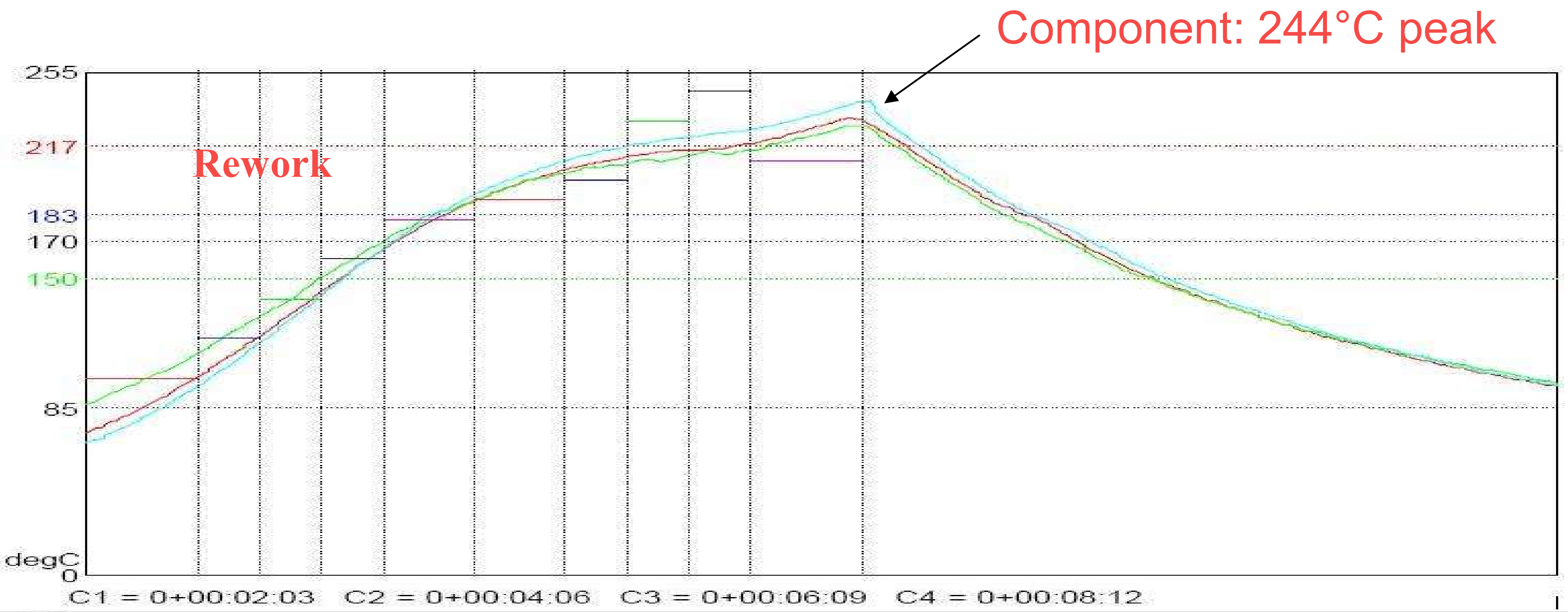
- Component
  - 29x29mm fully functional device, 1.3mm substrate thickness, 1mm pitch FCBGA 780 I/O Sn3Ag0.5Cu solder balls
- **Thickness: 1.3mm, Volume: 1093 Cumm**
- **J-STD-020C: 260°C**

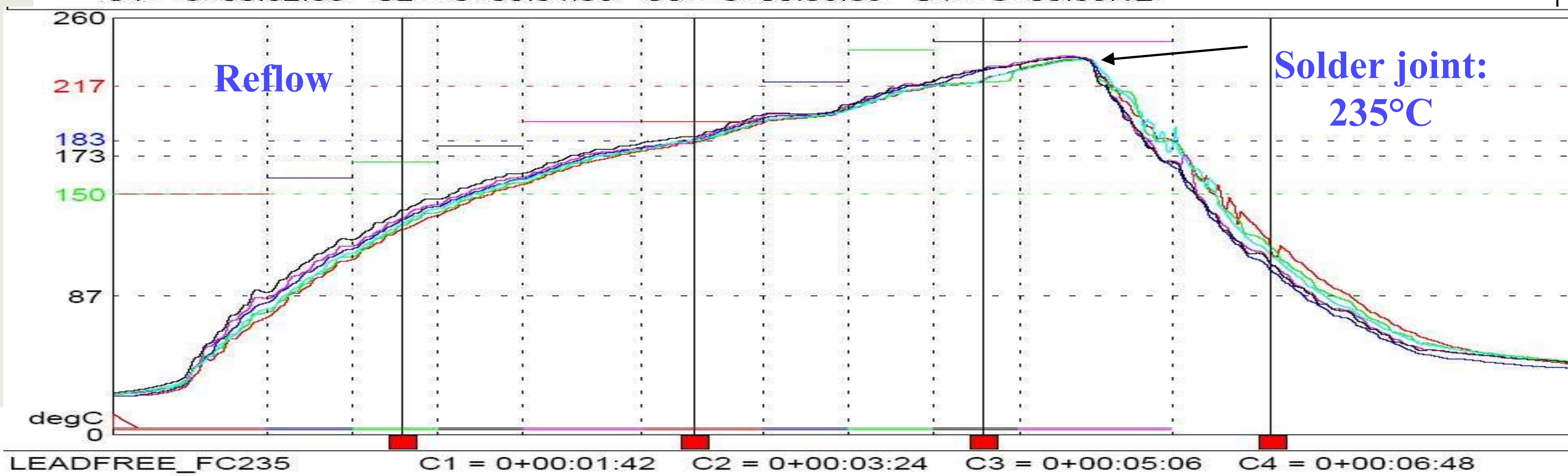
FCBGA Rework Tests:

- Standard Nozzle (no baffle metal plate in nozzle)
- With no baffle, delta T between solder joint and top of component body was 30°C (235°C for joint, 265°C for component body)
- Experimental nozzle design evaluated (baffle plate added in nozzle to deflect heat passing through component):

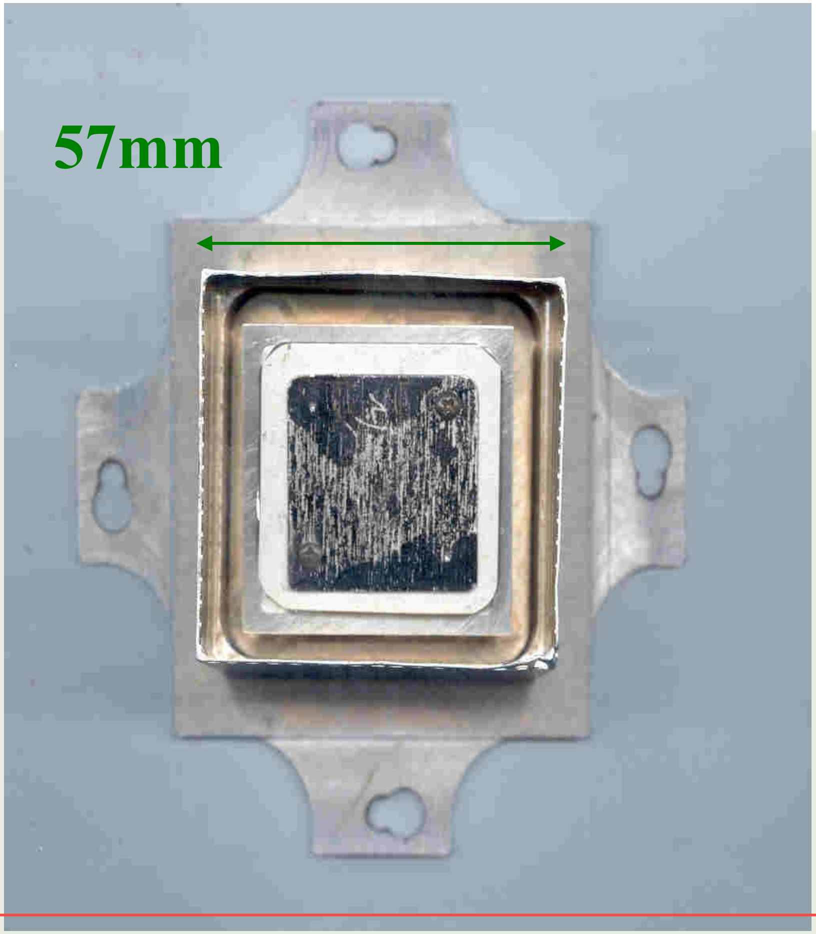


Lead-free Rework profile with experimental baffle nozzle vs Reflow oven profile





Experimental Rework Nozzle for FCBGA780



Component dimension is 29mm x 29mm

Keep out spacing around this component with rework nozzle is 14 mm

Typically keep out spacing in production goes down to 150mils (only 3.8 mm)

Rework nozzle is O.K. for test vehicle use but not production for this component type

Lead-free BGA/CSP/CBGA Rework summary

Lead-free SnAgCu rework		Min. Joint Temp/ °C	Component Peak/ °C	150mils from component on board/ °C
Chen	CSPs	247	259	Not measured
NEMI (1999)	PBGA	247	265	153
	PBGA	233	245	248
	CBGA	235	239	257
NEMI (2003)	uBGA	229	245	218
Gowda (1)	CSP	243	262	190
Gowda (2)	MLF	245	267	175
Furnanz	PBGA	240	255	Not measured
Sethuraman	CSP	231	265	218
Yoon (baffle)	FCBGA	229	244	Not measured
Yoon (no baffle)	FCBGA	235	265	Not measured

Min. Solder Joint temps, comp. peak temps and temperatures on the board at 150mils away from component are not easy to control during rework and exceed targets in many cases in published developmental work

Rework temperature summary

Chen et al.:	25°C delta T (CSPs)
NEMI lead-free rework (1999):	18°C delta T (PBGA)
NEMI lead-free rework (2003):	12°C delta T (PBGA/CBGA/uBGA)
Gowda et al. (1):	19°C delta T (CSP)
Gowda et al. (2):	22°C delta T (MLF)
Furnanz et al. :	15°C delta T (PBGA)
Sethuraman et al.:	34°C delta T (CSP)
Yoon et al.(baffle):	15°C delta T (FCBGA)
Yoon et al (no baffle):	30°C delta T (FCBGA)
Average delta T:	21°C

235°C joint temperature, component temperature: 256°C

- Results for thermocoupled boards where multiple profiling (5 to 50 times) conducted under test conditions over a period of time (up to 2 months).
- In production, there may not be thermocoupled boards. Also rework profiles need to be developed in hours/days. Delta T would likely be worse.

Lead-free Rework Machine Tolerances

- Limited or no data available for Rework Equipment Tolerances
- Rework Equipment Tolerances will likely be worse than Reflow ovens

Some Factors affecting rework machine tolerances (BGA/CSP rework)

1. **Rework Machine supplier and machine model number**
2. **No./ type and size of bottom heaters**
3. **Board size and thickness**
4. **Position, type and size of components on board**
5. **Single sided versus double sided board**
6. **Bottom heater and top nozzle heater settings and wattage of heaters**
7. **Variations in rework practices, top nozzle heater airflow rates across industry**
8. **Rework nozzle type (open, baffle) and nozzle dimensions**
9. **Rework Profile shape and length of profile and variable heating/cooling rates**
10. **Reduced ability to cool board quickly after rework compared to reflow ovens**
11. **Orientation of board in rework machine**
12. **Ability/time for rework process engineer to define/ develop the optimal rework profile.**

Many Factors to control and consider, more difficult process to control than reflow ovens

New BGA/CSP rework developments using the standard hot air convection rework equipment

- Nozzle redesigns : Adjust heat airflow through components to reduce delta T and temperatures from the component (try to reduce risk of adjacent component reflow)more work needed, some progress.
- Baffle nozzles

  More work needed, some progress. Issue with keep out spacing as may need larger nozzle size to allow sufficient heat to go through component
- Increased bottom side board heat to reduce top nozzle heat

  More work needed, some progress. Issue with more heat through bottom side of board. What is affect on board laminate material, (reliability and warpage), bottomside compnonent and adjacent component secondary reflow (reliability).
- Cool air flow through the rework component pick up tube to keep the top of the component lower in temperature than the solder joint: Developmental, insufficient production trials and reliability data

New BGA/CSP rework developments (Lazer rework)

- **Lazer heats the solder joints with lazer beam through the component:**
  - Can be beneficial but measurement of component top temperature difficult,
  - Require high power lazer for area array packages,
  - Increased manufacturing time to rework components,
  - Component die concern.
  - Insufficient reliability data

NEMI Phase 3 TSOP and 2512 Chip Rework

- **TSOP and 2512 Rework Operation (Solectron)**
  - 93mil thick
    - SnAgCu Solder iron tip temperature: 750°F (395°C)
    - SnPb Solder iron tip temperature: 725°F (385°C)
  - 135mil thick
    - SnAgCu Solder iron tip temperature: 750°F (395°C)
    - SnPb Solder iron tip temperature: 725°F (385°C)
  - Observations
    - No real issues during hand solder rework
    - 2 lead-free soldered TSOP components needed 2x rework. There was no obvious solder joint issue after 1x rework so assume component not solder joint issue.
    - Operators saw visual inspection differences, where the lead free soldered joints appeared more cratered whilst the tin-lead reworked joint appeared smooth and shiny.
      - This would need to be taken into consideration during solder joint inspection training for lead-free.

Mini-pot Connector Rework (Solectron)

- Mini-pot rework machine retrofitted for lead-free soldering. (Replace stainless steel parts which would erode with lead-free high tin containing solder)
- Solder pot material used was Sn0.7Cu (mp: 227°C).
- Initial work on 55mil thick OSP coated board (FR4: Tg 135°C) with through-hole connector has produced difficulties
- Good Holefill is difficult especially after removing the as-assembled part and attempting to assemble with a new part
- Max solder pot temp for this board would be 500°F (260°C). Increasing pot temperature to 525°F (272°C) delaminated board
- Reconducted the tests with SnAgCu solder (mp: 217°C) with similar results.

Rework Conclusions

- **Margin of error to maintain a lead-free minimum solder joint temperature of 230-235°C with maximum body temperature of 245°C-250°C is very tight during BGA/ CSP rework (for some of the best rework development engineers in the industry). New J-STD-020C standard to help to address this.**
- **Adjacent component temperatures were being exceeded at 150mils on the board in many cases for tin-lead and lead-free rework.**
- **Rework Equipment and Nozzles are still in the process of development for lead-free (Generally more difficult to control temperatures in rework that reflow: Need more process manufacturing margin).**
- **Other lead-free BGA/CSP rework techniques such as lazer are still in development**
- **Hand-soldering lead-free rework was conducted successfully**
- **Lead-free mini-pot connector rework is still in development**

Lead-free Component and Board Temperature Requirements

Agenda

- **Lead-free Soldering Temperatures compared with tin-lead soldering**
- **J-STD-020C and JEITA component temperature rating for lead-free soldering**
- **Lead-free PCB working group activity and input into standards groups**

Component assembly temperatures for lead-free soldering

- **One of the biggest challenges is the availability of components that can withstand the higher melting temperatures required for lead-free manufacturing.**
- **Today's tin-lead attachment (Sn37Pb) alloy melts at 183°C with typical reflow temperatures of 205-220°C.**
- **SnAgCu lead-free alloy's melting point is 217°C with typical reflow temperatures of 235-250°C.**
- **Due to these higher lead-free soldering temperatures, component suppliers need to re-qualify their parts**

  (J-STD-020: Moisture/ Reflow Classification for Nonhermetic Solid State Surface Mount Devices)

J-STD020B/ J-STD-020C and JEITA standard

JEDEC/ IPC J-STD-020B (July 2002)			
	Package Thickness > 2.5mm OR Volume > 350 Cumm	**Package Thickness < 2.5mm AND Volume < 350 Cumm**	
SnPb parts	225 +0/-5°C	240 +0/-5°C	
Lead-free parts	245 +0/-5°C	250 +0/-5°C	
JEDEC/ IPC J-STD-020C (July 2004)			
SnPb parts			
Package Thickness	**Volume: < 350Cumm**	**Volume: > 350Cumm**	
<2.5mm	240 +0/-5°C	225 +0/-5°C	
>2.5mm	225 +0/-5°C	225 +0/-5°C	
Lead-free parts			
Package Thickness	**Volume: < 350Cumm**	**Volume: 350 to 2000 Cumm**	**Volume: > 2000Cumm**
<1.6mm	260 +0°C	260 +0°C	260 +0°C
1.6mm to 2.5mm	260 +0°C	250 +0°C	245 +0°C
>2.5mm	**250 +0°C**	245 +0°C	245 +0°C
Note: Lead-free parts not rated to 260°C need to undergo one pass at 260°C to simulate rework			
Japan JEITA ED-4701/301A (2003)			
Lead-free parts			
Package Thickness	**Volume: < 350Cumm**	**Volume: 350 to 2000 Cumm**	**Volume: > 2000Cumm**
<1.6mm	260°C	260°C	260°C
1.6mm to 2.5mm	260°C	250°C	245°C
>2.5mm	**245°C**	245°C	245°C
Note: One classification temp. is different between J-STD-020C and JEITA ED-4701/301A standard			

J-STD-020C versus JEITA ED-4701/301A

- **Two main differences between JEITA and J-STD standard:**

2. >2.5mm thick and < 350Cum volume of component:

245°C rated for JEIDA but 250°C for J-STD-020C

4. J-STD-020C: If lead-free component is not rated to 260°C then it must be capable of one pass cycle at 260°C to simulate lead-free rework

- **New Draft J-STD-020D under review: Areas such as tolerances for lead-free component testing**
  - Currently 260°C +0°C for lead-free component testing compared with for example 225°C +0/-5°C for tin-lead component testing.

The current J-STD-020C is a good compromise between the need of the component suppliers with their difficulties in re-qualifying components to the higher lead-free soldering temperatures and the needs of the OEM/CEM assembler who requires these higher temperatures for lead-free soldering.

Lead-free soldering: PCBs

For printed wiring boards, more stringent test methods and/or specifications need to be agreed upon and standardized by the industry for lead-free soldering.

This is to ensure an adequate supply of appropriate more thermally robust laminate materials required for higher temperature lead-free assembly.

Formation of a Lead-free PCB working group to look at addressing these areas and input into the relevant standard committees:

- Solectron, Sun Microsystems plus other OEMs and one other CEM
- Karl Sauter (SUN): Chair

Reliability concerns with some common lead-free PCB material alternatives:

- Laminate material structural integrity (delamination, warpage)
- PCB through-hole via failures at higher lead-free reflow temperatures
- Solutions that are acceptable for consumer products may not meet OEM reliability requirements for high reliability/ long term products.

Laminate material suppliers and PWB manufacturers should develop/make available higher temperature lead free versions of their products much earlier than may be required by legislation due to the number of tests needed for the bare board and the time taken to conduct product level evaluations.

Large Thick Multilayer Boards (New Testing Requirements for Lead-free)

- **Higher temperature lead-free (SnAgCu alloy) assembly processing and rework will require laminate material able to withstand repeated thermal excursions up to 260°C.**
- **Some laminate material tests need to change to add preconditioning to simulate higher temperature lead-free (SnAgCu alloy) assembly processing and rework (copper peel strength testing, IST/HATS testing).**

Laminate Requirements for Higher Temperature Assembly Processing

- **Recommend Temperature of Decomposition (ASTM D-3850 test method) testing using the 2 percent weight loss for reporting the performance characteristics of more thermally robust laminate materials.**
- **Recommend all laminate material data sheets report T288°C (Time to delamination at 288°C) as well as T260°C**
- **Time to Delamination test results better indicate performance in higher temperature lead free assembly.**
- **Recommend CAF (Cathodic Anodic Filament) testing per IPC TM-650 Section 2.6.25.**
- **Recommend reporting 5X Thermal Shock at 260°C results as a key indicator of material performance in higher temperature lead free assembly applications.**
- **Most non-dicy cured FR-4 laminate materials made using Novolac-type catalyst are more thermally robust and should be part of this testing.**
  - Several non-dicy FR-4 laminate materials using Novolac-type catalyst have now been developed (with T288°C Time to Delamination data)

Laminate Requirements for Higher Temperature Assembly Processing (Continued)

- **Recommend all laminate suppliers separately report Z-axis CTE from:**

  25°C to the Material Tg, and

  Material Tg to at least up to 260°C

  since there is no longer a single industry standard assembly reflow temperature.

- **Recommend adding new specification addressing laminate material "machinability" or extent of microfracturing to be expected after PTH drilling.**
  - **Example: backlight test of cross-sectioned holes showing the extent of microfracturing out from the drilled hole wall.**

Via Reliability Testing

Consistent correlation with actual long term field life reliability requires that long term temperature cycling not exceed the Tg of the laminate used.

Due to the significant decrease in modulus that typically occurs shortly before the Tg is reached, the cycling temperature should be:

at least 10°C below Tg, preferably at 20°C below Tg

for better correlation with long term field life reliability.

Consistent correlation with actual field life/reliability requires that samples going through IST testing be pre-conditioned to represent assembly/rework processing.

- **Default number of IST samples to be run is 6 samples, each of which contains 195 vias.**
- **For good correlation with actual field life/reliability the number of IST coupons tested in a group should be increased so that the total number of vias tested is equivalent to the number of vias on the production board.**

Lead-free Pre-conditioning Reflow Profile

- **This should be a combination of a standard lead-free SMT profile combined with lead-free rework processing temperature ranges. Laminates are typically required to pass 5X through the recommended lead-free profile (surface mount, wave, rework steps).**
- **Lead-free Reflow Profile:**
  - **Ramp rate from room temperature of 1.0-1.5°C/sec with small maximum soak time of 120 seconds below 200°C**
  - **Maximum Temperature above liquidus (217°C) of 100 seconds**
  - **Peak temperature of 260°C+/-3°C for large thick multi-layer boards**
  - **Maximum of 20 seconds within 5°C of this peak temperature**
  - **Cool down rate of 2.0+/-0.5°C/sec to room temperature**

PC Thermocouple attachment technique is critical.

Use at least 3 thermocouples to properly profile raw card (front, middle, trailing edge).

Laminate materials are near the "cliff" at 260°C so coupon size should be representative and all efforts taken to ensure measurement accuracy.

IPC Standards Group Meetings, Minneapolis, USA (Oct. 2004)

Discussion of this PCB presentation in an expanded format to:

IPC 3-11 standards committee meeting (October 26th).

3-11 committee is pursuing Revision B of IPC-4101A "Specification for Base Materials for Rigid and Multilayer Printed Boards"

Consideration of input to following IPC standard groups/test methods:

- **5-33b Soldermask Performance Task Group responsible for IPC-SM-840, "Qualification and Performance of Permanent Solder Mask" (October 25th)**
- **PTH Via Hole Aspect Ratio Reliability for IST (IPC TM-650 Section 2.6.26)**
- **Time to Delamination (IPC TM-650 2.4.24.1)**