Fill the Void

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Outline/Agenda

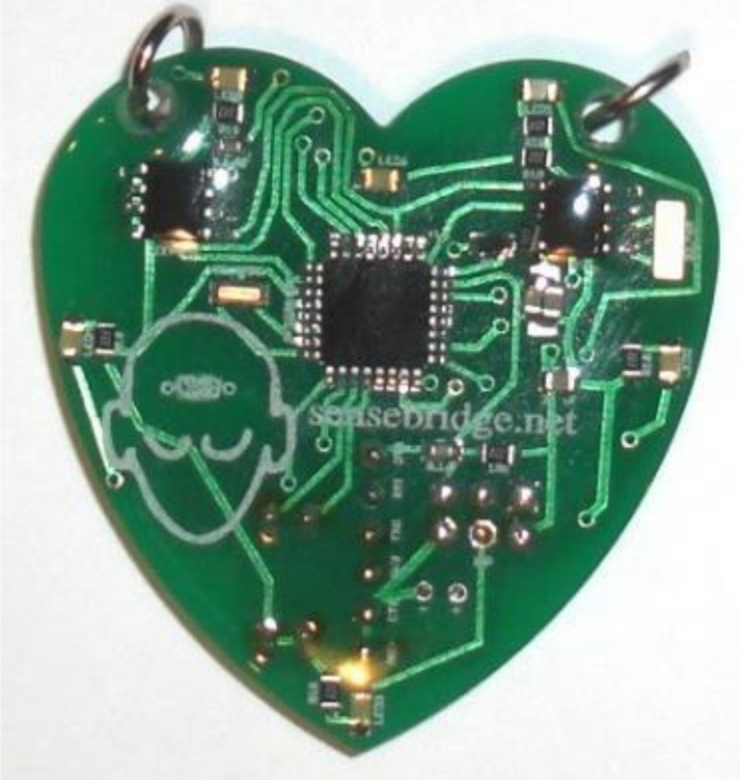
- Introduction
- Factors that Influence Voiding
- Voiding Results
- What Have We Learned About Voiding?
- Future Work
- Acknowledgements
- Q & A

Introduction

Do you have voids in your life?

Introduction

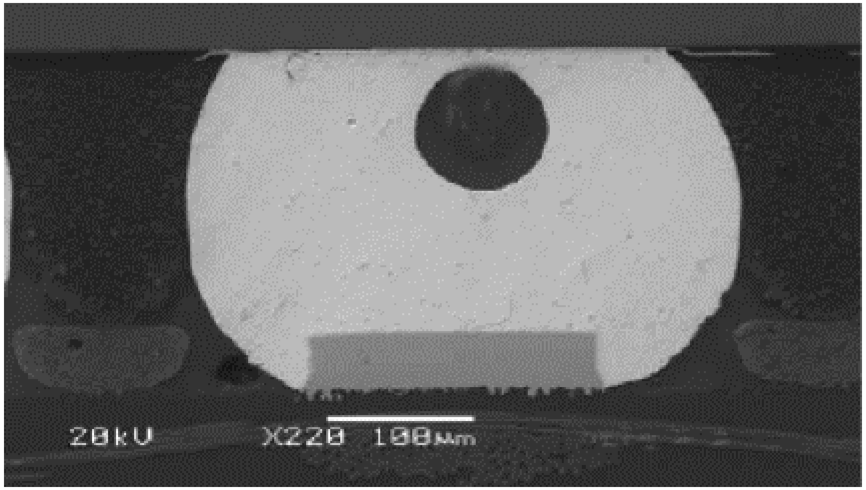
Good news! We have solutions!



Introduction

Void: (noun)

1. A completely empty space. “The black void of space.”
2. Gap in the solder joint where the solder does not fill the space completely.



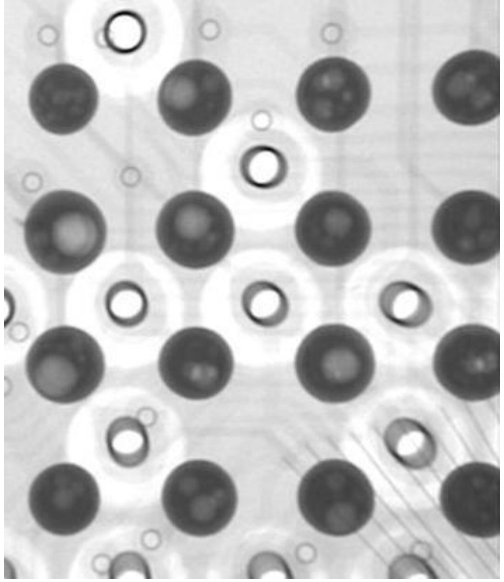


*Image from Nihon Superior, “Controlling the Voiding Mechanisms in the Reflow Soldering Process”, Proceedings of IPC APEX Expo 2016.

Introduction

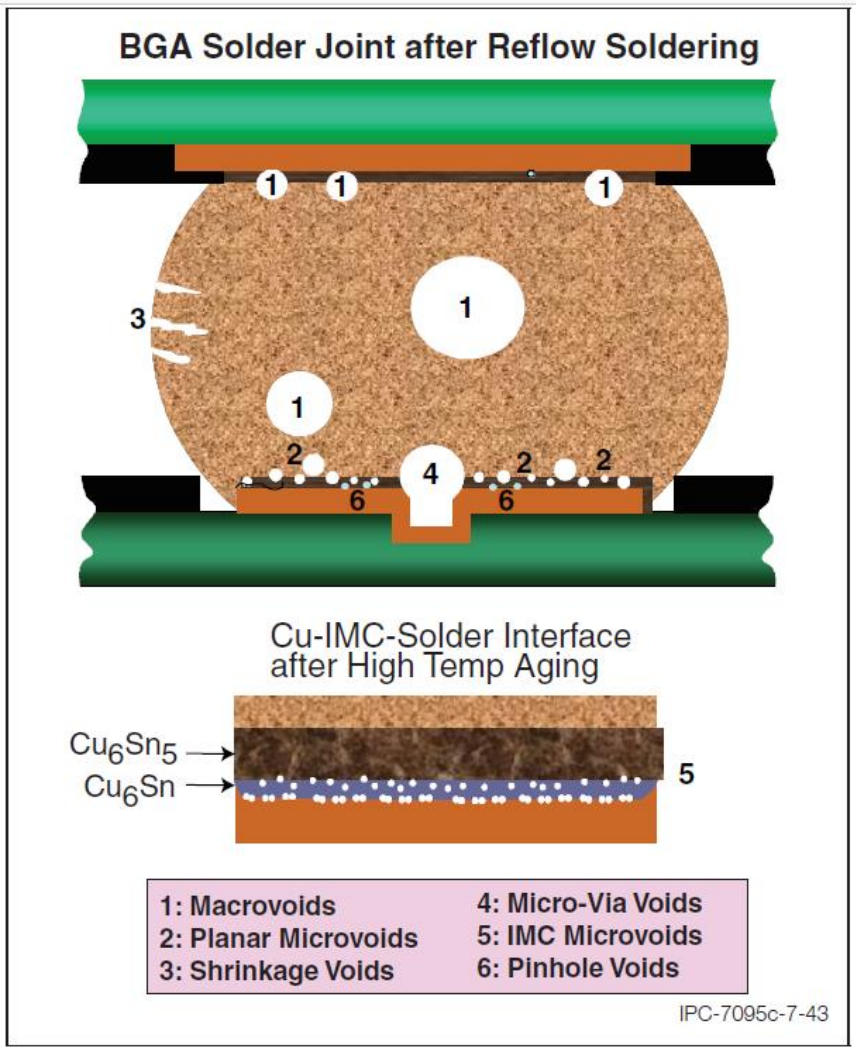


Figure 7-43 Typical Size and Location of Various Types of Voids in a BGA Solder Joint

*IPC 7095C, “Design and Assembly Process Implementation for BGAs”, 2013-January.

Void Limits

3.5.7 Voids in BGA Many companies use X-ray, In-circuit Test (ICT) and Automatic Optical Inspection (AOI) in combination to improve their process control for BGA solder joints. Some look for voids through X-ray to determine accept/reject criteria. Some level of voiding in any kind of solder joint is inevitable, but there is still debate as to what is acceptable or an excessive void. The proponents of voids argue that it is not the void that is bad, but its location. The review of voiding has many consider-ations, and in order to assist in process improvement

*IPC 7095C, "Design and Assembly Process Implementation for BGAs", 2013-January.

Void Limits

Table A-3 Corrective Action Indicator for Microvia in Pad Lands used with 0.5, 0.4 or 0.3 mm Pitch

Void Type	Void Description	Corrective Action Indicator: Class 1	Class 2	Class 3	Action Taken
Determined by cross section/X-ray laminography (sampling according to Section 7.6.3) at Component Incoming Evaluation					
A	Voids within the solder ball (prior to assembly)	Up to 90% balls may have voids Maximum Void size in any ball is 9% of Area (30% of the image diameter)			Investigate root cause in process & take corrective action
B	Voids at package interface (prior to assembly)	Up to 80% balls may have voids Maximum Void size in any ball is 6% of area (25% of the image diameter)	Up to 70% balls may have voids Maximum Void size in any ball is 4% of area (20% of the image diameter)	Up to 50% balls may have voids Maximum Void size in any ball is 2% of area (15% of the image diameter)	Investigate root cause in process & take corrective action
		All balls with cumulative voids no matter what size are considered			
Determined by cross section/X-ray laminography (sampling according to Section 7.6.3) Evaluation after Assembly					
C	Voids within the ball after PCA reflow	Up to 100% balls may have voids Maximum Void size in any ball is 25% of Area (50% of the image diameter)			Investigate root cause in process & incoming parts, take corrective action
D	Voids at the package interface after PCA reflow	Up to 100% balls may have voids Maximum Void size in any ball is 15% of area (40% of the image diameter)	Up to 80% balls may have voids Maximum Void size in any ball is 10% of area (32% of the image diameter)	Up to 60% balls may have voids Maximum Void size in any ball is 5% of area (22% of the image diameter)	Investigate root cause in process & incoming parts, take corrective action
		All balls with cumulative voids no matter what size are considered			
E	Voids at the mounting surface interface after PCA reflow	Up to 100% balls may have voids Maximum Void size in any ball is 15% of area (40% of the image diameter)	Up to 80% balls may have voids Maximum Void size in any ball is 10% of area (32% of the image diameter)	Up to 60% balls may have voids Maximum Void size in any ball is 5% of area (22% of the image diameter)	Investigate root cause in process & incoming parts, take corrective action
		Balls with cumulative voids smaller than 2% of the area (15% of the image diameter) are not counted			
Determined by transmission X-ray (sampling according to Section 7.6.3) for Process Evaluation either at Component Incoming or after Assembly					
A, B	Voids at incoming	Not Recommended			Investigate root cause in process & take corrective action
C, D, E	Voids after PCA reflow	Not Recommended			Investigate root cause in process & incoming parts, take corrective action

*IPC 7095C, “Design and Assembly Process Implementation for BGAs”, 2013-January.

Factors that Influence Voiding

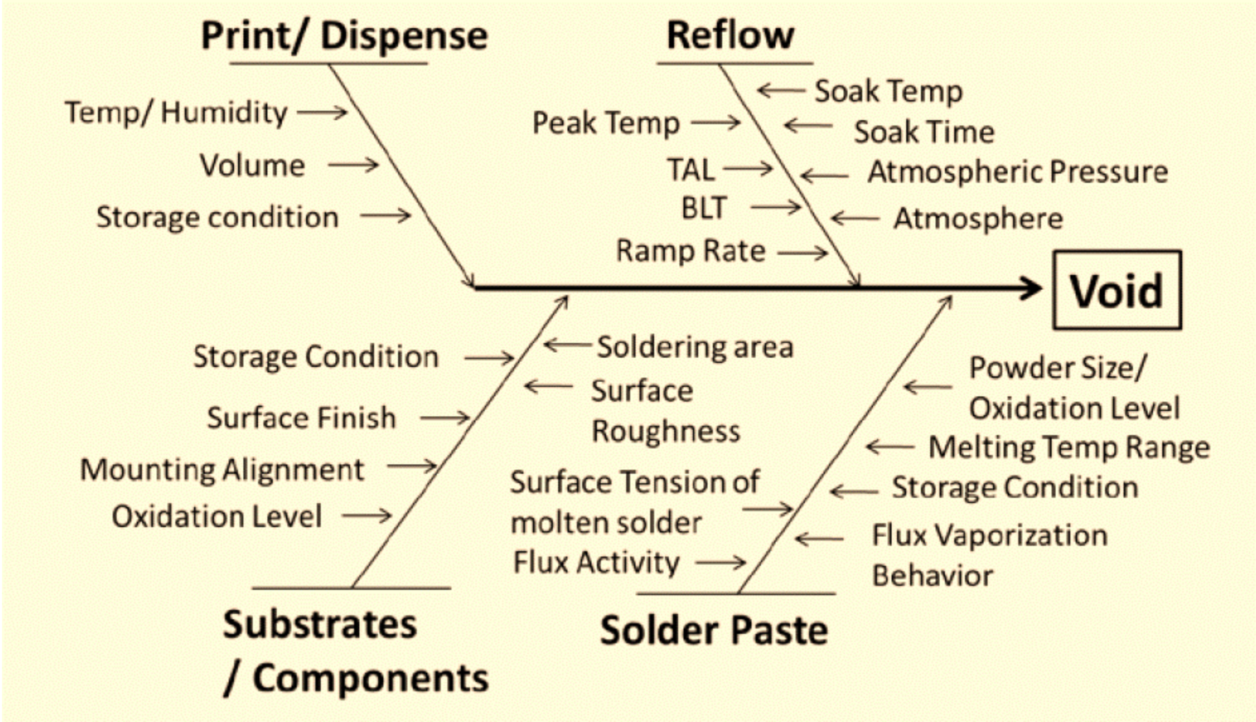
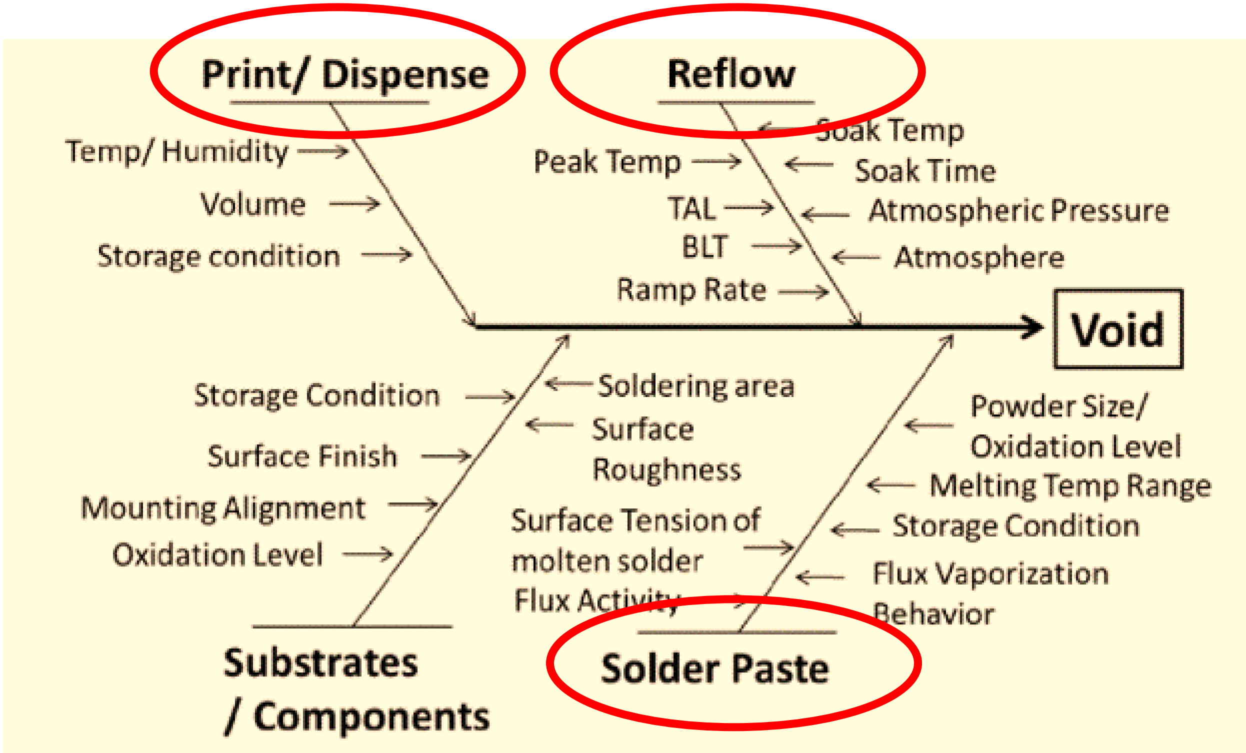


*Diagram from Nihon Superior, “Controlling the Voiding Mechanisms in the Reflow Soldering Process”, Proceedings of IPC APEX Expo 2016.

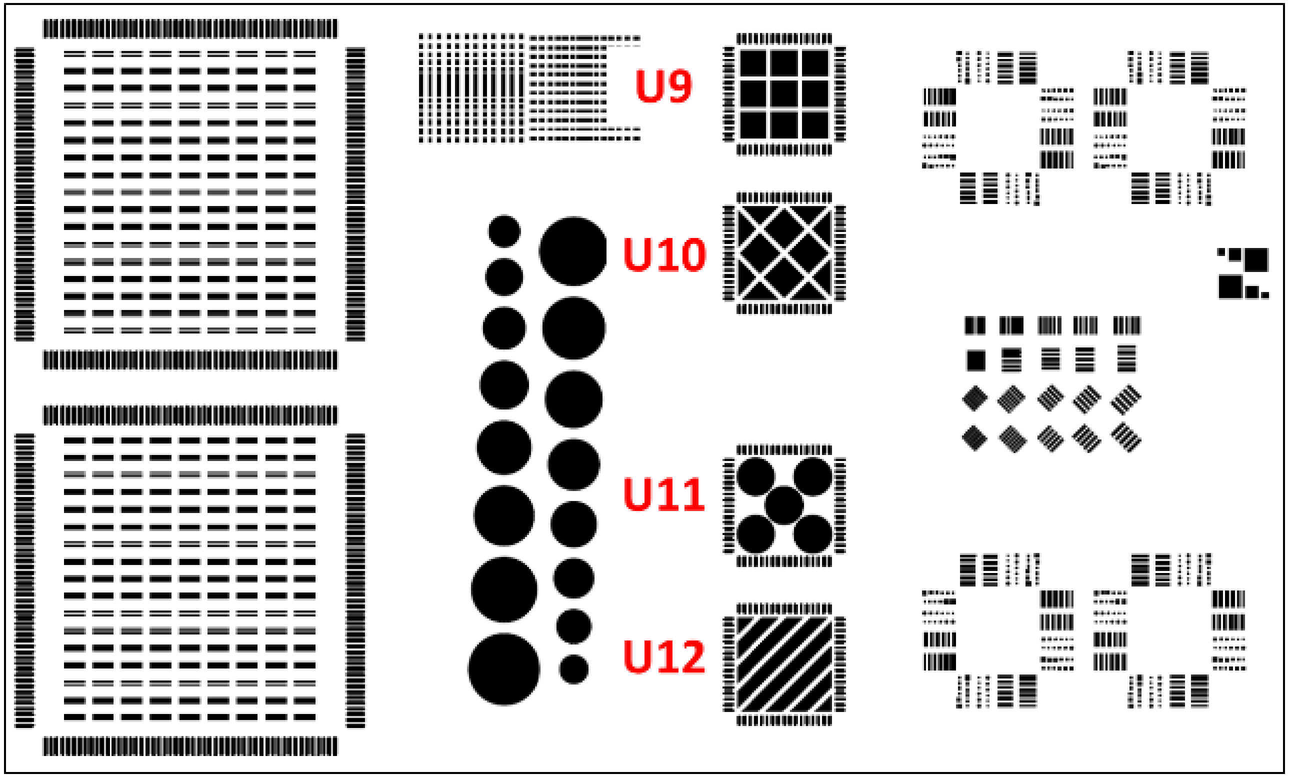
Factors that were Studied



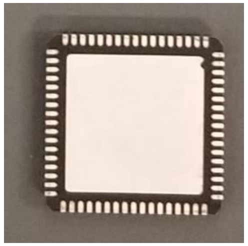
Factors that were Studied

PRINT / DISPENSE

Stencil Design was Varied on QFN Thermal Pads:



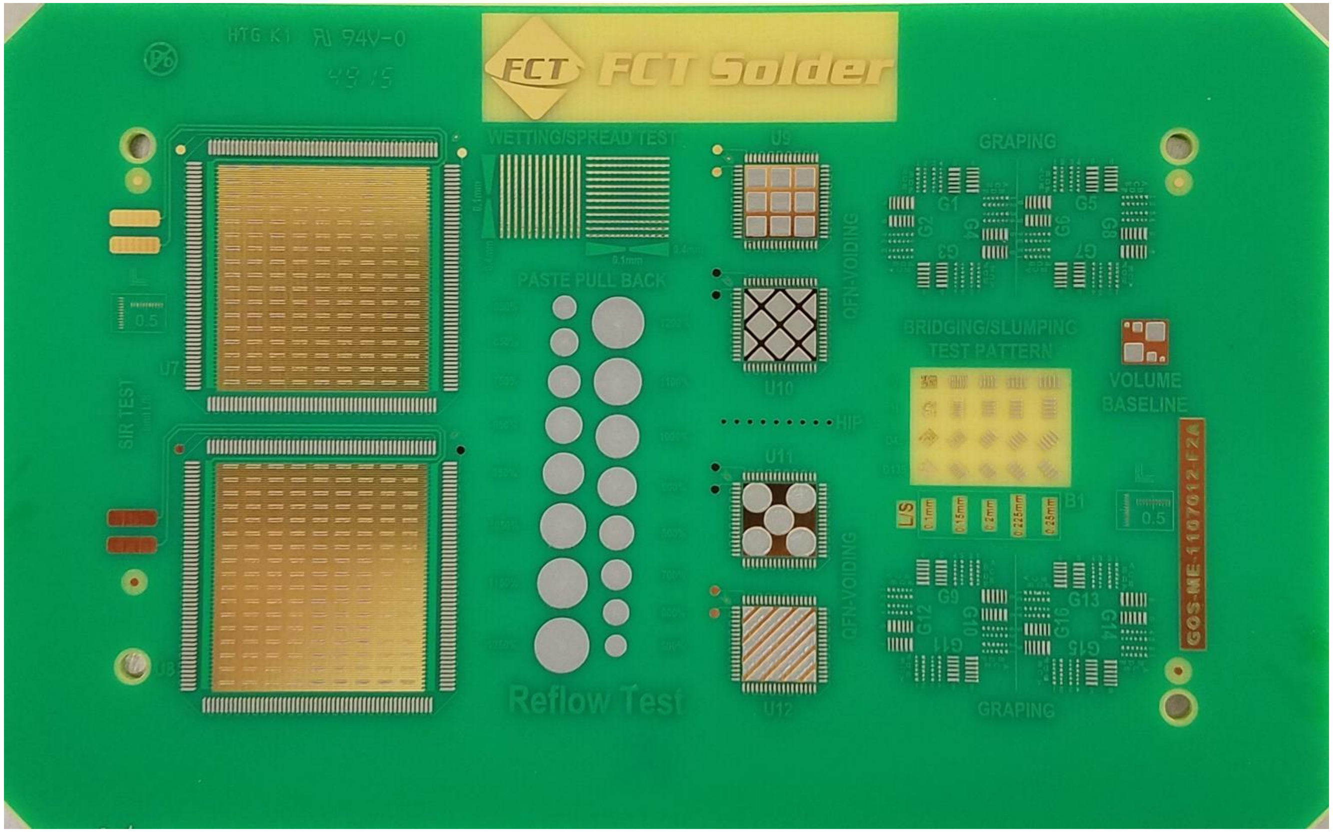
QFN 68 lead
10 mm body
0.5 mm pitch
Tin finish



Factors that were Studied

PRINT / DISPENSE

Printed paste on QFN Thermal Pads (65% Area Covered):

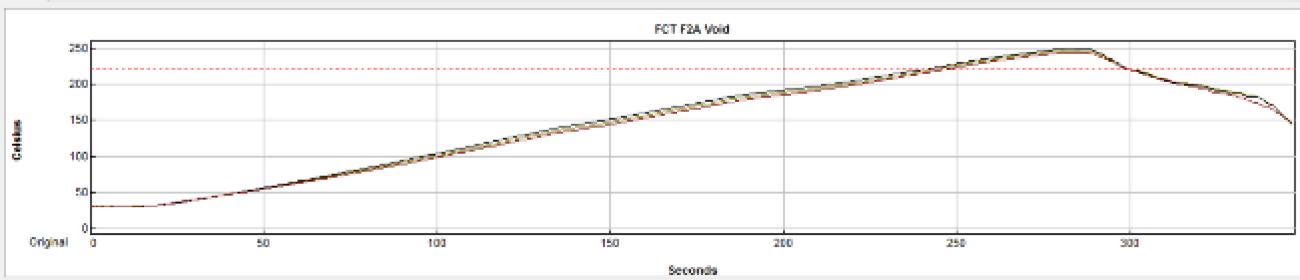


ENIG Surface Finish

Factors that were Studied

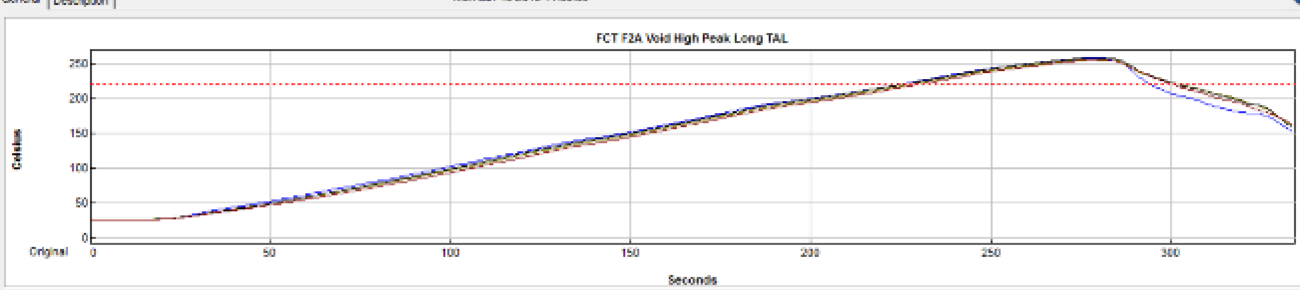
REFLOW - Reflow Profile was Varied:

General | Description | Fri Jun 10 2016 14:02:59



TCs	Max Rising Slope		Reflow Time /221C		Peak Temp		Time 25C-peak	
U11	1.01	-198%	56.64	-22%	247.06	21%	4.70	180%
U10	1.02	-195%	58.83	-8%	249.44	44%	4.72	183%
U12	0.98	-205%	53.00	-47%	244.82	-2%	4.72	183%
Delta	0.04		5.83		4.62		0.02	

General | Description | Mon Jun 13 2016 11:08:00



TCs	Max Rising Slope		Reflow Time /221C		Peak Temp		Time 25C-peak	
U9	1.09	-182%	68.48	57%	257.71	127%	4.63	150%
U11	1.10	-179%	74.32	95%	258.51	115%	4.62	148%
U10	1.11	-177%	74.88	99%	258.68	137%	4.64	157%
U12	1.11	-179%	69.49	63%	255.23	102%	4.62	148%
Delta	0.02		6.40		3.43		0.02	

RTS (Ramp to Spike)

TAL 53 – 59 sec
Peak 245 – 249 °C

Both

Ramp 1.1 °C/sec
Length 4.5 – 4.6 min

RTS-HT
(High Temperature)

TAL 68 – 75 sec
Peak 255 – 259 °C

Factors that were Studied

SOLDER PASTE

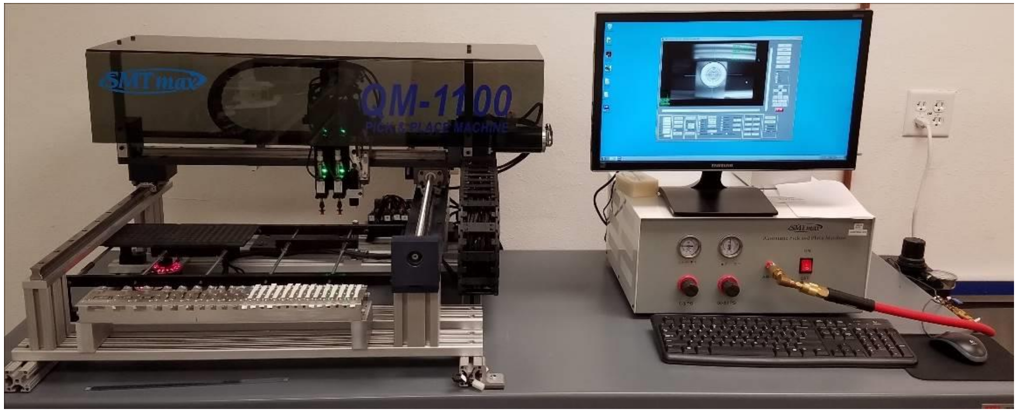
Two lead-free water soluble solder pastes were used:

- Paste A = 88.0% SAC305 Type 3. Moderate Activity.
- Paste B = 88.5% SAC305 Type 3. High Activity.

Equipment

Printer: 30 mm/sec, 1.0 lb/in, 1.5 mm/sec separation

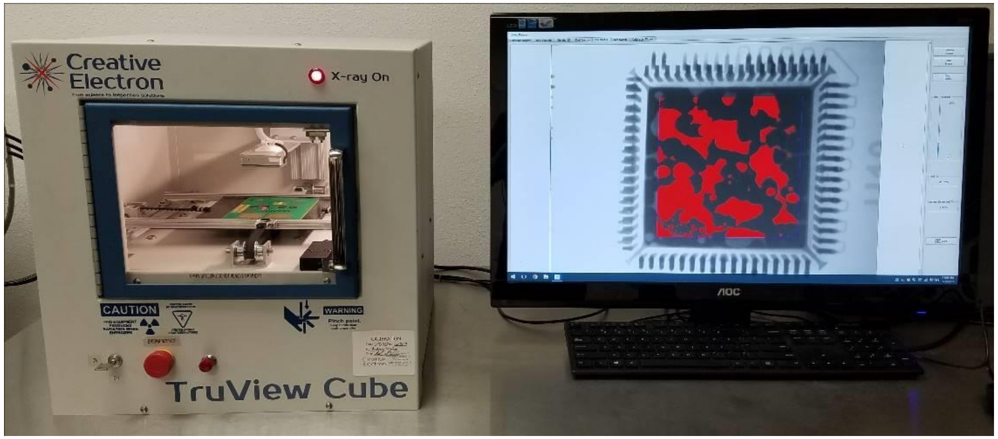
Pick and Place



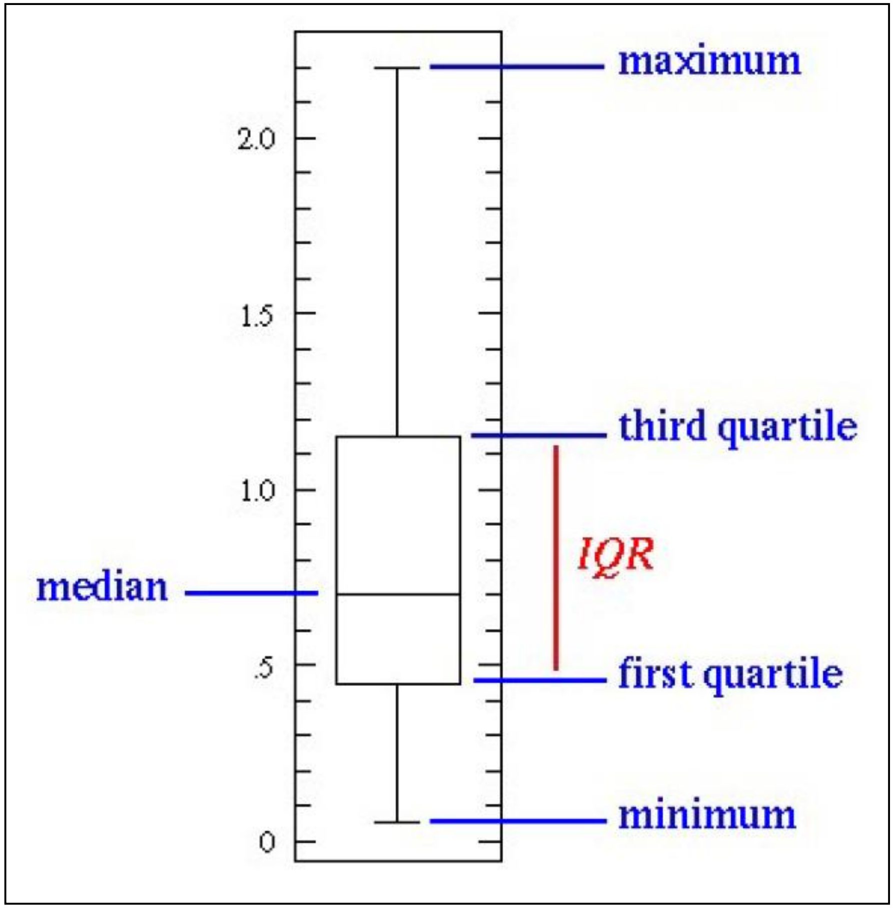
Equipment

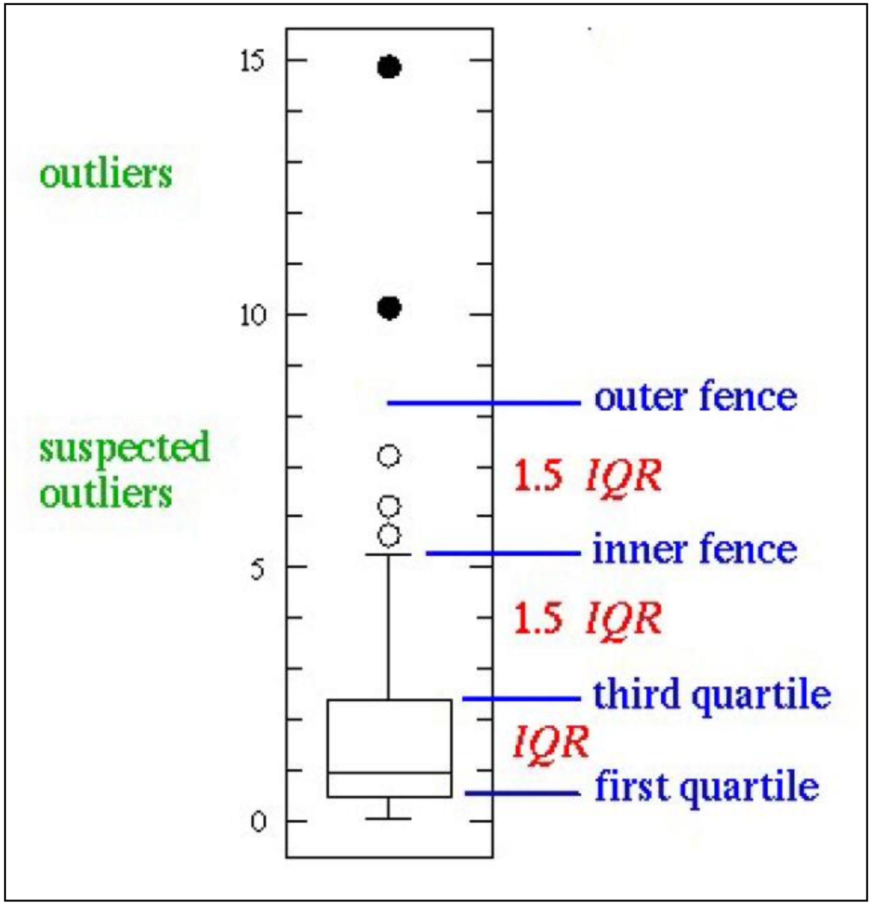
Reflow Oven:
simulates 10 zone,
reflow in air

X-Ray: voltage 70 kV,
current 400 µA

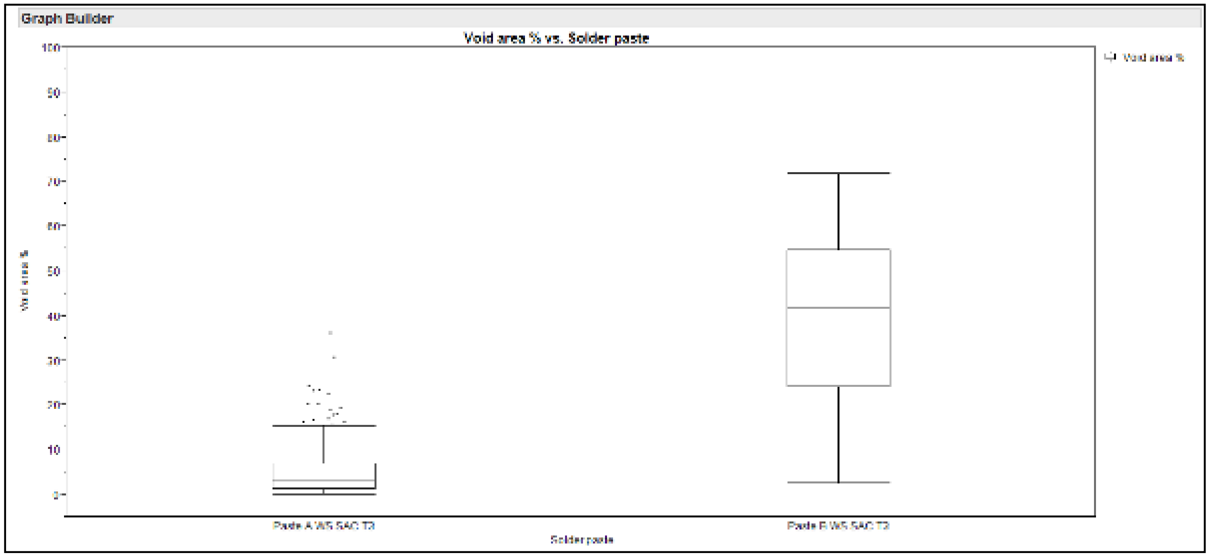


Box and Whisker Plot

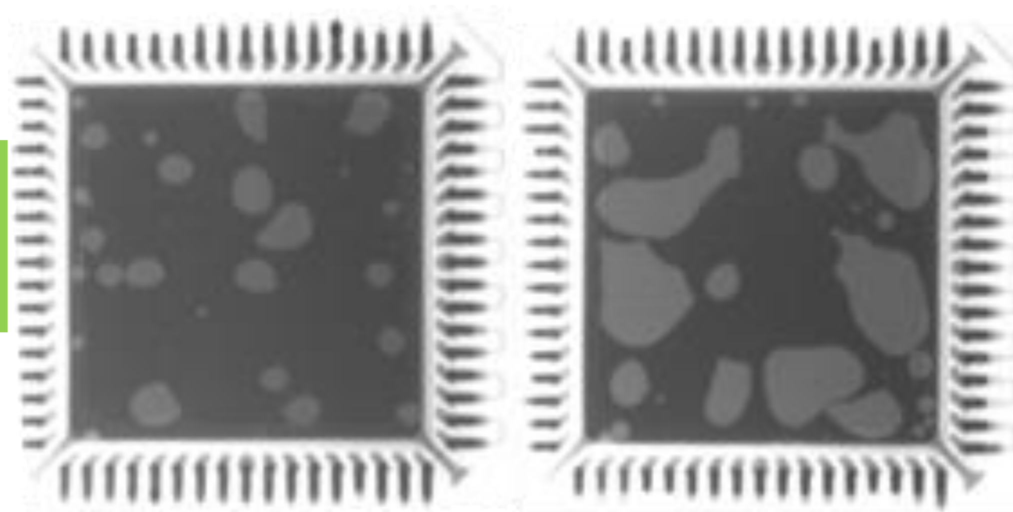




Voiding Results – Solder Paste



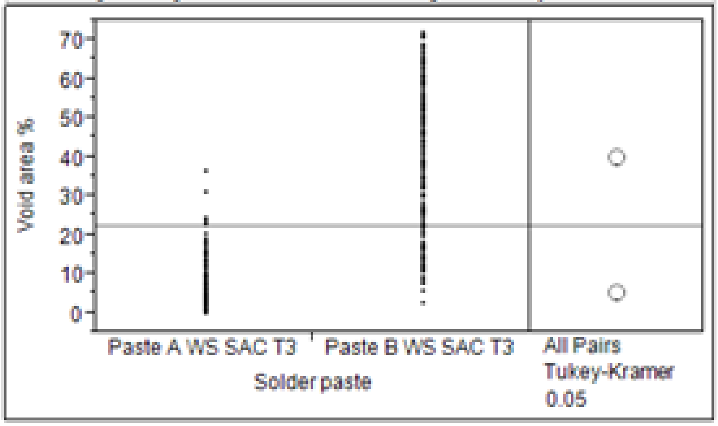
SOLDER PASTE A



SOLDER PASTE B

Tukey-Kramer HSD Testing

Oneway Analysis of Void area % By Solder paste



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Confidence Quantile

q*	Alpha
1.96494	0.05

LSD Threshold Matrix

Abs(Dif)-HSD

	Paste B WS SAC T3	Paste A WS SAC T3
Paste B WS SAC T3	-2.376	32.208
Paste A WS SAC T3	32.208	-2.376

Positive values show pairs of means that are significantly different.

Connecting Letters Report

Level			Mean
Paste B WS SAC T3	A		39.825417
Paste A WS SAC T3		B	5.242083

Levels not connected by same letter are significantly different.

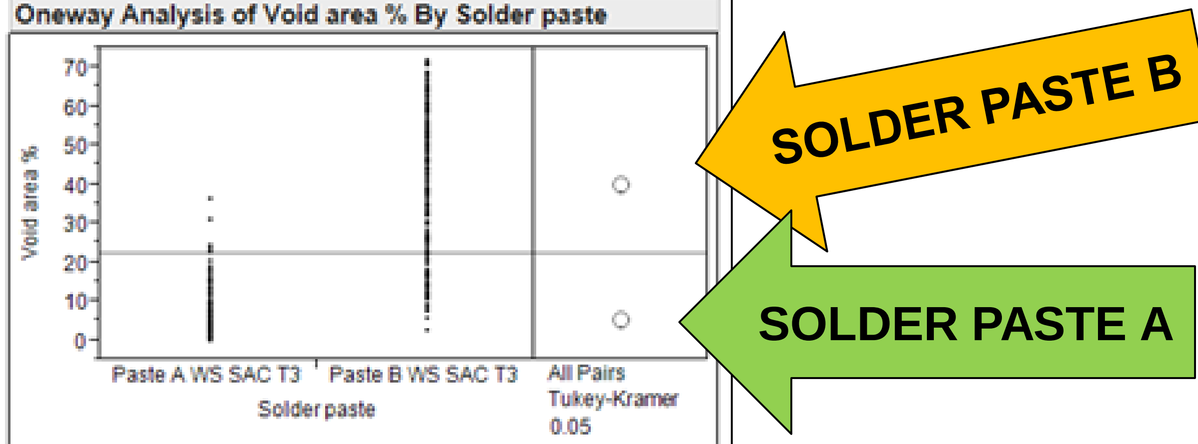
Data sets represented by circles

95% confidence level

Connecting letters shows differences

Voiding Results – Solder Paste

Oneway Analysis of Void area % By Solder paste



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

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1.96494	0.05

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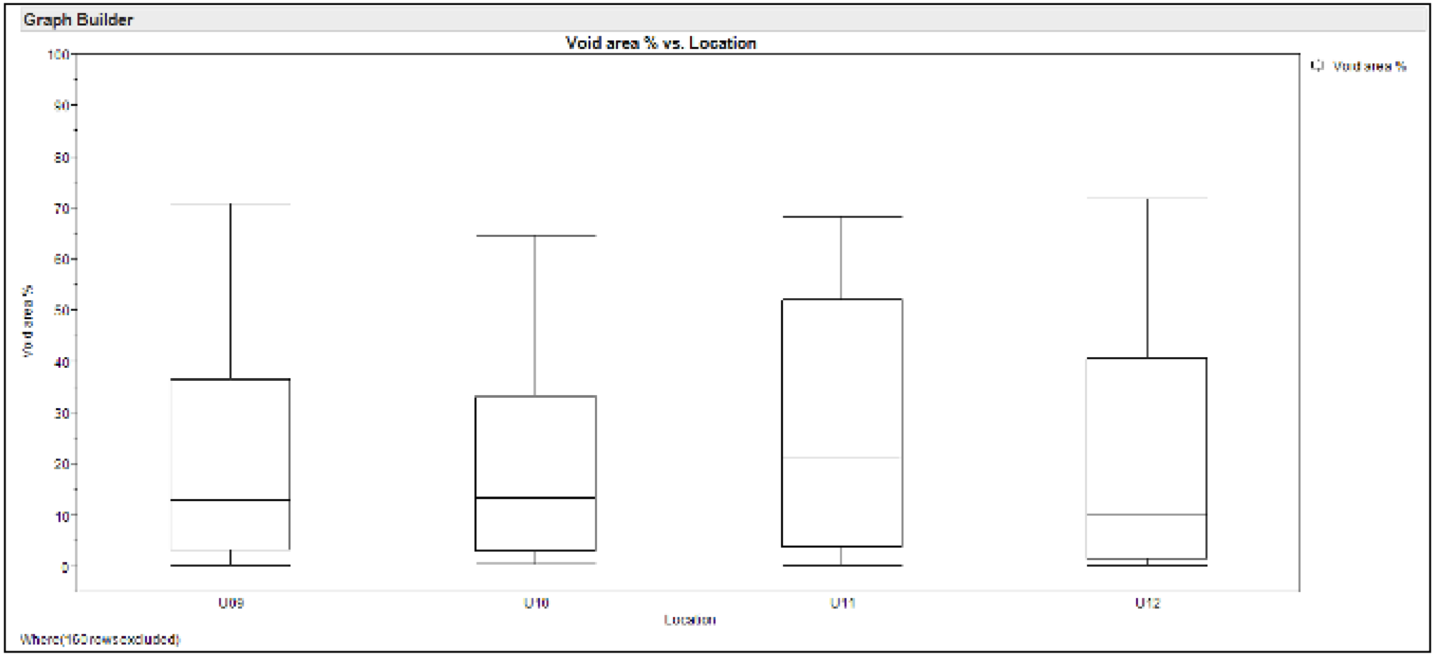
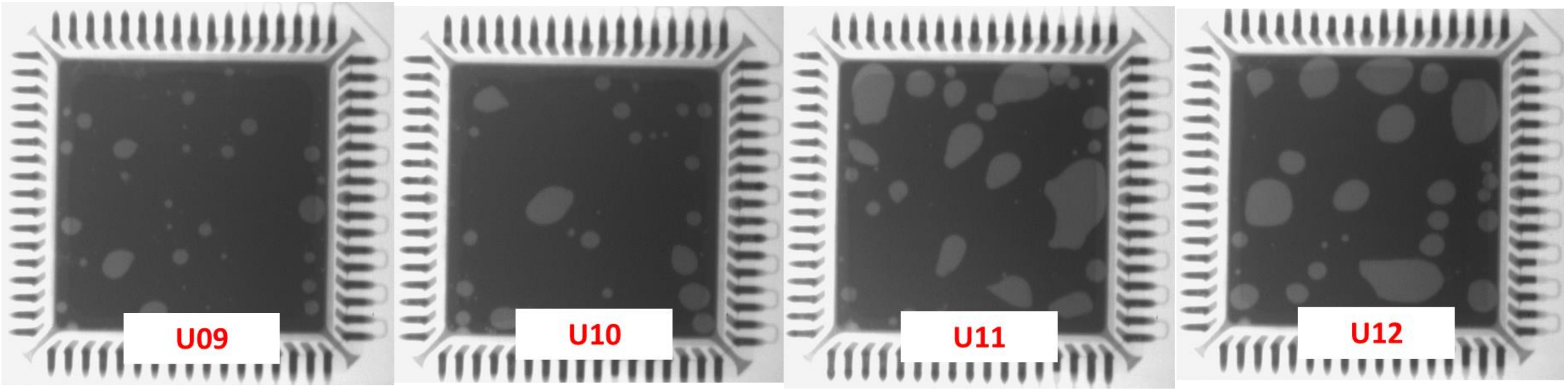
Level			Mean
Paste B WS SAC T3	A		39.825417
Paste A WS SAC T3		B	5.242083

Levels not connected by same letter are significantly different.

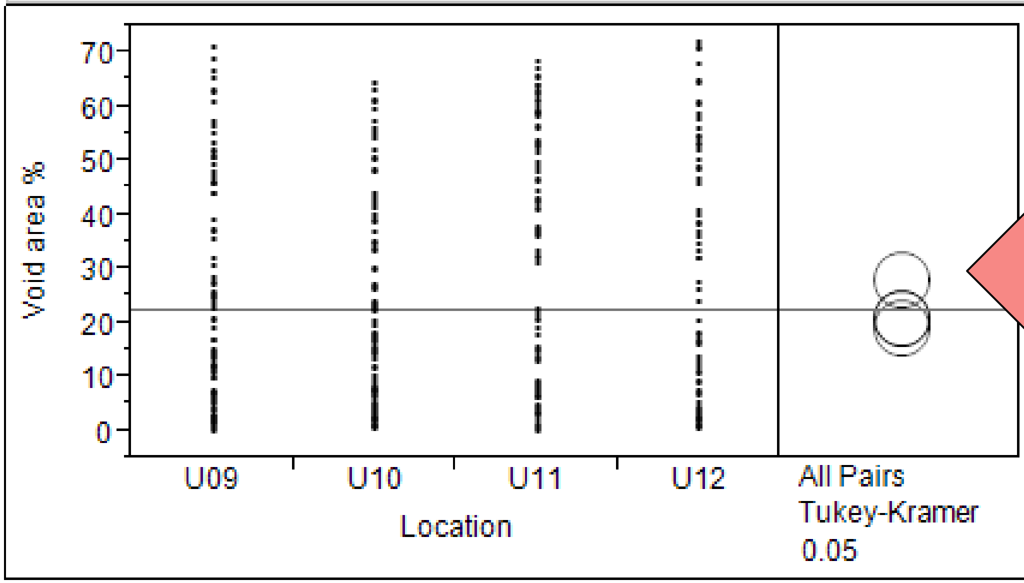
Voiding Results – Stencil Design





Voiding Results – Stencil Design

Oneway Analysis of Void area % By Location



5-Dot (U11) has Higher Voiding

Means Comparisons

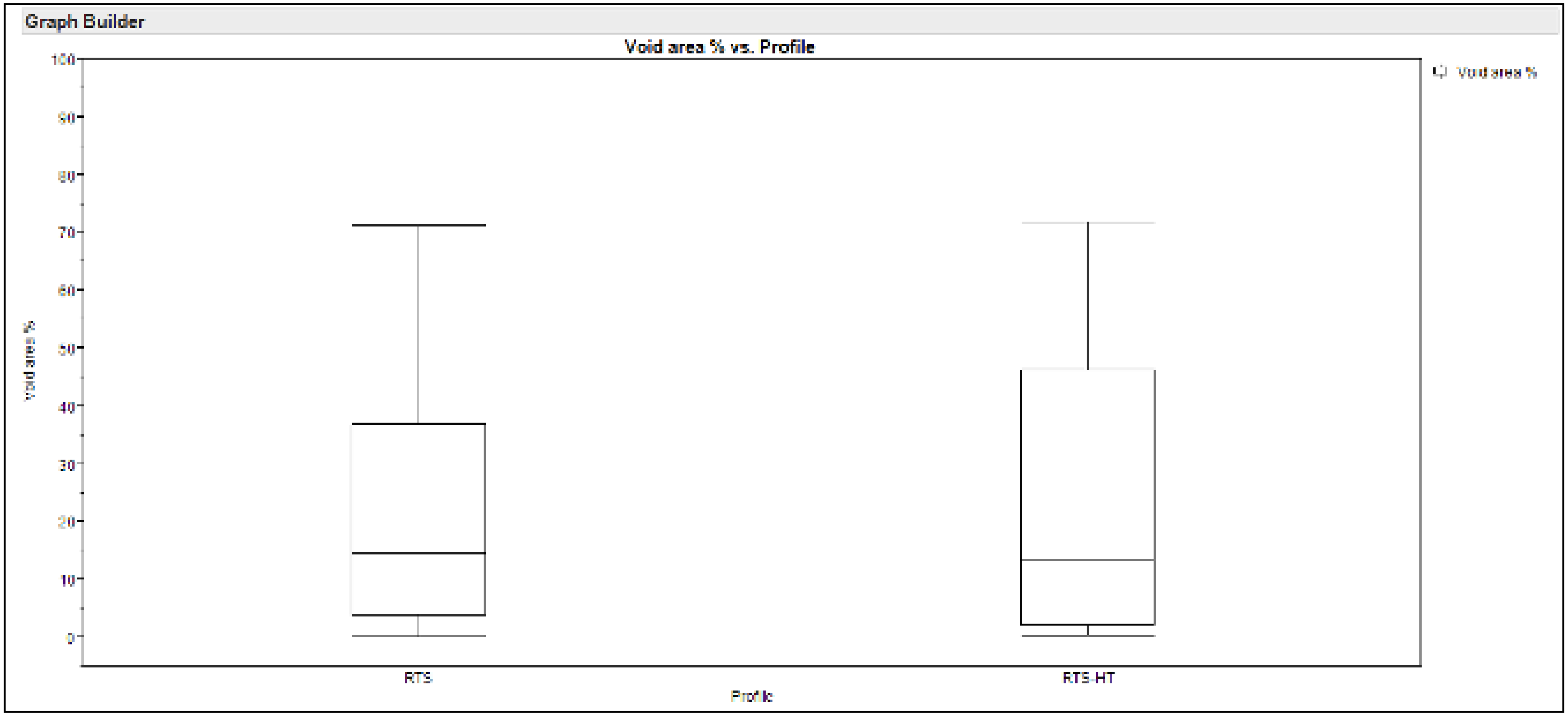
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
U11	A		28.481667
U12		B	21.196667
U09		B	21.186667
U10		B	19.270000

Levels not connected by same letter are significantly different.

Voiding Results – Reflow Profile

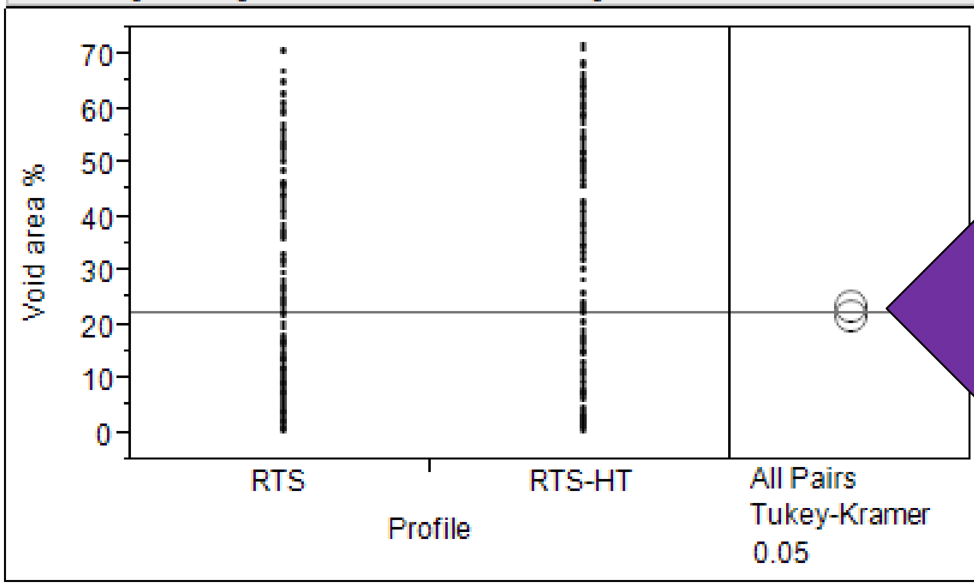


RTS

RTS-HT

Voiding Results – Reflow Profile

Oneway Analysis of Void area % By Profile



No Significant Difference

Means Comparisons

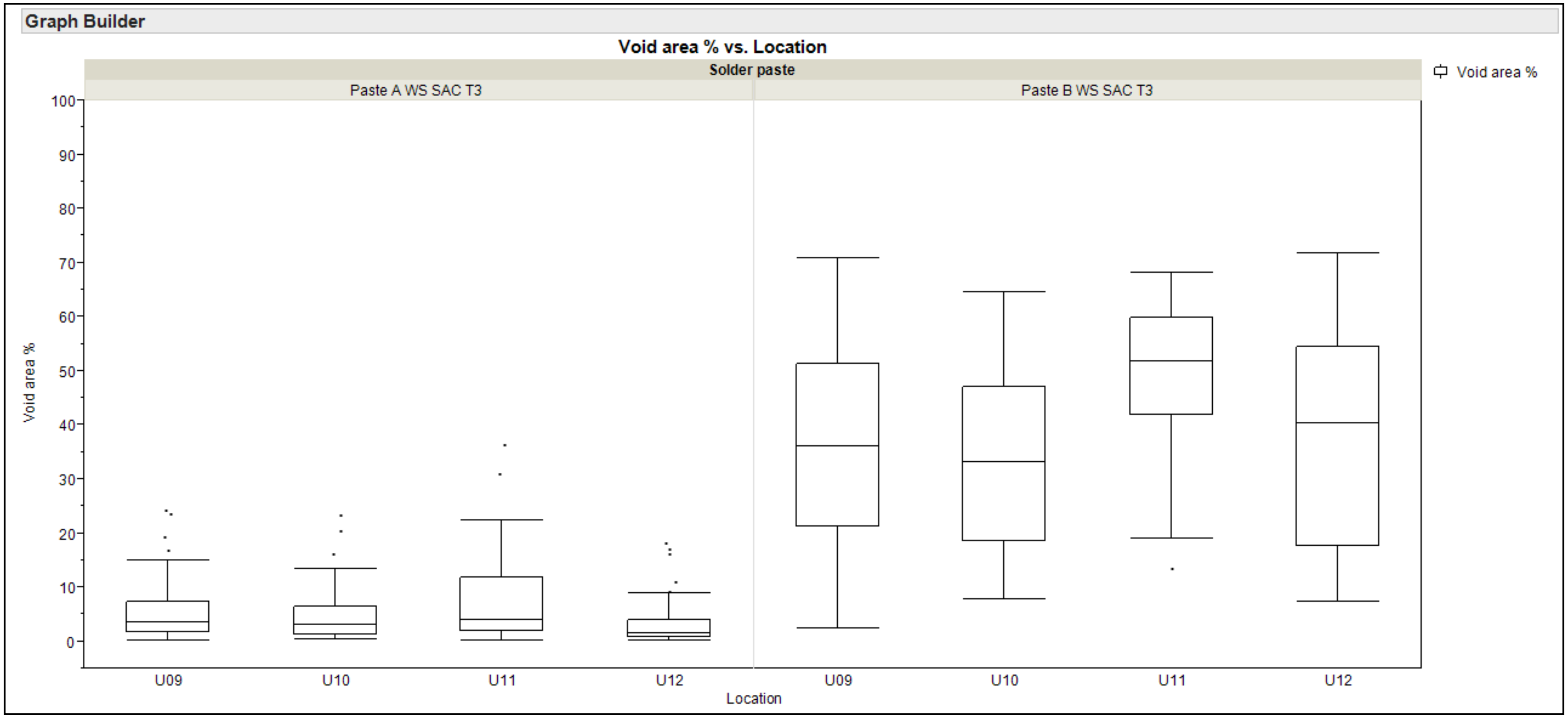
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
RTS-HT	A	23.230417
RTS	A	21.837083

Levels not connected by same letter are significantly different.

Voiding Results – Stencil Design by Solder Paste

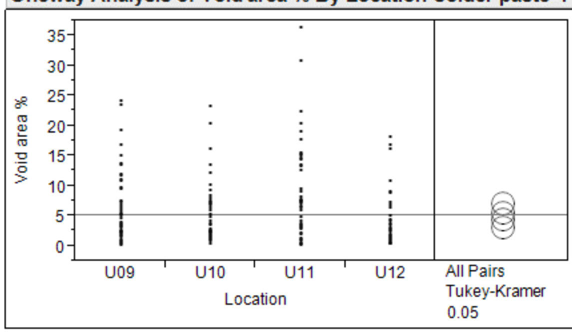


SOLDER PASTE A

SOLDER PASTE B

Voiding Results – Stencil Design by Solder Paste

Oneway Analysis of Void area % By Location Solder paste=Paste A WS SAC T3



Means Comparisons

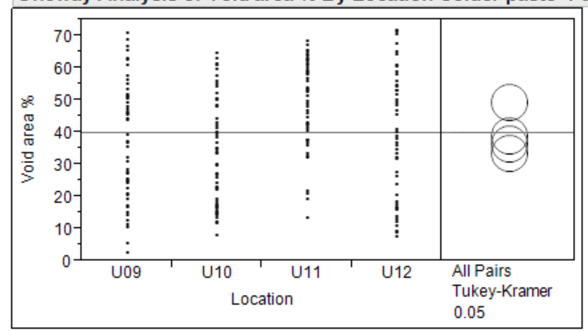
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
U11	A		7.3250000
U09	A	B	5.6283333
U10	A	B	4.7000000
U12		B	3.3150000

Levels not connected by same letter are significantly different.

Oneway Analysis of Void area % By Location Solder paste=Paste B WS SAC T3



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

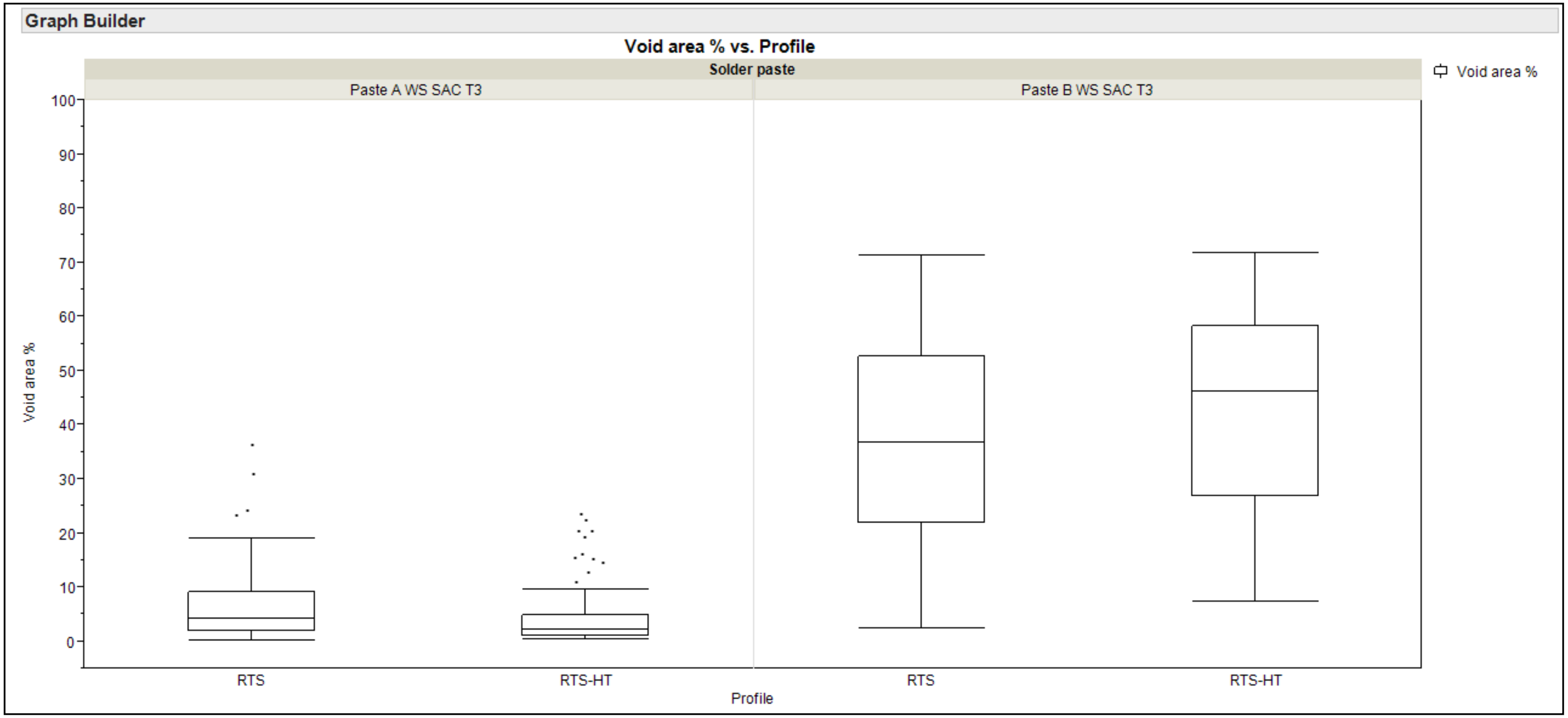
Level			Mean
U11	A		49.638333
U12		B	39.078333
U09		B	36.745000
U10		B	33.840000

Levels not connected by same letter are significantly different.

SOLDER PASTE A

SOLDER PASTE B

Voiding Results – Reflow Profile by Solder Paste

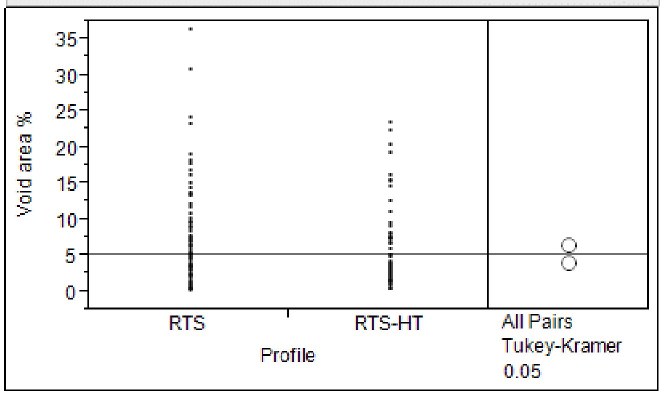


SOLDER PASTE A

SOLDER PASTE B

Voiding Results – Reflow Profile by Solder Paste

Oneway Analysis of Void area % By Profile Solder paste=Paste A WS SAC T3



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

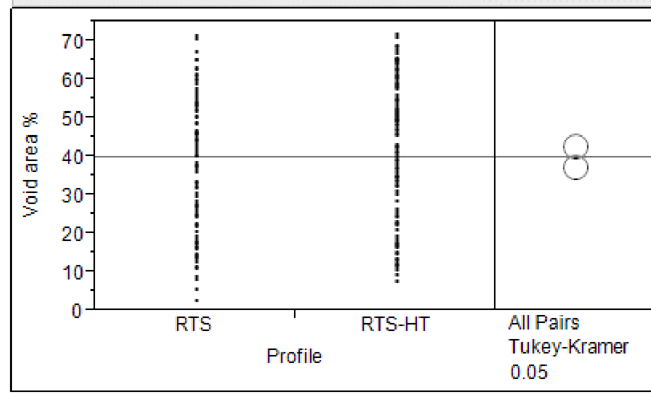
Connecting Letters Report

Level		Mean
RTS	A	6.4300000
RTS-HT	B	4.0541667

Levels not connected by same letter are significantly different.

SOLDER PASTE A

Oneway Analysis of Void area % By Profile Solder paste=Paste B WS SAC T3



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

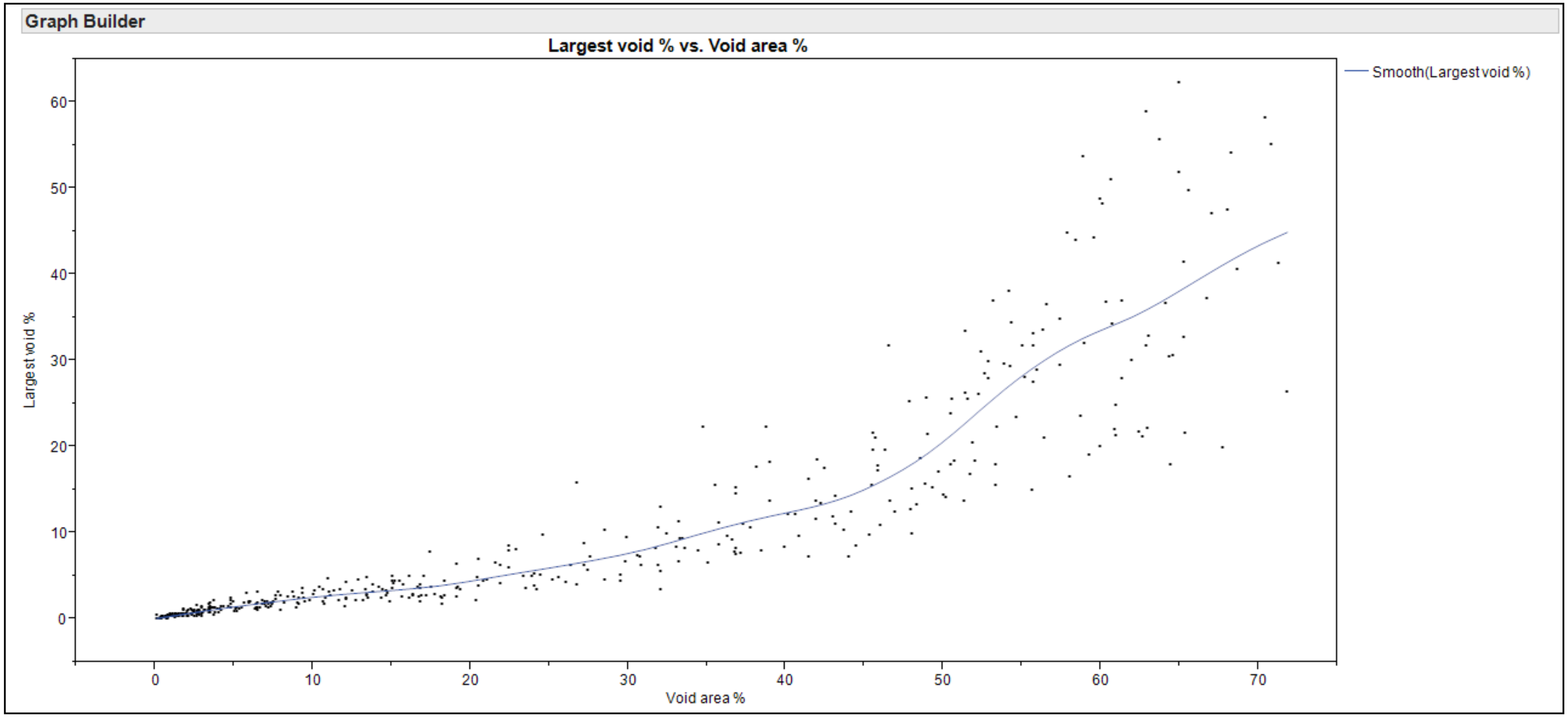
Level		Mean
RTS-HT	A	42.406667
RTS	B	37.244167

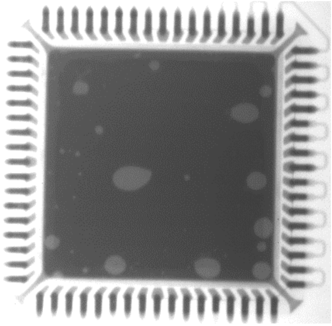
Levels not connected by same letter are significantly different.

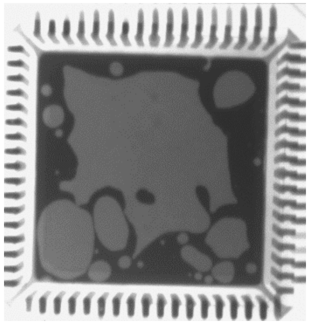
SOLDER PASTE B

Void Size

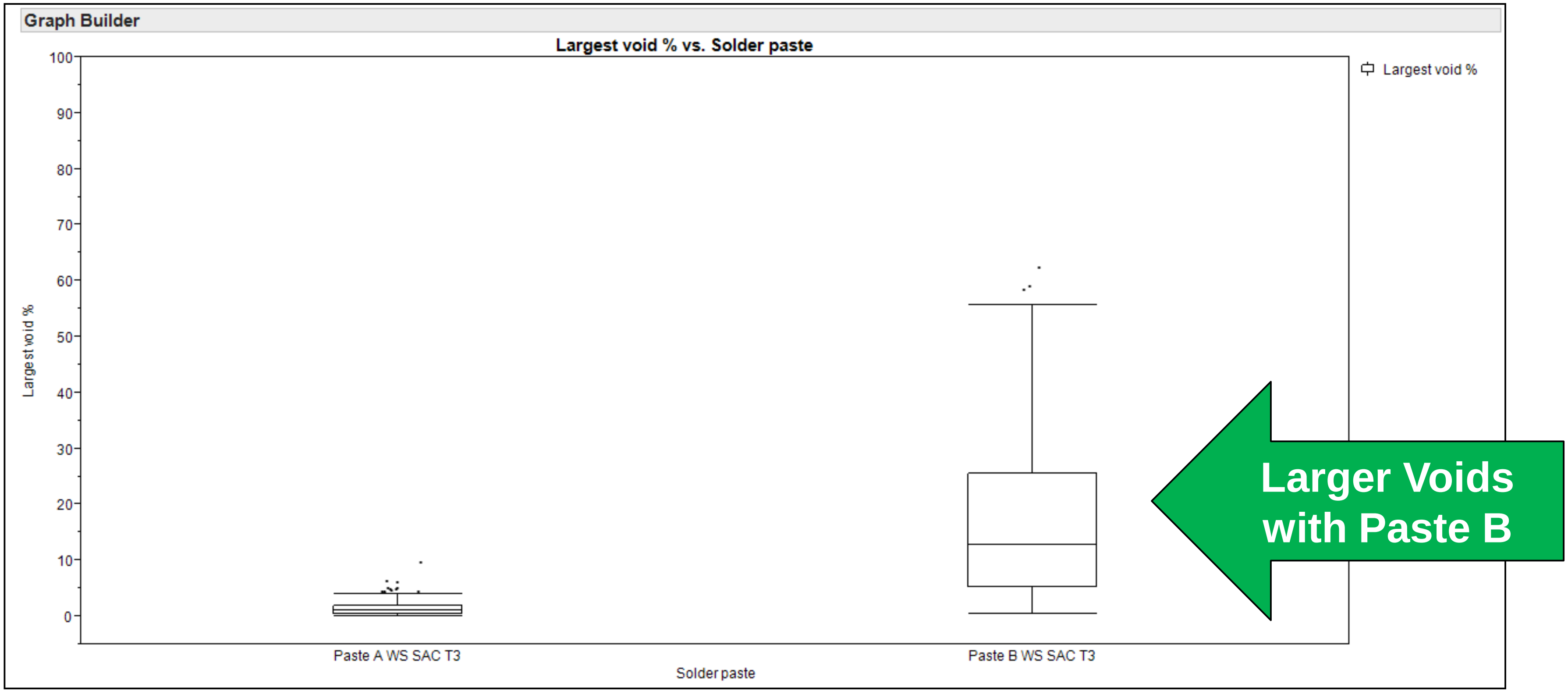
Voiding Results – Largest Void



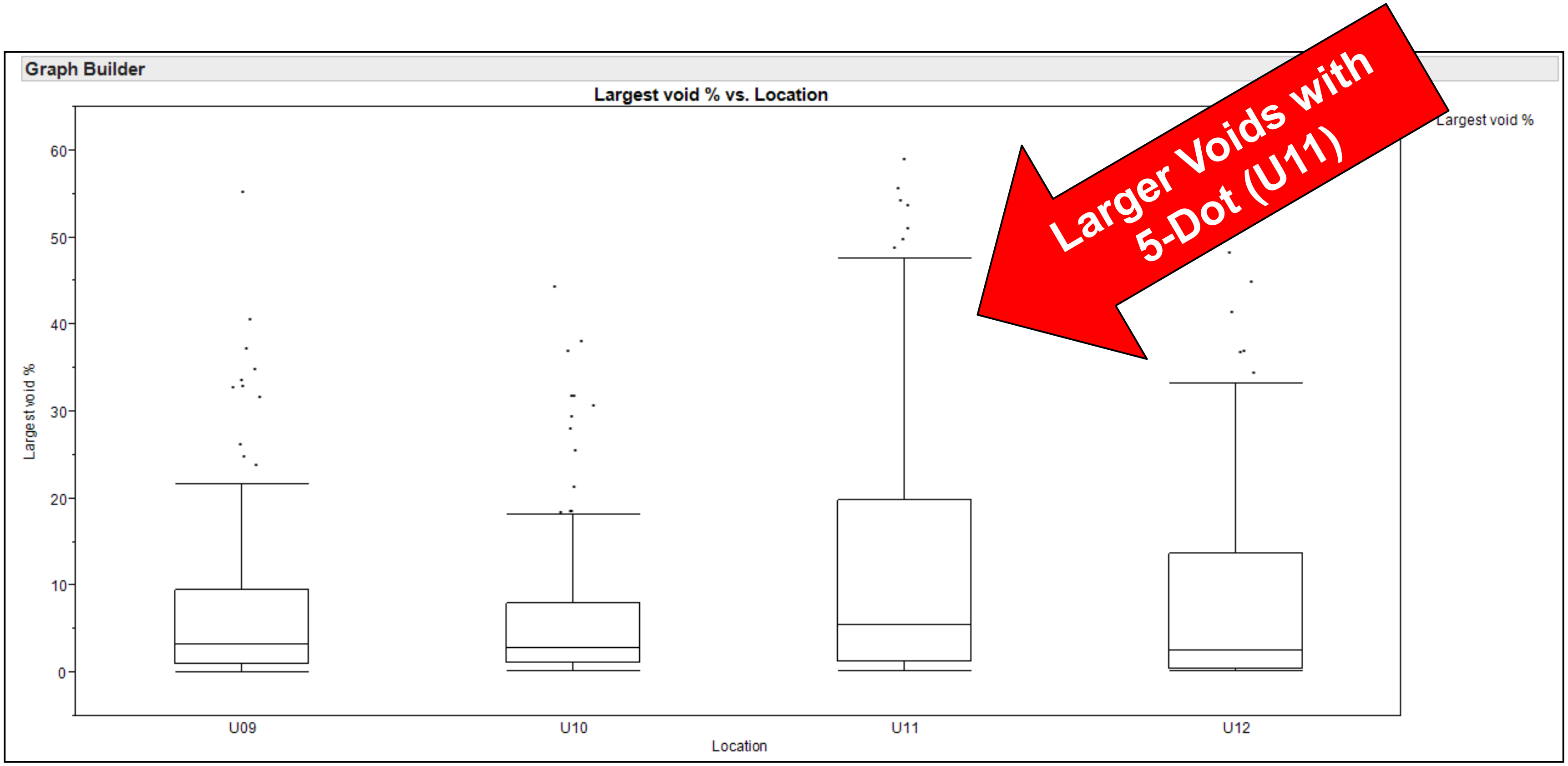




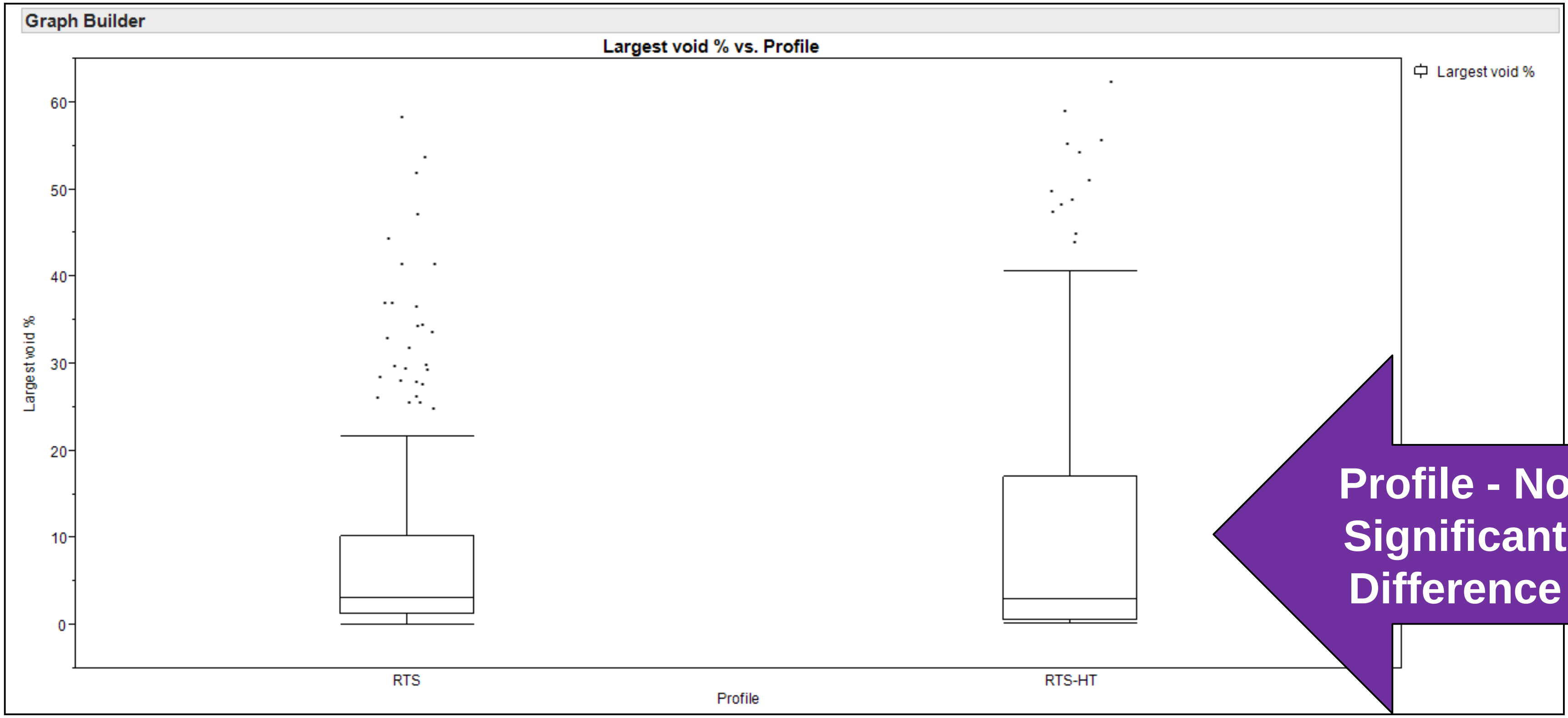
Voiding Results – Largest Void by Solder Paste



Voiding Results – Largest Void by Stencil Design



Voiding Results – Largest Void by Reflow Profile



Profile - No Significant Difference

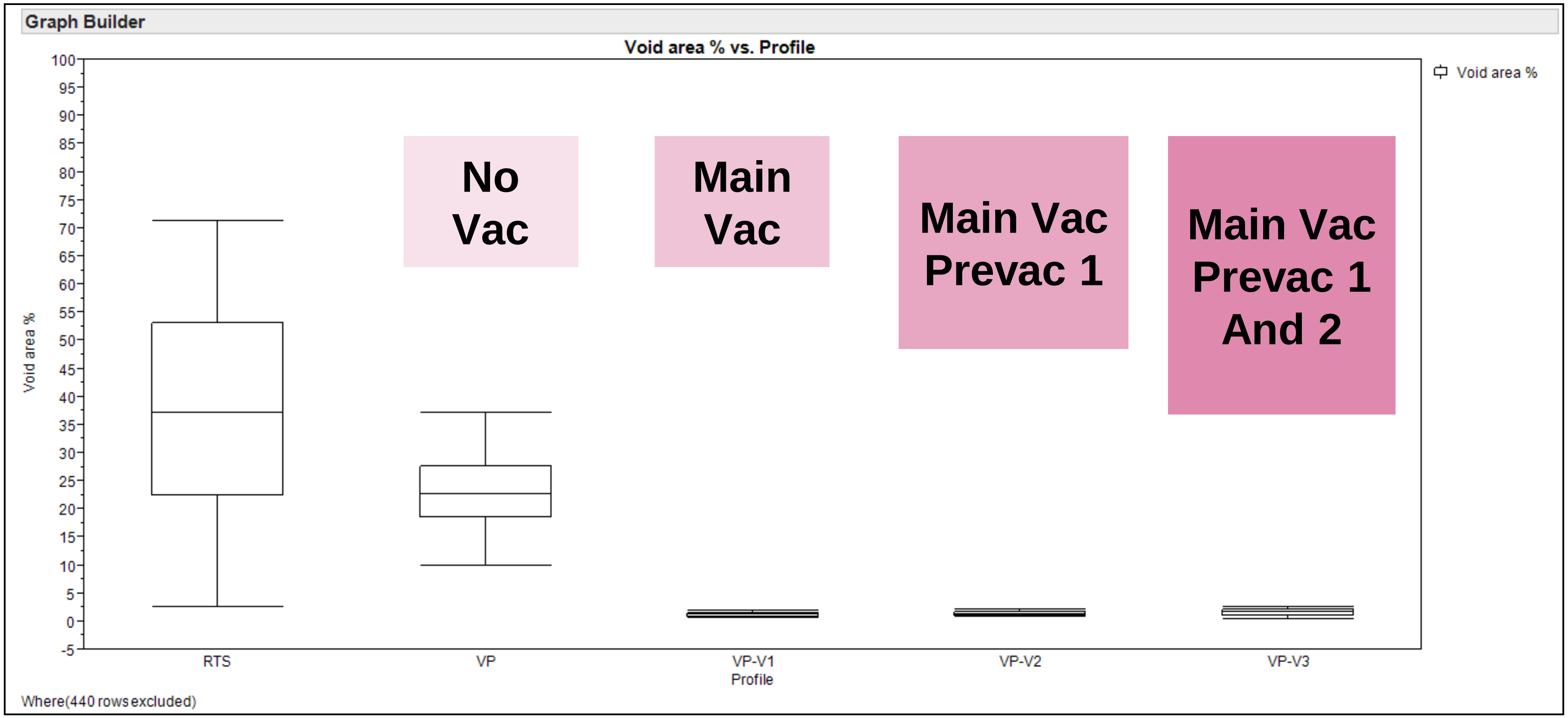
Previews of Coming Attractions

- Voiding with vapor phase reflow and vacuum
- Using vapor phase with vacuum to rework voids

Vapor Phase Reflow

- No vacuum
- Main Vac – during liquidus
- Prevac 1 – before heating
- Prevac 2 – during heating before liquidus

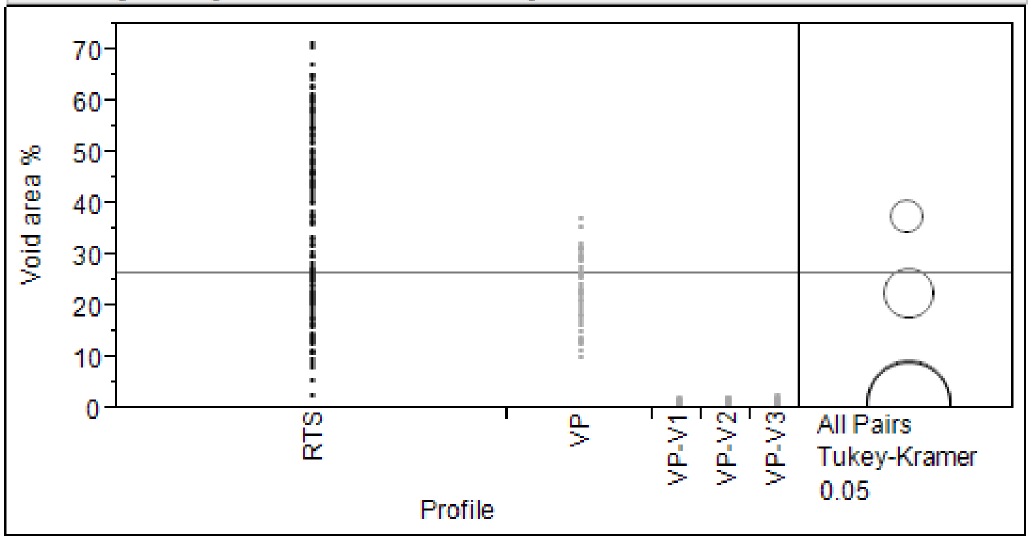
Voiding Results – Vapor Phase



- Solder Paste B SAC305 T3
- Linear ramp profile in vapor phase

Voiding Results – Vapor Phase

Oneway Analysis of Void area % By Profile



Excluded Rows 440

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

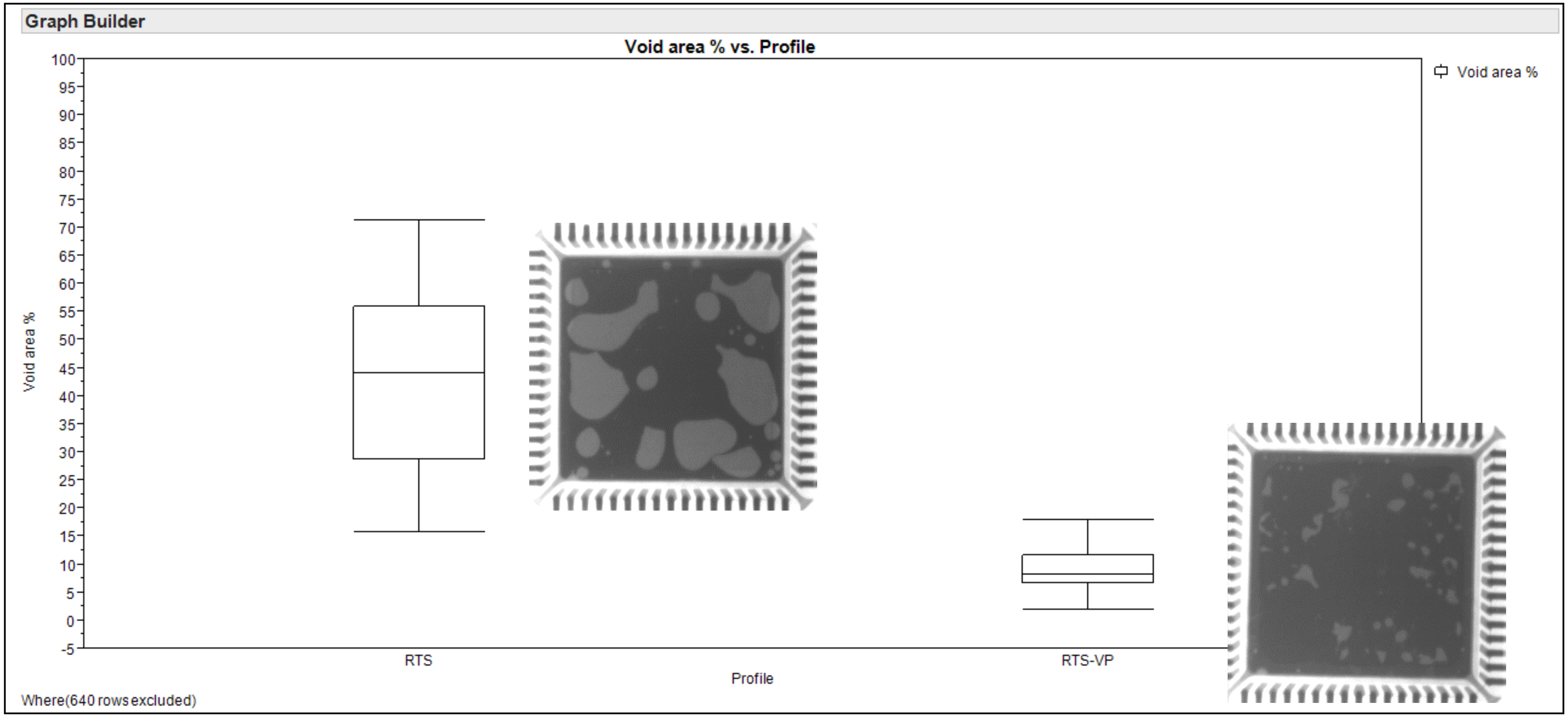
Connecting Letters Report

Level				Mean
RTS	A			37.614375
VP		B		23.006667
VP-V3			C	1.580000
VP-V2			C	1.385000
VP-V1			C	1.205000

Levels not connected by same letter are significantly different.

Vapor phase with vacuum lowers voiding dramatically

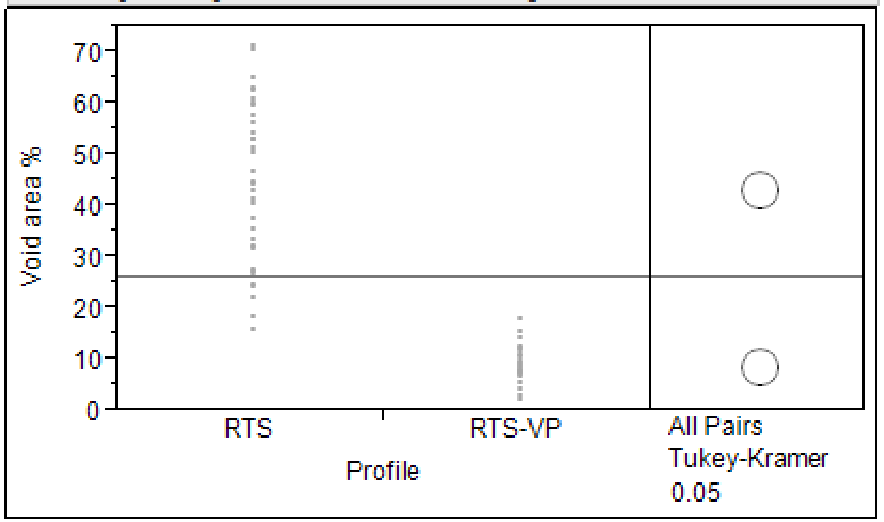
Voiding Results – Vapor Phase as a Rework Method



- Solder Paste B SAC305 T3
- 1st convection reflow – 2nd vapor phase with vacuum

Voiding Results – Vapor Phase as a Rework Method

Oneway Analysis of Void area % By Profile



Excluded Rows 640

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
RTS	A	43.465000
RTS-VP	B	8.770000

Levels not connected by same letter are significantly different.

Vapor phase with vacuum can rework voids

What Have We Learned About Voiding?

- Solder paste B generated higher voiding and larger voids than solder paste A

- The 5-Dot stencil pattern generated higher voiding and larger voids than the other designs.

- The RTS profile generated higher voiding with solder paste A, while the RTS-HT profile generated higher voiding with solder paste B

- As total void area increases, the largest void size increases.

How to Fill the Void

- ✓ Use a solder paste that generates low voiding in your process.
- ✓ Optimize the stencil design to minimize voiding.
- ✓ Optimize the reflow profile for your solder paste to minimize voiding.

Future Work

Voiding mitigation work is ongoing and results will be presented in future papers. Some of the variables being studied are as follows:

- Vapor phase reflow with vacuum
- Convection reflow using nitrogen
- No clean vs. water soluble solder pastes
- Particle size of the solder powder used (T3, T4, T5)
- Manufacturer of the solder powder
- Additional stencil designs are being tested

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