



New England Lead Free Electronics Consortium

Greg Morose

Toxics Use Reduction Institute

University of Massachusetts Lowell



Lead-free Electronics Challenges

1. Which lead-free solders?



2. What process modifications?



3. Which component finishes?



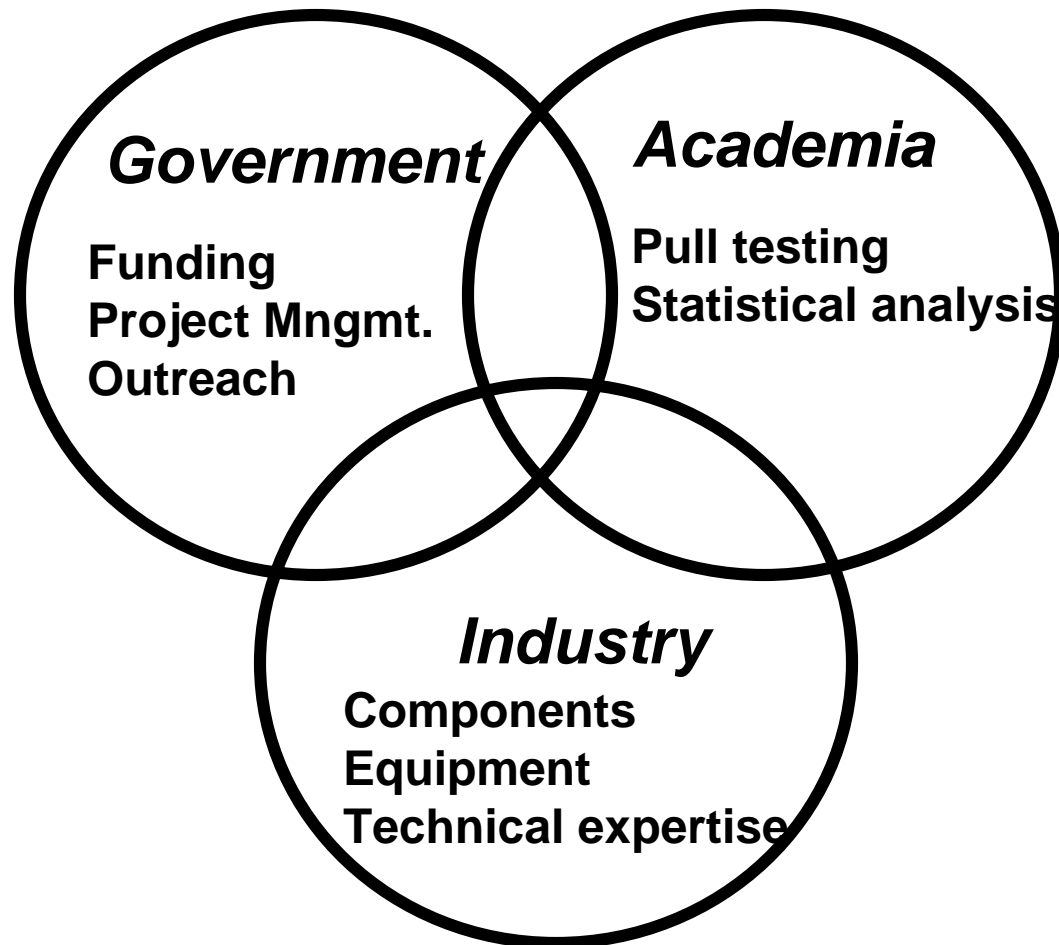
4. Which board finishes?



Lead-free Electronics Initiatives

- **Industry association sponsored initiatives**
- **Company specific initiatives**
- **Government/academia/industry partnerships**

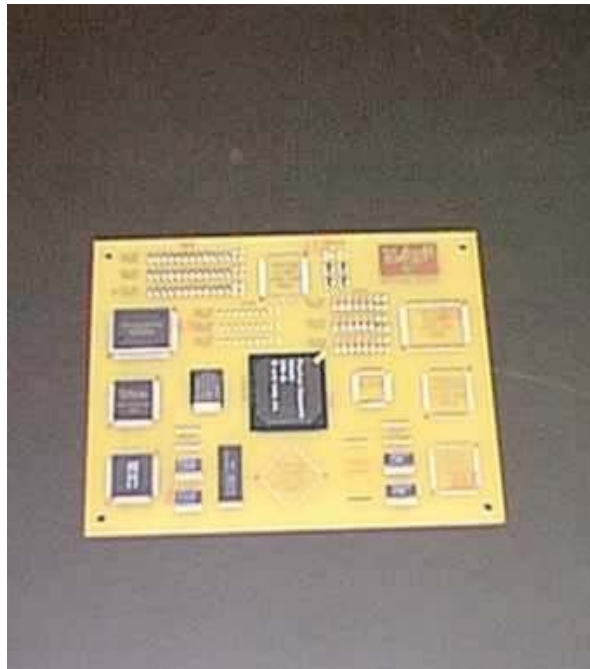
New England Lead-free Electronics Consortium



Consortium: Previous Work

Phase I: 2001-2002

- 66 test vehicles
- Type 1: 4" x 5.5" FR-4 board, single layer, single sided, SMT only (Assembly Class B)



Phase I – Parameters

- **Solder Alloys**

- Sn/Ag/Cu(95.5/3.8/0.7)
- Sn/Ag (96.5/3.5)
- Sn/Bi (57/43)

- **PWB Surface Finishes**

- OSP (Organic Solder Protectants)
- Electroless Nickel Immersion Gold (ENIG)

- **Thermal Profiles**

- Soak with 60sec, 90sec, 120sec above liquidus
- Linear with 60sec, 90sec, 120sec above liquidus temp.

- **Reflow Environment**

- Nitrogen vs. Air reflow

Consortium: Previous Work

Phase II: 2002-2004

- 100 test vehicles
- Type 1: 6" x 9" board, single layer, single sided, SMT only (Assembly Class B)



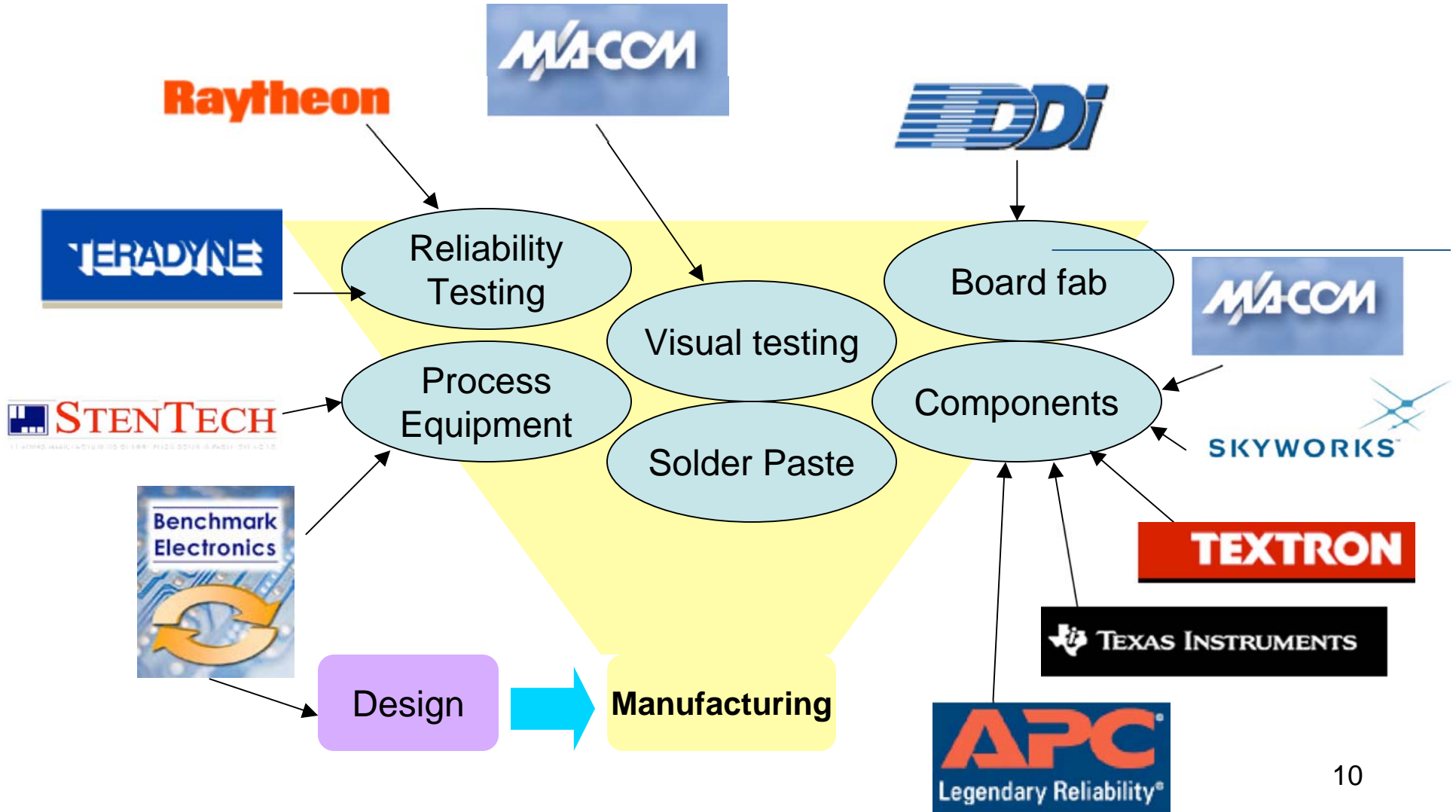
Phase II – Parameters

- 1. PWB Finishes** – Solder Mask Over Bare Copper with Hot Air Solder Leveling (SMOBC/HASL), Matte Tin (Sn), Immersion Silver (Ag), Organic Solder Preservative (OSP), and Electroless Nickel Immersion Gold (ENIG).
 - 2. Reflow Atmospheres** – Two Treatments – Air and Nitrogen.
 - 3. Solder Pastes** – 95.5Sn-3.8 Ag-0.7Cu alloy from three different suppliers (A, B and C), all incorporating no-clean fluxes.
 - 4. Component Lead Finishes** – matte tin, tin/silver/copper, nickel/palladium/gold, and nickel/gold.
- Sn-Pb eutectic solder PWB using the solder treatments as control PWBs.**

Phase III

- Implementation not experimentation, test vehicle simulates production board for Class 2 (Dedicated Service Electronics Products)
- Focus on solder joint integrity
- Funding: U.S. EPA

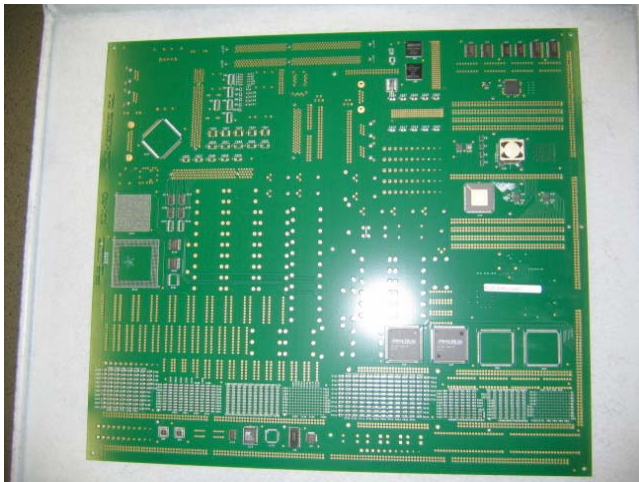
New England Lead-free Consortium – Phase III



New England Lead-free Consortium



Phase III Test Vehicle



Board Quantity: 40

Board Layers: 20

Board Thickness: 0.110"

Board Size: 16" x 18"

Laminate Materials:

Supplier A

Supplier B

Assembly: 1,700 components double sided
(SMT, THT, fine pitch, BGA)

Phase III Components

Component Types:

SMT (Qty: 1,650): BGAs, uBGAs, SOICs, resistors, capacitors, QFPs, etc.

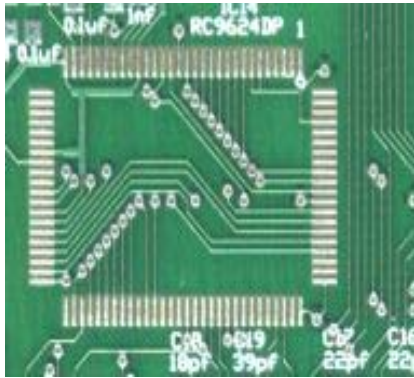
THT (Qty: 50): Connectors, resistors, relays, inductors, etc.



Component Lead Finishes:

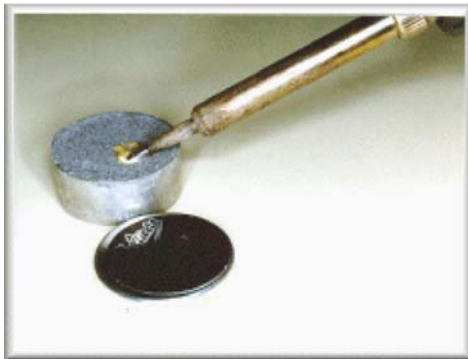
- SnPb
- NiPdAu
- Sn
- Au
- PdAg
- matte Sn
- NiAu
- SnNi
- SnAgCu
- SnBi

Phase III Parameters



Surface Finishes:

- Electroless nickel immersion gold (ENIG)
- Immersion Silver
- Organic solder protectants (OSP)



Solder paste:

Lead free SAC 305 no clean
(Supplier A, Supplier B)

Tin/Lead (Supplier A, Supplier B)

Phase III Stencil

Material: Stainless steel laser cut and electropolished

Thickness: 6 mils (step down to 5 mils for uBGAs)

Top Stencil Apertures:

10% standard reduction

Bottom Stencil Apertures::

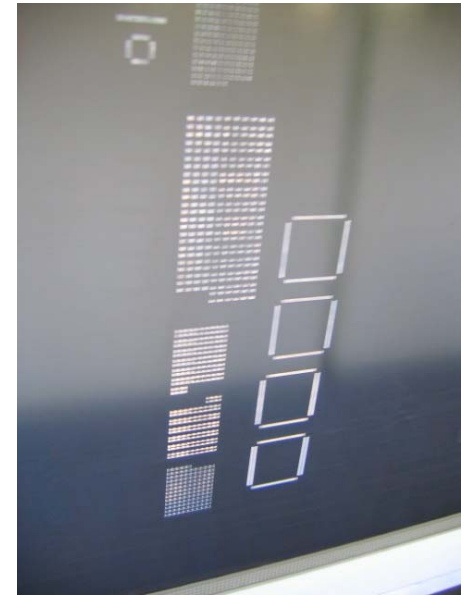
For leaded devices – 10% expansion in length for both directions and a 1 to 1 ratio for width

For fine pitch devices – based on pad size

For discretes – 10% increase in length on termination side only, and a 1 to 1 ratio for width

Aperture Styles:

For discretes – radial aperture, home plate, kings crown, and standard



DOE – Lead-free Boards

Board	Solder Paste	Surface Finish	PWB Laminate	Components	Testing
1	LF - A	ENIG	Laminate - A	SMT, THT	HALT
2	LF - A	ENIG	Laminate - A	SMT	TC
3	LF - A	ENIG	Laminate - B	SMT, THT	TC
4	LF - A	ENIG	Laminate - B	SMT	HALT
5	LF - A	Imm. Ag	Laminate - A	SMT, THT	HALT
6	LF - A	Imm. Ag	Laminate - A	SMT	TC
7	LF - A	Imm. Ag	Laminate - B	SMT, THT	TC
8	LF - A	Imm. Ag	Laminate - B	SMT	HALT
9	LF - A	OSP	Laminate - A	SMT, THT	HALT
10	LF - A	OSP	Laminate - A	SMT	TC
11	LF - A	OSP	Laminate - B	SMT, THT	TC
12	LF - A	OSP	Laminate - B	SMT	HALT

DOE – Lead-free Boards

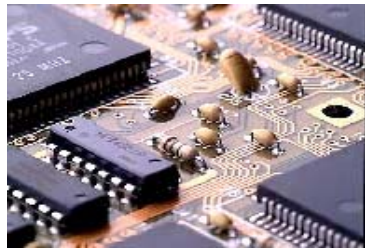
Board	Solder Paste	Surface Finish	PWB Laminate	Components	Testing
13	LF - B	ENIG	Laminate - A	SMT, THT	HALT
14	LF - B	ENIG	Laminate - A	SMT	TC
15	LF - B	ENIG	Laminate - B	SMT, THT	TC
16	LF - B	ENIG	Laminate - B	SMT	HALT
17	LF - B	Imm. Ag	Laminate - A	SMT, THT	HALT
18	LF - B	Imm. Ag	Laminate - A	SMT	TC
19	LF - B	Imm. Ag	Laminate - B	SMT, THT	TC
20	LF - B	Imm. Ag	Laminate - B	SMT	HALT
21	LF - B	OSP	Laminate - A	SMT, THT	HALT
22	LF - B	OSP	Laminate - A	SMT	TC
23	LF - B	OSP	Laminate - B	SMT, THT	TC
24	LF - B	OSP	Laminate - B	SMT	HALT

DOE – Tin/Lead Boards

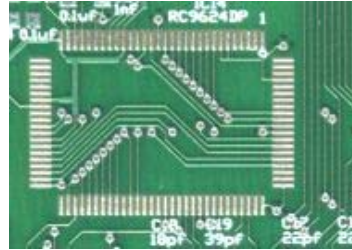
Board	Solder Paste	Surface Finish	PWB Laminate	Components	Testing
25	SnPb - A	ENIG	Laminate - B	SMT, THT	HALT
26	SnPb - A	ENIG	Laminate - B	SMT	TC
27	SnPb - B	ENIG	Laminate - B	SMT, THT	TC
28	SnPb - B	ENIG	Laminate - B	SMT	HALT
29	SnPb - A	Imm. Ag	Laminate - B	SMT, THT	HALT
30	SnPb - A	Imm. Ag	Laminate - B	SMT	TC
31	SnPb - B	Imm. Ag	Laminate - B	SMT, THT	HALT
32	SnPb - B	Imm. Ag	Laminate - B	SMT	TC
33	SnPb - A	OSP	Laminate - B	SMT	HALT
34	SnPb - A	OSP	Laminate - B	SMT, THT	TC
35	SnPb - B	OSP	Laminate - B	SMT	HALT
36	SnPb - B	OSP	Laminate - B	SMT, THT	TC



Phase III Overall Process



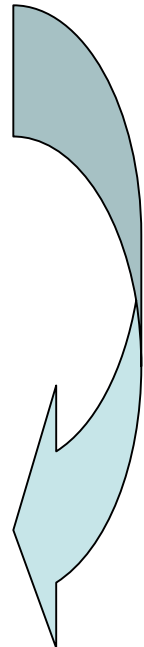
Board Design



Board
Fabrication, IST



Placement &
Reflow



Pull & Shear
Test

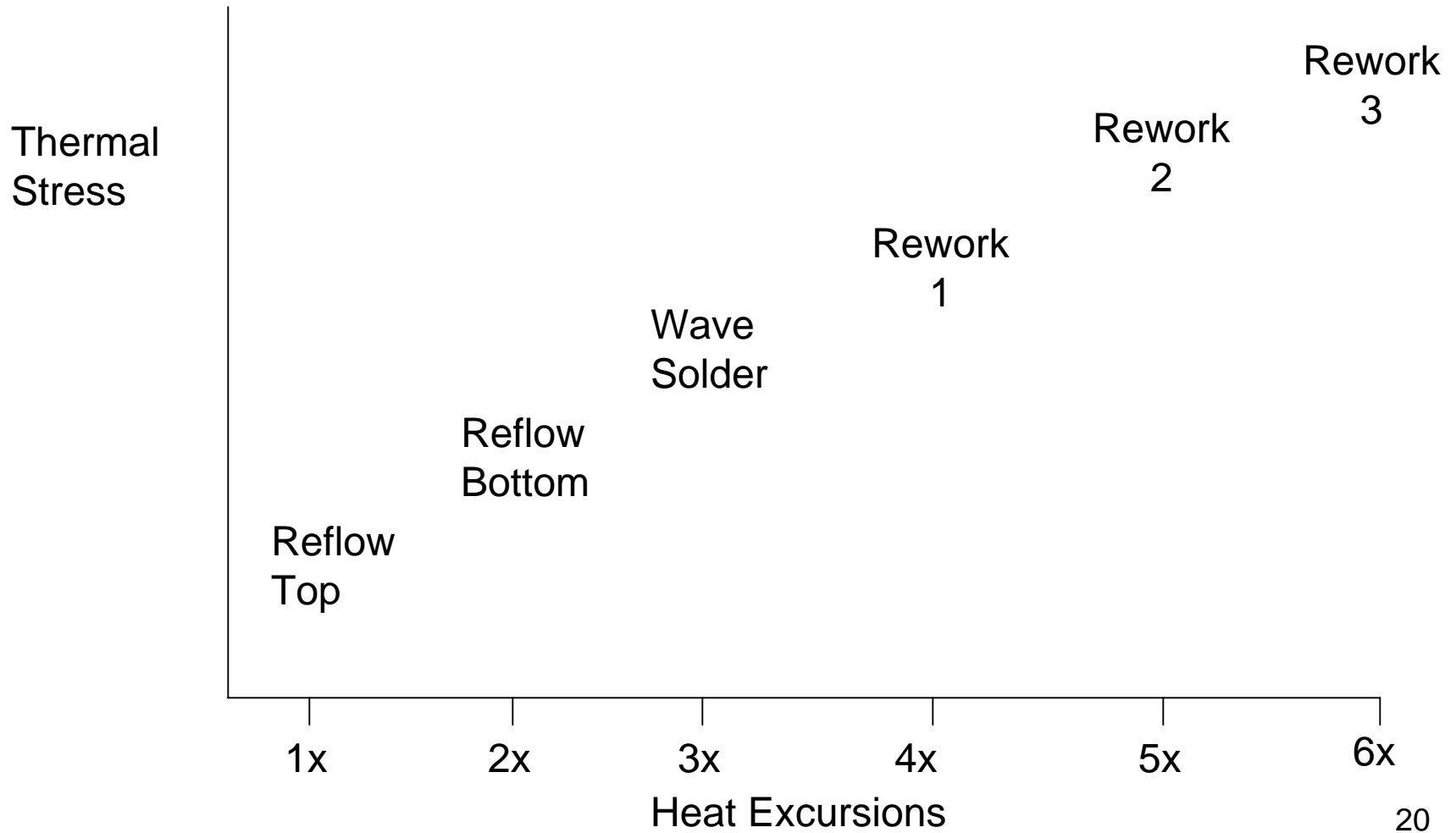


Thermal Cycling &
HALT

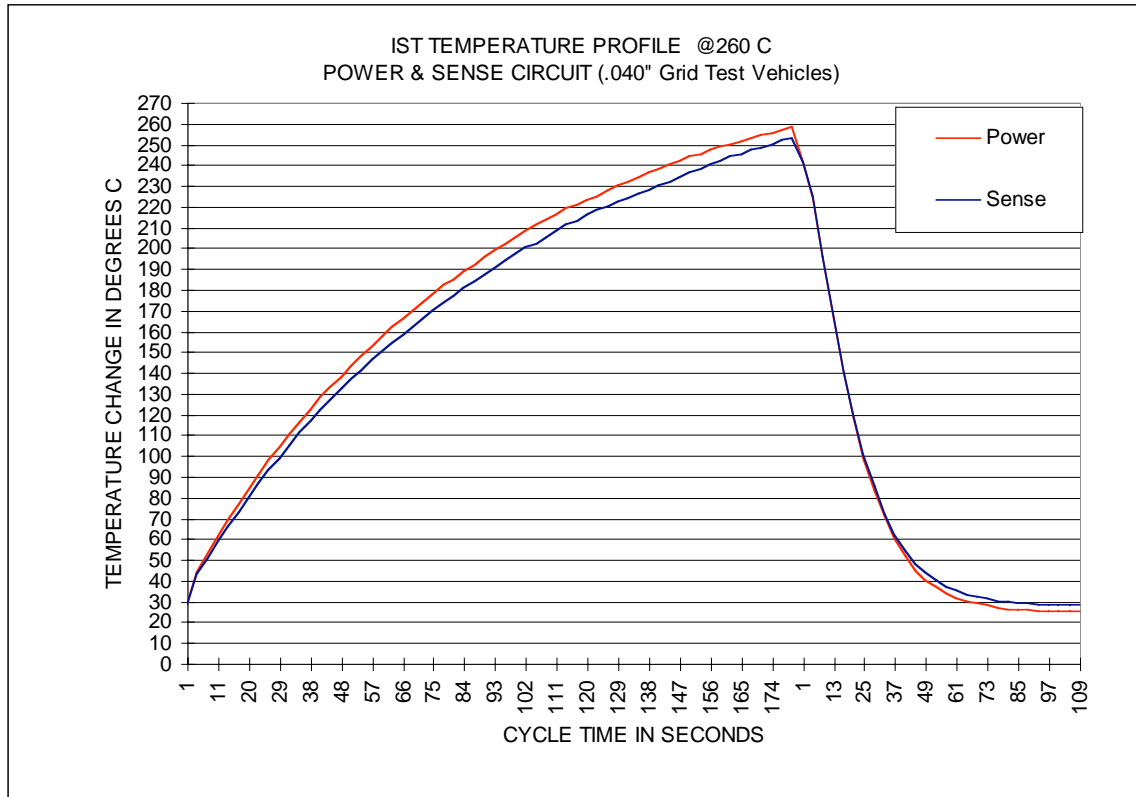


AOI, Visual, and
X-Ray Inspection

Thermal Excursions



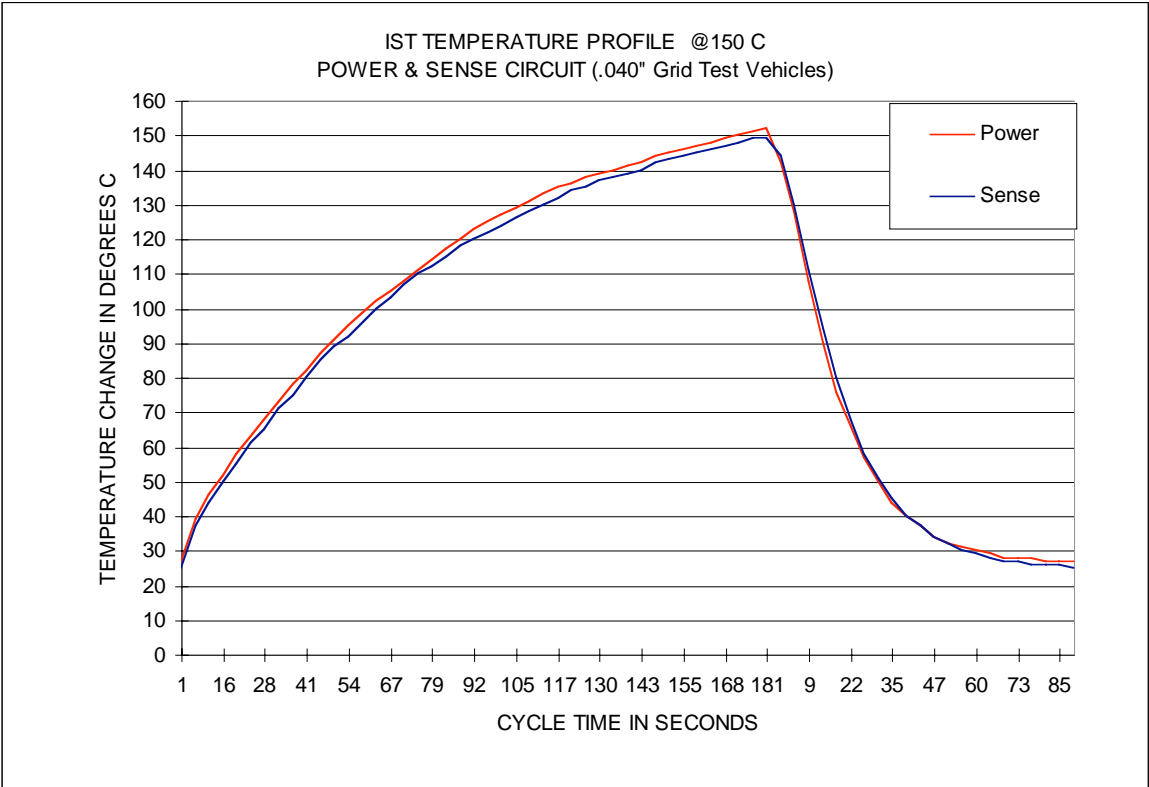
IST Preconditioning Profile (260 C)



Location:
Dynamic Details Inc.
Sterling, Virginia

6 test coupons: 3X
6 test coupons: 6X

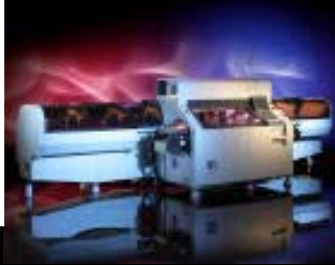
IST Temperature Profile (150 C)





IST Results

Material	Finish	Precondition Cycles	P/F	Cycle Failure Occurred	No. Of IST Cycles
A	ENIG	3x	P		500
A	OSP	3x	F	Cycle 3	
A	Ag	3x	P		500
A	ENIG	6x	F	Cycle 5	
A	OSP	6x	F	Cycle 5	
A	Ag	6x	P		500
B	ENIG	3x	P		500
B	OSP	3x	P		29
B	Ag	3x	P		500
B	ENIG	6x	P		500
B	OSP	6x	F	Cycle 1	
B	Ag	6x	P		500



Printing Process



Blades: 19 inch stainless steel, 9 mils

Separation Speed: 0.047 inches/second for all boards

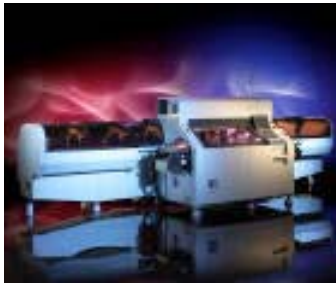
Blade pressure: 30 lbs for all boards

Print Speed:

Lead Boards: 0.8 inches/second for all boards

Lead-free Boards: 2.0 inches/second for first five boards (bottom only), 1.5 inches/second for all remaining boards

Placement Process



Universal Placement

Machine 4791 HSP:

High speed placement of discretes
(resistors and capacitors)



Universal Placement

Machine GSM:

Placement of other
SMT components
(SOIC, BGA, uBGA,
QFP, etc.)

Reflow Process



Reflow Oven: Vitronics Soltec XPM 1030

Reflow Atmosphere: Air only

Software: Datapaq

Heating Zones: 10

Cooling Zones: 3

Line Speed: 25.0 in/min

Profile: Ramp to Peak

Reflow Process



Target Maximum Temperature:

Lead: 208 – 218 degrees C

Lead-free: 240 – 248 degrees C

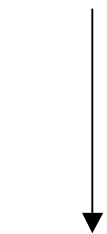
Target TAL:

Lead: 60 – 90 seconds

Lead-free: 60 – 90 seconds

THT Process

Tape → Flux → Insert → Preheat → Solder → Change Nozzle



Tape



Change nozzle ← Solder ← Preheat ← Insert ← Flux

THT Process

Parameter	Lead Boards	Lead-free Boards
Alloy	Tin/Lead	SAC 305
Flux	Alpha 3215	Alpha 3215
Preheat Temperature	110 degrees C	110 degrees C
Solder pot temperature	260 degrees C	280 degrees C
Dwell time	12 seconds	12 – 20 seconds

Visual Inspection

Location: Hudson, NH, Benchmark Electronics

Method:

- Seven experienced and trained inspectors
- Review AOI Results for false/true calls
- Magnification: 10x
- Standard: IPC 610D, Class 2
- Identify defects/process indicators



Visual Inspection - Categories

Description	Tin/Lead	Lead-free	Defect	Process Indicator
209: Bent pin	Y	Y	X	
261: Tombstone	Y	Y	X	
602: Solder bridge	Y	Y	X	
615/616: Non-wetting	Y	Y	X	
626: Disturbed solder	Y	Y	X	
713: Foreign matter	Y	Y	X	
606: Pinholes, blowholes	Y	Y	X	X
613: Insufficient solder	Y	Y	X	X
672: Solder balls	Y	Y	X	X
205: Misregistration	Y	Y		X
270: Raised part	Y	Y		X
603: Solder splatter	Y	Y		X
612: Excess solder	Y	Y		X
620: Unsoldered lead		Y		x
701: Delamination		Y		X
770: Damaged/missing pad	Y	Y		X

Visual Inspection Results

Board #	Total Unique SMT Defects	Total Unique THT Defects	Board #	Total Unique SMT Defects	Total Unique THT Defects
1	35	19	13	15	27
2	9	N/A	14	3	N/A
3	6	20	15	8	15
4	3	N/A	16	2	N/A
5	49	19	17	15	6
6	4	N/A	18	6	N/A
7	0	1	19	14	19
8	11	N/A	20	8	N/A
9	65	19	21	7	34
10	39	N/A	22	11	N/A
11	24	15	23	9	11
12	8	N/A	24	9	N/A

Visual Inspection Results

Board Number	Total Unique SMT Defects	Total Unique THT Defects
25	23	0
26	3	N/A
27	7	3
28	5	N/A
29	175	10
30	3	N/A
31	36	1
32	25	N/A
33	2	N/A
34	25	5
35	8	N/A
36	30	0

Visual Inspection Conclusions

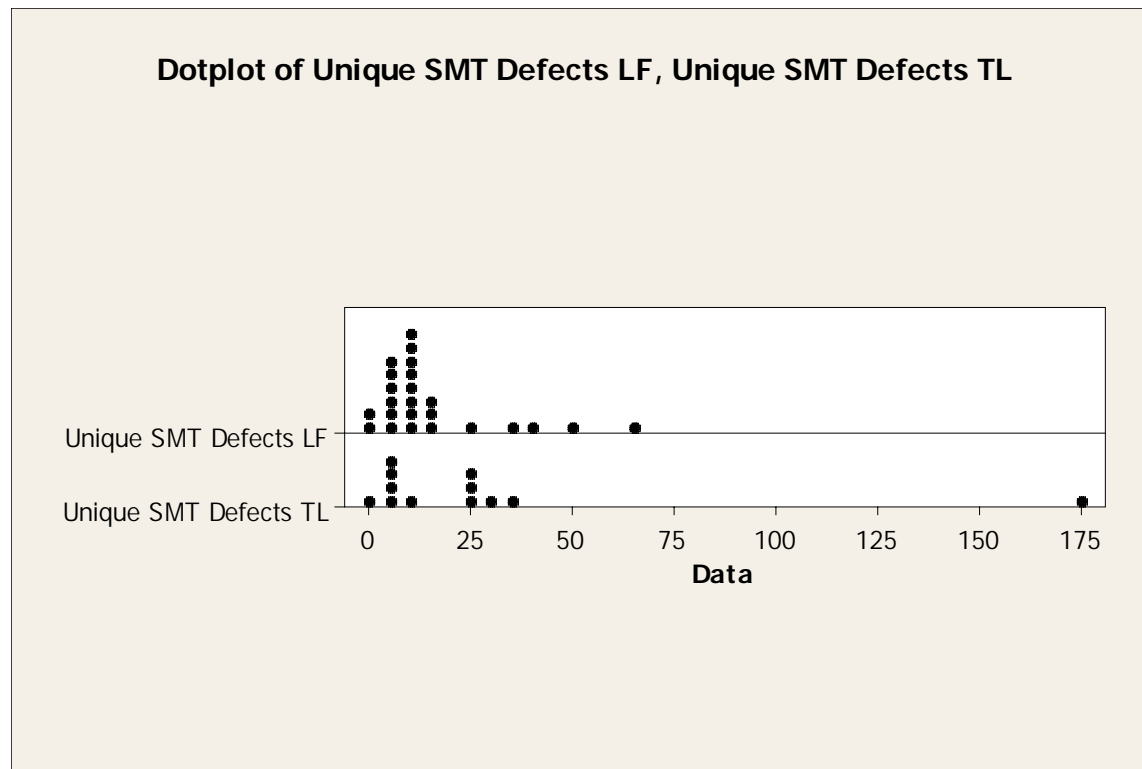
DOE Lead-free Boards:

For the parameters chosen for this experiment, there is no statistical difference for solder paste supplier, surface finish, or laminate material supplier.

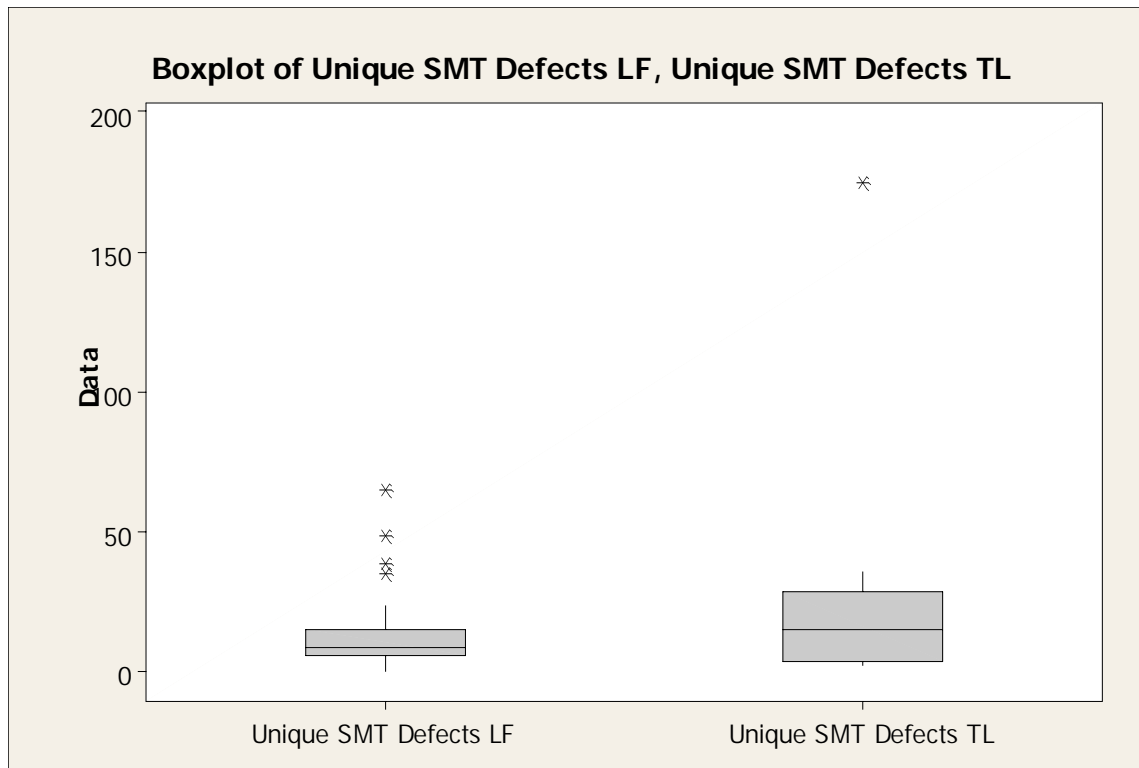
DOE Tin/Lead Boards:

For the parameters chosen for this experiment, there is no statistical difference for solder paste supplier or surface finish.

SMT: Tin/Lead vs. Lead-free



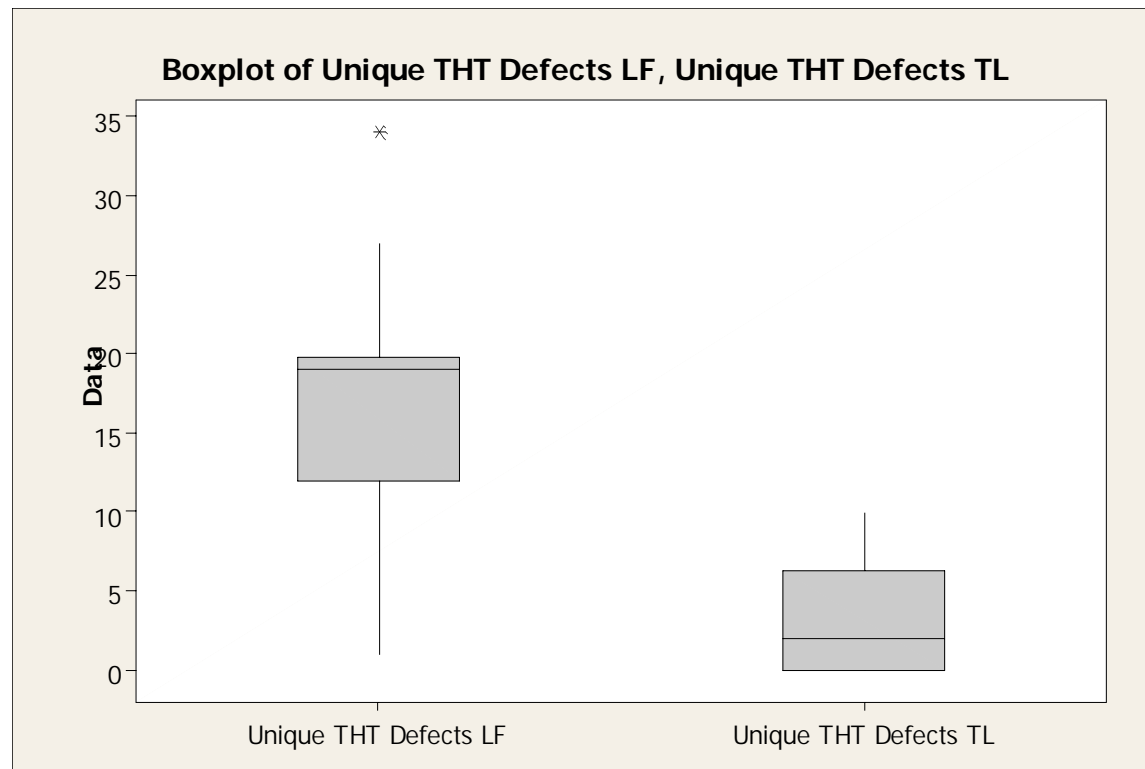
SMT: Tin/Lead vs. Lead-free



Mean: 15
Std Dev: 16

Mean: 28
Std Dev: 47

THT: Tin/Lead vs. Lead-free



Mean: 17
Std Dev: 8.7

Mean: 3
Std Dev: 3.9

Visual Inspection Conclusions

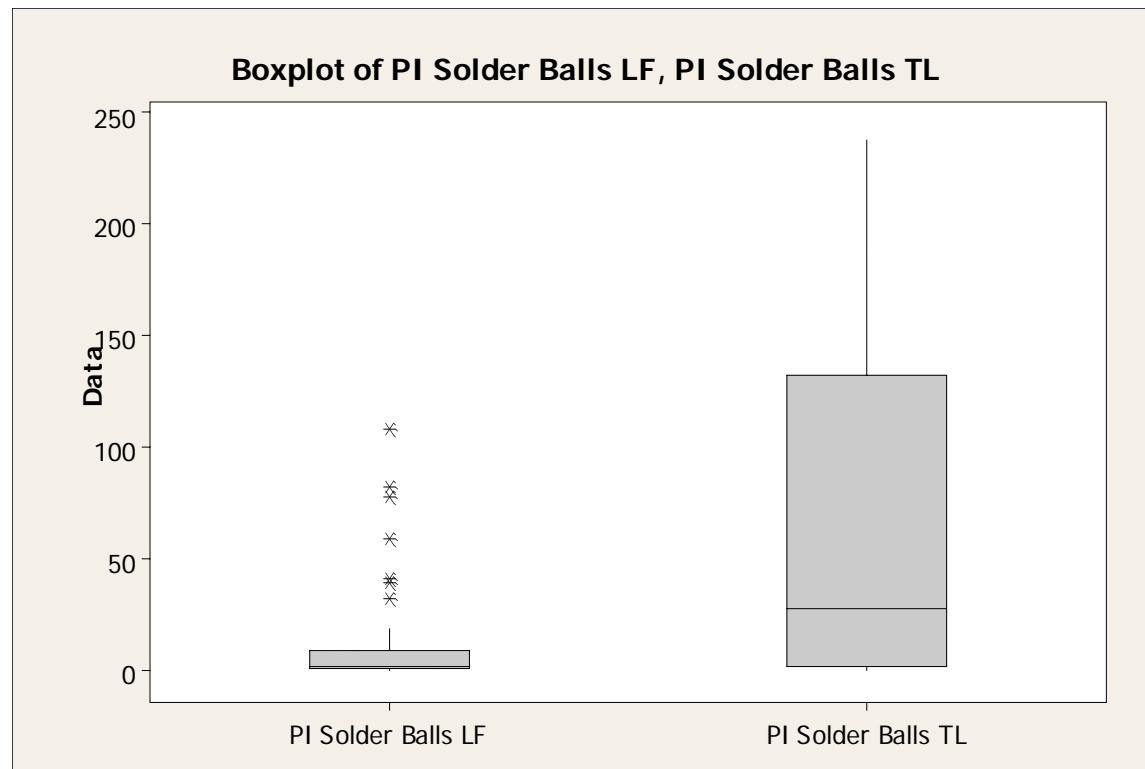
SMT Defects:

There is no statistical difference in SMT defects between test vehicles using lead-free and tin/lead solder paste.

THT Defects:

There is a statistical difference in THT defects between test vehicles using lead-free and tin/lead solder paste. The test vehicles with tin/lead solder paste had less defects than the test vehicles with lead-free solder paste.

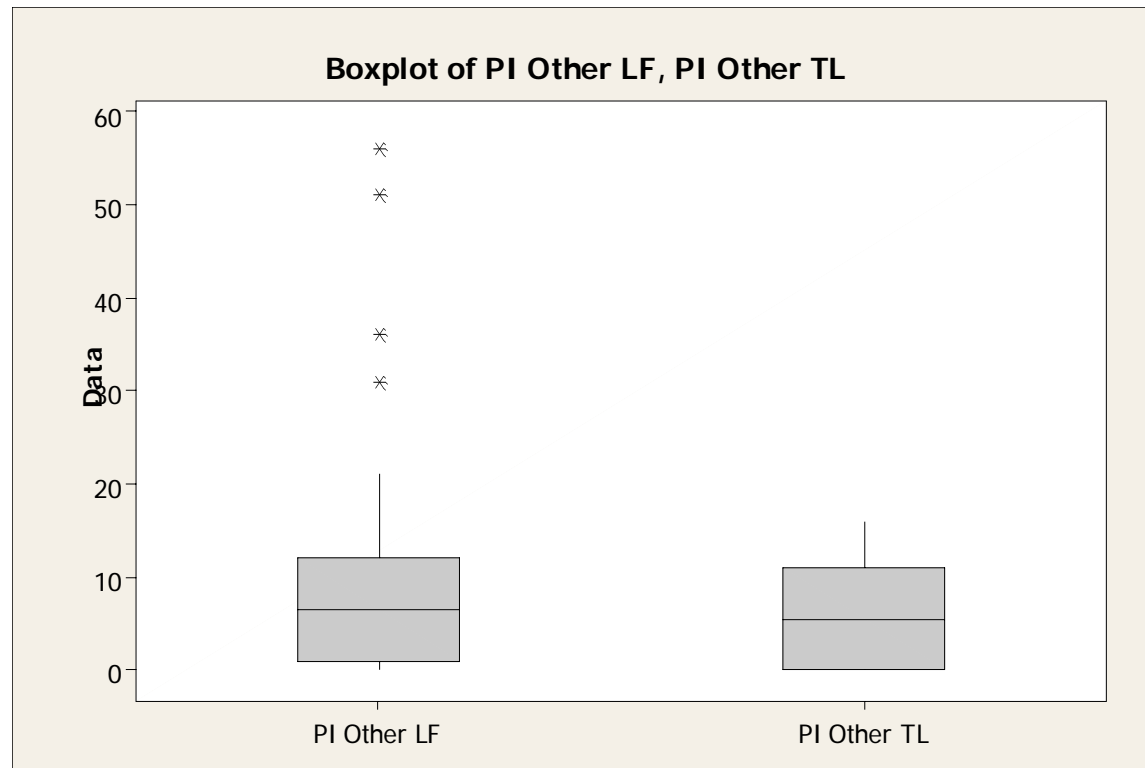
Process Indicators – Solder Balls: Tin/Lead vs. Lead-free



Mean: 12
Std Dev: 23

Mean: 67
Std Dev: 82

Process Indicators - Other: Tin/Lead vs. Lead-free



Mean: 9.8
Std Dev: 12

Mean: 6.1
Std Dev: 5.7

Visual Inspection Conclusions

Process Indicators – Solder Balls

There is a statistical difference in solder ball process indicators between test vehicles using lead-free and tin/lead solder paste. The test vehicles with tin/lead solder paste had more solder balls than the test vehicles with lead-free solder paste.

Process Indicators - Other

There is no statistical difference in other process indicators between test vehicles using lead-free and tin/lead solder paste.

Thermal Cycling

Raytheon

Location: Andover, MA, Raytheon

Method:

Meet the requirements of IPC-9701, test condition TC1
2,000 Cycles

Cycle Time:

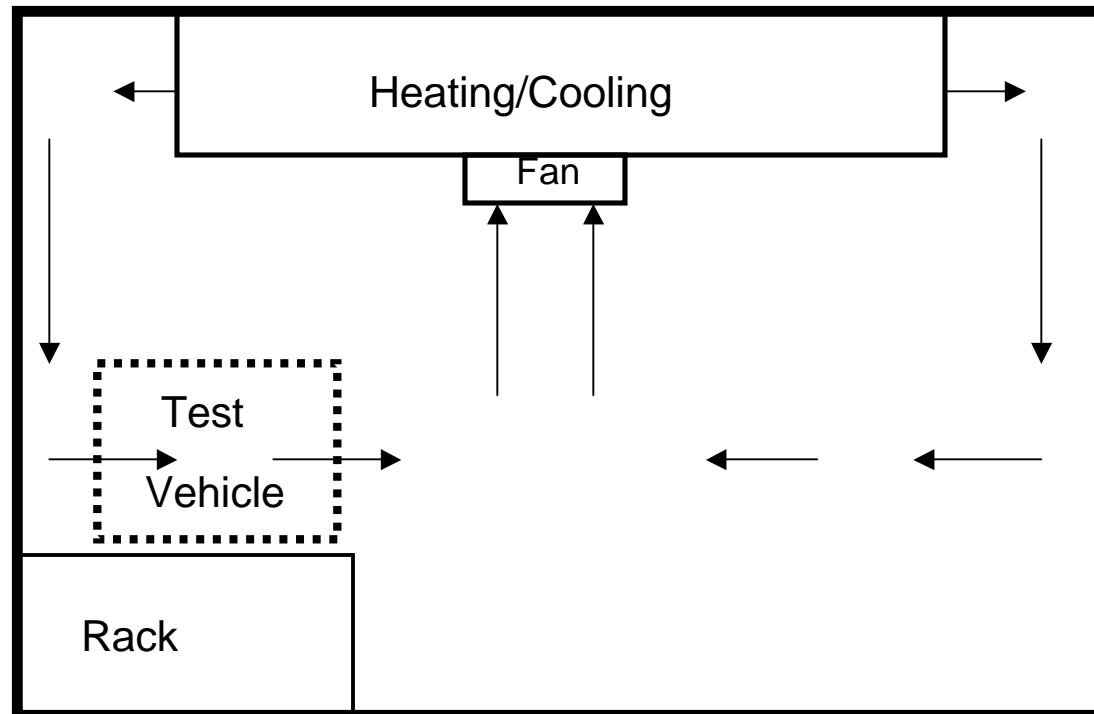
Approx. 40 minutes per cycle

- Ramp rate: 10 degrees C per minute
- 10 minute dwell time at 0 C
- 10 minute dwell time at 100 C

Results:

Available August 2005

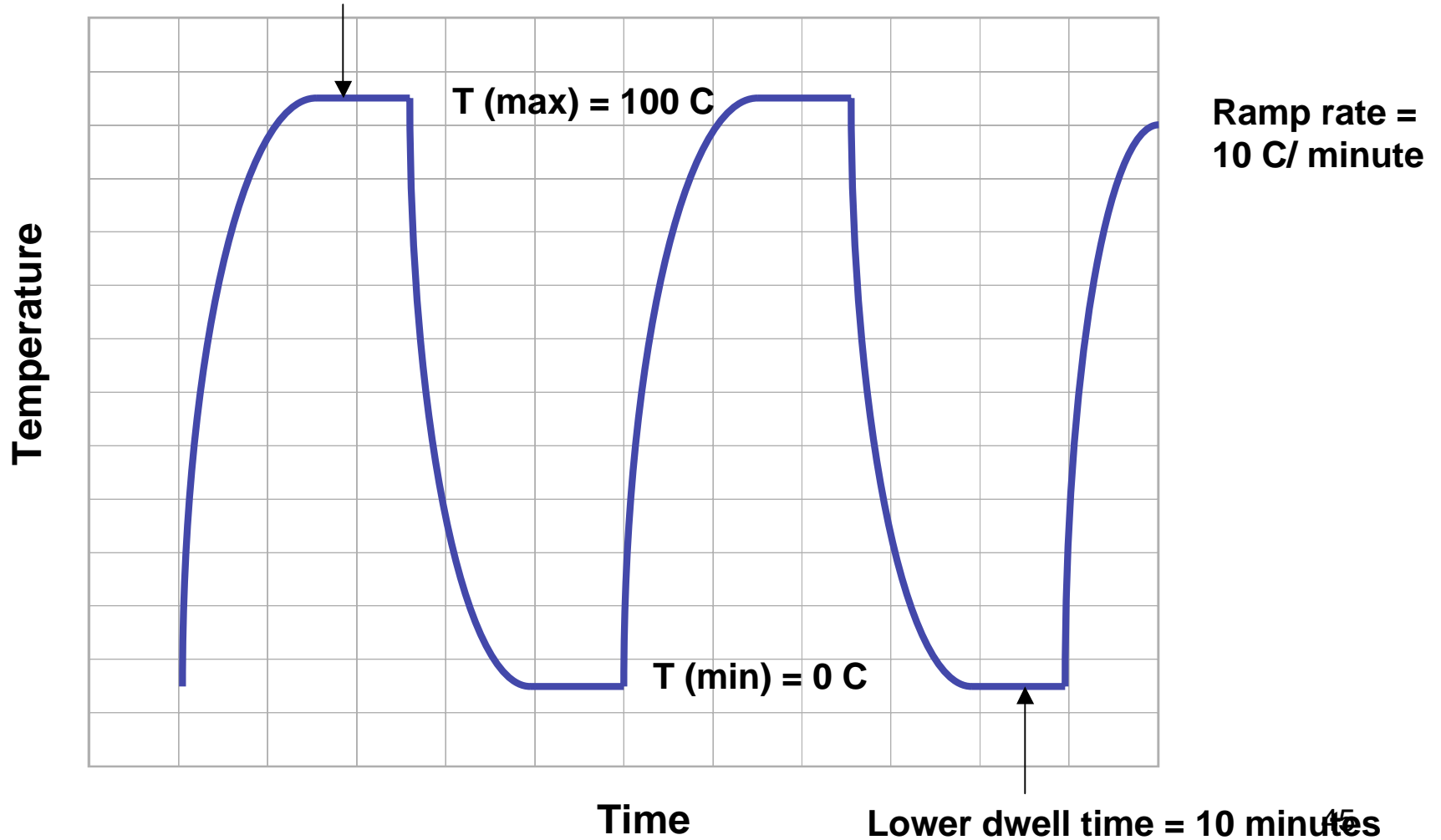
Thermal Cycling - Setup



Thermotron F125 CHV37-30

Thermal Cycling

Upper dwell time = 10 minutes



Highly Accelerated Life Testing (HALT)



Location: North Reading, MA, Teradyne

Method:

Equipment: Qualmark HALT/HASS System

Temperature Cycling: -40 degrees C to 140 degrees C

Vibration: Static to 65 Grms

Results:

Available July 2005



Pull Testing

Location: Lowell, MA, University of Massachusetts



Method:

Equipment: Instron pull test machine
45 degree angle to get vertical and shear stress
Pull rate of 1" per minute, record the peak pull force

Results:

Pre-reliability testing: Available May 2005

Post-reliability testing: Available August 2005



Phase III - Timeline

Activity	Timeline
Board Design	Nov 04 – Jan 04
Board Fabrication	Feb 05 – Mar 05
Build Process	Mar 05 – Apr 05
Visual & X-ray Inspect	Apr 05 – May 05
Thermal Cycling & HALT	May 05 – Aug 05
Shear/Pull Tests & Publish Results	Aug 05 – Oct 05

Consortium Information

For further information about the consortium, please contact:

Greg Morose
Toxics Use Reduction Institute
(978) 934-2954
Gregory_Morose@uml.edu

Or visit our website:

<http://www.turi.org/content/content/view/full/339/>