

iNEMI Lead-free Micro-BGA, CBGA, Mictor Connector and Through-Hole PDIP Rework Evaluations

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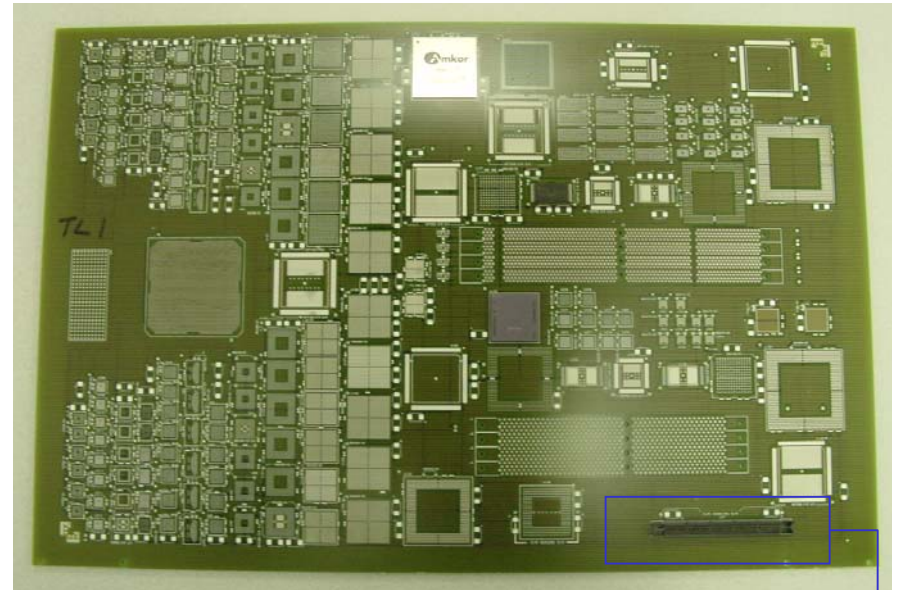
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Background

- iNEMI (InterNational Electronics Manufacturing Initiative) company collaboration (2003 to 2005) to develop Tin-lead and Lead-free rework processes for double-sided printed circuit boards in three thicknesses (0.062”, 0.093” and 0.135”) with electrolytic NiAu and Immersion Ag surface finishes on a variety of components.
- The following parts of the work presented
 - Phase 1: HP “Yunque” test board: Mictor connector rework
 - Phase 2: NEMI Payette reliability test board: CBGA, UBGA, DIP 16 rework

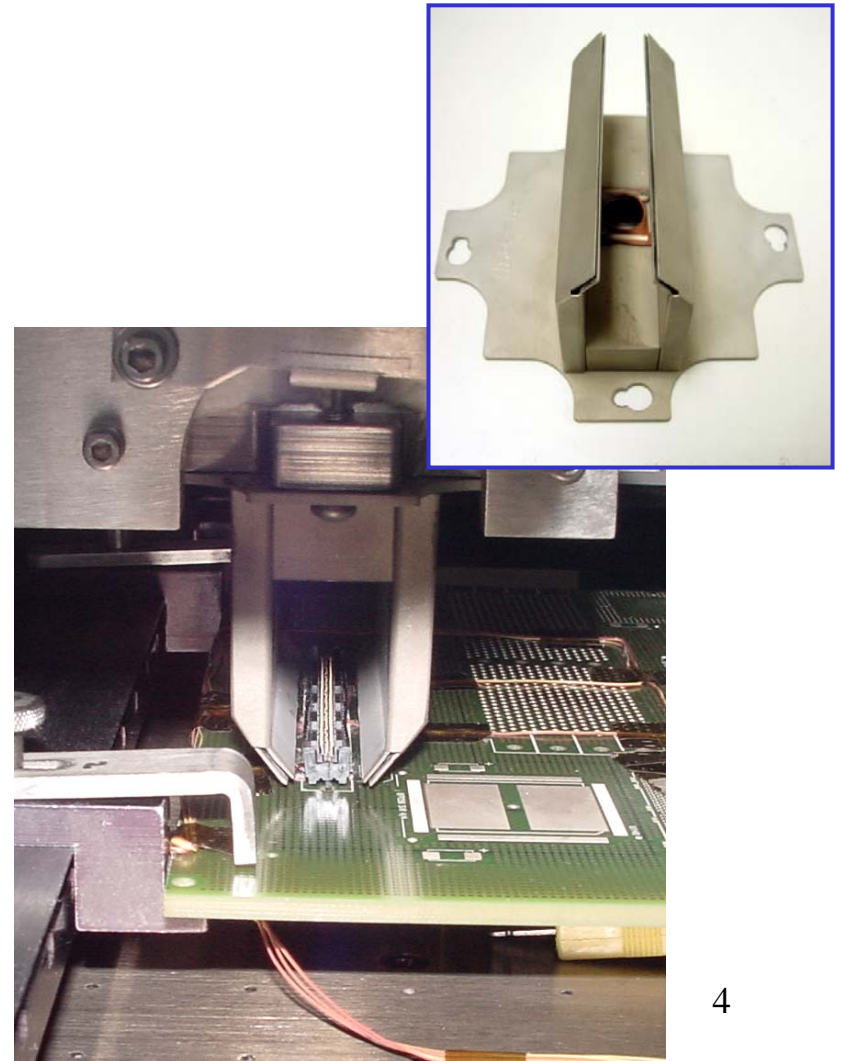
Mictor Connector Rework (Phase 1)

- Mictor Connector Rework development conducted on HP Yunque test board.
- Board dimension: 12" x 18" x 0.135".
- HP's Yunque test vehicle.



Test Vehicle and Component Used

- HP's Yunque Test Board
 - High Tg Laminate Material (Tg: 170°C)
 - Board Thickness and Finish: 0.062”(NiAu board finish),0.135”(Imm.Ag finish)
 - Board Dimensions: 18”x12”
- Component
 - 5 Segment Mictor Connector 190 pin
 - Component Pitch: 25mil
 - Component coating: pure tin
 - Board Location: J17 (close to edge of the board)



Phase 1 Mictor rework

- All four rework profiles were developed on 63mil and 135mil thick boards, two for SnPb and two for lead-free SnAgCu.
- Multiple attempts were conducted to improve rework profiles to reduce the large delta T between solder joint and component package with limited success.
- A significant thermal gradient also observed from one end of the connector to the other.

Phase 1 Mictor Rework Profiles

Parameters

Target Parameters	SnPb			LF SAC		
	Target	62mil	135mil	Target	62mil	135mil
SMT Solder Joint Min. Temp (°C)	200	196.1	216.7	230.0	219.4	236.7
PTH Solder Joint Min. Temp (°C)	200	195.1	196.7	230.0	212.8	219.4
Connector Max Temp. (°C)	245	206.1	215.0	245.0	230.6	245.0
Max Temp Delta Between Solder Solder Joints (°C)	10	13.3	19.4	10.0	28.9	27.8
Temp Btwn Lowest Solder Joint and Conn. Body (°C)	45	11.0	18.3	15.0	17.8	25.6
Minimum Time Above Liquidous (TAL) - (sec)	45	65.0	102.0	45.0	0.0	29.0
Maximum Time Above Liquidous (TAL) - (sec)	120	115.0	156.0	120	110.0	131.0
Board Temp. 50mil Away from Comp.	-	198.0	208.0	-	230.0	240.0
Board Temp. 150mil Away from Comp.	-	195.0	201.0	-	225.0	233.0

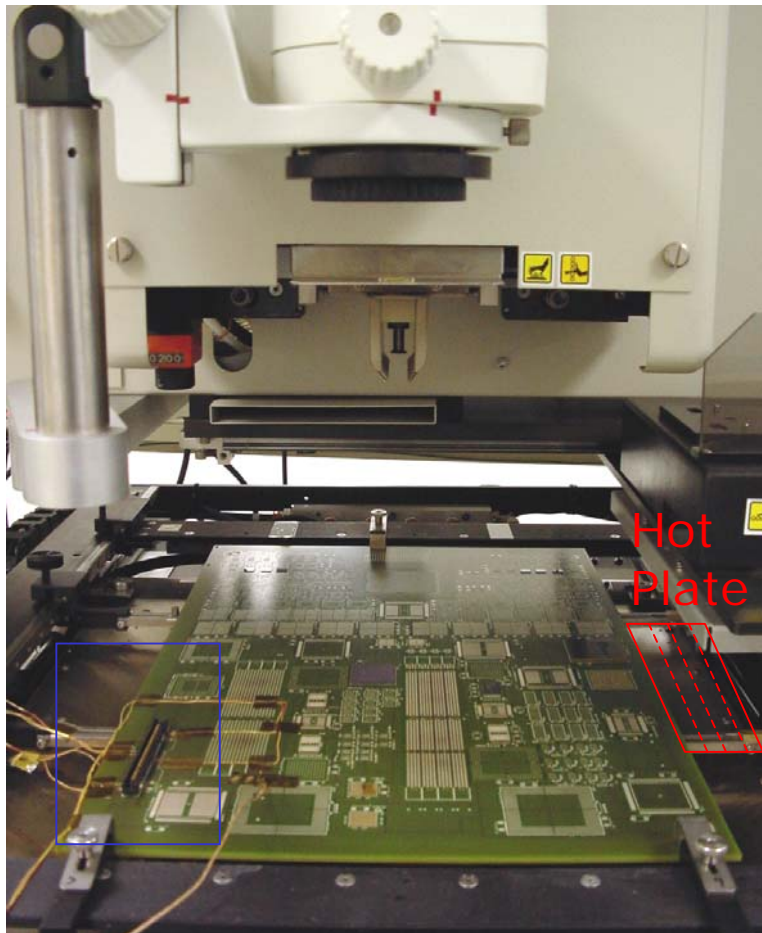
Phase 1 Mictor Rework

- Bottom-side heater was not uniformly distributing convection heat along the component.
- Location of the Mictor component near to the board edge
- Part of the board where the component was located was not directly over the pre-drilled holes where the hot gas were escaping.
- Insufficient heat into the board at this location so excessive top nozzle was used: resultant large delta T between solder joint and component (29°C).
- **Evaluation: Investigate “Resized” board**

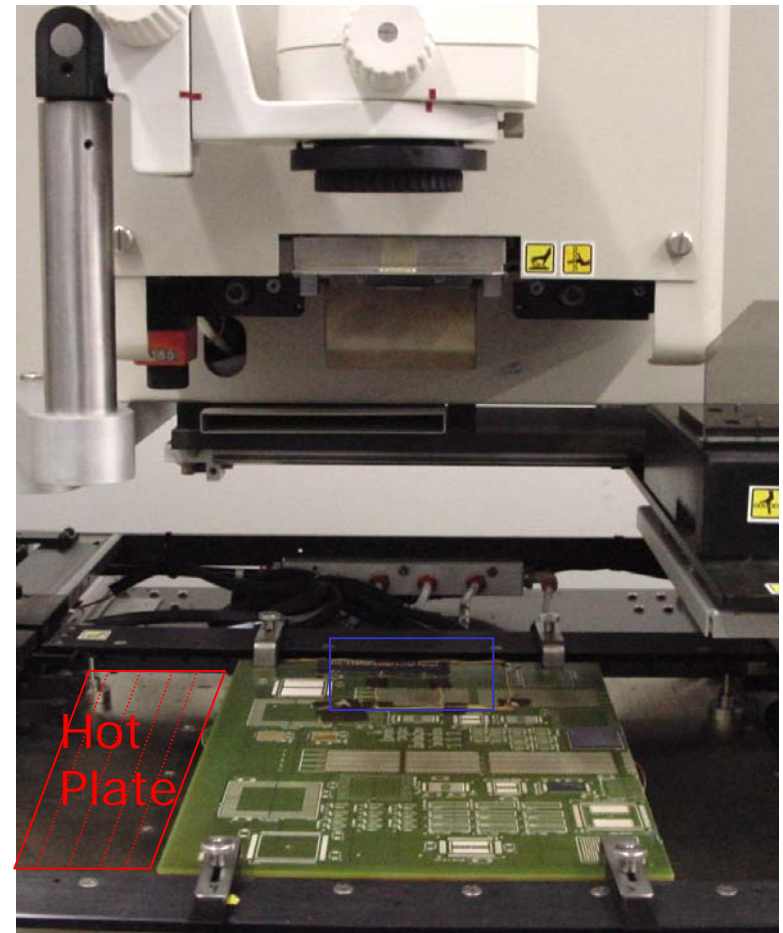
Setup for the “As Assembled” Board and the “Resized” Board

Full Assembly Setup

1/2 Size Assembly Setup



12 x 18 inch



12 x 9 inch

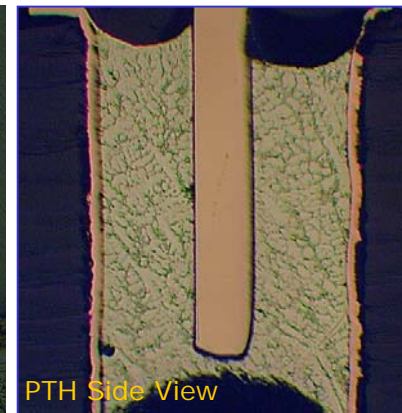
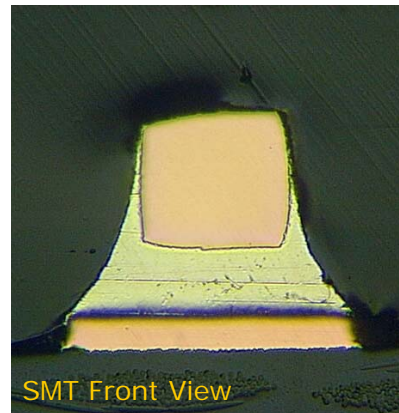
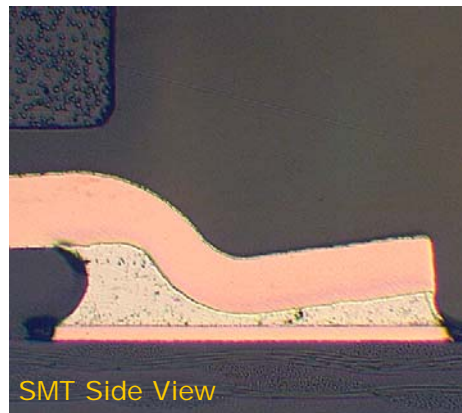
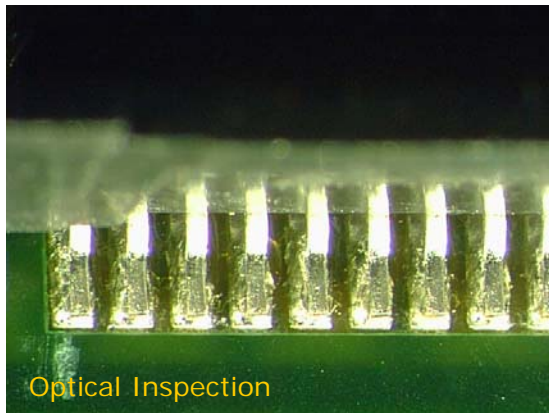
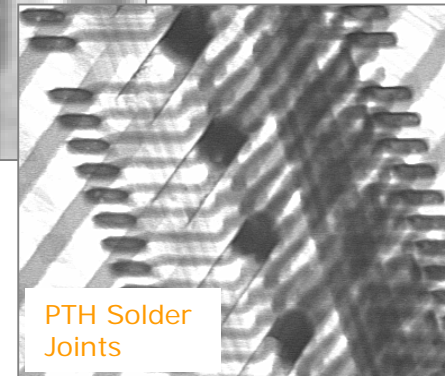
Comparison Between Full Board and the Half Sized Board Profiles

- Minimum peak temperature of 230°C was achieved for the SMT leads while we did note that the PTH connector body still reached 253°C.
- Delta T from 26°C to 23°C from full to half size board

Target Parameters	Lead-free SAC - 135mil		
	Target	Full Size	Half Size
SMT Solder Joint Min. Temp (°C)	230.0	236.7	250.6
PTH Solder Joint Min. Temp (°C)	230.0	219.4	230.0
Connector Max Temp. (°C)	260.0	245.0	253.3
Max Temp Delta Between Solder Joints (°C)	10.0	27.8	22.8
Temp Btwn Lowest Solder Joint and Conn. Body (°C)	15.0	25.6	23.3
Minimum Time Above Liquidous (TAL) - (sec)	45.0	29.0	94.0
Maximum Time Above Liquidous (TAL) - (sec)	120	131.0	167.0
Board Temp. 50mil Away from Comp.	-	240.0	243.0
Board Temp. 150mil Away from Comp.	-	233.0	241.0

Phase 1 Mictor rework

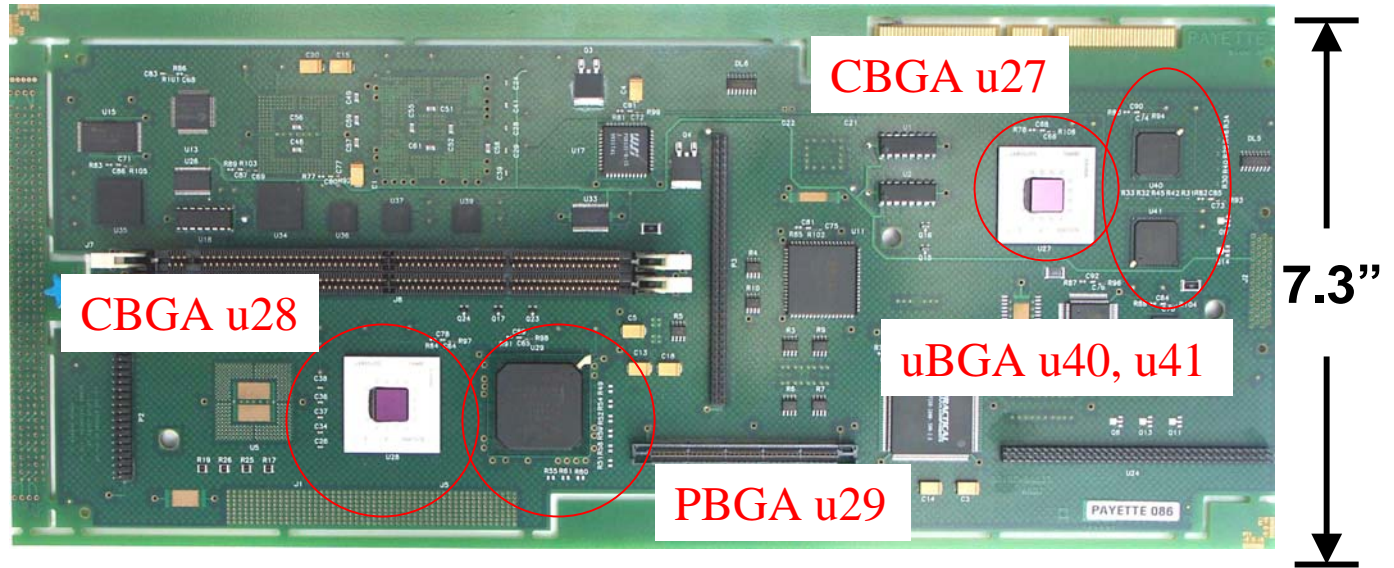
- One rework operation was successfully performed using the lead-free profile developed **on 135mil thick half sized board.**



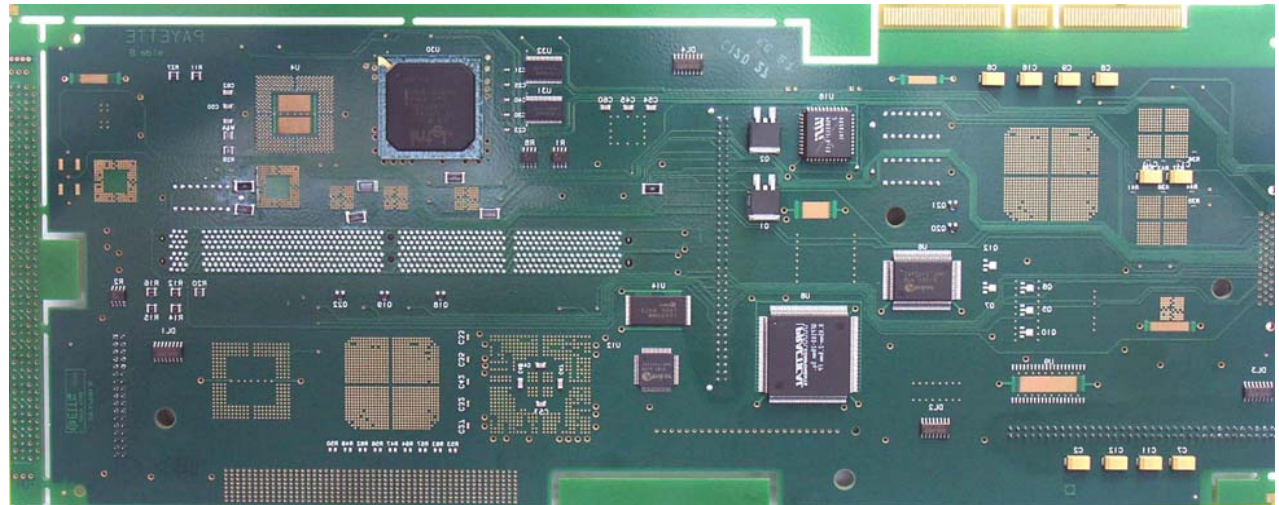
CBGA and uBGA Rework (Phase 2)

NEMI Payette board

Side A (topside)
14 Cu layers,
0.093" and
0.135" thick,
Electrolytic NiAu
and Imm Ag



Side B (bottom)
(SMT + Wave)



17"

Phase 2 uBGA and CBGA Rework

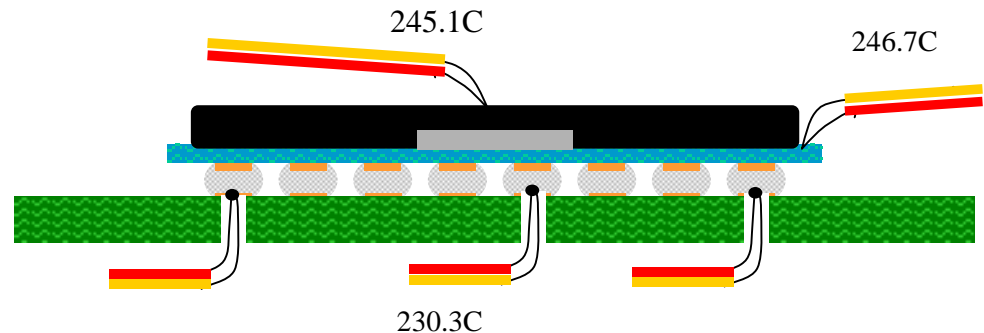
- Conventional hot gas rework equipment
- Board thickness and surface finish:
 - 0.093” (Imm Ag and Electrolytic NiAu)
 - 0.135” (Electrolytic NiAu)
- Components and U location:
 - uBGA256 1mm pitch (locations U40, U41)
 - CBGA937 1mm pitch (locations U27, U28)
- Component spheres:
 - SnPb
 - SnAgCu
- No-clean Solder Pastes:
 - Sn3.9Ag0.6Cu
 - Sn37Pb
- Atmosphere: Air
- No. of copper layers: 14
- Laminate type : High Temp Laminate FR4 (Tg: 170°C)

Rework Temp. Profile Comparison

- Challenge
 - Minimize top package temperature while allowing sufficient heat to form a solder connection
- Lead-free Rework Observations
 - Tighter process due to package temperature limitation
 - Minimum, 230°C for solder joint temperature for rework
 - Lead-free profiles took approximately ~35% longer than SnPb profiles

Phase 2 Rework Profiling Target Parameters

Process	Min. Joint Temp (C)	Time Above Liquidus (sec)	Max Body Temp (C)
SnPb	200 - 205	45 - 90	220 - 240
LF SnAgCu	230 - 235	45 - 90	245 - 260



Actual Monitored Rework Reflow Values

CBGA and uBGA Rework (Phase 2)

- For the lead-free profile, the minimum solder joint temperatures were approximately 230°C while the maximum package temperature was approximately 245°C.
- In most cases, the board temperature 150mils away from the rework component was above the liquidus reflow temperatures (which was also the case during tin-lead rework).

CBGA and uBGA Rework (Phase 2)

- For lead-free rework, bottom side heater set point needed to be elevated compared to SnPb reflow profiles.
 - Help minimize the top nozzle heaters from over heating the top of the package beyond its JEDEC 020C package temperature limitations.
- Increasing the bottom side heaters was found to have an adverse effect on bottom side and adjacent components in terms of exceeding liquidus temperatures.

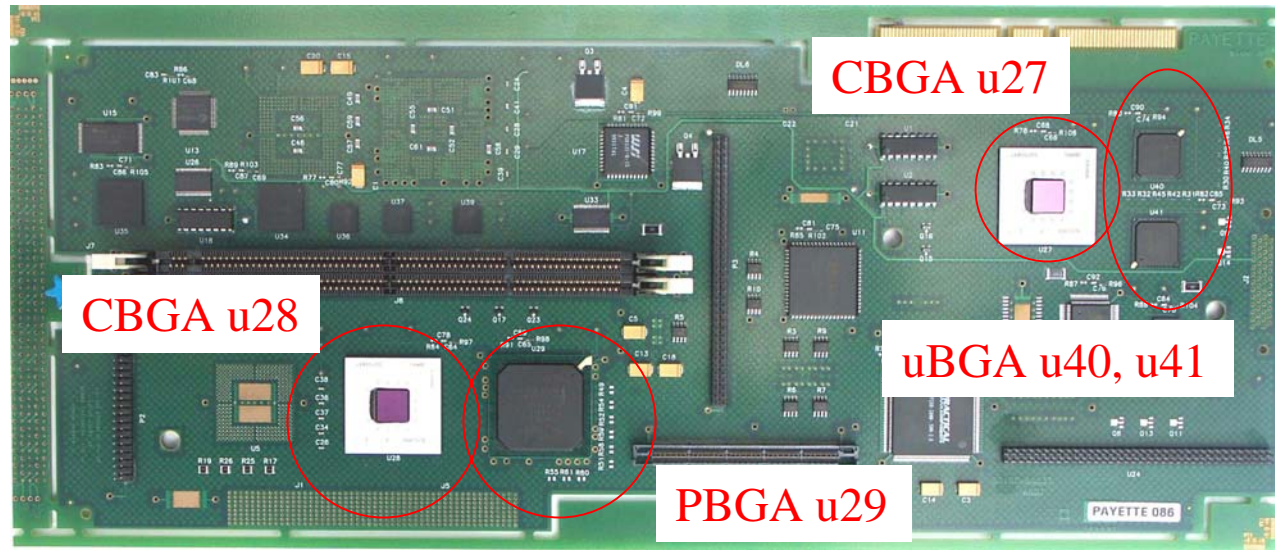
CBGA and uBGA Rework (Phase 2)

- During the uBGA rework, it was observed that the nearby CBGA at location U27 (near board edge) was affected by the heat resulting in open connections.
- Not observed for an adjacent uBGA that was also spaced at a similar distance to the CBGA.
- For a PBGA544 component which was reworked near to the other CBGA at U28 (close to center of board) there were no similar opens reported at U28 CBGA location.

CBGA and uBGA Rework (Phase 2)

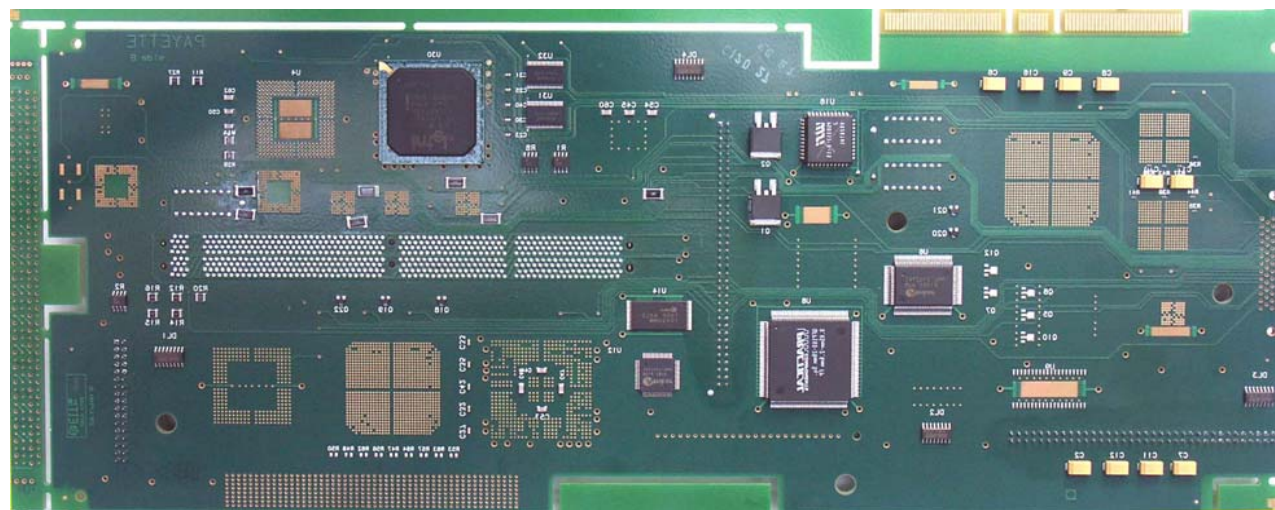
NEMI Payette board

Side A (topside)
14 Cu layers,
0.093" and
0.135" thick,
Electrolytic NiAu
and Imm Ag



7.3"

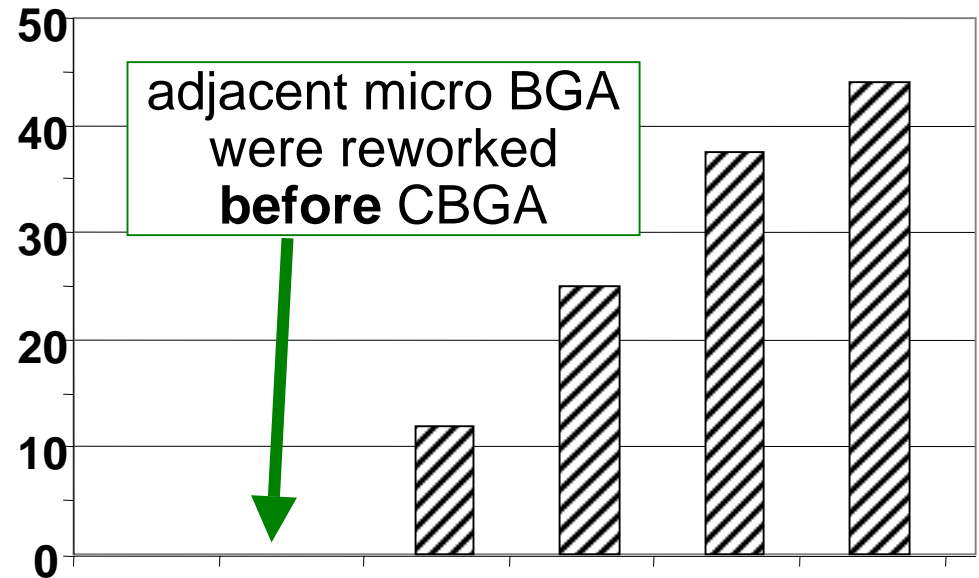
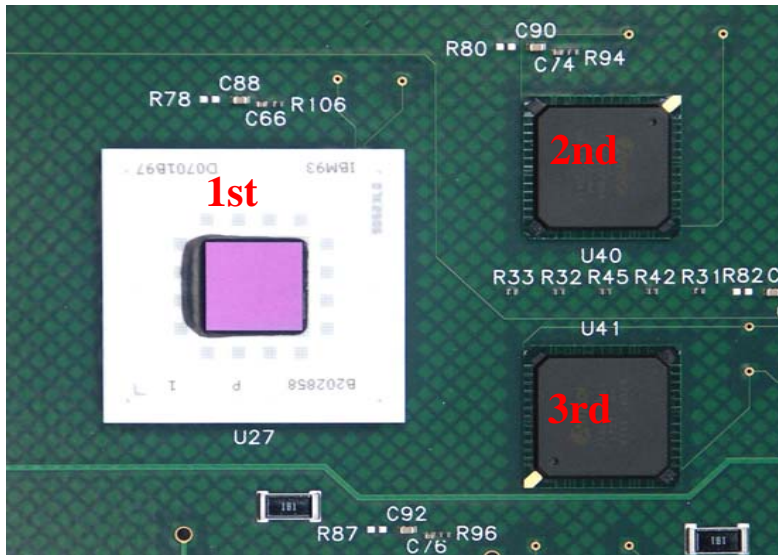
Side B (bottom)
(SMT + Wave)



17"

Rework Order Impact on the Yield of CBGAs

% Fail



Imm Ag 93
SAC 93
SnPb 93
SnPb 135
SAC 135

CBGA Rework Conditions

CBGA and uBGA Rework (Phase 2)

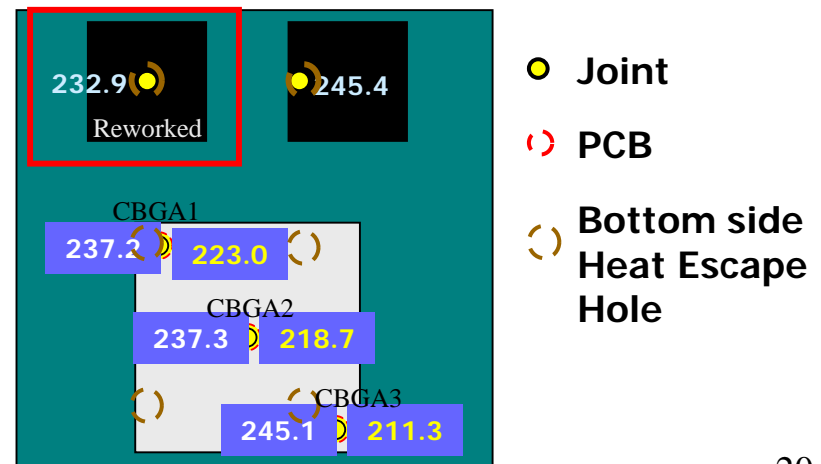
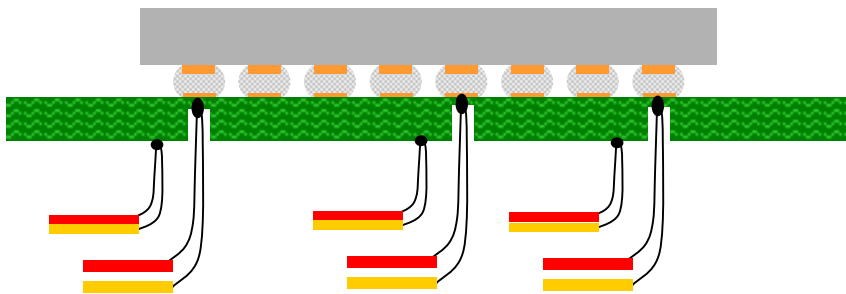
- Shielding of the CBGA using kapton tape during rework of the uBGA employed with no subsequent opens observed post rework.
- However, reliability was found to have decreased for the U27 CBGA after ATC testing.
- A side experiment to better understand the thermal characteristics of adjacent heating.

CBGA-uBGA Interaction Study

- Observations:
 - Adjacent CBGA had liquidus temperatures (0.65” away)
 - Thermal gradient across the CBGA package (see table)

Joint and Package Temp Monitored Values

TC Location	Peak Temp (C)
Reworked uBGA Joint	232.9
Adjacent uBGA Joint	245.5
CBGA 1 Joint	223.0
CBGA 1 Bottom PCB	237.2
CBGA 2 Joint	218.7
CBGA 2 Bottom PCB	237.3
CBGA 3 Joint	211.3
CBGA 3 Bottom PCB	245.1



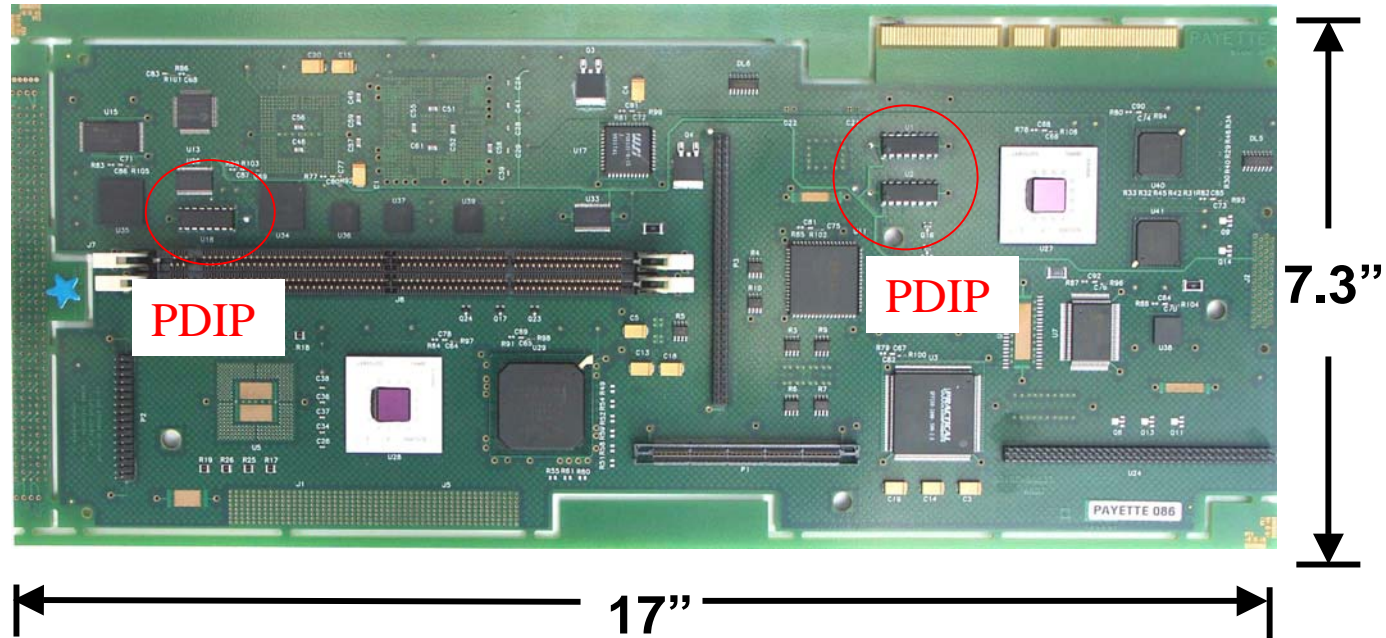
Some parts of CBGA solder joints below liquidus temperature

DIP16 (Phase 2)

- NEMI Payette board
 - Board thickness and finish: 0.135” (Electrolytic NiAu)
 - Board Dimension :17” x 7”
- Component: PDIP16 (tin-lead and lead-free pure tin)
 - 3 U locations: u1, u2, u18
- Mini-pot Solder fountain equipment
 - Wave flux: No-clean water based VOC-free
 - Atmosphere: Air
 - Pre-heater (when needed) : Hot Air Convection BGA Rework
 - Rework nozzle:0.484” (12.29mm) x 0.955” (24.26mm)

DIP16 Rework (Phase 2)

Side A (topside)
14 Cu layers,
0.135" thick,
Electrolytic NiAu



Note: For these experiments, bare boards were assembled, removed and reworked with DIP16 components using only a mini-pot wave rework machine with no other components populated

“1st pass” Wave Soldering of DIP16 components with Mini-pot Machine

- Considerations:
 - No Board Preheat
 - Goal: Achieve 100% holefill
- Results:
 - SnPb solder holefill
 - 260°C pot temperature
 - 5 to 8 seconds dwell time
 - SnAgCu solder holefill
 - 274°C pot temperature
 - 10 seconds dwell time

DIP16 Component Removal with Mini-pot machine

- Consideration:
 - No Board Preheat
 - Goal: Achieve 100% holefill
- Results
 - SnPb solder
 - 260°C pot temperature
 - 6 seconds dwell time
 - SnAgCu solder
 - 274°C pot temperature
 - 15 to 20 seconds dwell time

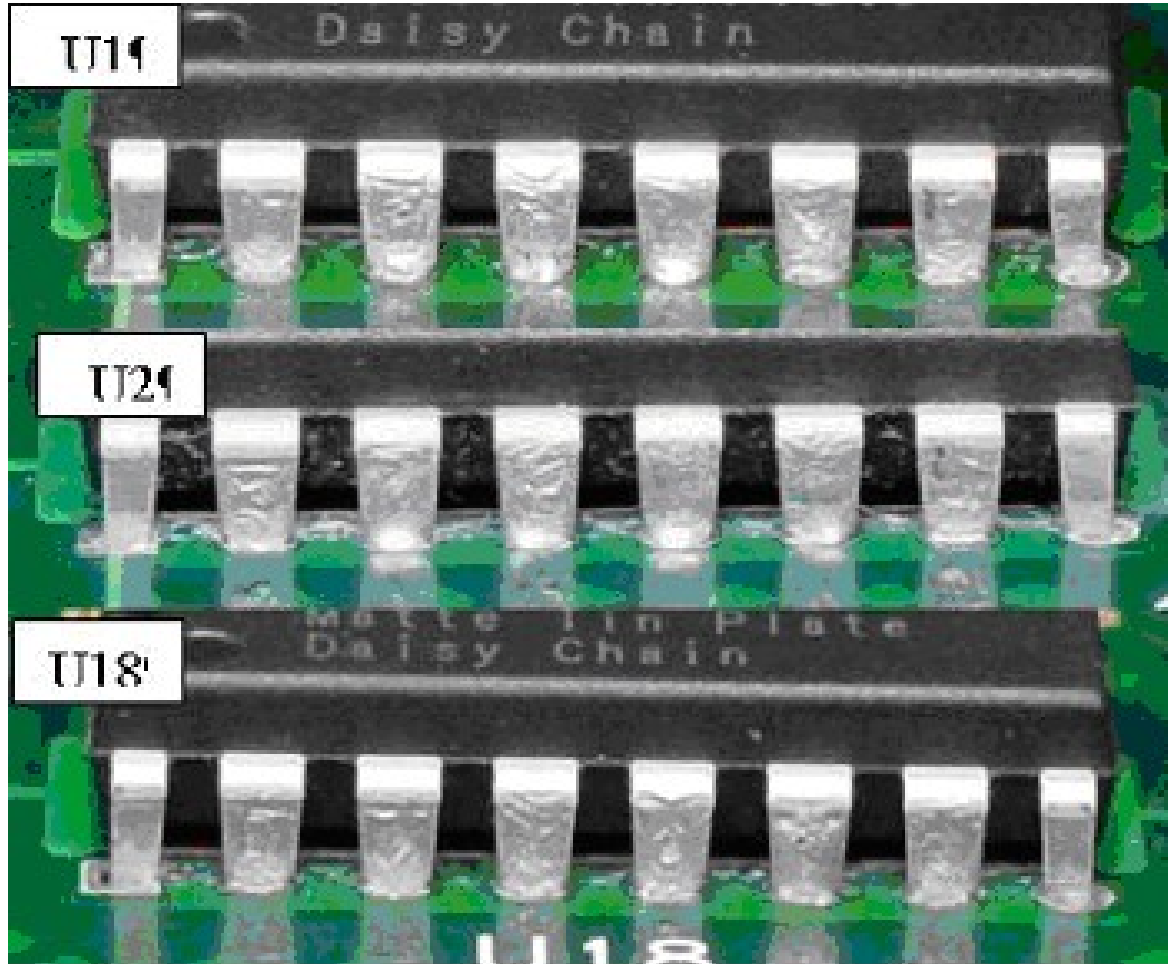
PDIP 2nd Pass **Rework** Soldering with Mini-pot

- Consideration:
 - No Board Preheat
 - Goal: Achieve 100% holefill
- Results:
 - SnPb solder
 - 260°C pot temperature
 - 12 seconds dwell time
 - **SnAgCu solder**
 - 274°C pot temperature
 - **30 seconds** dwell time

Total Soldering Times with Mini-pot Wave Rework Machine

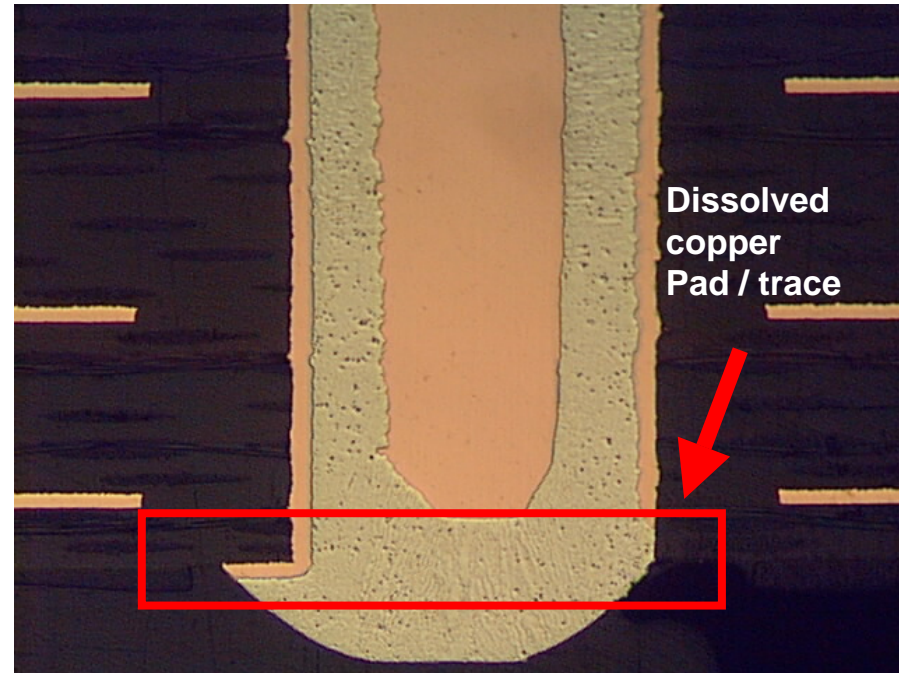
- Process: **Wave, removal, rework** (No board Preheat used)
- SnPb solder
 - 260°C pot temperature
 - 26 seconds dwell time
- **SnAgCu solder**
 - 274°C pot temperature
 - 60 seconds dwell time
 - Increased pot temperatures and dwell times needed for lead-free SnAgCu solder

Examples of SnAgCu Reworked PDIP Components



Mini-Pot Results Showing PCB Copper Dissolution of Reworked PDIP16 Solder Joint (SnAgCu, NiAu board, 135 mil thick)

- Challenge
 - Simulate current production process
 - Remove and replace a PDIP without board preheat
- Rework Observations
 - Achieving sufficient holefill resulted in the copper pad/trace dissolution on the bottom-side



Cross-section View of Solder Joint (274°C)

Total time in mini-pot= 60sec

Enough time to dissolve nickel layer

DIP 16 Rework (SnAgCu) Board **Preheat** Evaluations

- Board preheat was evaluated for lead-free SnAgCu 1st pass and reworked PDIP16 component.
- Preheat performed using a BGA hot gas rework machine.
- The topside board temperature for a non-preheated board was 80°C.
- Preheating the board to 120°C topside using the BGA hot gas rework machine followed by DIP rework showed better hole-fill at reduced dwell times.

Typically current SnPb production processes for these types of boards do not use board preheat for mini-pot rework.

Phase 1 Conclusions (Mictor)

- Due to the location of the Mictor connector relative to the bottom heaters (at board edge), an increased delta T between joint and component observed.
- When the board was cut in half (which could not be done in real life), a more uniform temperature delta was observed on board with reduced delta T between joint and component.
- More development needed for better bottom-side heat distribution to reduce top nozzle heat needed for rework machines especially on larger sized boards (12 x 18 inch).
- New development program to investigate heat into a board during rework (iNEMI rework optimization project).

Phase 2 Conclusions (CBGA/ UBGA rework)

- For the CBGA and uBGA rework, the board temperature (150mils away from component) exceeded the liquidous temperature for SnPb and SnAgCu soldering.
- Issue when reworking the uBGA256 near to the CBGA at location U27. Adjacent CBGA underwent a **partial** double reflow reducing solder joint integrity.
- Bottom-side heat and thermal uniformity critical to bring board to proper lead-free rework temperatures.
- Rework machines need more development with emphasis on optimized lead-free rework profiles, optimized machine development and machine repeatability.
- These are under investigation in new iNEMI rework optimization project.

Phase 2 Conclusions (DIP16 Wave Rework)

- SnAgCu solder needs more dwell time and higher solder pot temperatures to achieve similar results to SnPb wave rework.
- SnPb rework soldering used 260°C for 12 seconds dwell time.
- SnAgCu rework soldering used 274°C for 30 seconds dwell.
- Copper barrel knee dissolution on NiAu boards observed during SnAgCu mini-pot rework from higher pot temperatures and dwell times. Total time in mini-pot (wave, removal, rework) was 60 seconds at 274C compared to 26 sec at 260C for SnPb.
- Preheating the board prior to lead-free soldering exhibited better soldering results, one area of investigation in new iNEMI rework optimization study as well as different component types from DIP16.

Acknowledgements

- Authors would like to thank all the participants of the NEMI lead-free assembly and rework project.