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No Lead

Implementing Lead-Free: Two Case Studies

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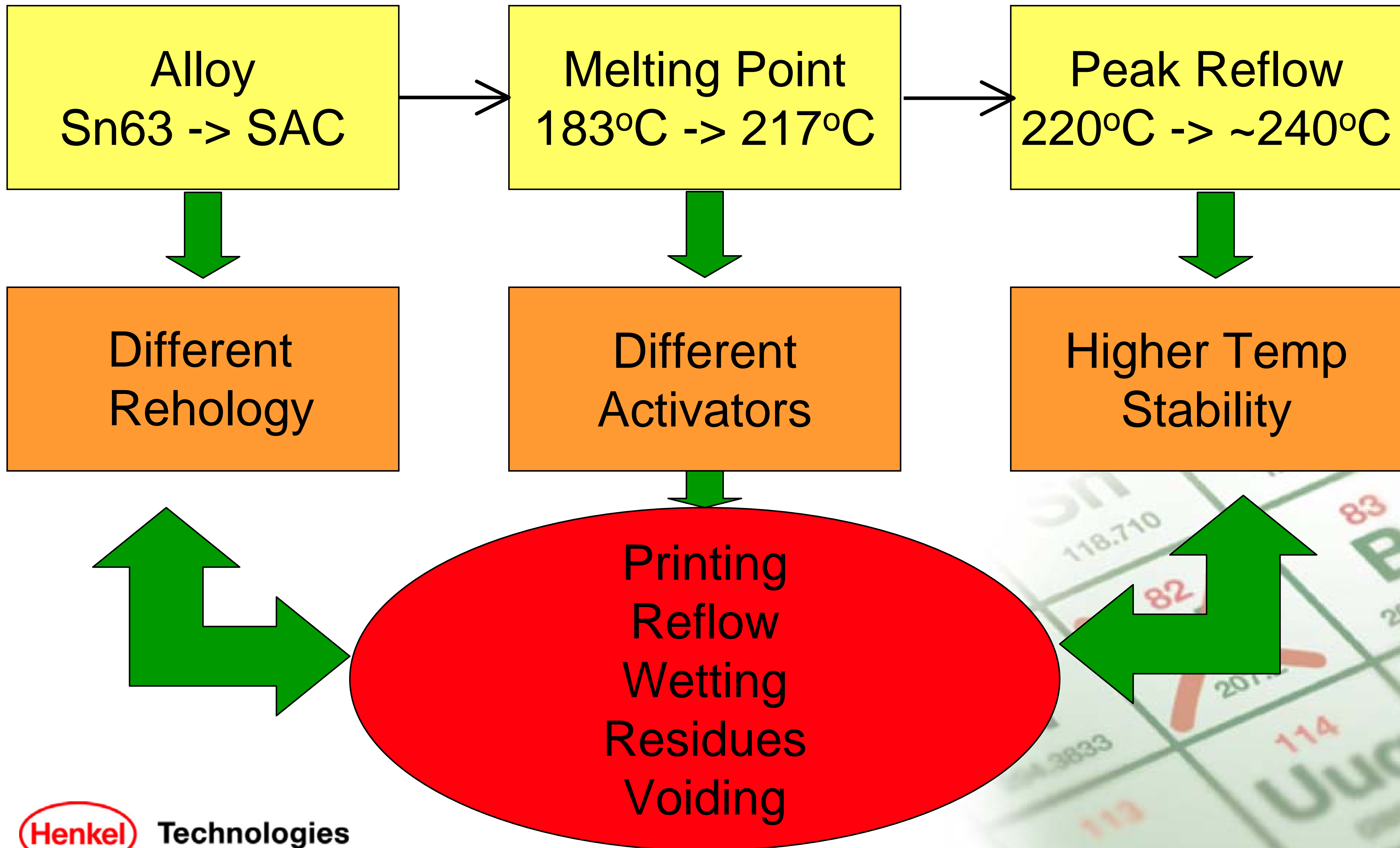
RoHS - 2006

- The deadline to implement RoHS is fast approaching
- Pb-free is the biggest impact
- Alloy changes lead to paste and process changes
- Can it be done?

New Technologies



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Material Changes → Process Changes

- New Materials for Pb-free Process
  - Solder Paste
  - Board Finishes
  - Components

- Changes to these *will* lead to process changes

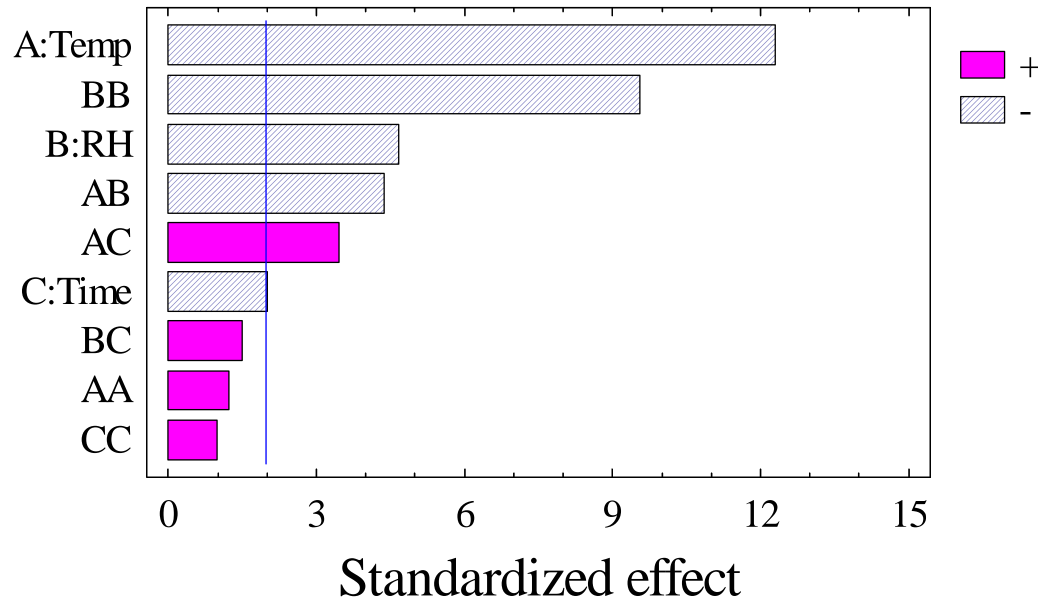
Design of Experiments (DOE)

- Used to explore the cause and effect relationship between numerous process variables and the output

Control Factors / Levels	Solvent	Squeegee Material	Squeegee Pressure, Kg	Squeegee Speed, mm/s	Snap off Speed, mm/s	Down Delay, s	Wipe Frequence, Pannels/Wipe	Wiper Speed, mm/s
	A	B	C	D	E	F	G	H
1	Yes	MetalPhoto	5.8	70	3	0	2	88
2	No	E-Blade	6.4	90	1	0.15	3	121
3		MPM	7	110	2	0.3	4	159

Design of Experiments (DOE)

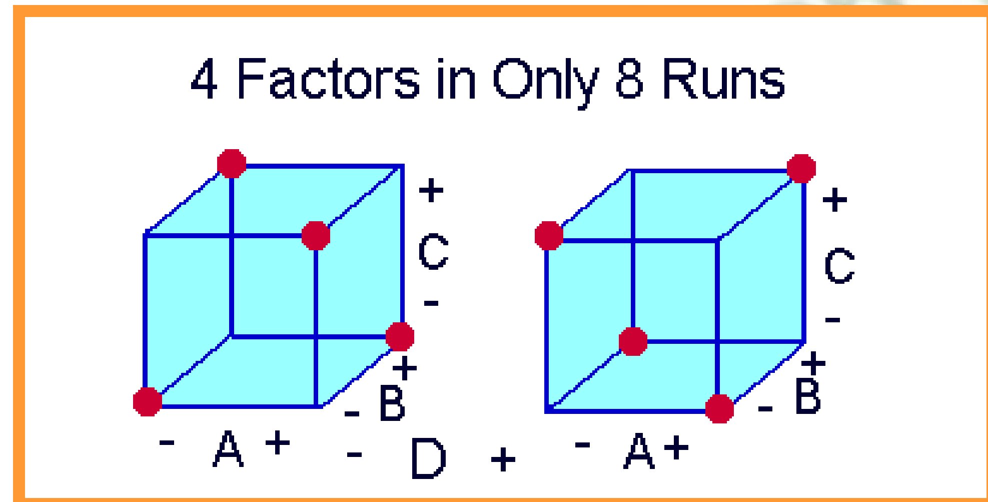
- Critical Factors
- Variable Interactions
- Response Surface



Design of Experiments (DOE)

- Reduce experimental size by doing "fractional factorial" DOE
- Choose critical variables
- Loose some interaction data

Four Factors (A-D)
2 Levels Each
$2^4 = 16$



Design of Experiments (DOE)

- Common applications for DOE:
  - Solder Paste Printing
  - Solder Reflow
  - Surface Finish Evaluation
  - Stencil Evaluation

Background

- Two consumer hand-held device manufactures (A and B)
- High volume manufacturing
- Different criteria and/or different measurement methods
- Both producing Pb-free product ***today***
  - and have been for 1+ years

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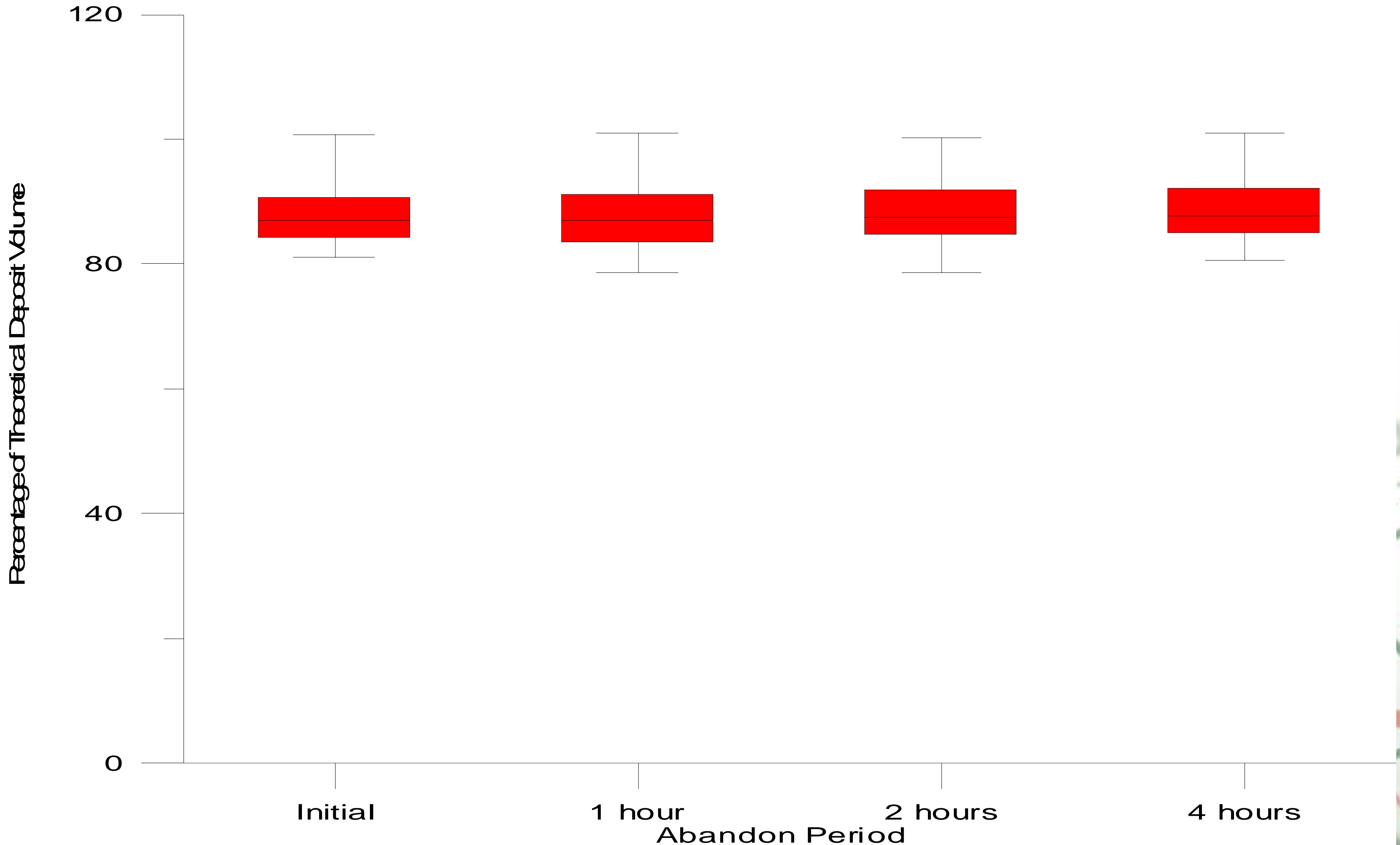
Presentation Outline

- Paste volume volumetric assessments
- Reflow process window evaluation
- Placement/self-centering assessment evaluations
- Tackiness measurements
- Solder joint quality evaluations
- Voiding assessment
- Wetting analysis
- Surface insulation resistance (SIR) testing

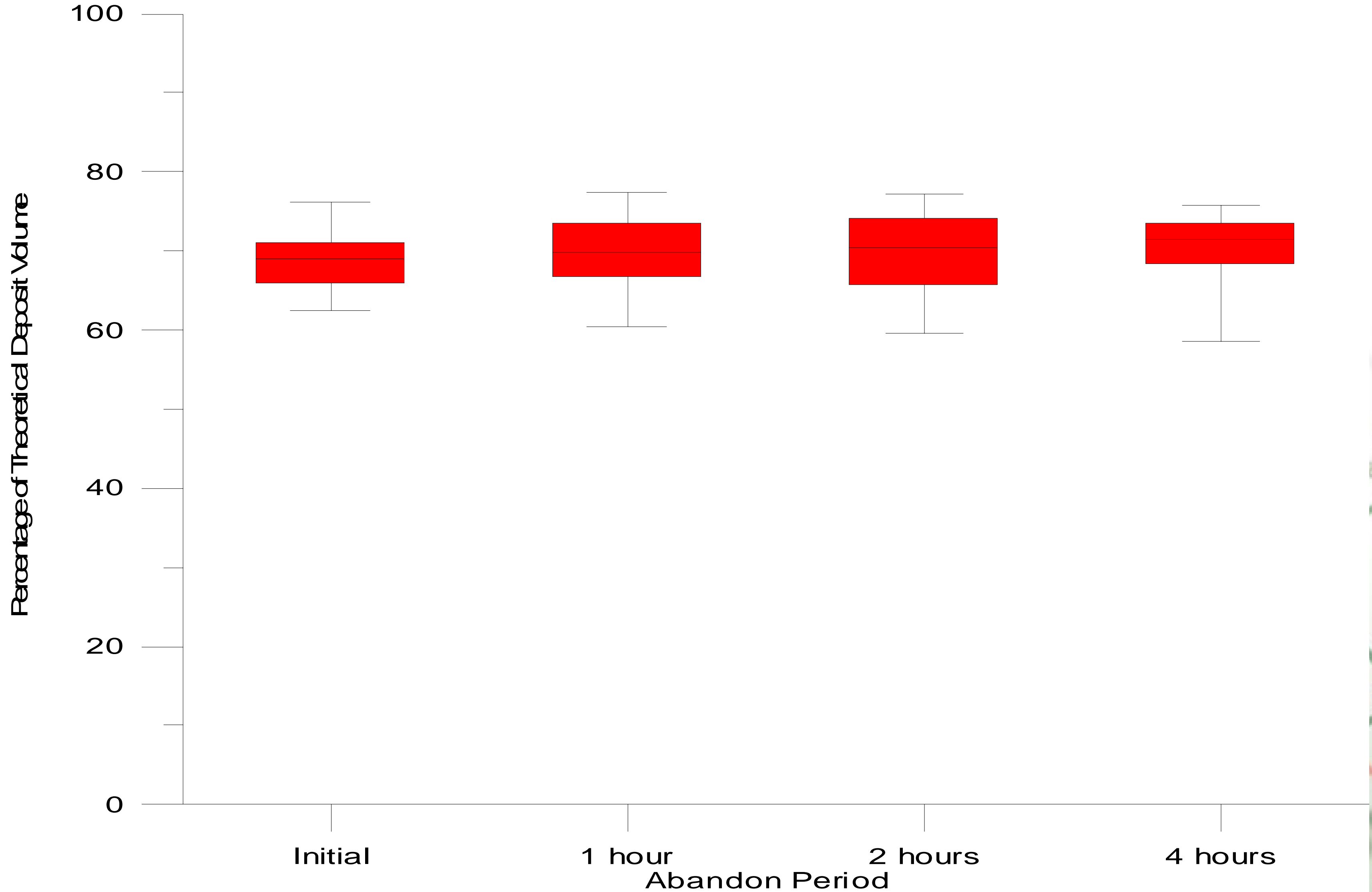
Printing Performance – Manufacturer A

- Determine aperture limit
  - 10mm to 18mm circular apertures
  - 12 mm to 25mm square apertures
  - 9mm x 50 mm to 18 mm x 50 mm rectangular apertures
- Determine abandon time performance
  - Time between prints 1, 2, and 4 hours
- Paste volume measured using laser profolometer system

Abandon Time



Abandon Time



Printing Performance – Manufacturer B

- Determine best parameters for fastest printing

- Visual and 2-D inspection of print sites

Printing Parameters – Manufacturer B

Optimum printing - high print definition

Acceptable printing - good paste roll and aperture fill

Marginal printing - irregular paste deposits

6
5
4
3
2
Pressure Kg

20 40 60 80 100 120 140 160 180 200 250

Speed mm/s

Marginal printing - poor paste release

Unacceptable printing - paste skipping irregular aperture fill

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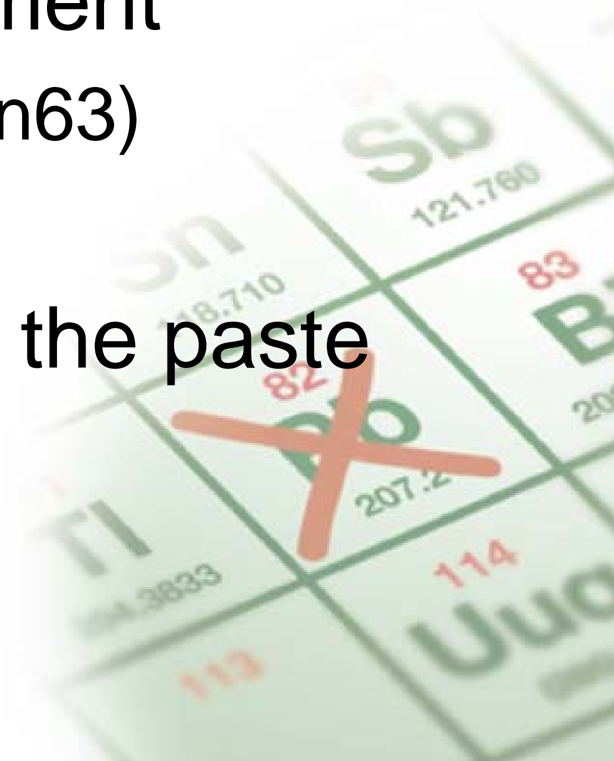
Tackiness – Both A and B

- Solder paste needs to hold components once they are placed
- Standard IPC test method
- Tackiness needs to be maintained for up to 4 hours
- Both materials maintain tackiness up to 24 hours (less than 10% change)

Component alignment – Manufacturer B

- Placement machines make errors
- PCB manufacturers make errors
- Two factors govern self-alignment
  - Alloy surface tension (SAC > Sn63)
  - Paste wetting (SAC < Sn63)
- How much misplacement can the paste overcome?
  - Is it enough?



Changing from Sn63 to SAC
Comparison of Alloy Properties

Alloy	Sn62	SnAg3.8Cu0.7
Melting point	179C	217C
Density (g/mm2)	8.5	7.5
Surface tension @ 260C in air	481 mNm-1*	548 mNm-1**
Wetting angle on Cu (deg)	12*	43

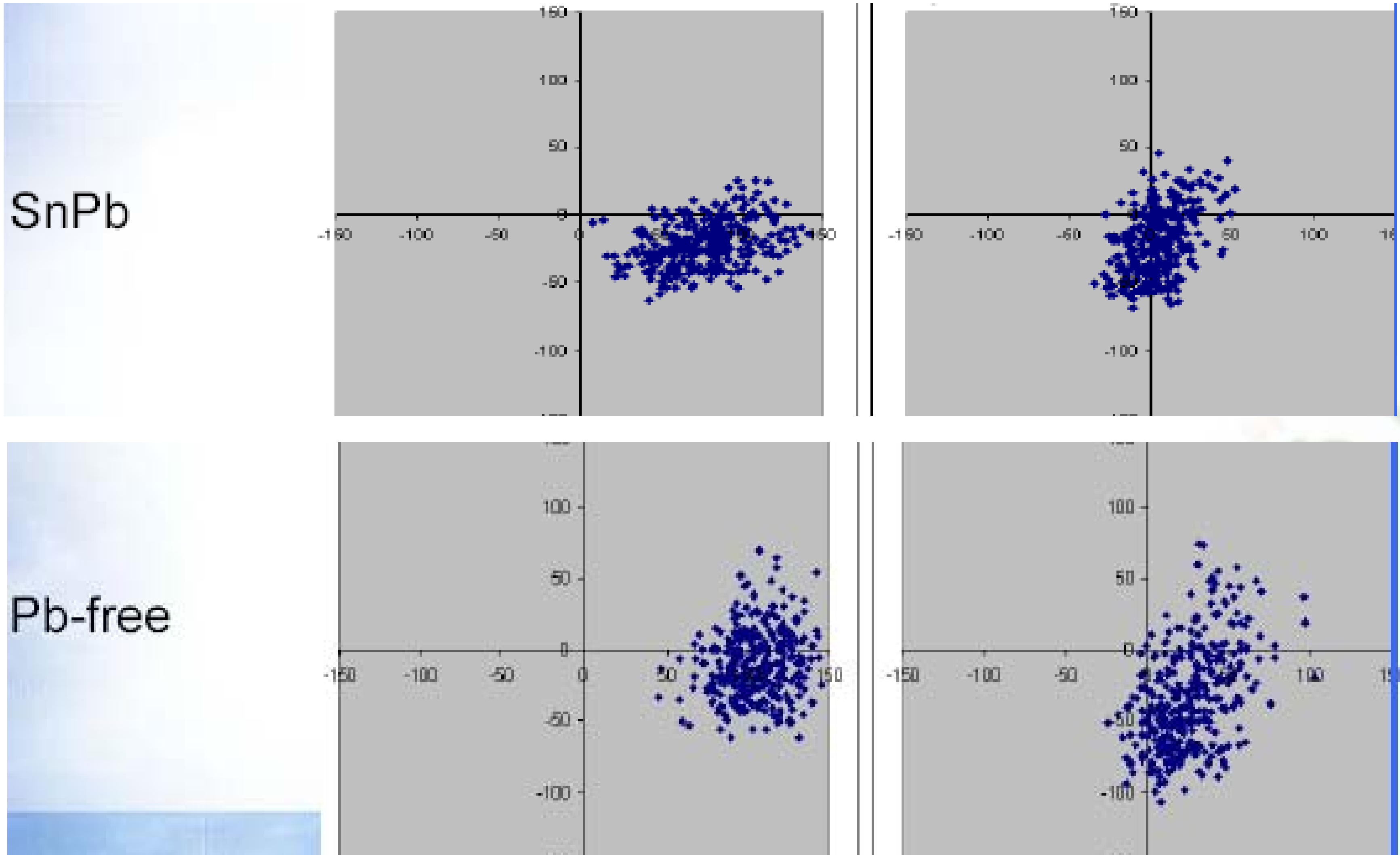
* Values for Sn60Pb40

** Values for pure tin

Component alignment – Manufacturer B

- Components intentionally misplaced off center
- Displacement measured
- Final location recorded
- Compare to Sn/Pb controls

Component alignment – Manufacturer B



Component alignment – Manufacturer B

Average positioning error after reflow oven

-70 130

Process Window

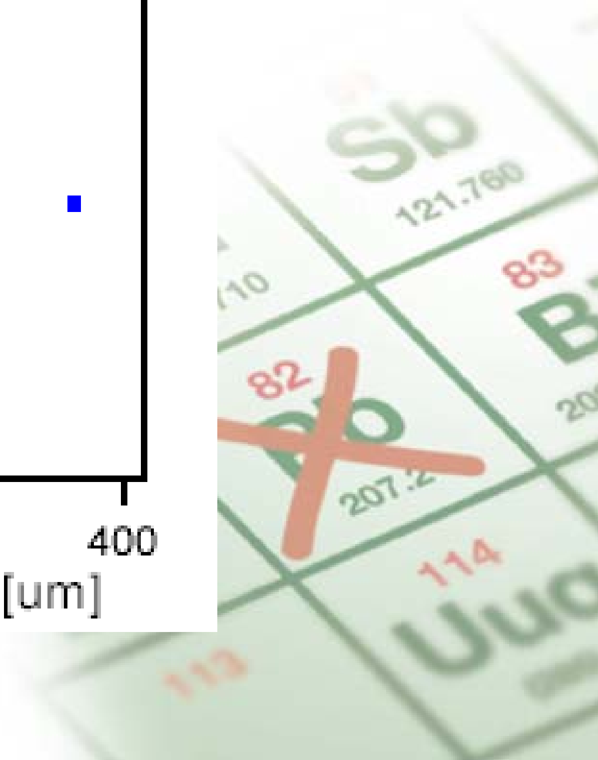
- -Sn63
- -SAC

Average positionin error (after reflow oven) [um]

100 0 -100

-200 -100 0 100 200 300 400

Placement deviation (before reflow oven) [um]



Reflow Process Window

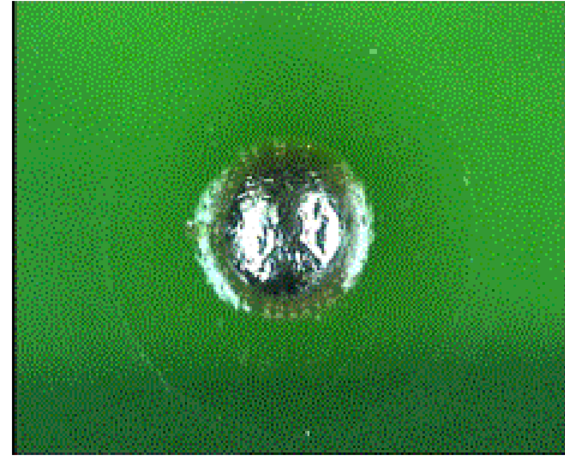
- Higher melting temp alloy (34°C difference)
- Higher peak reflow temperature (15-40°C)
- Component performance
- Oven control
- Delta T on PCBs

Reflow Process Window – Man. A

		Time above Liquidus (TAL)		
		60 s	70 s	80 s
Peak Temperature	229°C	RP1	RP4	RP7
	237°C	RP2	RP5	RP8
	245°C	RP3	RP6	RP9

Solder Coalescence

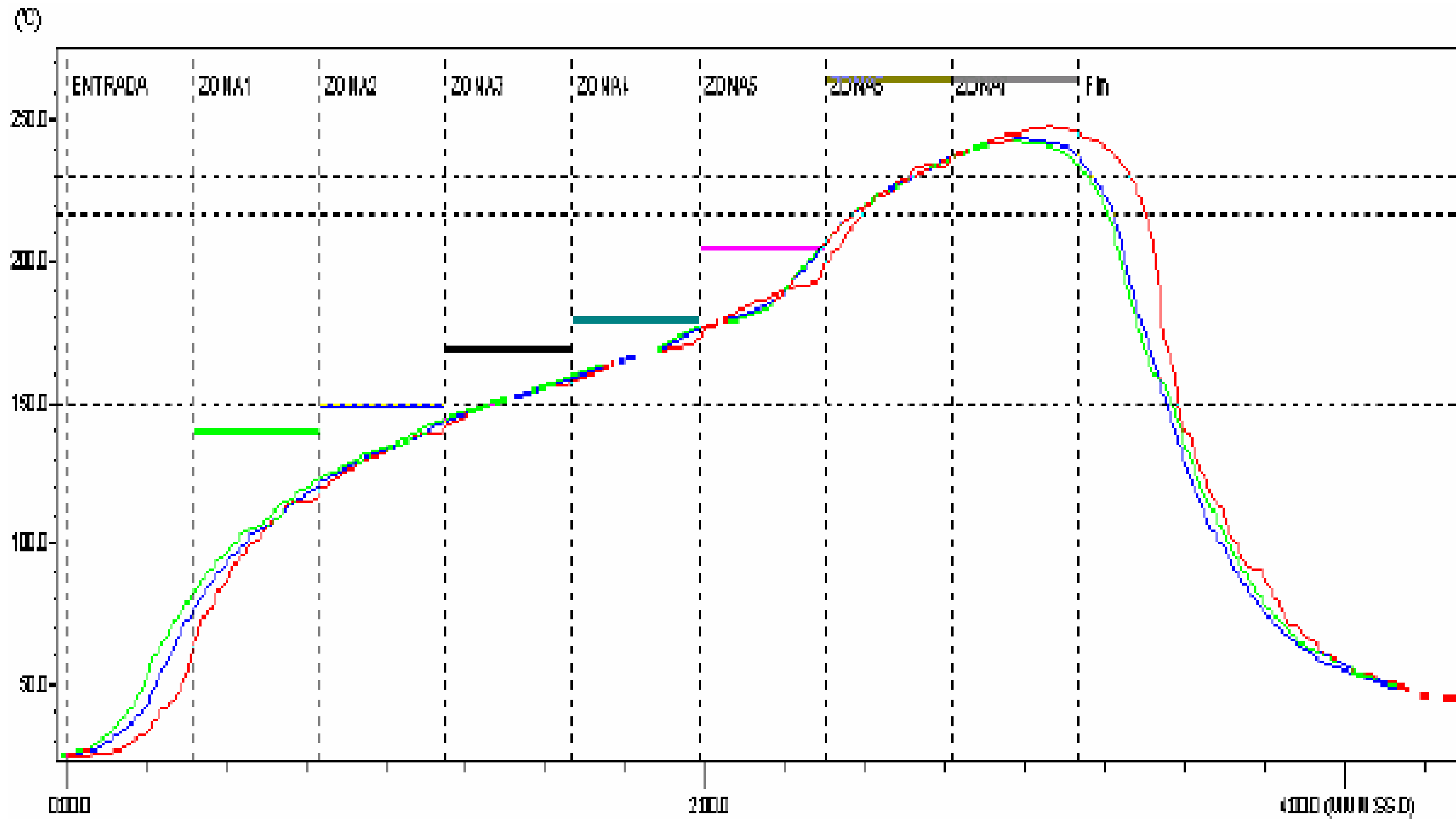
Poor


Good

Solder performance:
Solder needs to coalesce, even if printed off-pad

Good coalescence observed under all profiles RP1 through RP9

Manufacturer B Reflow Profile



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Wetting Angle

SUBSTRATE	REFLOWED ALLOY PELLET (Sn +)					
	0.5Cu	3.5Ag	3.8Ag0.7Cu	3.5Ag0.5Sb	3.8Ag0.7Cu0.5Sb	37Pb
Cu	42	43	43	41	43	12
Ag	19	26	24	30	33	13
Sn37Pb	19	19	22	20	22	5
Sn0.7Cu	15	11	18	11	10	17
Au over Ni	9	6	10	14	5	4

Wetting Angle on Copper

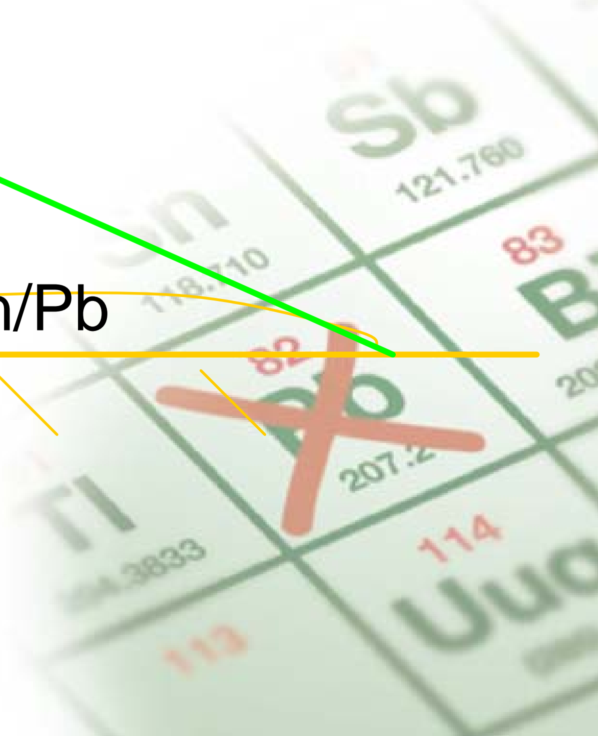
43^0

96SC

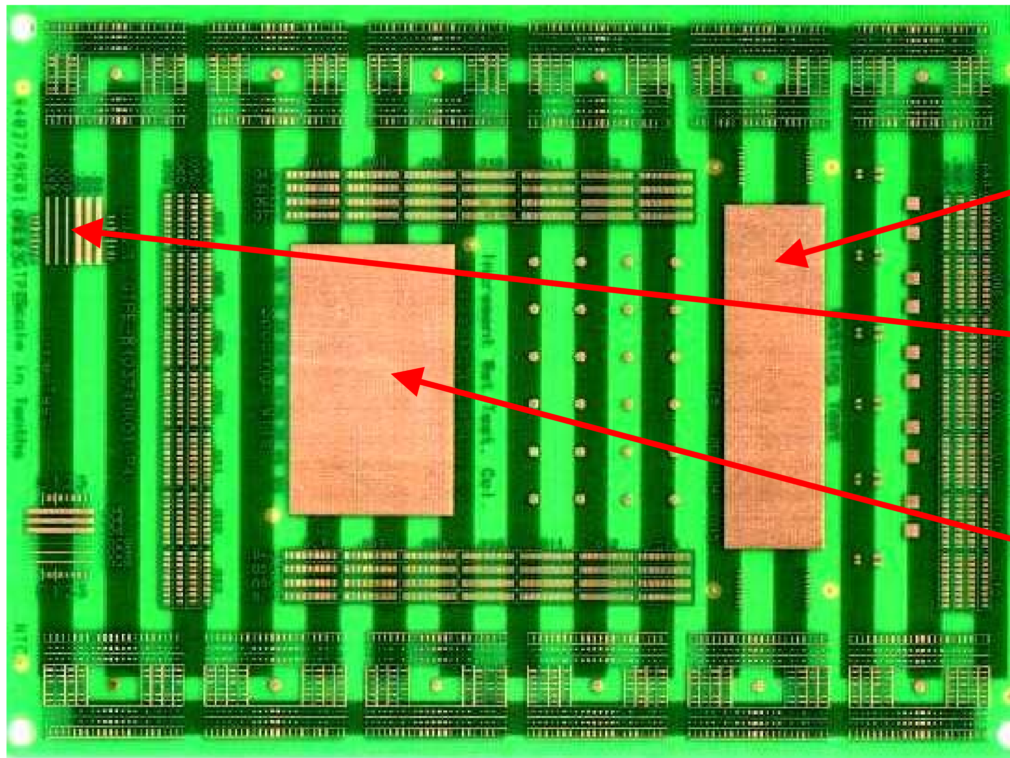
14^0

Sn/Pb

Copper



Manufacturer A – Wetting Performance



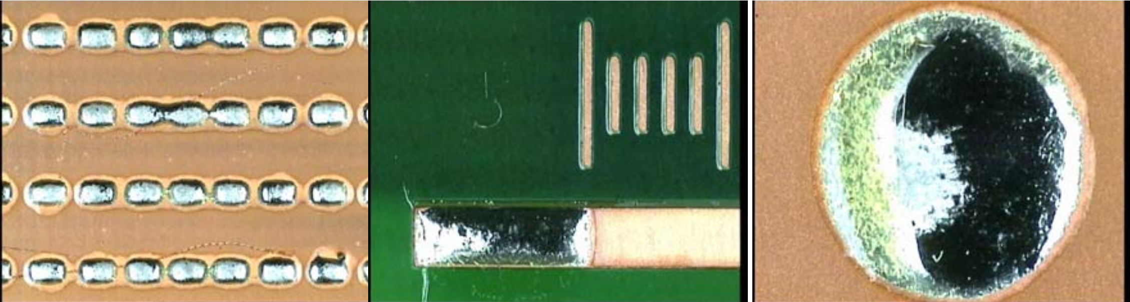
Circular Wetting Test Area

Line Wetting Test Area

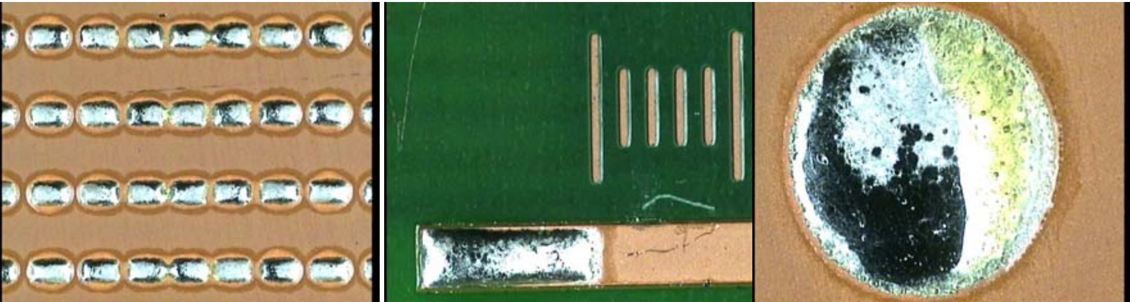
Incremental Wetting Test Area

Wetting Performance – OSP Finish

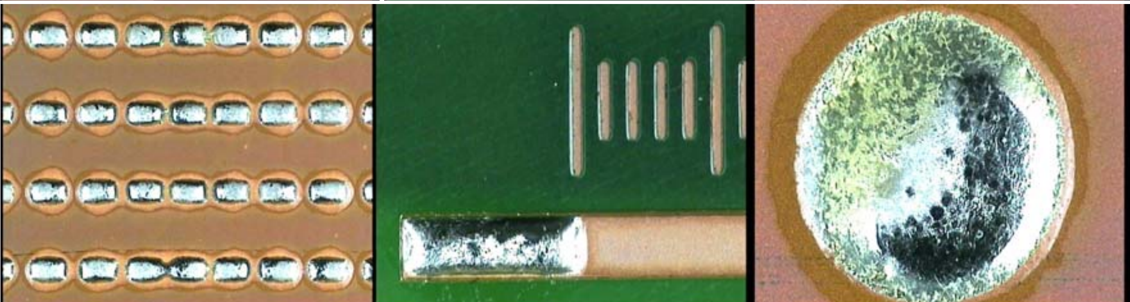
Incremental	Line	Spread	



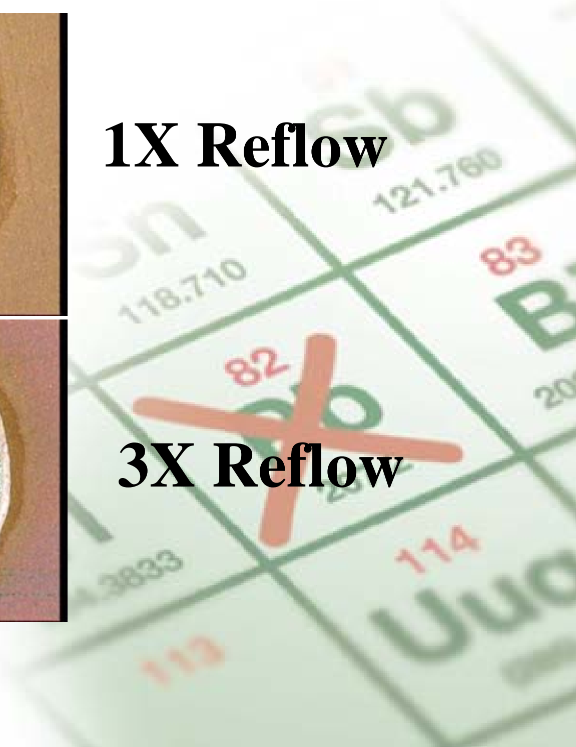
Fresh Board



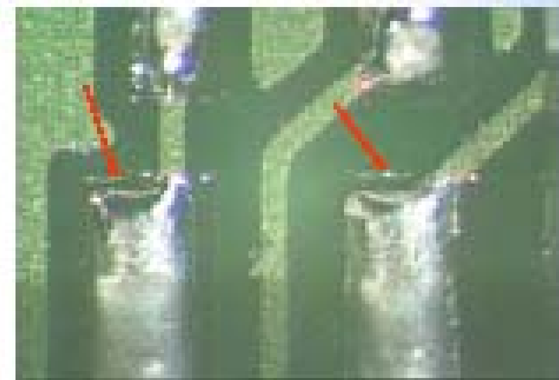
1X Reflow



3X Reflow

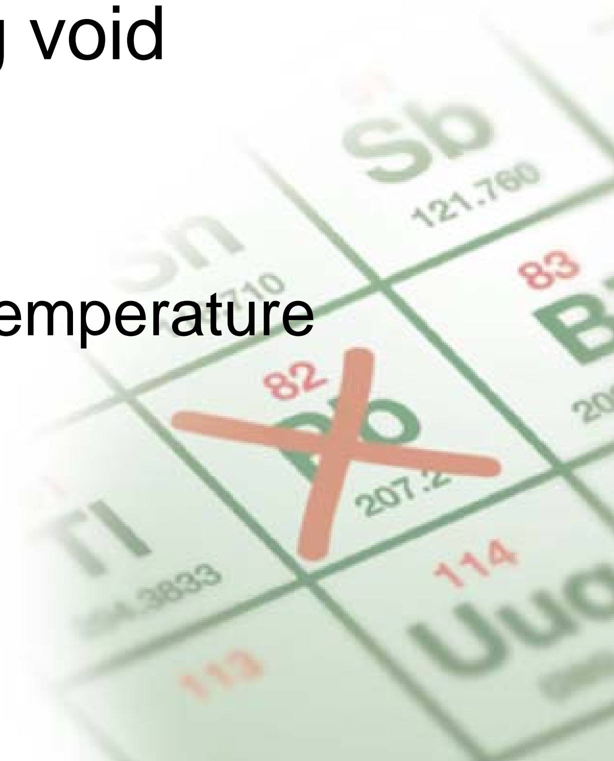


Component Wetting

	Low Temp Reflow Profile (229^oC Peak)	Optimum Reflow Profile (240^oC Peak)
QFP Wetting		
Capacitor Wetting		

Voiding in Pb-free Solder

- Voids in solder joints are more prevalent in Pb-free assemblies
  - Acceptable level of voids is unknown
  - Elimination of voids is the best course of action
- SAC Alloy Properties influencing void formation (Vs Sn/Pb)
  - Higher alloy surface tension
  - Higher reflow (alloy solidification) temperature
  - Reduced wetting speed



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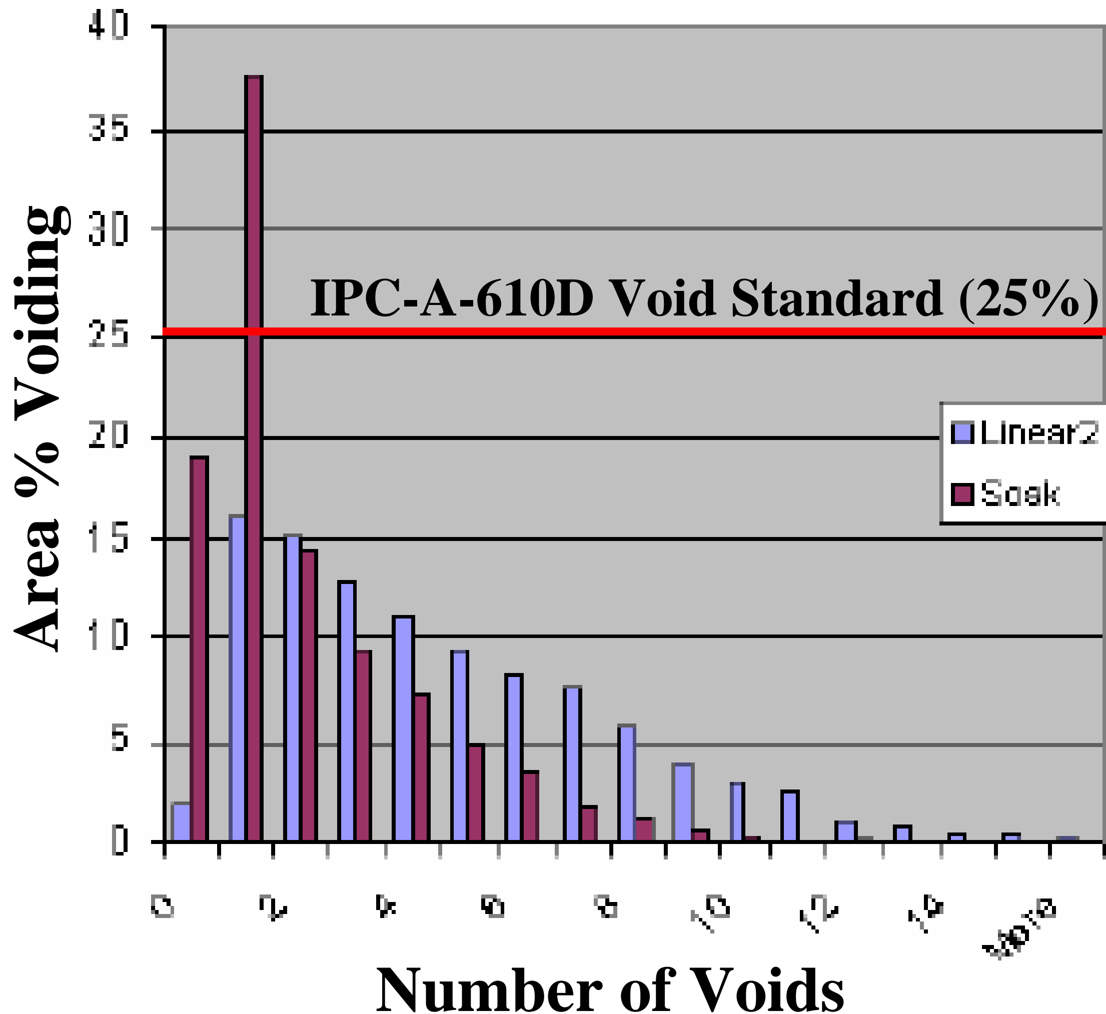
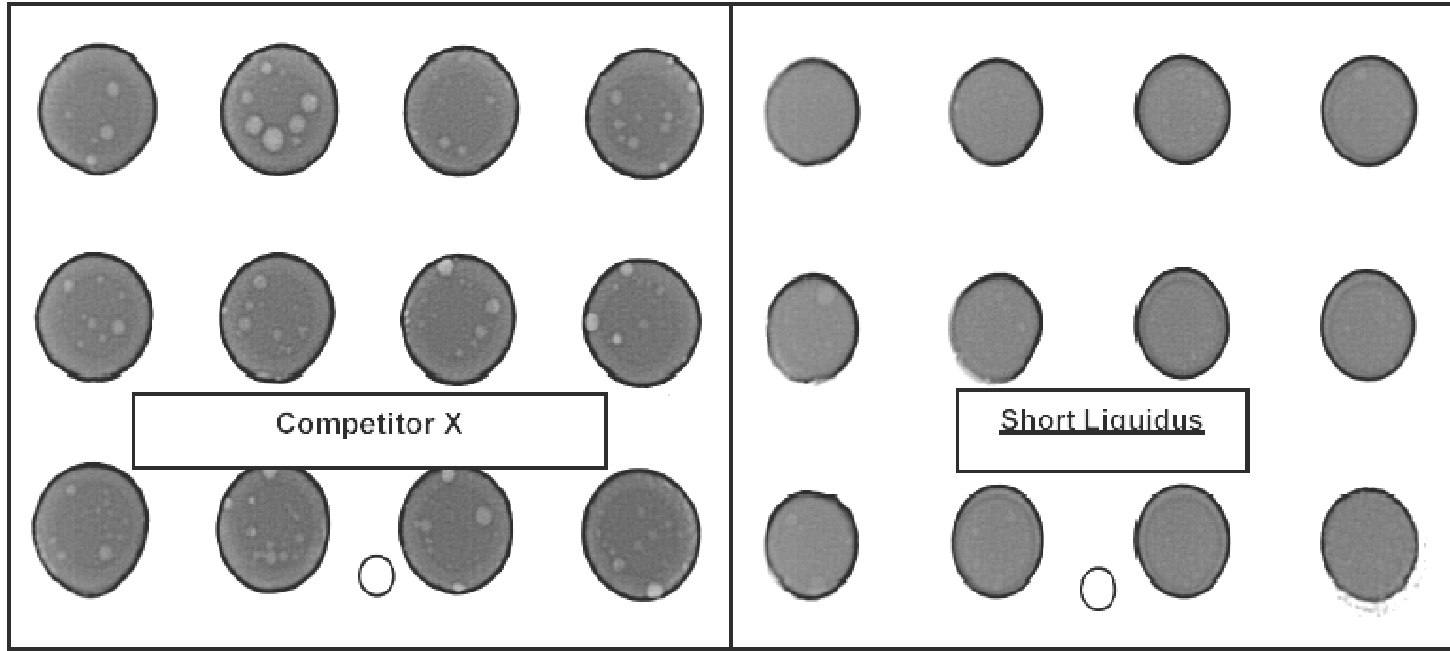
Manufacturer B -Voiding by profile



- Comparison of voiding by profile type
  - Linear versus Soak
- Soak produces fewer voids – Profile in use today
- Most voids below 20% area

Voiding Performance Comparison – Manufacturer A

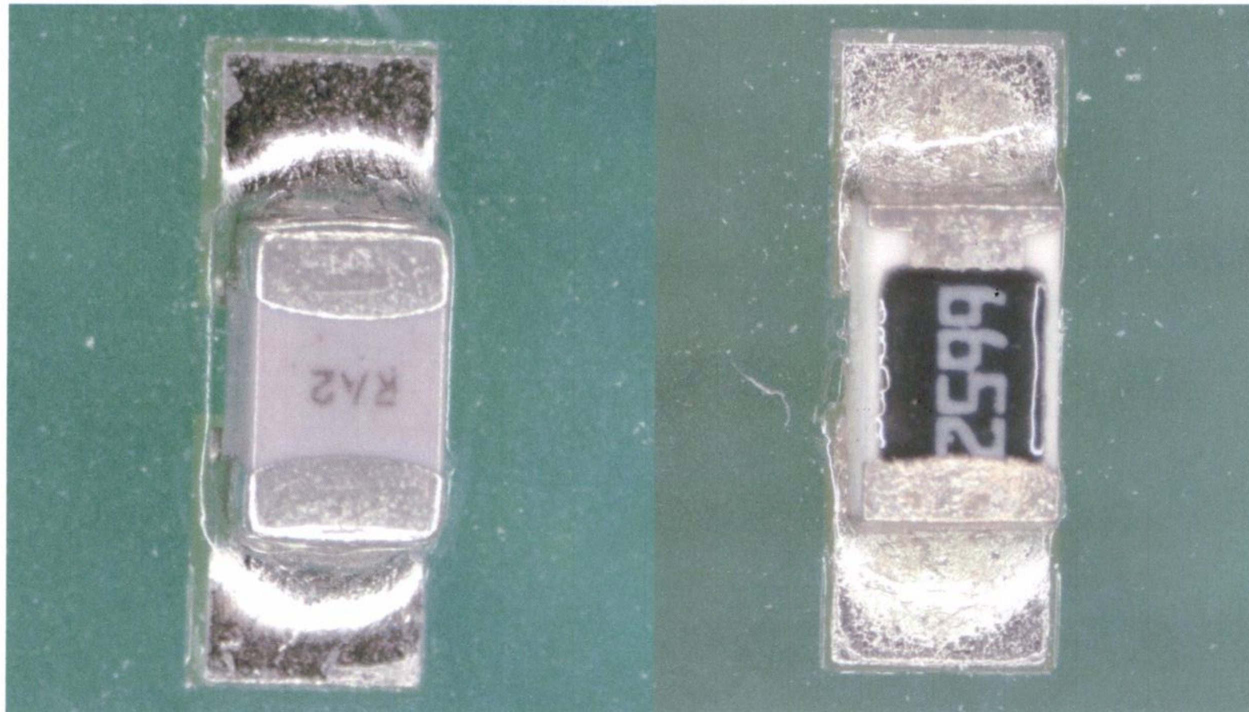


- Comparison of two Pb-free Solder pastes
- Both reflowed with the same profile on the same board with identical components
- The material on the right produces less voiding

Beyond Engineering

- Even if you choose the best solder paste, components and process…it is not enough
- Operators need to be trained to understand the differences with Pb-free

Key Inspection Differences



SAC – Rougher, dull, appearance

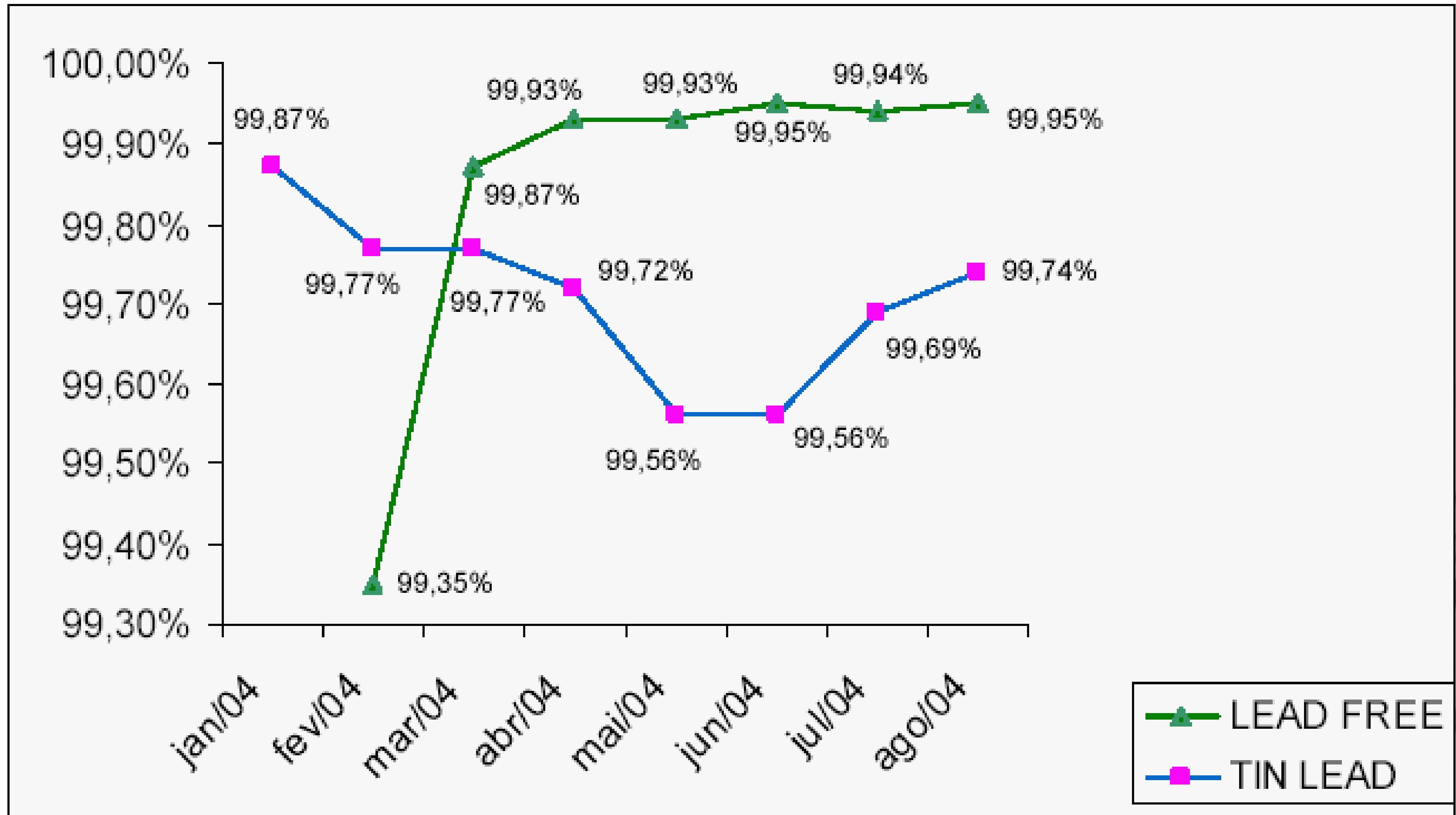
Less bright and shiny

THIS IS OK!

Operator Training

- Manufacturer B working with us conducted operator training
- Review of characteristics of Pb-free Paste
  - Wetting Performance
  - Wetting Angle
  - Solder Joint Appearance
- All Operators went through 2 training courses
- 32 hours total over 2 months

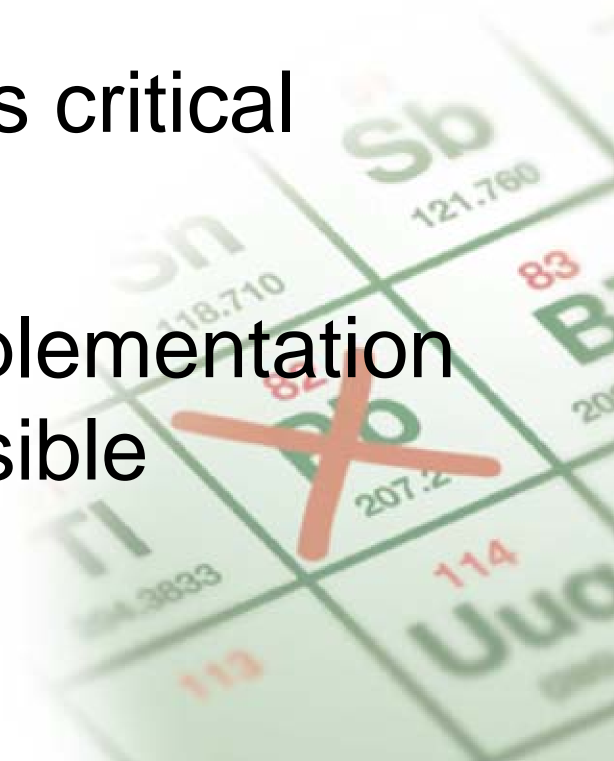
Yield Performance – Full Time Manufacturing



After 2 months, yield is *better* with Pb-free!!

Pb-free Manufacturing

- Pb-free Cell Phones have been in production for over 1 year
- Choosing the right materials is critical
- With the right training and implementation Pb-free manufacturing is possible



Acknowledgements

V. Goudarzi (Motorola) and G. Freeman (Henkel), “Making the Centigrade”, *Circuits Assembly*, February 2005.

A. Reis, G. Almeida (Nokia) and J. Moriya (Tecsolda), “Lead-Free Technology Implementation”, IMAPS Brazil, October 2004.

Thank You

Questions?

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