

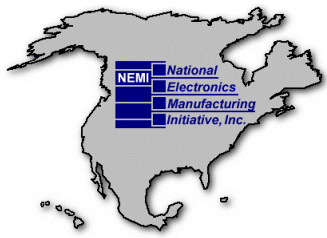


NEMI Lead-free Rework Development Phase 3

March 2004

Jasbir Bath, Solectron

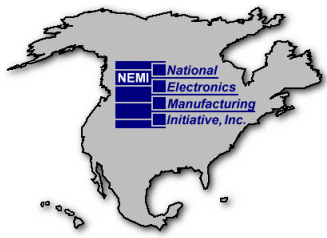
Connect with and Strengthen Your Supply Chain



NEMI Assembly and Rework Project

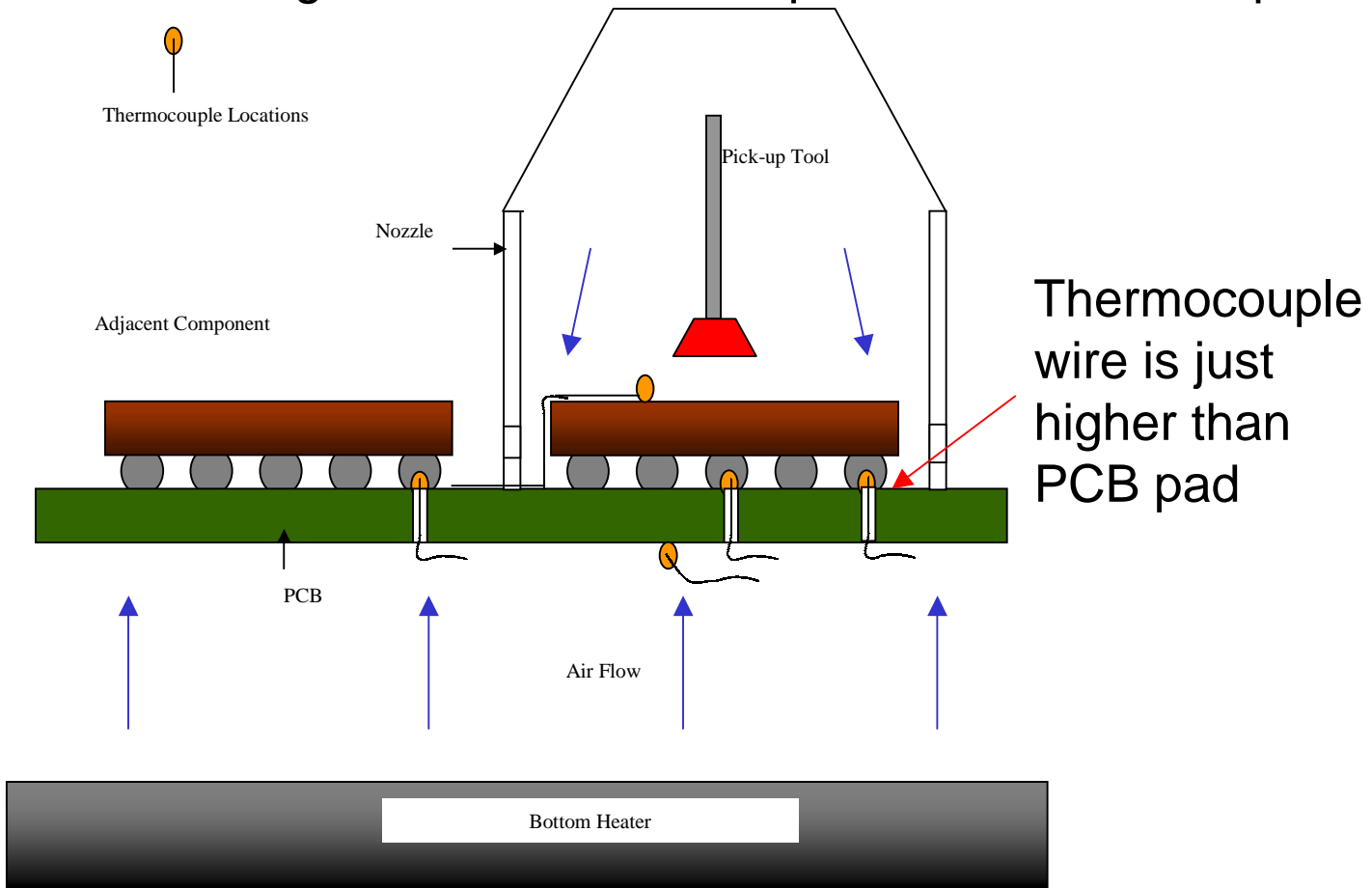
- Develop a baseline Lead-free manufacturing process for medium to high-end computer products (**Assembly, Rework and Reliability**)

- **Rework Group**
 - Development of tin-lead and lead-free rework process for area array, leadframe and through-hole components on reliability test vehicle (HP Payette board)
 - Focus on BGA/CSP rework development processes



Typical BGA/CSP Rework profiling process

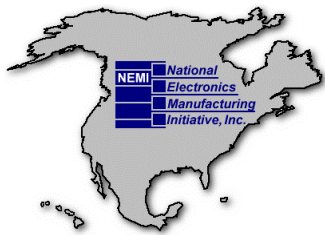
The biggest concern is high ΔT between top surface of the component and solder joint



Thermocouple wire is just higher than PCB pad

Heat flow using rework machine **similar to blue arrows**

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



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

Hot air Convection Reflow oven (1st pass Assembly)

- Delta T between solder joint and components is usually 2 to 3°C

Reflow Oven Example

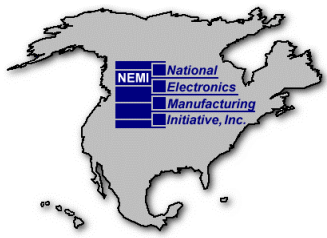
- **Tin-lead** Solder joint peak is 205°C.
- **Tin-lead** Component top package temperature peak is 208°C
- **Lead-free SnAgCu** Solder joint peak is 235°C.
- **Lead-free Component** top package temperature peak is 238°C

Hot air Convection BGA/CSP rework machine

- Delta T between solder joint and components usually **15 to 25°C**

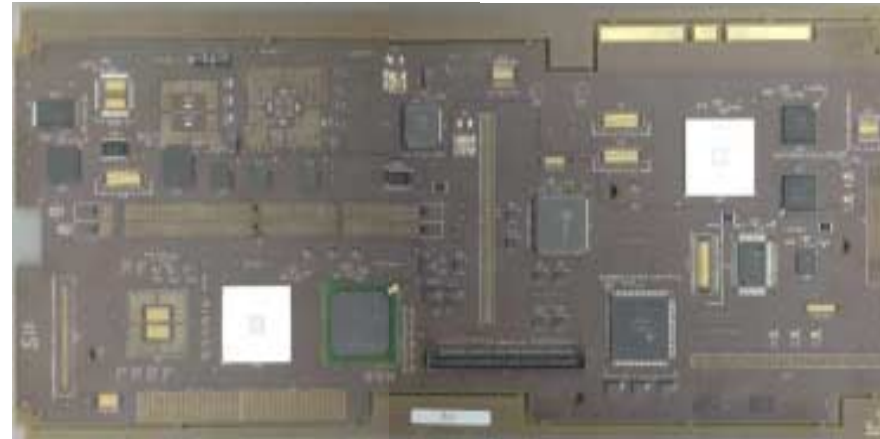
Rework Example

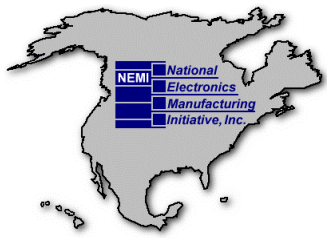
- **Tin-lead** Solder joint peak is 200°C.
- **Tin-lead** Component top package temperature peak is 215-225°C
- **Lead-free SnAgCu** Solder joint peak is 230°C.
- **Lead-free Component** top package temperature peak is **245-255°C**



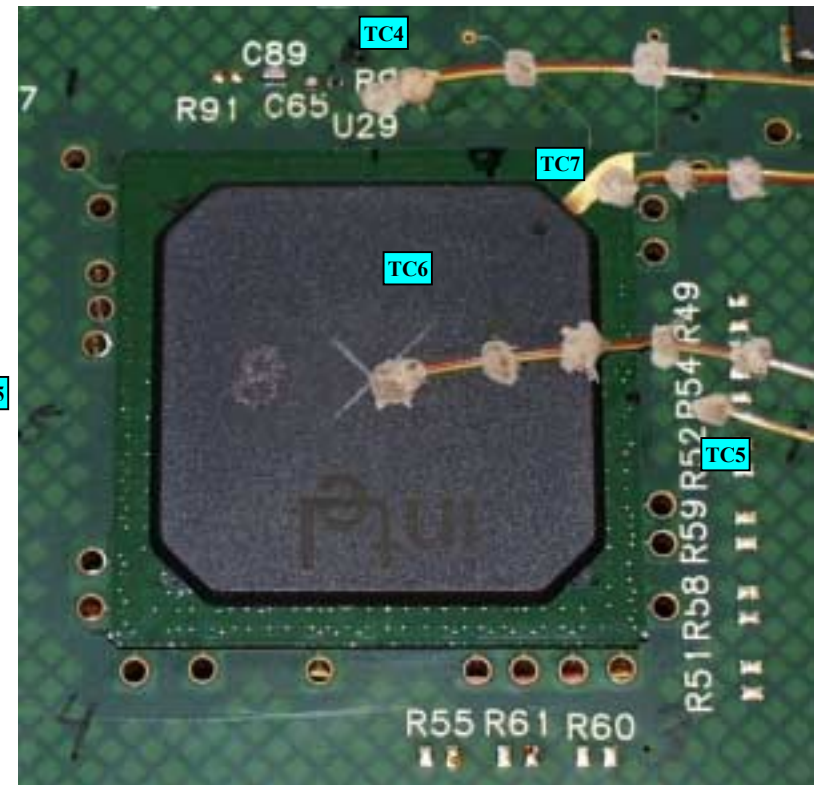
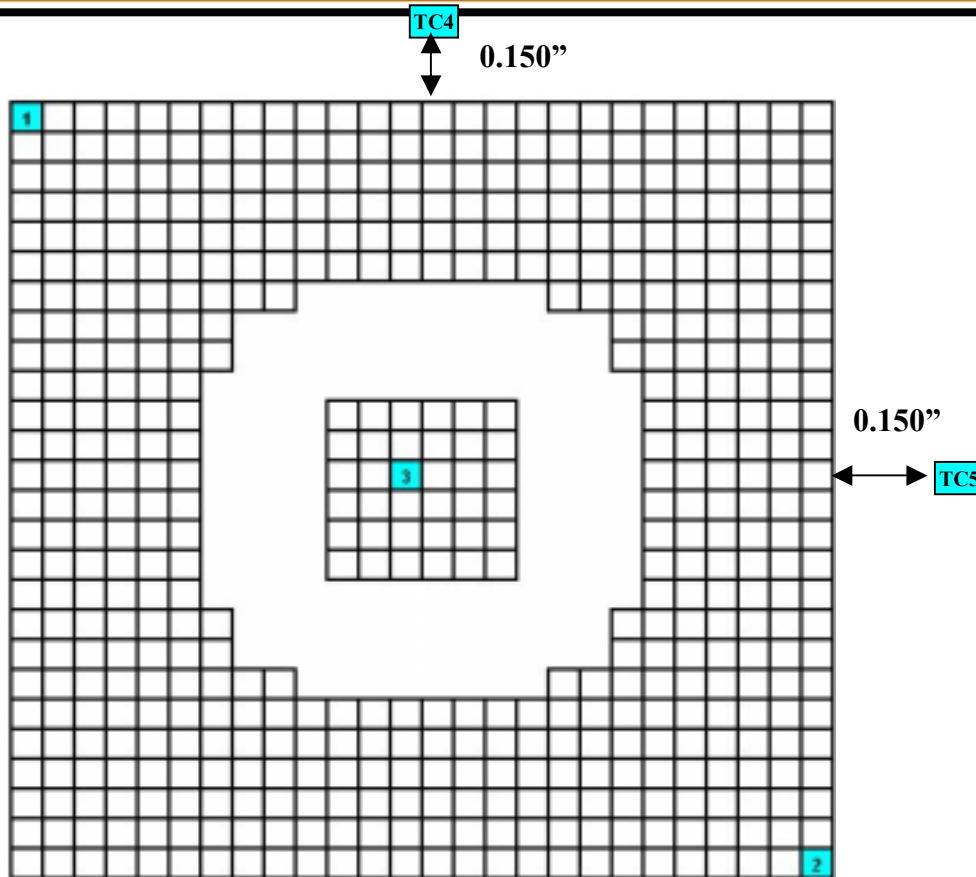
Phase 3 Rework Overview

- **Test Board: HP Payette**
- **2 board thicknesses: 93mil and 135mil**
- **Board dimensions: 7 x 17inch**
- **Approx: 14 copper layers**
- **FR4 Tg: 170°C**
- **2 Board Surface Finishes: Electrolytic NiAu and Immersion Ag**
- **Production Hot air convection rework machine (Machine X)**
 - **uBGA256 rework at Jabil**
 - **PBGA544 rework at Intel**
 - **CBGA933 rework at HP**





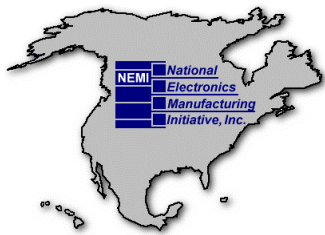
Example Thermocouple Placements for Phase 3 Rework Payette Board PBGA544 component



Thermocouples placed on solder joint: corners (TC1,TC2 and center (TC3)

Thermocouples placed on component body: center (TC6) and corner (TC7)

Thermocouples placed 150mils from component on board: TC4 and TC5




Phase 3 Rework profiling acceptance criteria

Lead-free SnAgCu rework:

- **Minimum solder joint temperature: 230- 235°C**
- **Solder joint time over reflow (217°C): 45-90 seconds**
- **Maximum component body temperature: 245-250°C (J-STD-020B)**

Tin-lead SnPb rework:

- **Minimum solder joint temperature: 200- 205°C**
- **Solder Joint time over reflow (183°C): 45-90 seconds**
- **Maximum component body temperature: 220-240°C (J-STD-020B)**



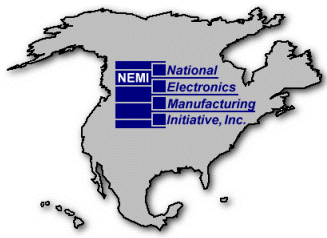
Lead-free Rework Development

Phase 3 Payette board

Results on uBGA256 (Jabil)

uBGA256 Rework Development
Jabil Circuits

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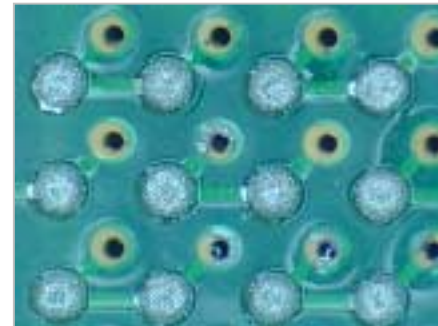


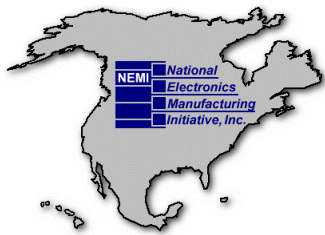
uBGA256 Rework Overview

- **Rework Site: Jabil**
- **Nozzle Size: 17mm x 17mm**
- **Redress Method: Non-contact scavenger-type suction device**
- **Paste Deposit: Screen print on board**

**Lead-free uBGA256 component
(17mm x 17mm, 1mm pitch)**

- **Thickness: 1.3 mm**
- **Volume: 376 Cummm**
- **J-STD-020B: 245°C**
- **JEITA ED-4701/301A: 260°C**





Phase 3 uBGA256 Rework Profile Results (Jabil)

93mil thick board

Lead-free rework profile:

Minimum Peak solder joint temperature: 230°C

Component top temperature: 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 temperature: 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 temperature: 245°C (16°C delta T).

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

Tin-lead rework profile:

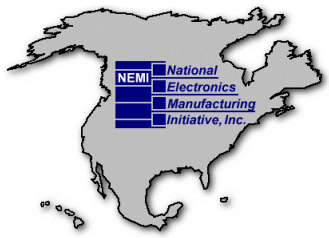
Minimum Peak solder joint temperature: 199°C

Component top temperature: 210°C (11°C delta T)

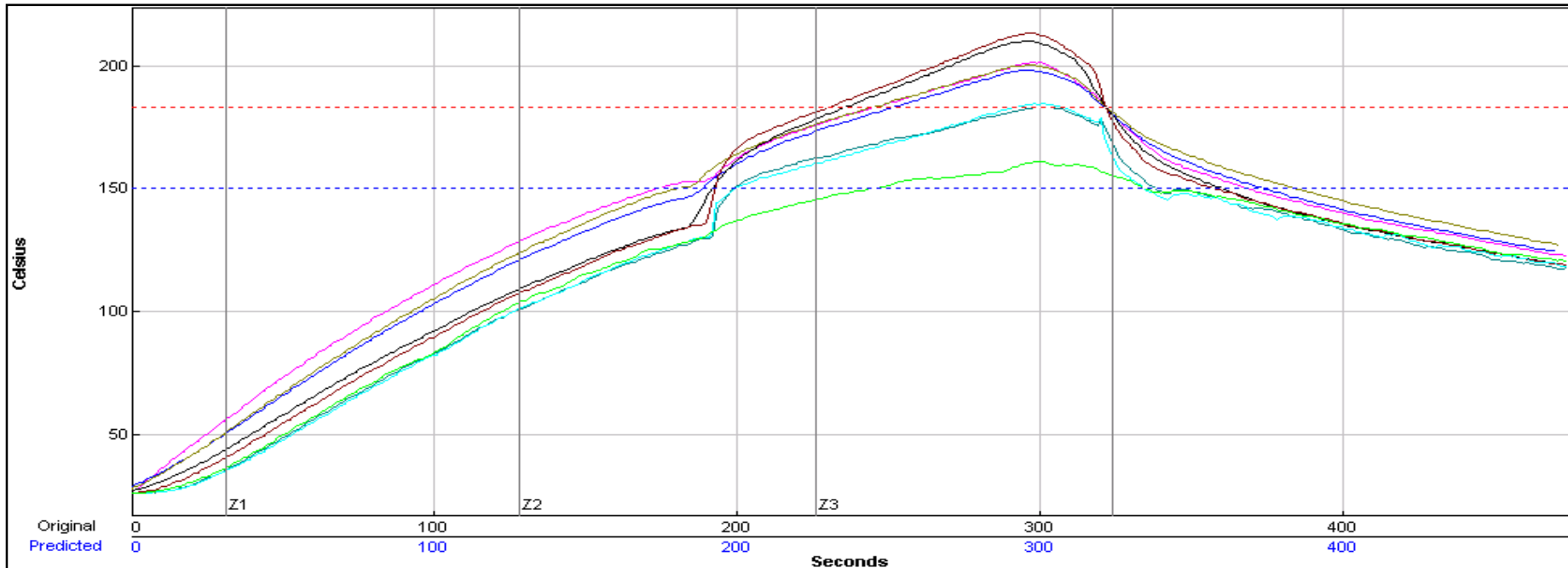
Temperature at 150mils from component on board: **183°C**

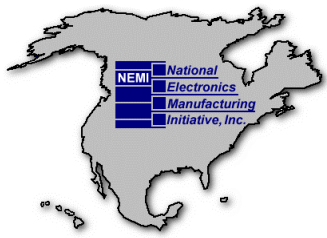
Profiles are within acceptance criteria.

Temperatures 150mils away from the component on the board exceeding solder alloy reflow temperature apart from 135mil lead-free boards

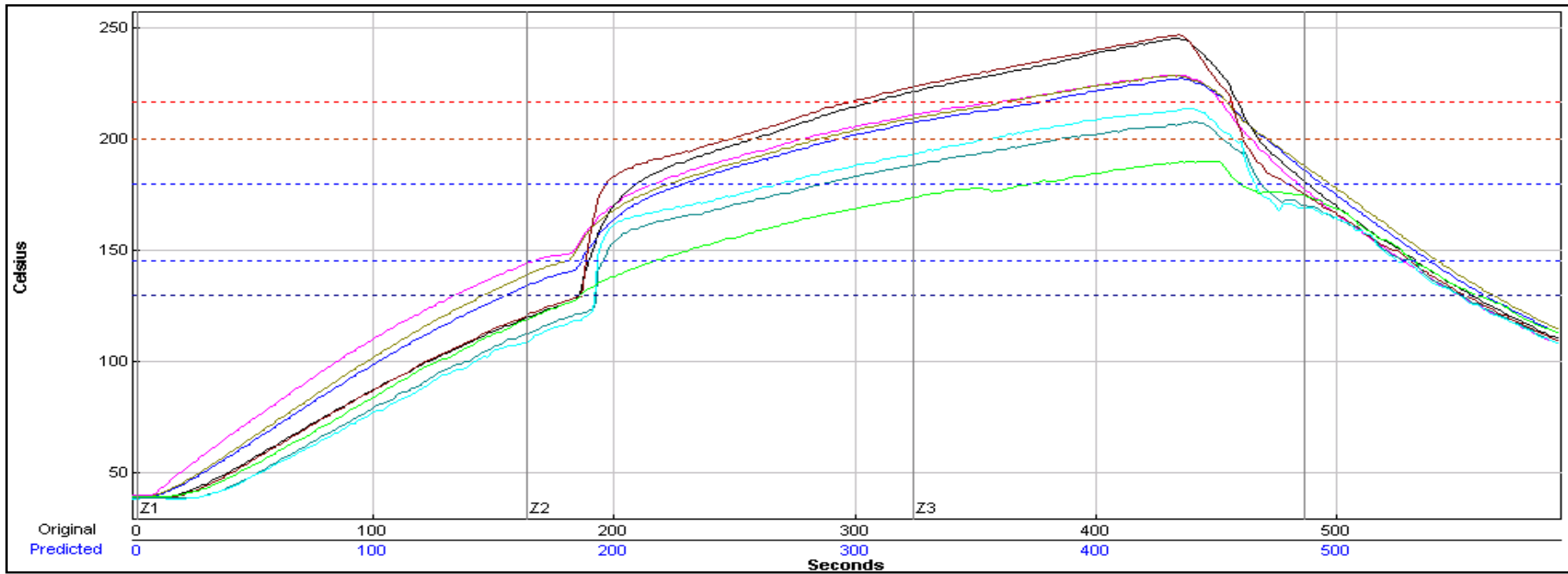


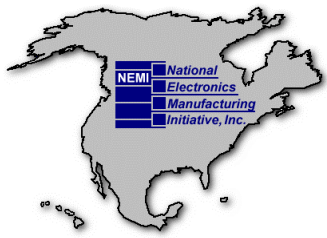
Payette 0.135": Tin-Lead Rework Profile (uBGA)





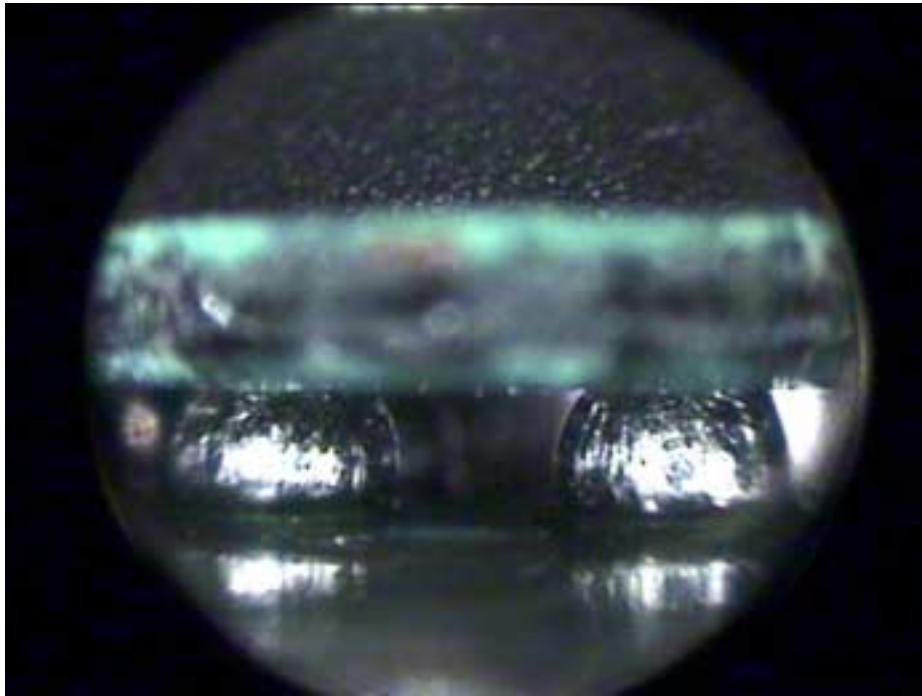
Payette 0.135": Lead-free Rework Profile (uBGA)



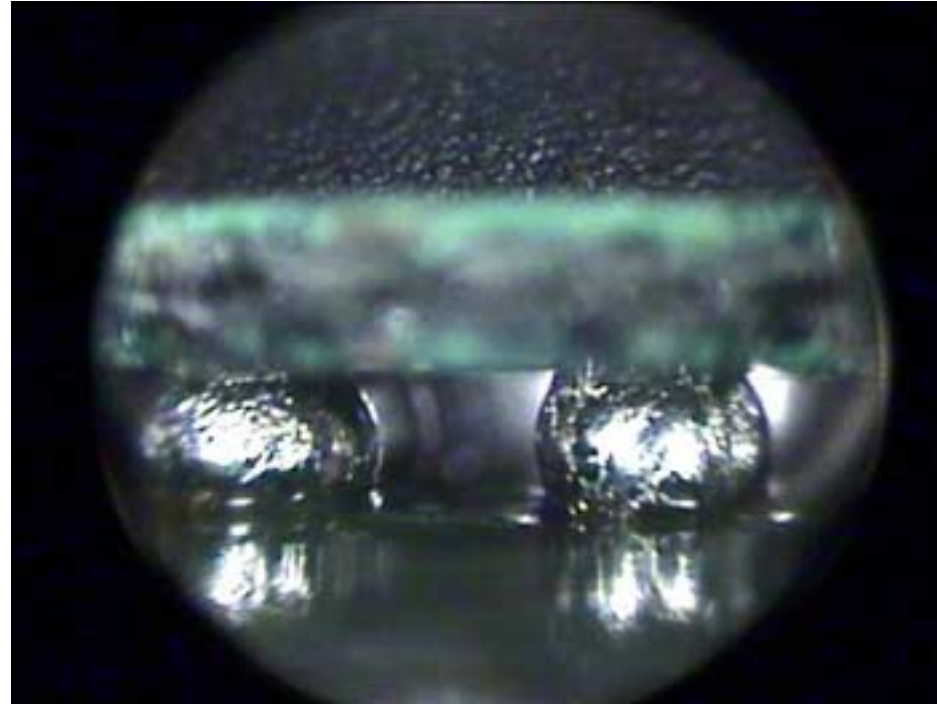


uBGA256 rework visual inspection

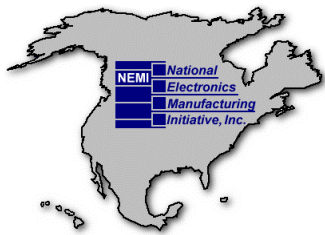
U40 SnPb rework



U40 SnAgCu rework




No real difference in visual appearance



Rework of uBGA component on Payette Reliability Test Board Summary

➤ **Issues and Challenges Observed**

- High bottom heater set point was used to reflow solder joints while minimizing package temperature.
 - Risk: Secondary reflow of adjacent components and bottom side components.
- A few adjacent CBGA components have registered opens (all combinations) and shorts (on lead-free attachments) post uBGA rework.
- Distance from uBGA to CBGA on board is 0.65inch (16mm)

A faint, light gray outline map of North America, including the United States, Canada, and Mexico, serves as a background for the text.

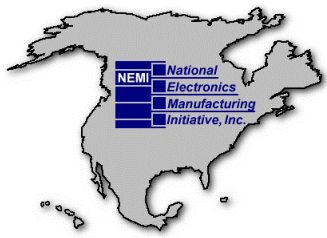
Lead-free Rework Development

Phase 3 Payette board

Results on PBGA544 (Intel)

PBGA544 Rework Development
Intel Corp.

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PBGA Rework Overview

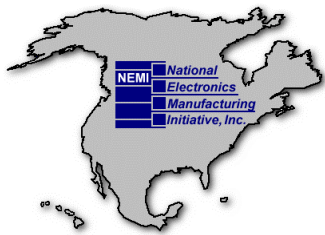
- Rework Site: Intel
- Nozzle Size: 35mm x 35mm
- Redress Method: Solder Wick
- Paste Deposit: Screen print on part



**Lead-free PBGA544 component
35mm x 35mm, 1.27mm pitch**

- Thickness: 1.9mm
- Volume: 2328 Cumm
- J-STD-020B: 245°C
- JEITA ED-4701/301A: **250°C**





Phase 3 PBGA544 Rework Profile Results (Intel)

93mil thick

Lead-free:

Minimum Peak solder joint temperature: 234°C

Component top temperature: 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 temperature: 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 temperature: 245°C (12°C delta T).

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

Tin-lead:

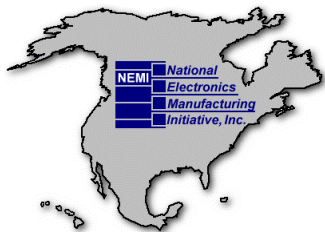
Minimum Peak solder joint temperature: 201°C

Component top temperature: 217°C (16°C delta T)

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

Joint and Component Profiles are within acceptance criteria.

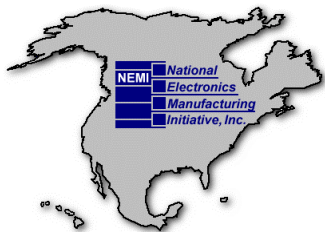
Temperatures 150mils away from the component on the board exceeding solder alloy reflow temperature for all cases



SnPb PBGA544 Profile Parameters

(Package corner temperature is higher than package top center)

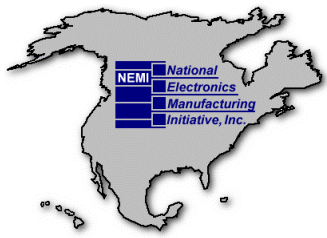
Profile Parameters	Target	Results			
		0.135" U29	0.135" U30	0.093" U29	0.093" U30
Minimum Temperature For Solder Ball	200°C	200.5°C	203.8°C	203.3°C	201.6°C
Maximum Package Temperature	220°C	Top:216.3°C Corner:219.8°C	Top:217.2°C Corner:225.0°C	Top:215.0°C Corner:218.1°C	Top:216.5°C Corner:222.0°C
Maximum Temperature Delta Between Solder Ball Thermocouples (ΔT_{x-y})	10°C	5.1°C	3.6°C	2.2°C	5.5°C
Temperature Between Lowest Solder Ball & Package Top (ΔT_z)	20°C	Top:15.8°C Corner:19.3°C	Top:13.4°C Corner:21.2°C	Top:11.7°C Corner:14.8°C	Top:14.9°C Corner:20.4°C
Time Above Liquidous (TAL)	45-90sec	84.94sec	90.55sec	83.76sec	79.30sec
Heating Rate	0.5-2.5°C/sec	1.28°C/sec	1.10°C/sec	1.26°C/sec	1.31°C/sec
Cooling Rate	TBD	-1.02°C/sec	-0.91°C/sec	-1.04°C/sec	-1.20°C/sec
Soak Time (120-183°C)	TBD	80.80sec	83.60sec	90.02sec	86.57sec



SnAgCu PBGA544 Rework Profile Parameters

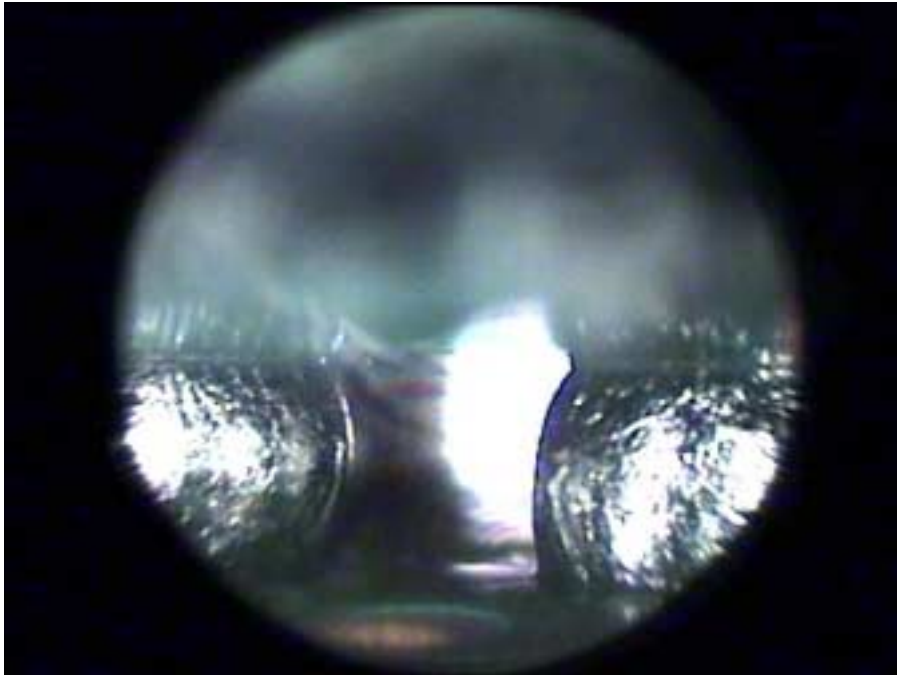
(Package corner temperature is higher than package top center)

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:245.1°C Corner:246.7°C	Top:244.0°C Corner:249.7°C	Top:245.1°C Corner:244.5°C	Top:244.7°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

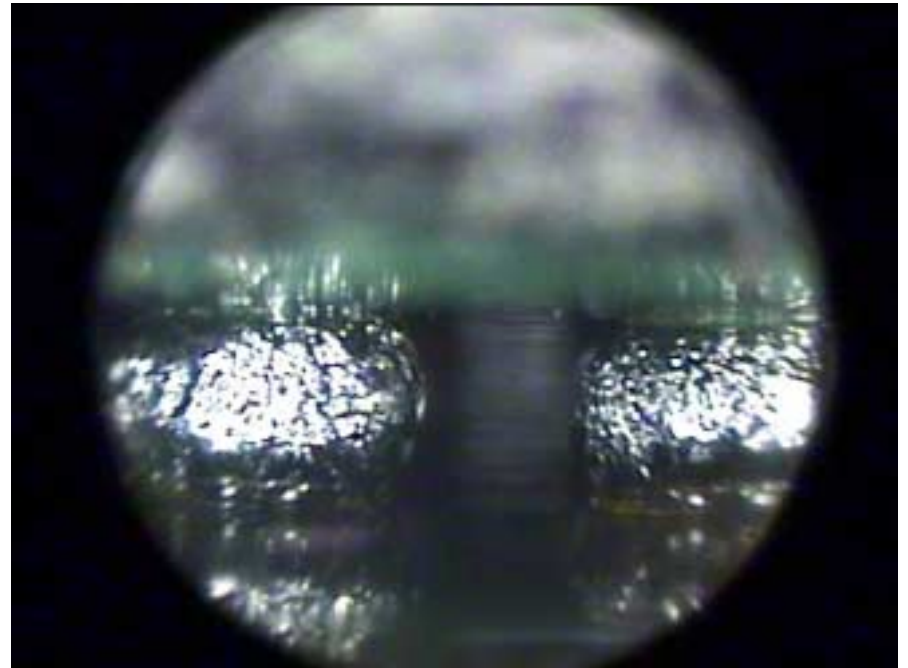


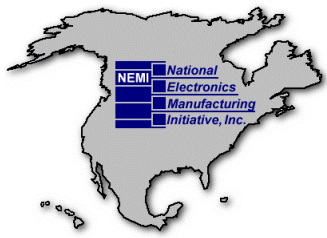
PBGA544 Rework Visual Inspection

U29 SnPb rework



U29 SnAgCu rework





Rework of PBGA Component on Payette Reliability Test Board Summary

➤ Issues and Challenges Observed

- High bottom heater set point was used to reflow solder joints while minimizing package temperature.
 - Risk: Secondary reflow of adjacent components and bottom side components although profiling of bottom side components no issues.
- Distance from PBGA to CBGA on board is 0.8inch (20mm). Double reflow issue with uBGA close to CBGA was not noticed when reworking the PBGA for the adjacent CBGA



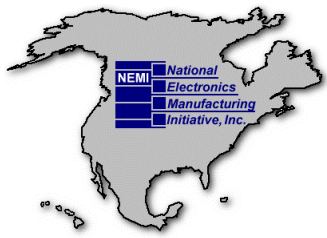
Lead-free Rework Development

Phase 3 Payette TQ Rework

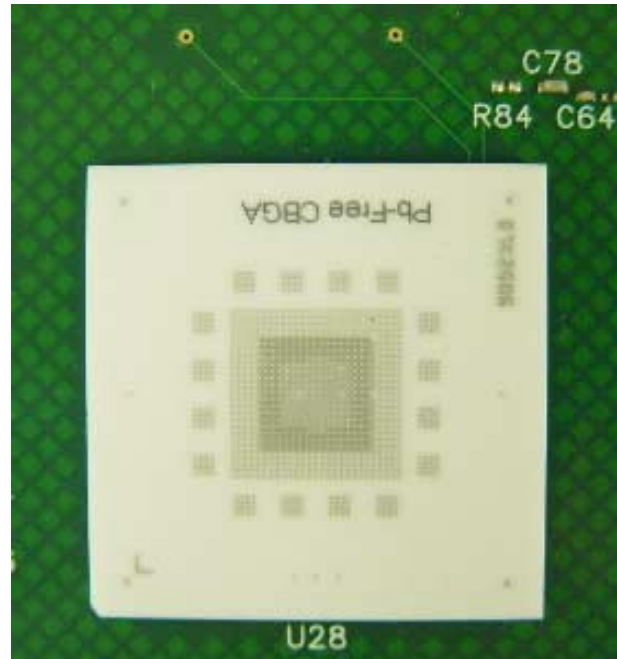
CBGA 937 Rework Development

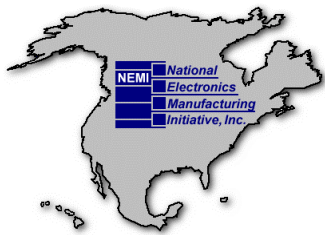
HP

Connect with and Strengthen Your Supply Chain



Lead-free CBGA on 135mil thick Payette board



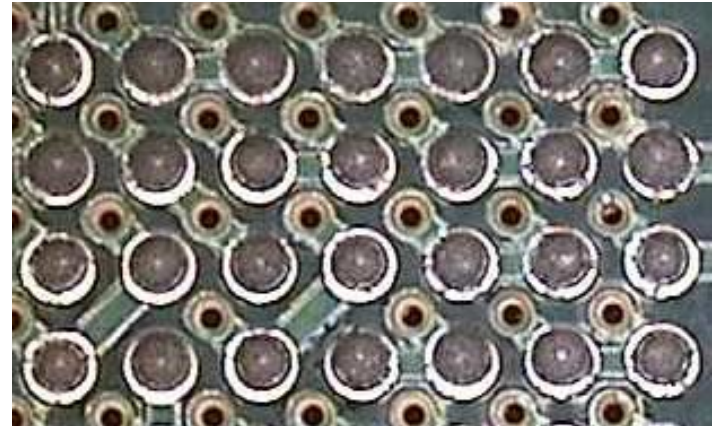


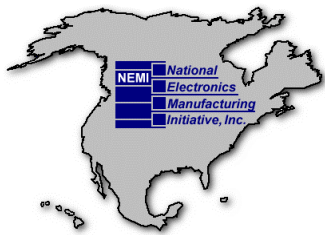
CBGA Rework Overview

- Rework Site: HP
- Redress Method: Non-contact scavenger-type suction device
- Paste Deposit: Paste Dispense

Lead-free CBGA933 (32.5mm x 32.5mm, 1mm pitch)

- Thickness: 1.6mm
- Volume: 1690 Cumm
- J-STD-020B: 245°C
- JEITA ED-4701/301A: **250°C**





Phase 3 CBGA933 Rework Profile Results (HP)

93mil thick

Lead-free:

Minimum Peak solder joint temperature: 239°C

Component top temperature: 239°C (0°C delta T).

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

Tin-lead:

Minimum Peak solder joint temperature: 199°C

Component top temperature: 201°C (2°C delta T)

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

135mil thick

Lead-free:

Minimum Peak solder joint temperature: 235°C

Component top temperature: 238°C (3°C delta T).

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

Tin-lead:

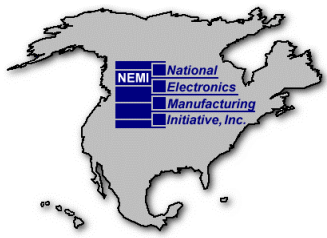
Minimum Peak solder joint temperature: 201°C

Component top temperature: 202°C (11°C delta T)

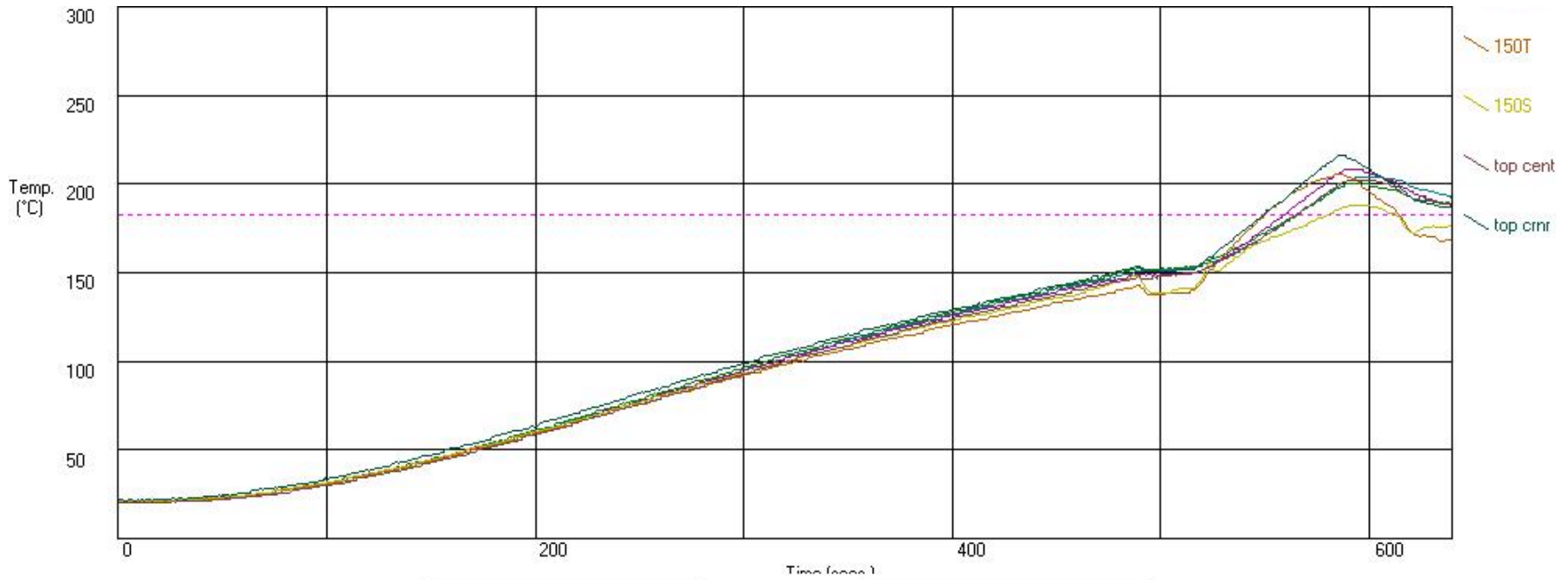
Temperature at 150mils from component on board: **206°C**

Joint and Component Body Profiles are within acceptance criteria.

Temperatures 150mils away from the component on the board exceeding solder alloy reflow temperature apart from 135mil lead-free boards



SnPb: Payette 0.135" Profile



- Solder Joint (coldest)

- Temperature: 201°C

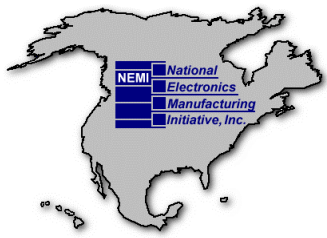
- Time >183°C: 75 sec

- Top of Package Center

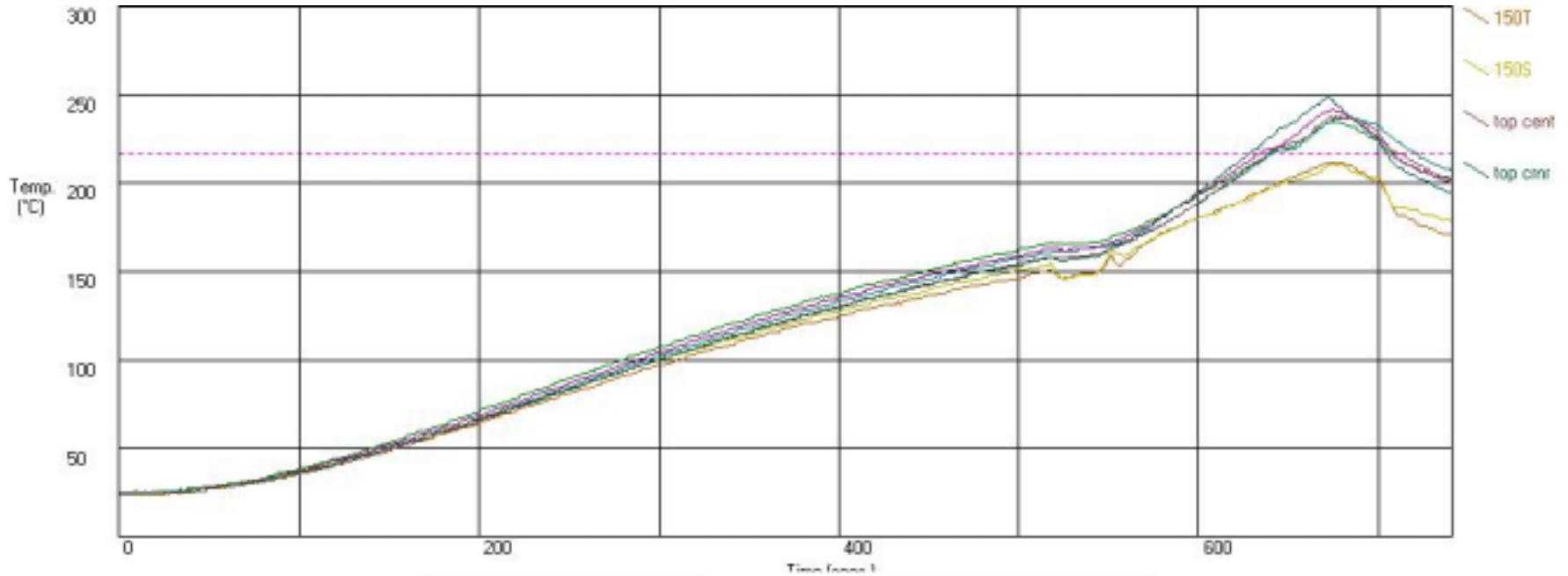
- Temperature: 202°C

- Time >183°C: 74 sec

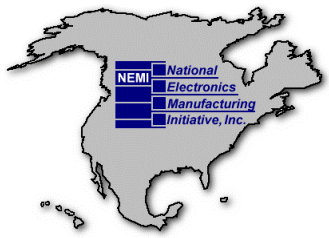
- Temperature at 0.150" away from package: 206°C



Lead-free: Payette 0.135" Profile

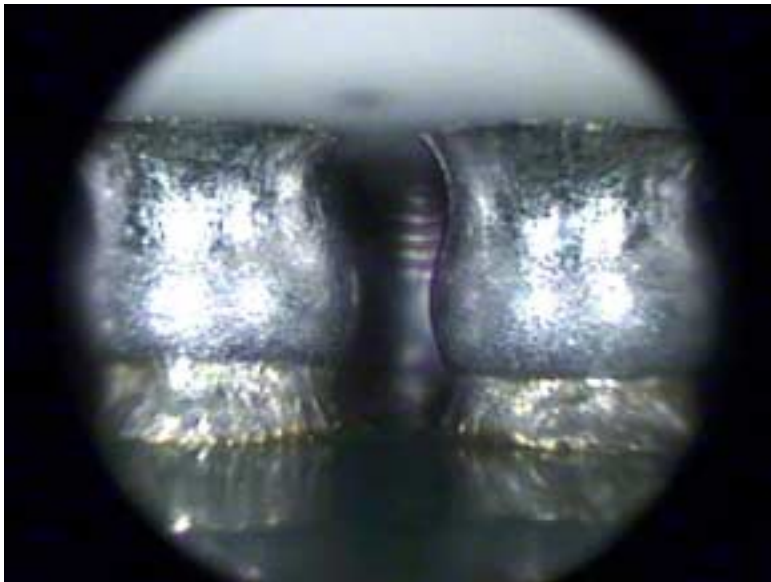


- Solder Joint (coldest)
 - Temperature: 235°C
 - Time >217°C: 66 sec
- Top of Package Center
 - Temperature: 238°C
 - Time >217°C: 71 sec
- Temperature at 0.150" away from package: 212°C

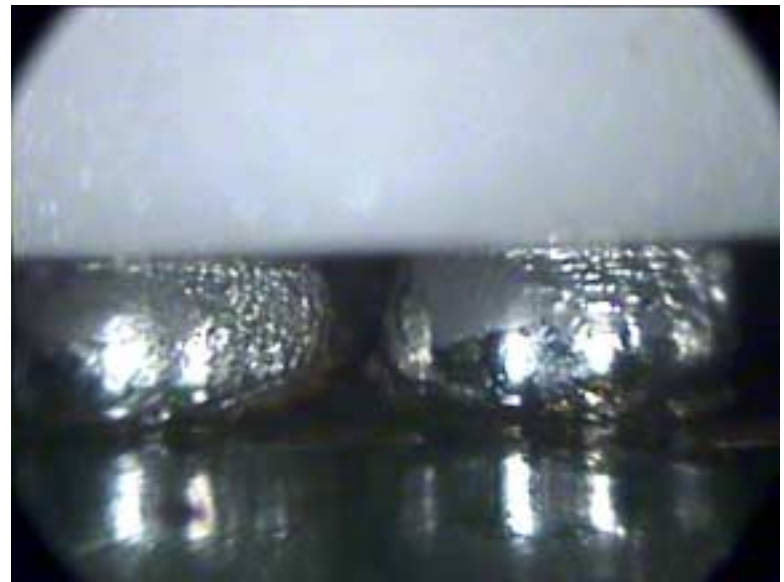


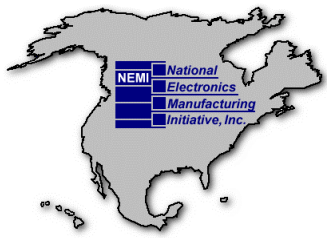
Visual Inspection after CBGA933 rework

U27 SnPb Rework



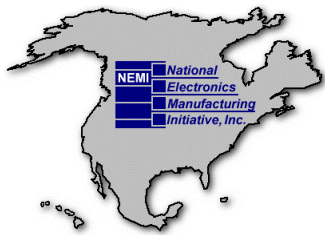
U27 Lead-free SnAgCu Rework





Rework of CBGA component on Payette Reliability Test Board Summary (HP)

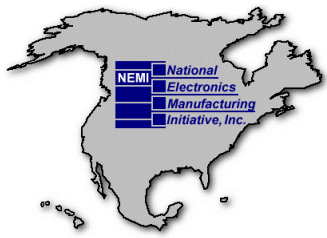
- **Issues and Challenges Observed**
 - During rework there tended to be fairly excessive PCB warpage (in the convex or upward direction)



Phase 3 Conclusions

Lead-free CBGA/PBGA/uBGA rework

- Phase 3 development showed lead-free rework could be developed successfully on 93mil and 135mil thick boards
- Increasing bottom side board preheat was found effective in reducing delta T between solder joint and component body
- Component Body Temperatures indicated in J-STD-020B were being conformed to for the three cases shown in Phase 3
- 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 (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.
- A particular issue was noticed after uBGA rework for an adjacent CBGA component which seems to undergo partial double reflow.
- Payette boards in Phase 3 have been reworked and will be in ATC reliability testing shortly



Acknowledgements

- **Thanks to all participants in the NEMI lead-free rework project**