APEX EXPO IPC 2017

TECHNOLOGY'S TURNING POINT

TURN ELECTRONICS MANUFACTURING INSPIRATION INTO INNOVATION

Fill the Void II: An Investigation into Methods of Reducing Voiding

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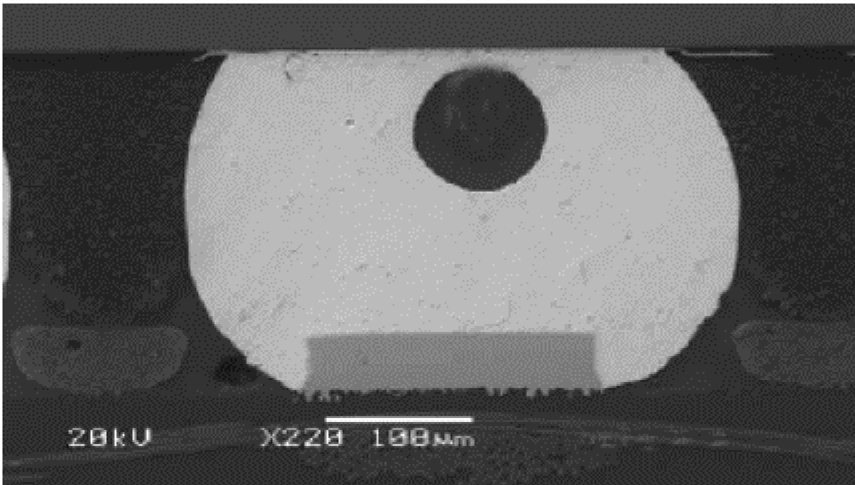
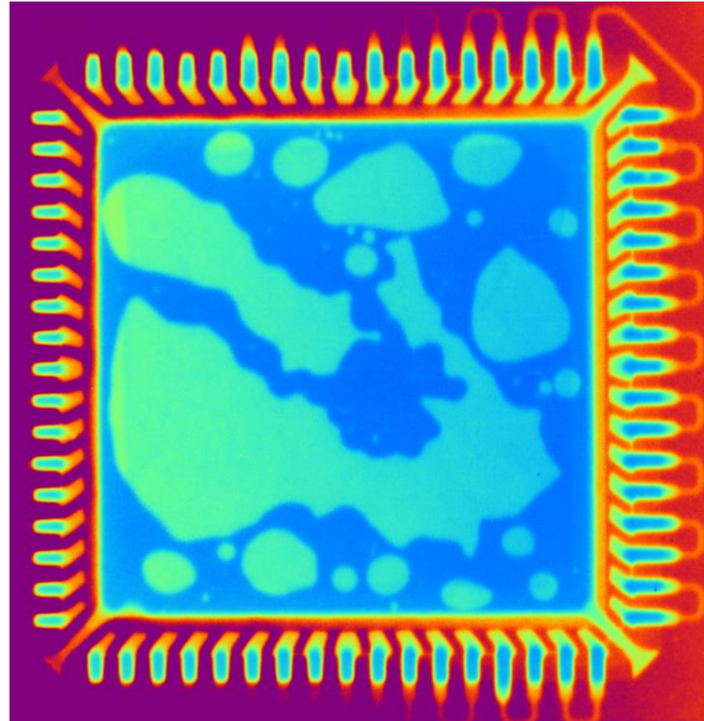
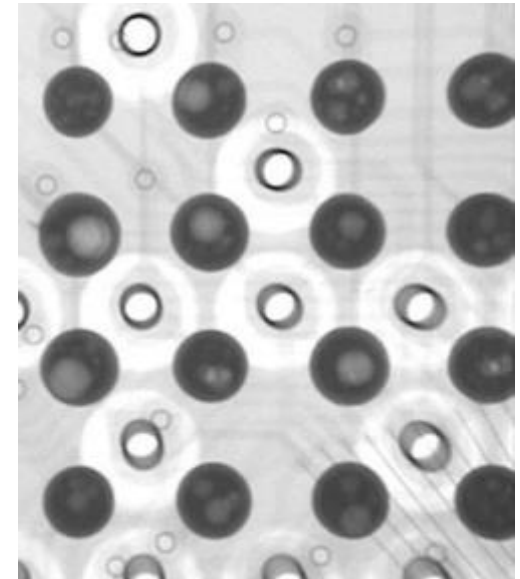
Outline

- Introduction on Voiding
- Voiding Factors
- Methodology
- Voiding Results
- Recommendations to "Fill the Void"
- Future Work
- Acknowledgements
- Questions?

Introduction on Voiding







Introduction on Voiding

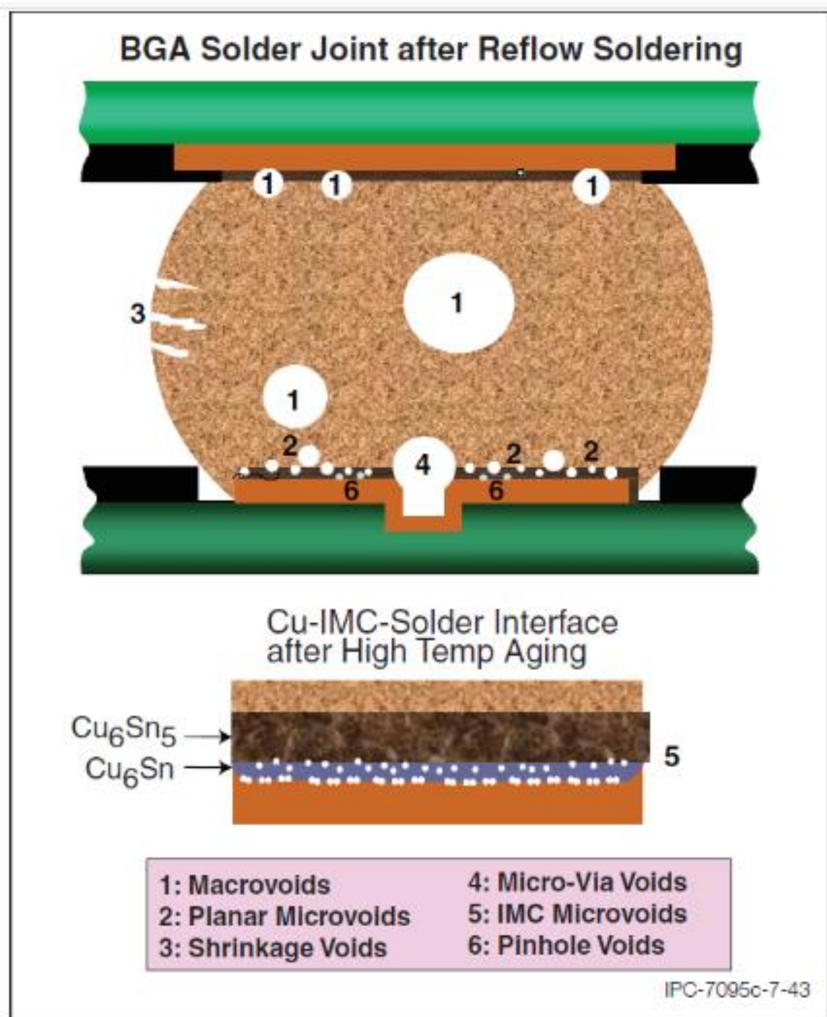
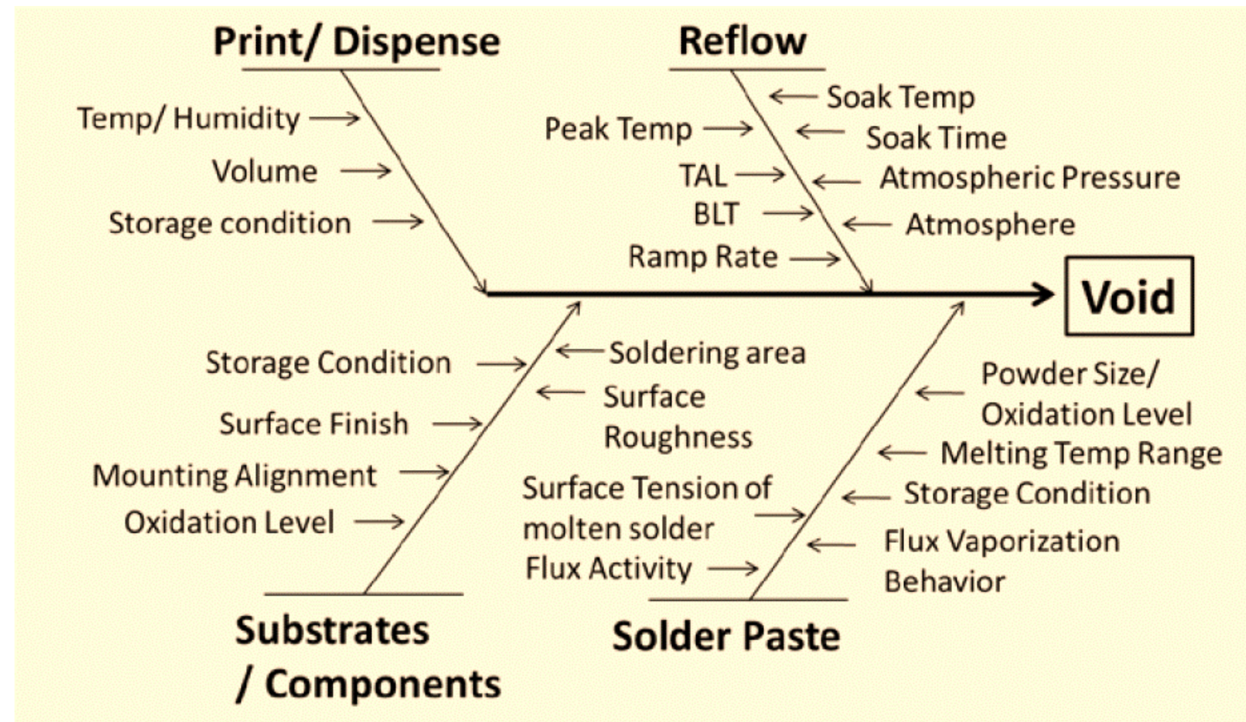


Figure 7-43 Typical Size and Location of Various Types of Voids in a BGA Solder Joint

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

Factors That Influence Voiding



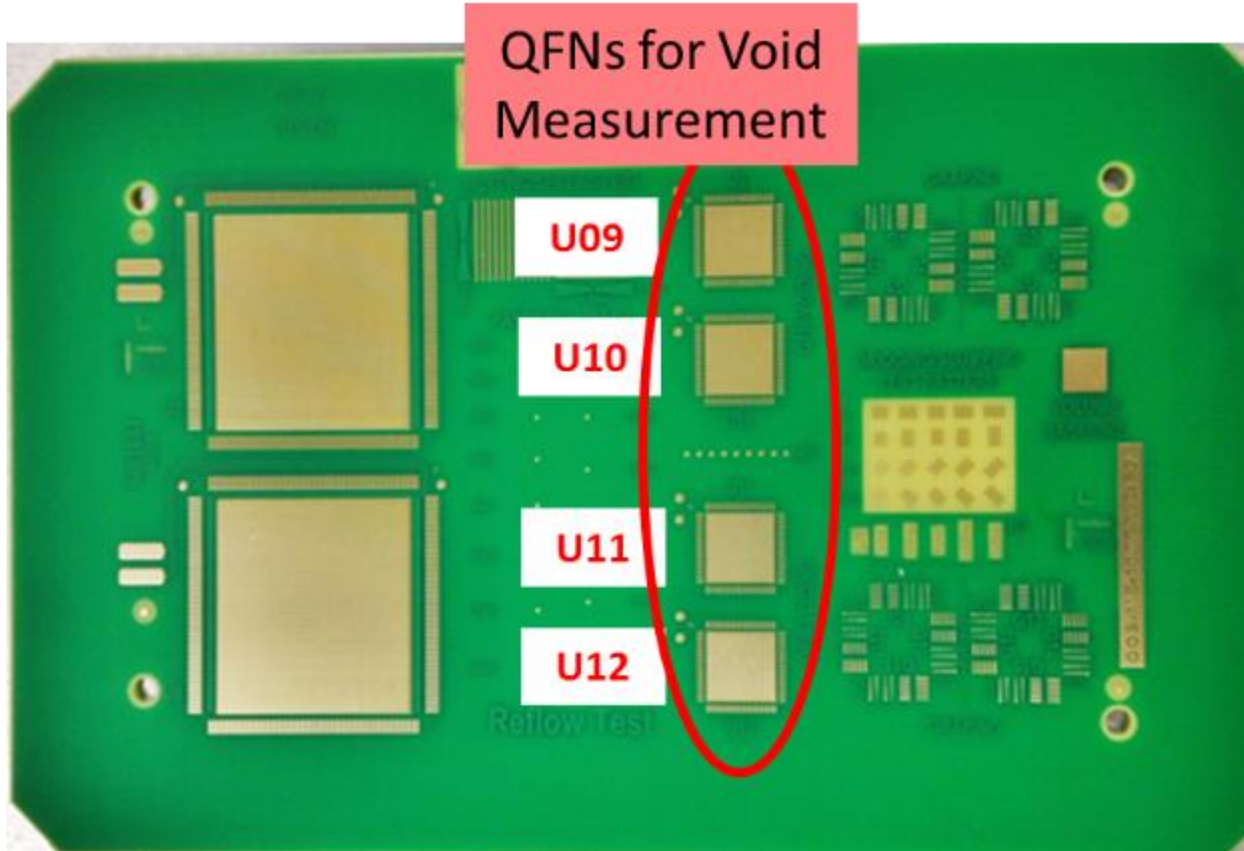
*Reference: K.Sweatman et al., "Controlling the Voiding Mechanisms in the Reflow Soldering Process", Proceedings of IPC APEX Expo 2016.

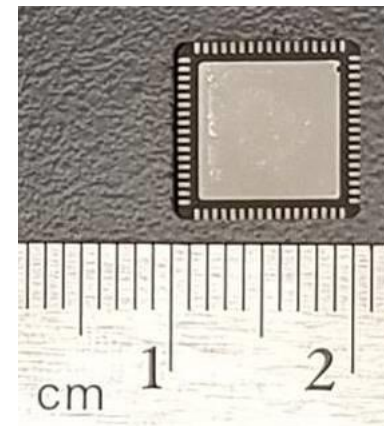
Factors Studied

- Solder Paste: water soluble, no clean, solder powder size and manufacturer
- Stencil Design: cross hatch, 5-dot, diagonal stripe
- Surface Finish: ENIG and OSP
- Convection Reflow Profiles: RSS, RTS, air and nitrogen
- Vapor Phase Reflow: with and without vacuum
- Rework Voids using Vapor Phase with Vacuum

Methodology

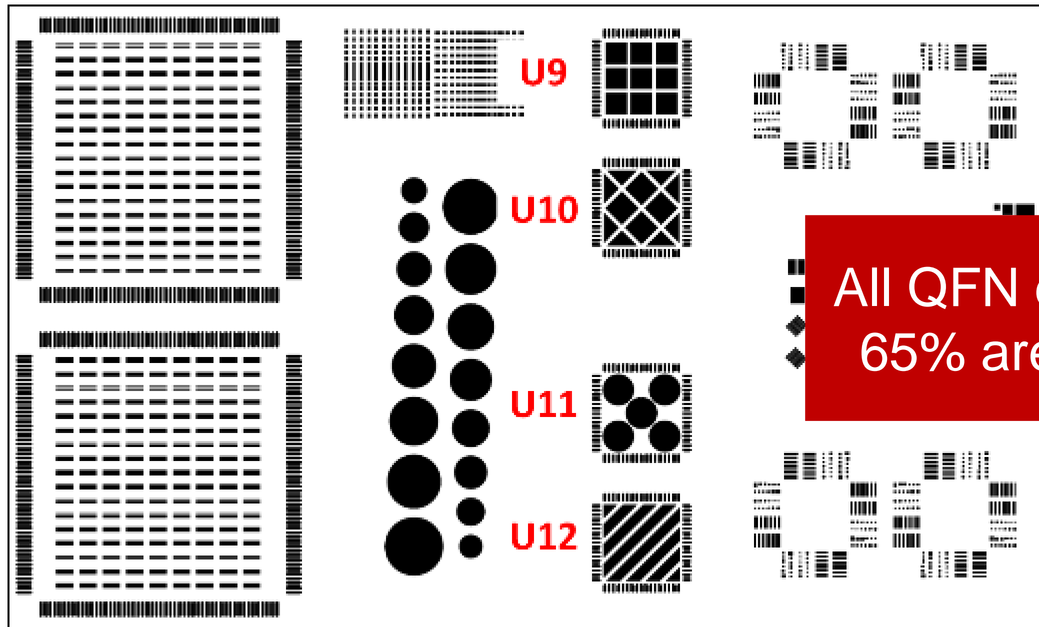
Methodology - Materials

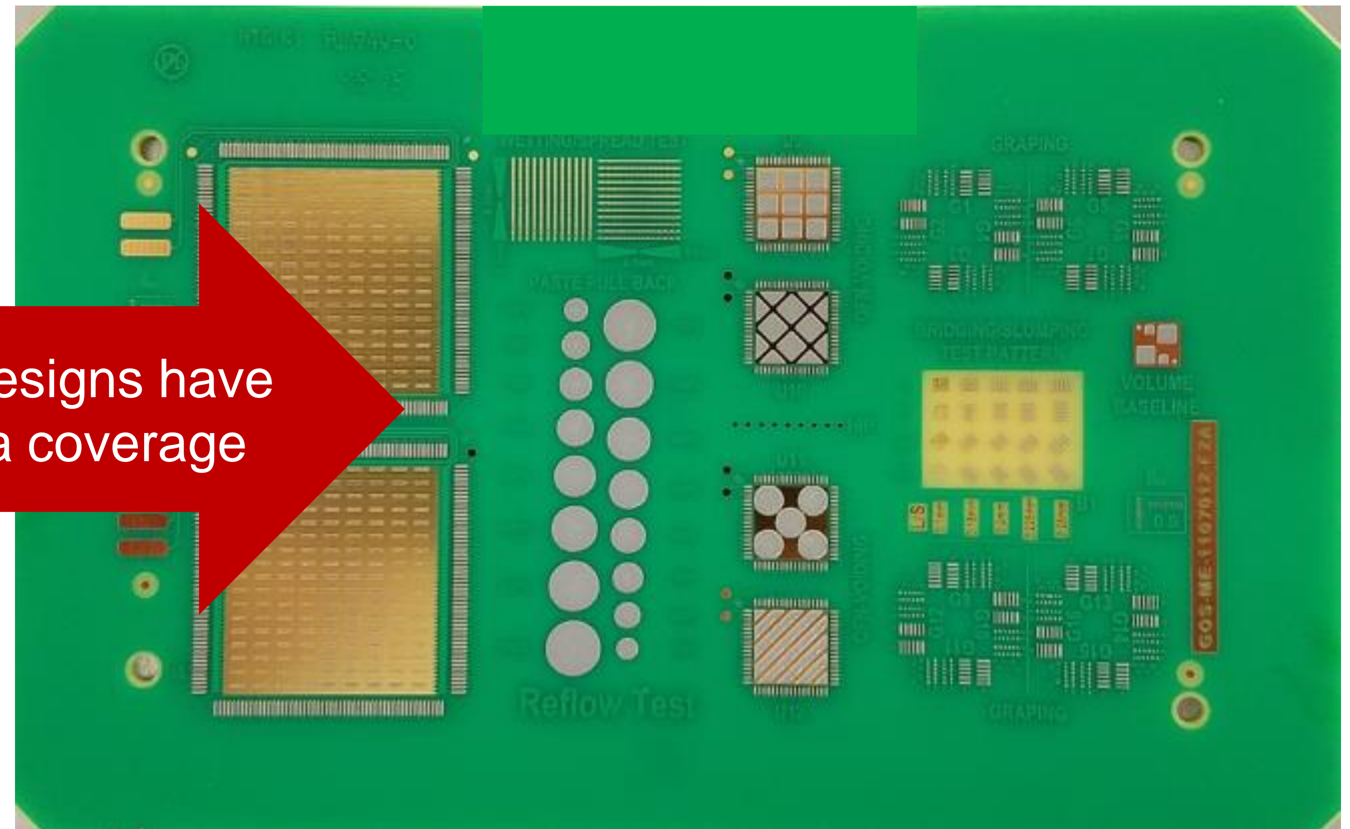




QFN 68 lead
10 mm body
0.5 mm pitch
Tin finish

Methodology – Stencil Design





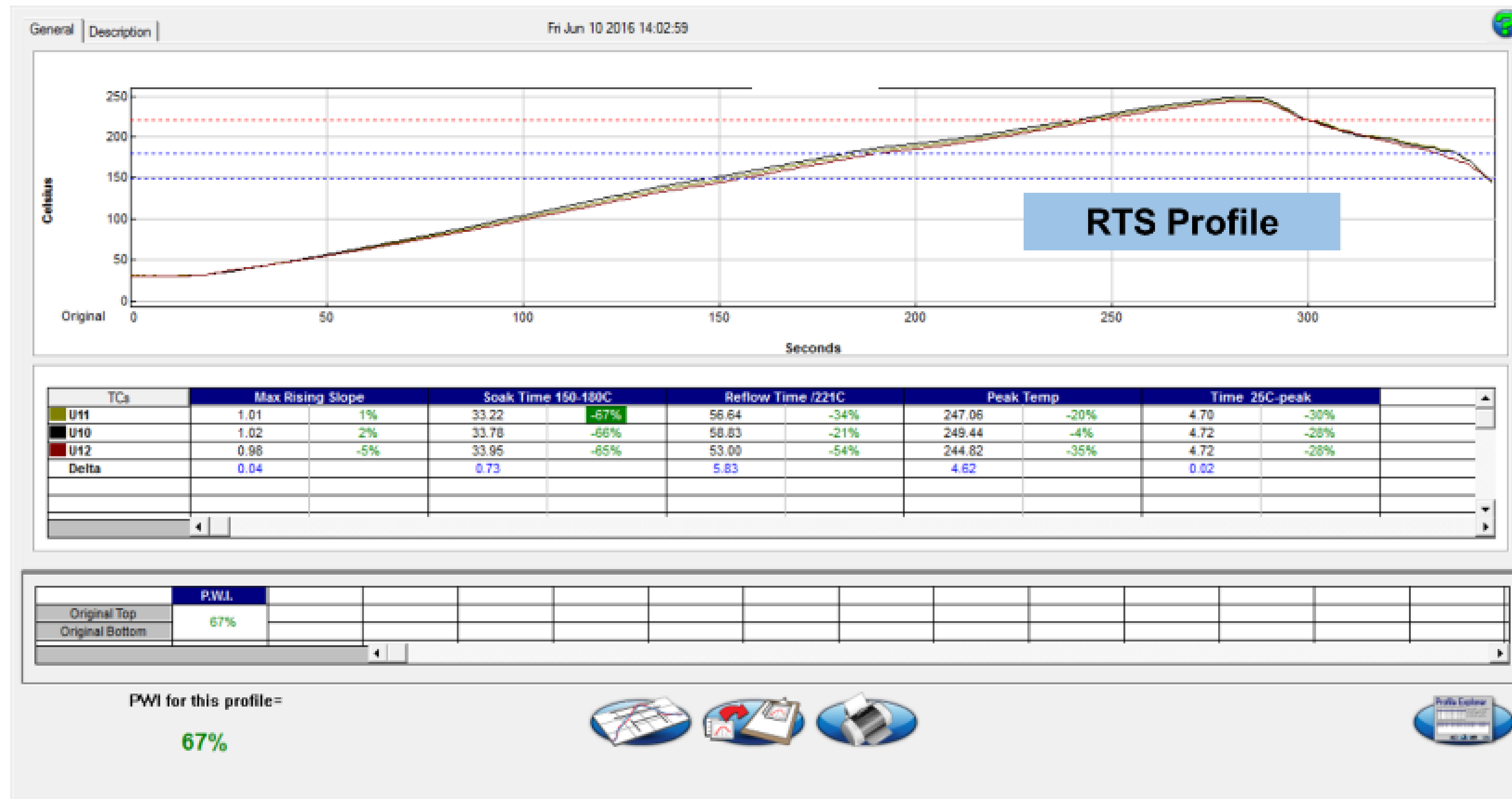
All QFN designs have 65% area coverage

Methodology – Solder Pastes

Solder Paste Flux Code	Flux Type	IPC Solder Powder Size	Metal Content (% wt)
A	Water soluble – moderate activity	Type 3	88.0
B	Water soluble – high activity	Type 3	88.5
B	Water soluble – high activity	Type 4	88.3
B	Water soluble – high activity	Type 5	88.1
C	No clean	Type 3	88.5
D	No clean – pin testable	Type 3	88.4
E	Water soluble – moderate/low activity	Type 3	89.0

All were made with SAC305 (Sn – Ag 3.0% - Cu 0.5%) alloy.

Methodology – Reflow Profile



TCs	Max Rising Slope		Soak Time 150-180C		Reflow Time /221C		Peak Temp		Time 25C-peak	
U11	1.01	1%	33.22	-67%	56.64	-34%	247.06	-20%	4.70	-30%
U10	1.02	2%	33.78	-66%	58.83	-21%	249.44	-4%	4.72	-28%
U12	0.98	-5%	33.95	-65%	53.00	-54%	244.82	-35%	4.72	-28%
Delta	0.04		0.73		5.83		4.62		0.02	

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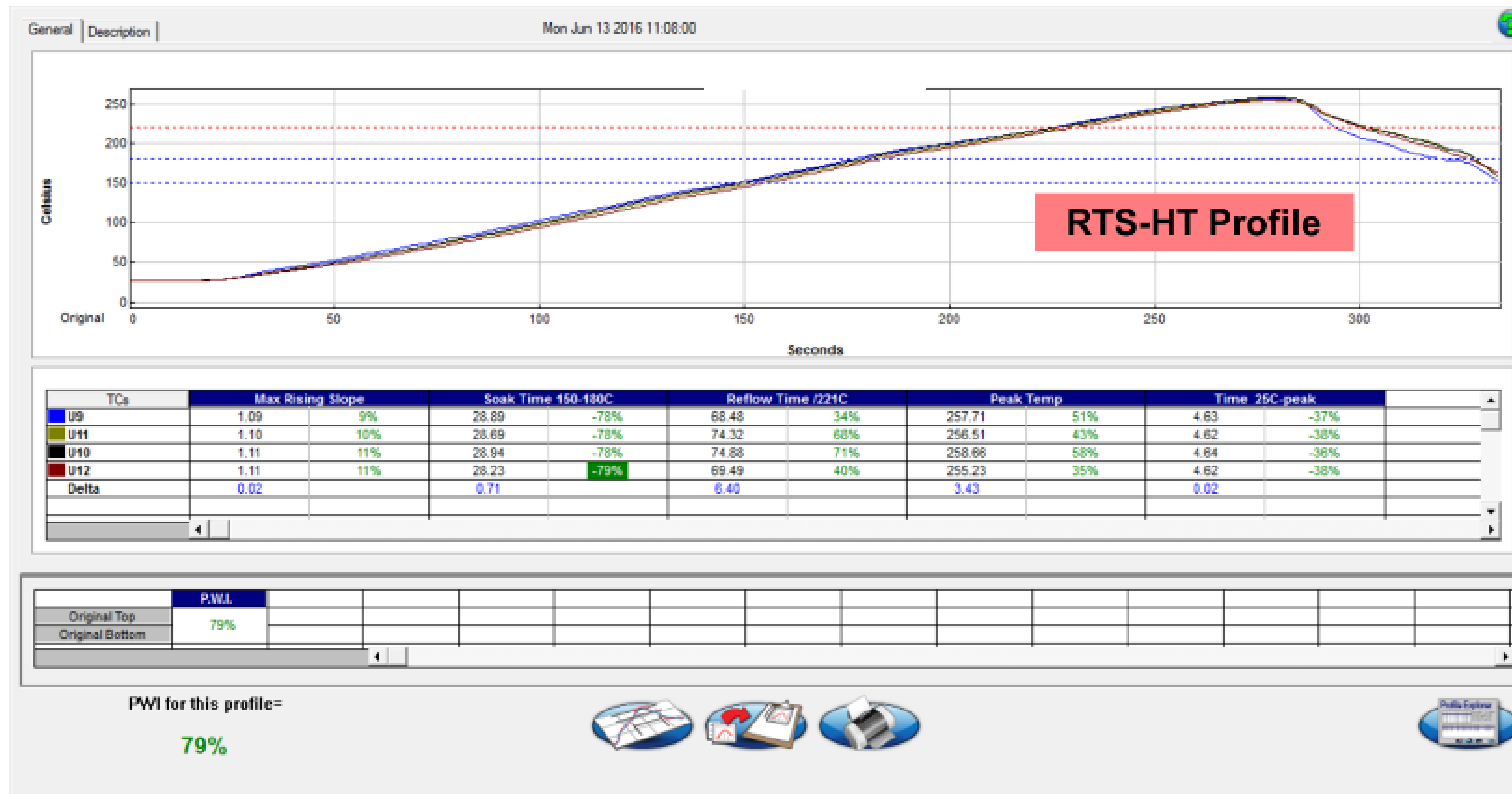
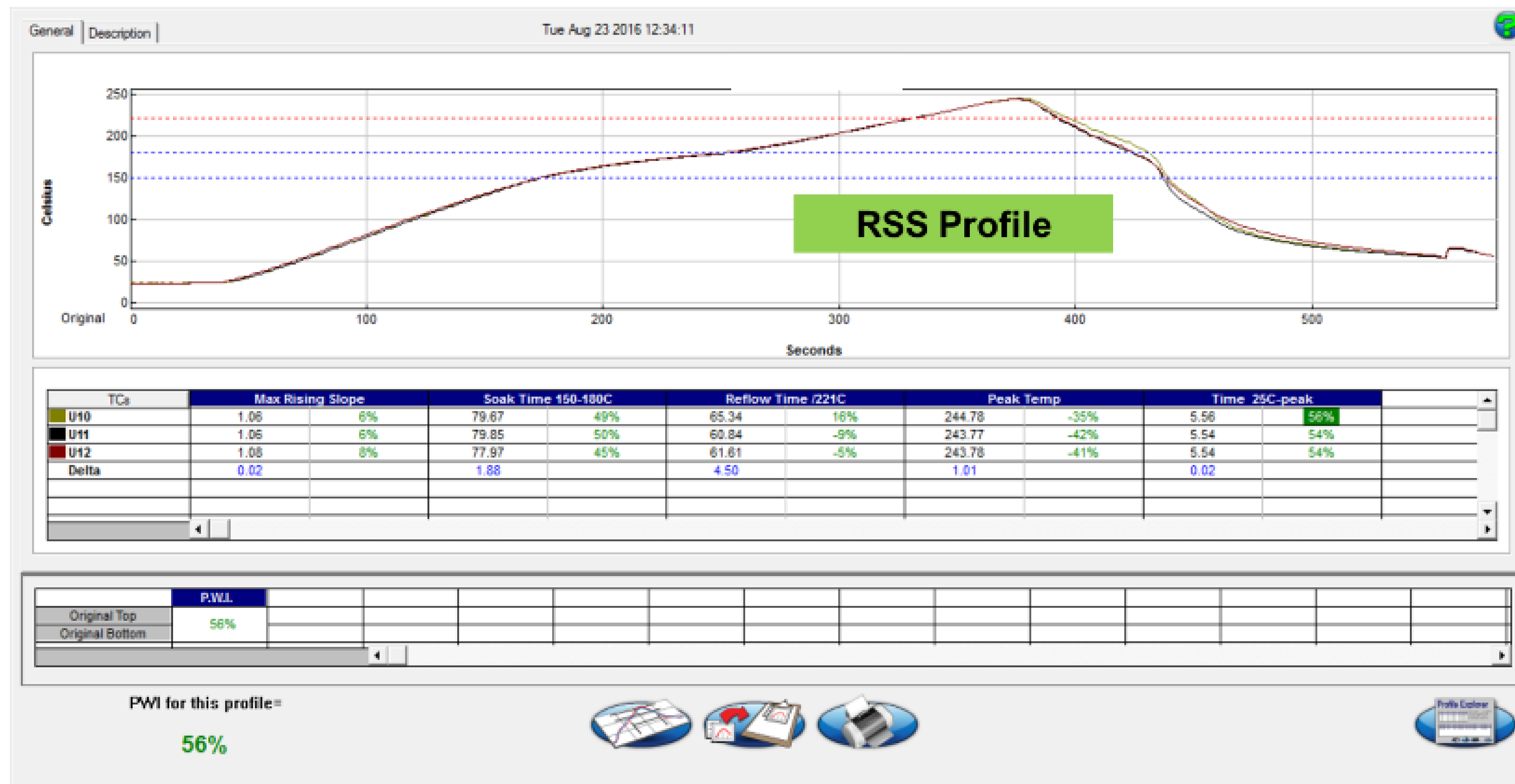
Methodology – Reflow Profile



TCs	Max Rising Slope		Soak Time 150-180C		Reflow Time /221C		Peak Temp		Time 25C-peak	
U9	1.09	9%	28.89	-78%	68.48	34%	257.71	51%	4.63	-37%
U11	1.10	10%	28.69	-78%	74.32	68%	256.51	43%	4.62	-38%
U10	1.11	11%	28.94	-78%	74.88	71%	258.66	58%	4.64	-36%
U12	1.11	11%	28.23	-79%	69.49	40%	255.23	35%	4.62	-38%
Delta	0.02		0.71		6.40		3.43		0.02	

	P.W.I.
Original Top	79%
Original Bottom	

Methodology – Reflow Profile

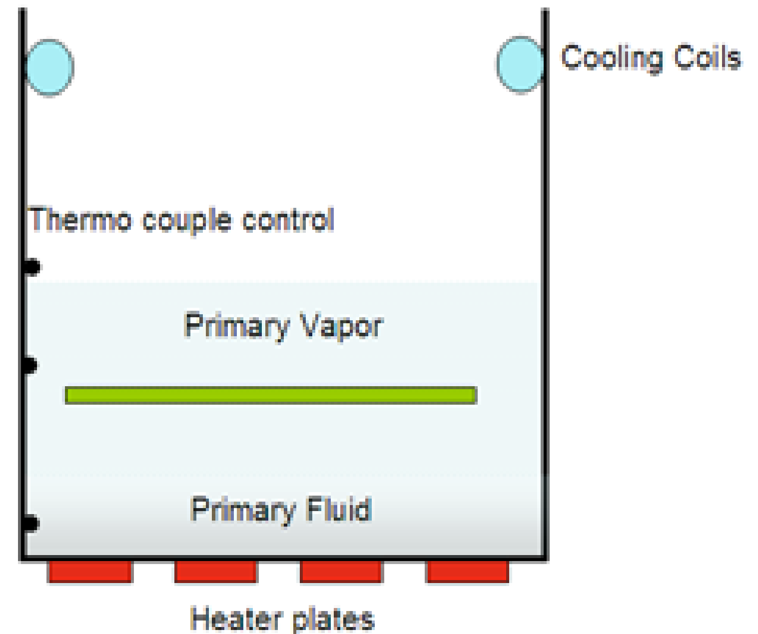


TCs	Max Rising Slope		Soak Time 150-180C		Reflow Time /221C		Peak Temp		Time 25C-peak	
U10	1.06	6%	79.67	49%	65.34	16%	244.78	-35%	5.56	56%
U11	1.06	6%	79.85	50%	60.84	-9%	243.77	-42%	5.54	54%
U12	1.08	8%	77.97	45%	61.61	-5%	243.78	-41%	5.54	54%
Delta	0.02		1.88		4.50		1.01		0.02	

Methodology – Reflow Profile

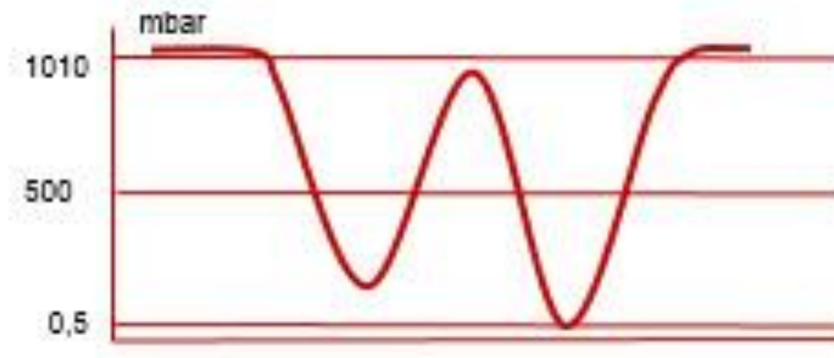
Setting	RTS Profile	RTS-HT Profile	RSS Profile
Ramp rate	0.98 – 1.02 °C/sec	1.09 – 1.10 °C/sec	1.06 – 1.08 °C/sec
Soak time (150-180 °C)	No added soak 33 – 34 sec	No added soak 28 – 29 sec	Soak added 78 – 80 sec
Reflow Time (>221 °C)	53 – 59 sec	68 – 75 sec	61 – 65 sec
Peak temperature	245 to 249 °C	255 to 259 °C	244 to 245 °C
Profile length (25 °C to peak)	4.70 minutes	4.60 minutes	5.50 minutes

Methodology – Vapor Phase

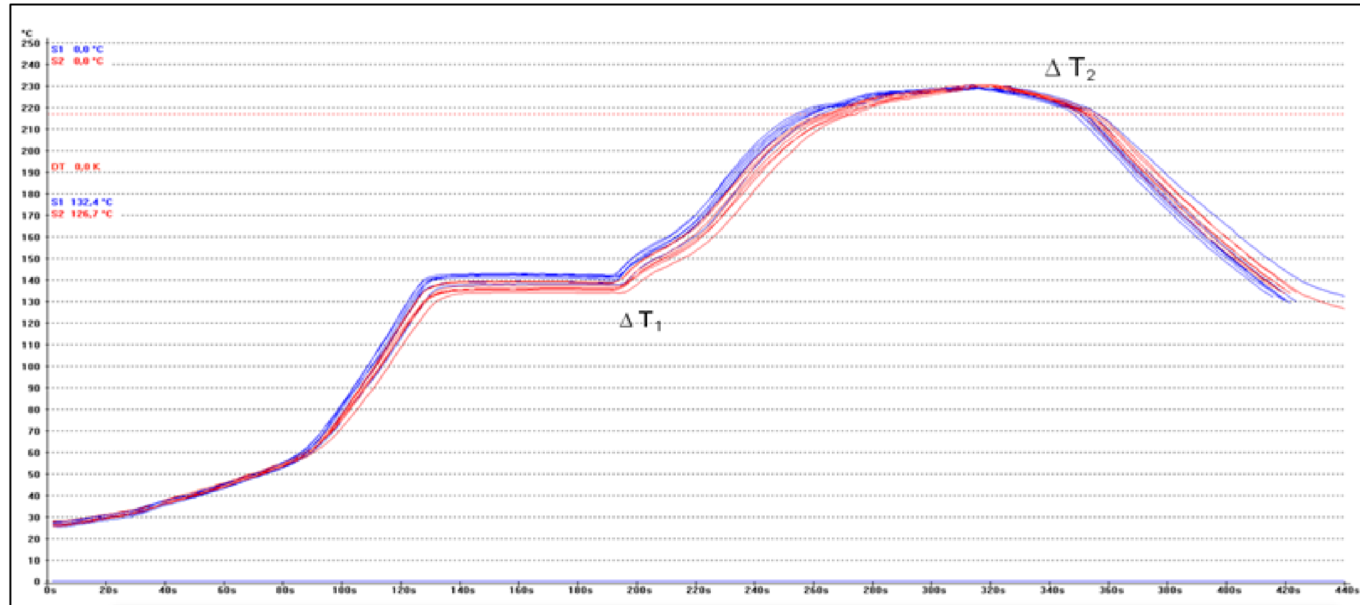


Methodology – Vapor Phase Vacuum

Vapor Phase Tests	Vacuum Cycle	Vacuum Description
VP	Vapor phase reflow – no vacuum	None
VP-V1	Main vacuum only	- 750 mbar for two 5 sec steps
VP-V2	Prevac 1 plus main vacuum	Prevac 1 on raw paste before heating
VP-V3	Prevacs 1 & 2 plus main vacuum	Prevac 2 during ramp up

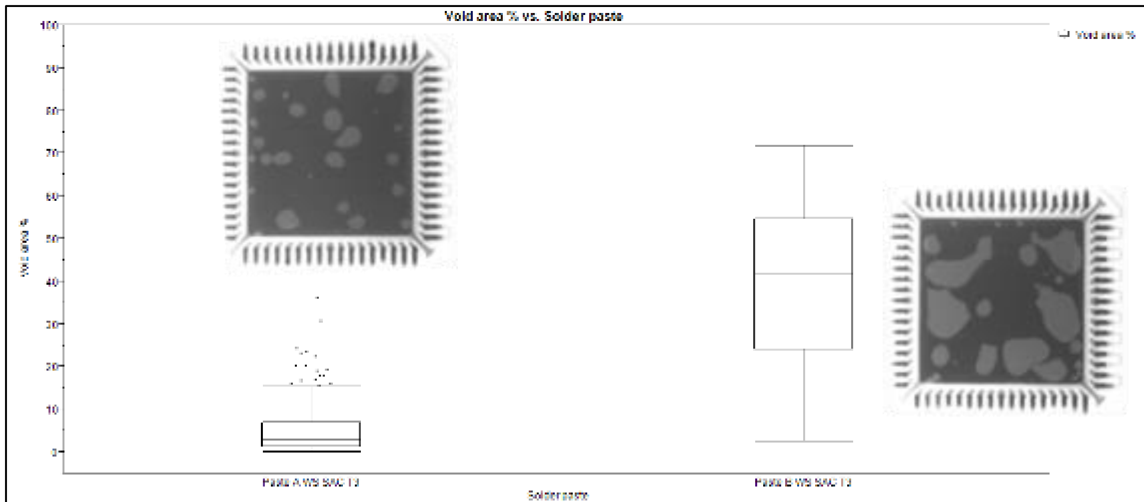


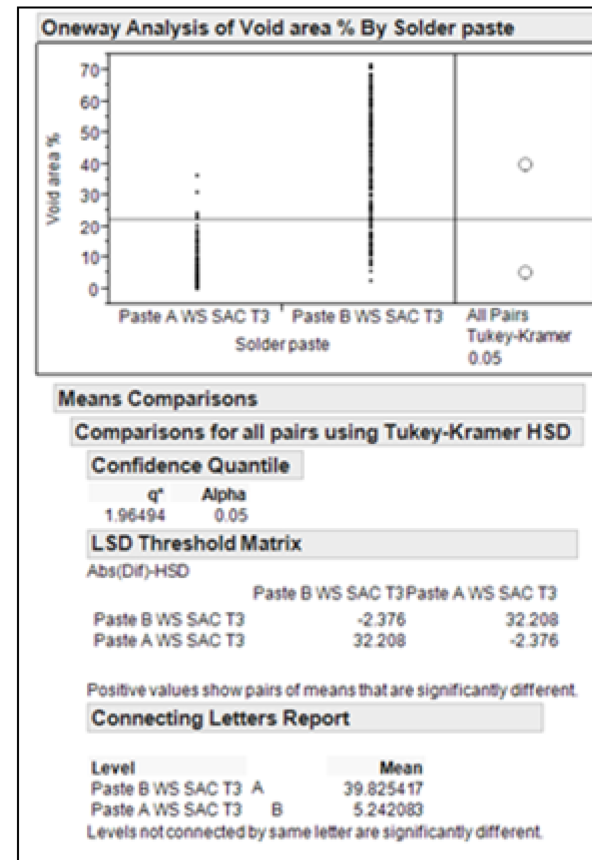
Methodology – Vapor Phase



Setting	Vapor Phase Profile
Soak Time (135 – 145 °C)	80 seconds
Reflow Time (> 221 °C)	70 seconds
Peak Temp	230 °C

Methodology - Statistics





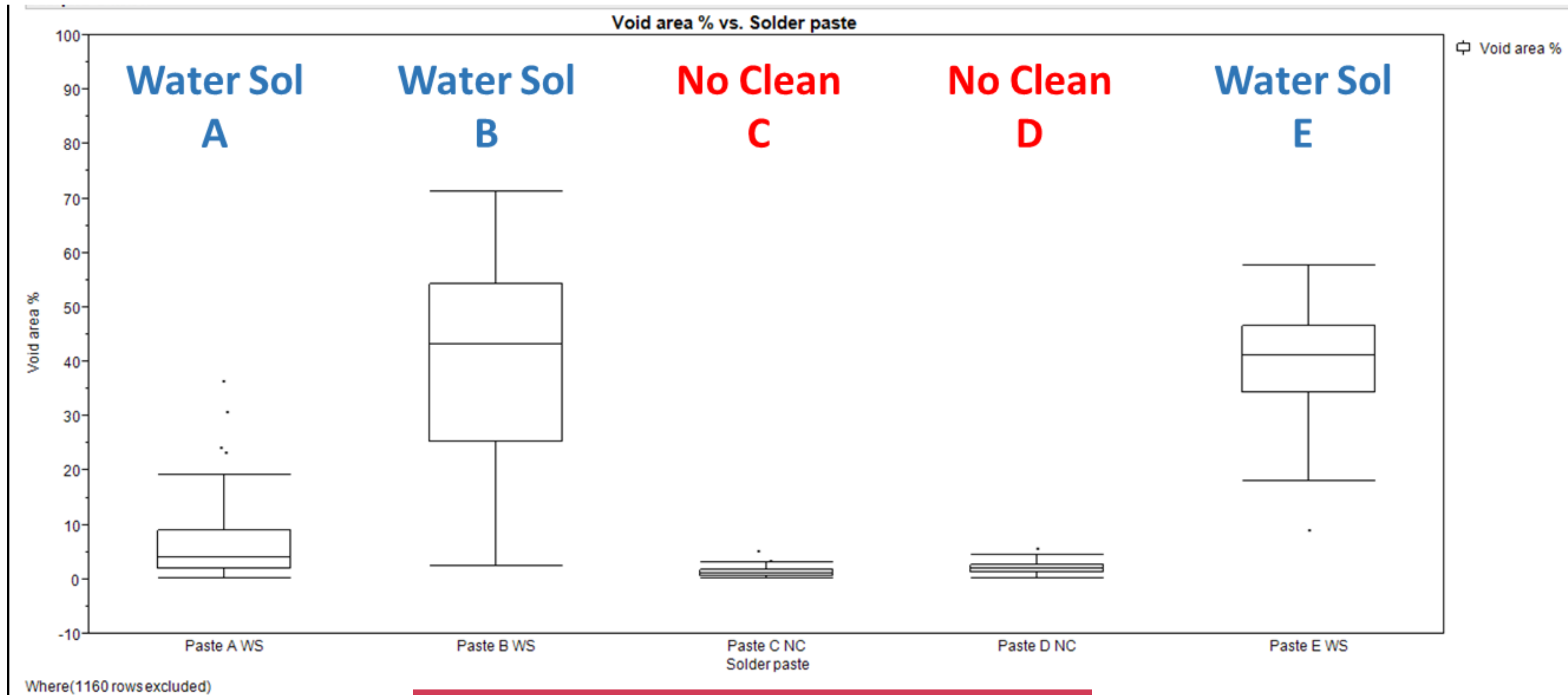
Data sets represented by circles

95% confidence level

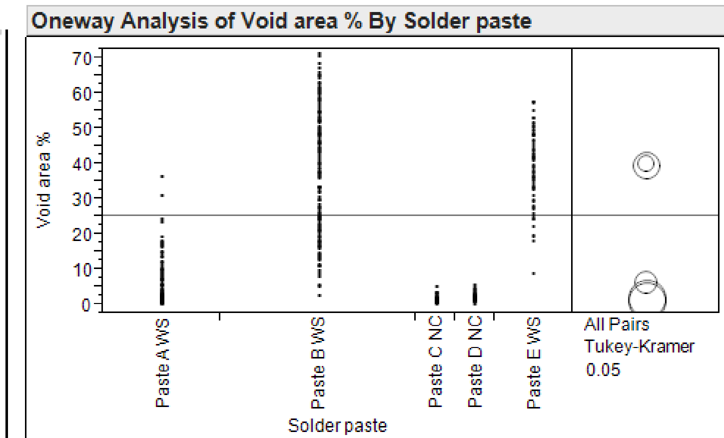
Connecting letters shows differences

Voiding Results

Voiding Results – Solder Paste



SAC 305 T3 - RTS Profile



Excluded Rows 1160

Means Comparisons

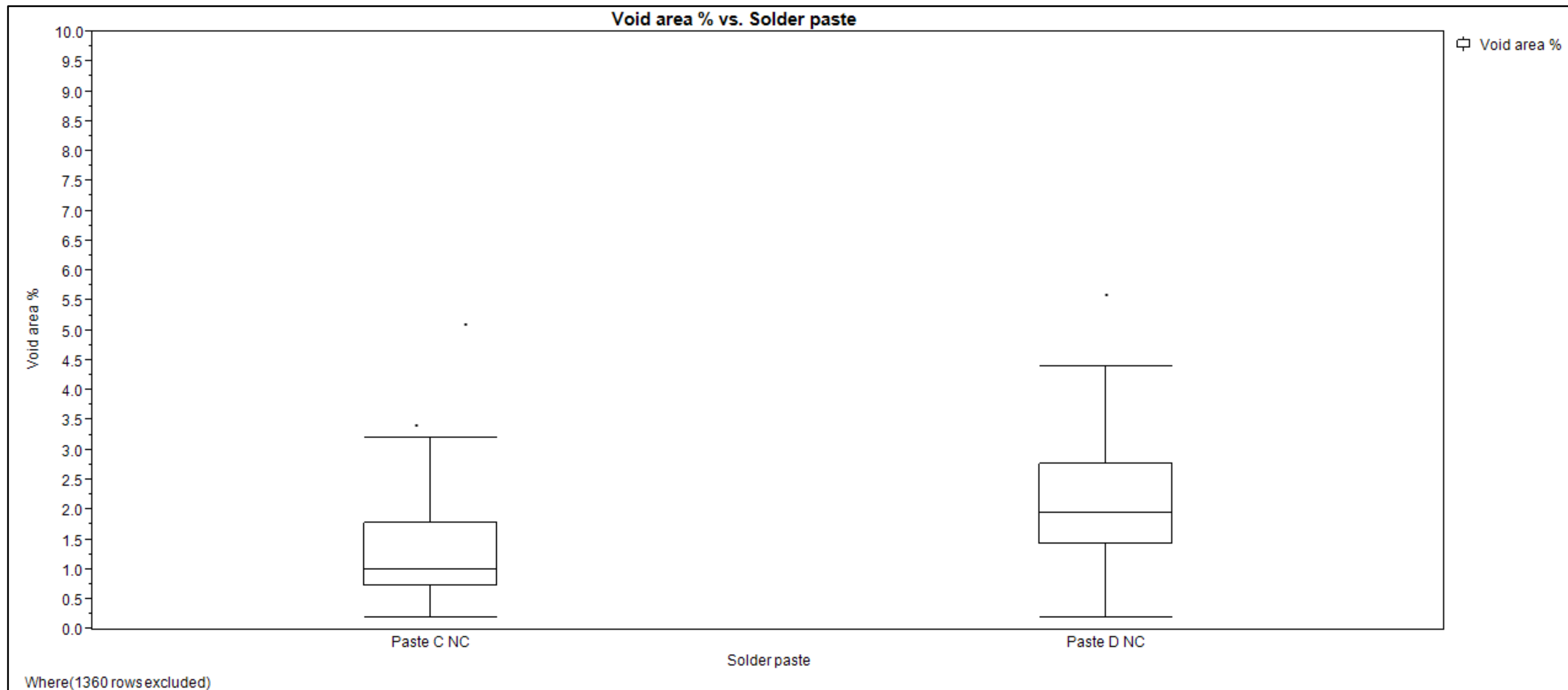
Comparisons for all pairs using Tukey-Kramer HSD

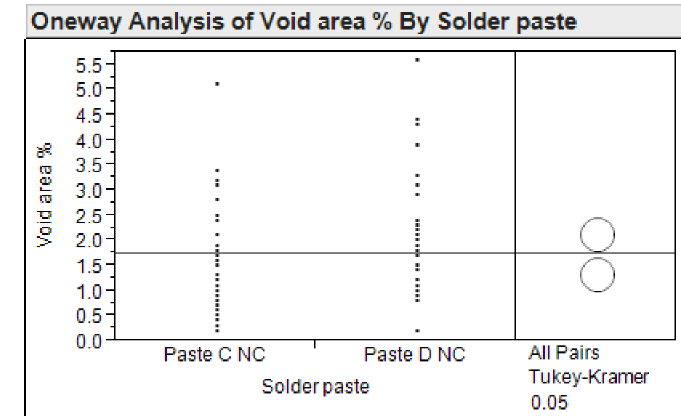
Connecting Letters Report

Level			Mean
Paste B WS	A		40.151500
Paste E WS	A		39.597500
Paste A WS		B	6.430000
Paste D NC		B	2.155000
Paste C NC		B	1.357500

Levels not connected by same letter are significantly different.

Voiding Results – No Clean Paste





Excluded Rows 1360

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

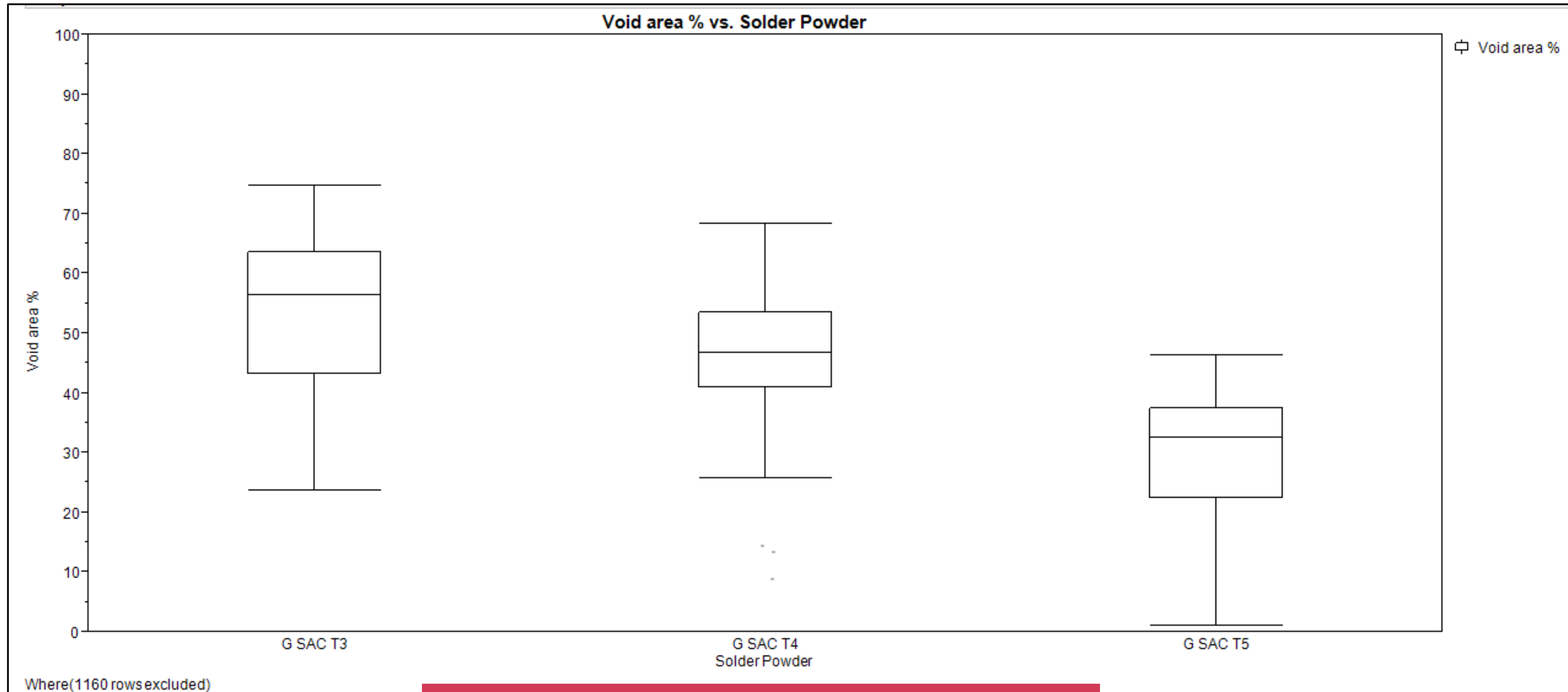
Connecting Letters Report

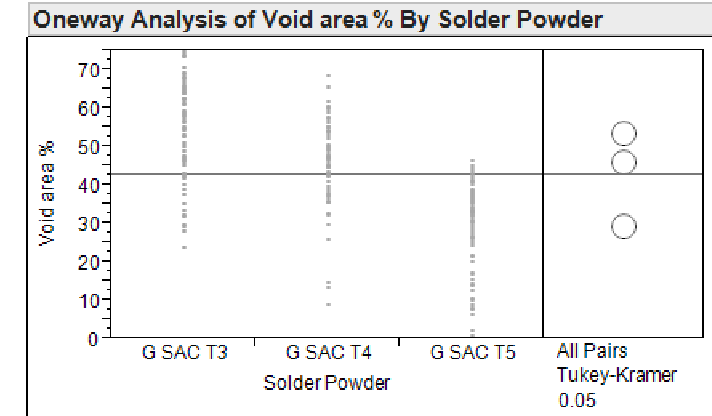
Level			Mean
Paste D NC	A		2.1550000
Paste C NC		B	1.3575000

Levels not connected by same letter are significantly different.

SAC 305 T3 - RTS Profile

Voiding Results – Powder Size





Excluded Rows 1160

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

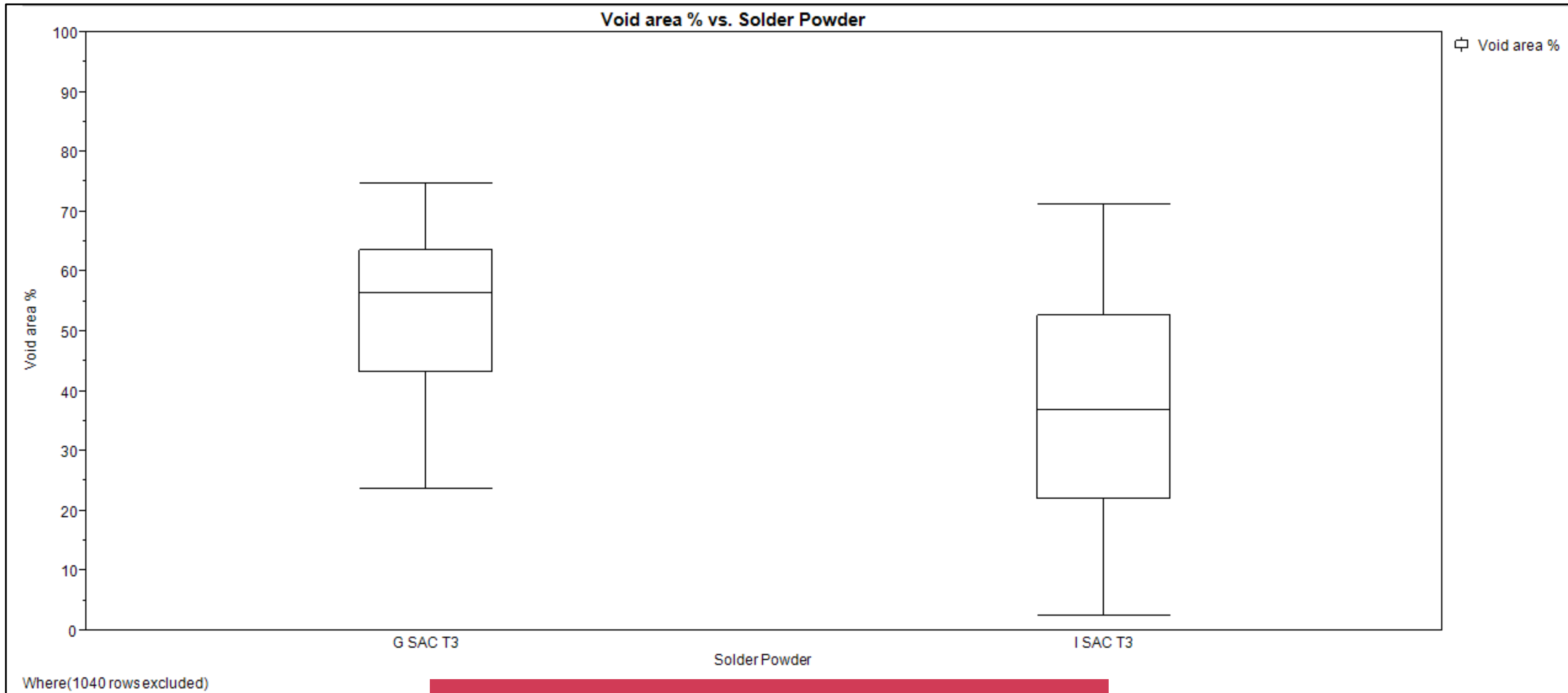
Connecting Letters Report

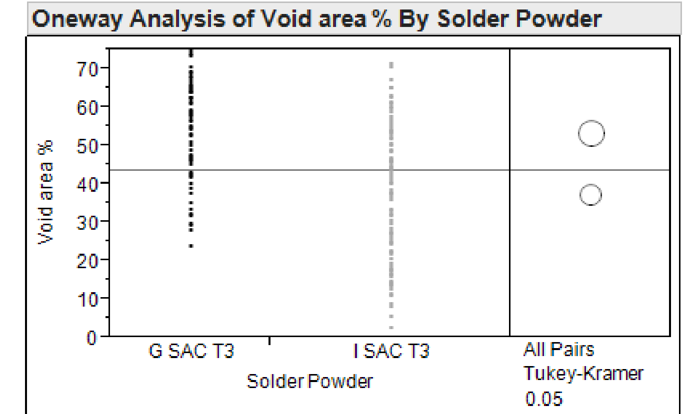
Level				Mean
G SAC T3	A			53.348750
G SAC T4		B		46.000000
G SAC T5			C	29.266250

Levels not connected by same letter are significantly different.

Solder Paste B – RTS Profile

Voiding Results – Powder Mfg





Excluded Rows 1040

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

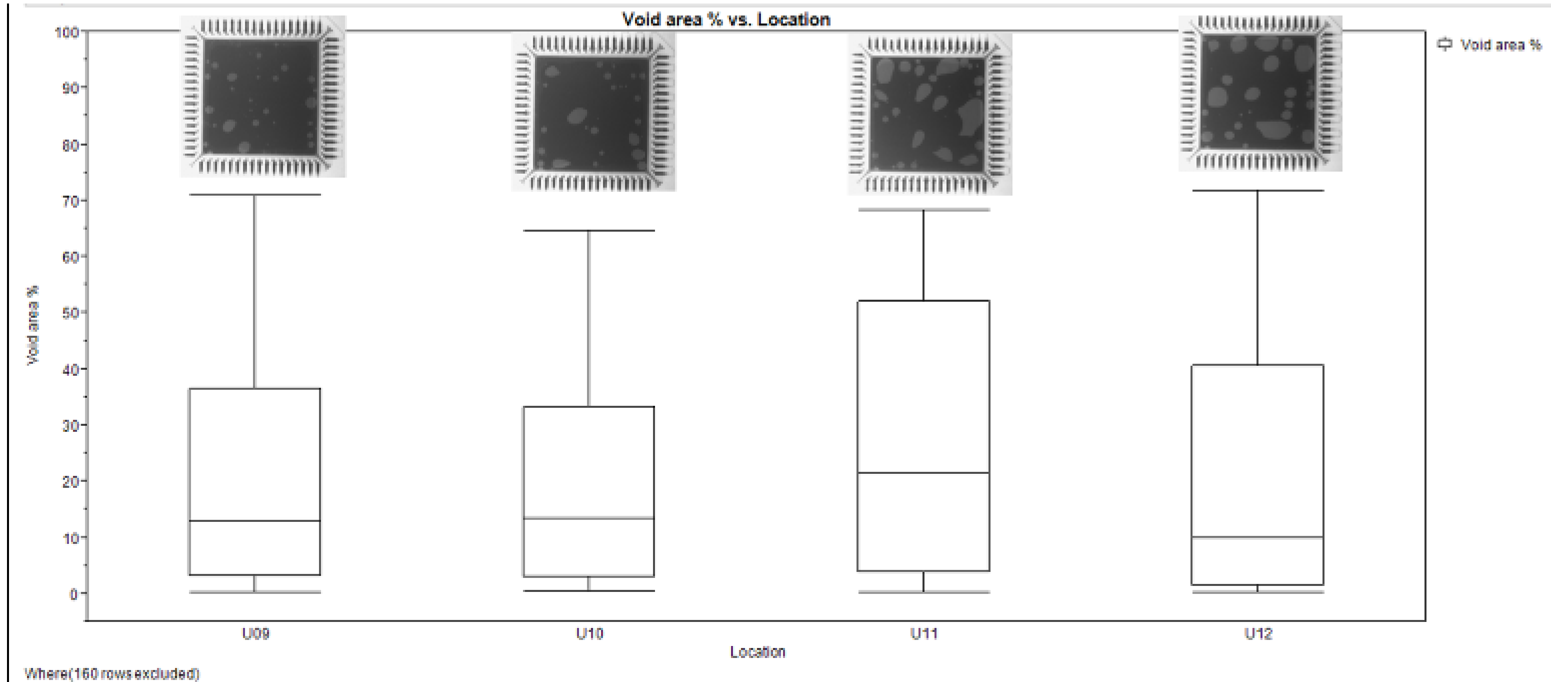
Connecting Letters Report

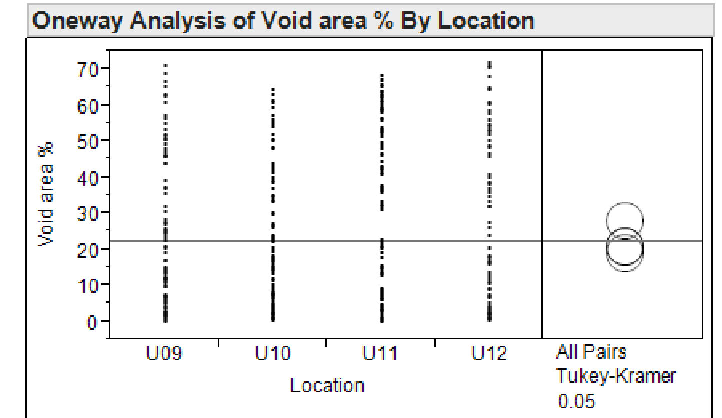
Level		Mean
G SAC T3	A	53.348750
I SAC T3	B	37.244167

Levels not connected by same letter are significantly different.

Solder Paste B – RTS Profile

Voiding Results – Stencil Design





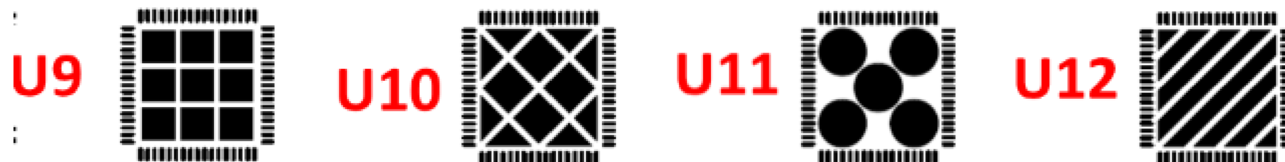
Means Comparisons

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 – Surface Finish

Void area % vs. Board

Void area %

100
90
80
70
60
50
40
30
20
10
0

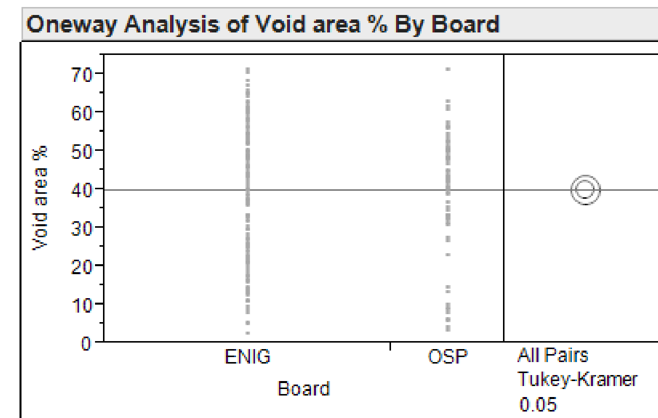
Void area %

ENIG
OSP

Board

Where(760 rows excluded)

Oneway Analysis of Void area % By Board



Excluded Rows 760

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

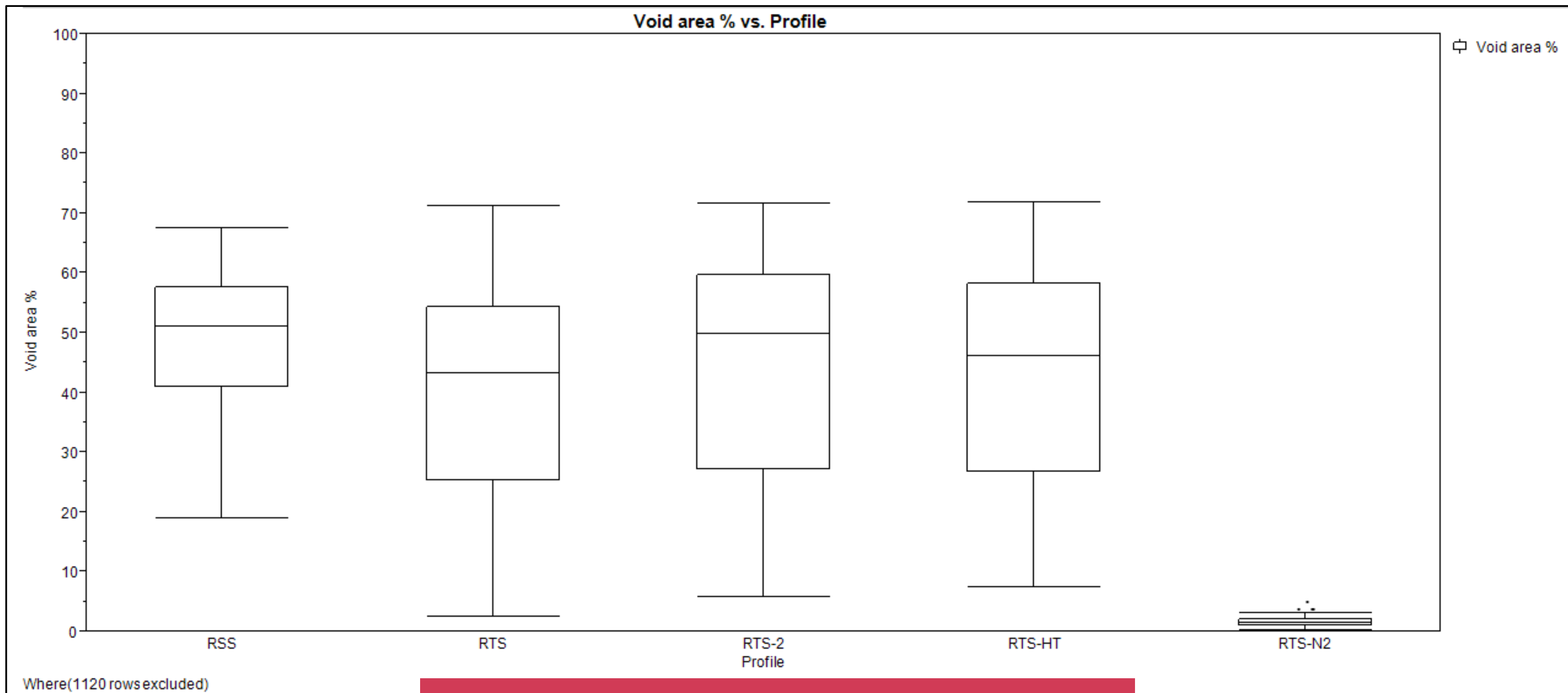
Connecting Letters Report

Level		Mean
ENIG	A	40.151500
OSP	A	40.056250

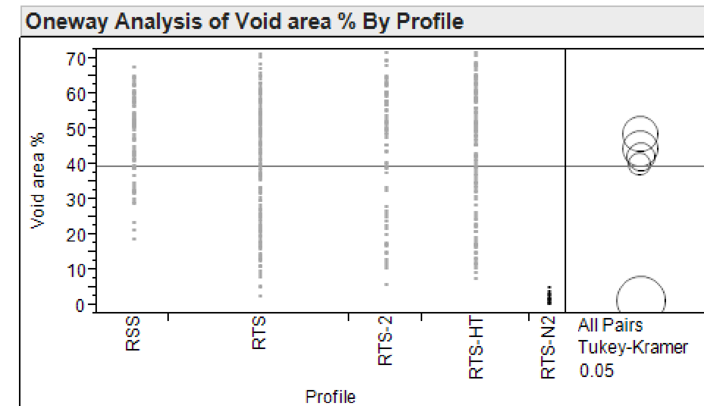
Levels not connected by same letter are significantly different.

Solder Paste B SAC T3 – RTS Profile

Voiding Results – Reflow Profile



Solder Paste B SAC T3



Excluded Rows 1120

Means Comparisons

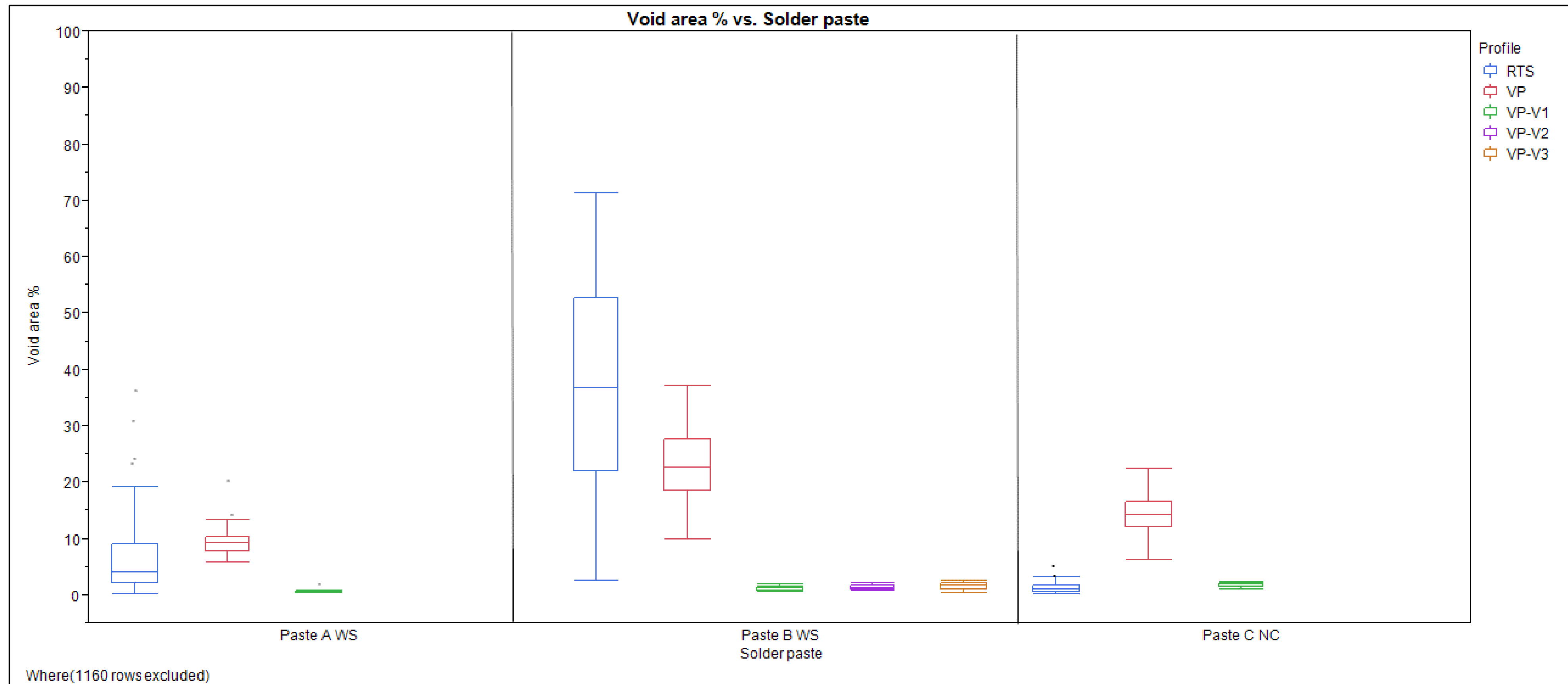
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
RSS	A			48.626250
RTS-2	A	B		44.666250
RTS-HT	A	B		42.406667
RTS		B		40.151500
RTS-N2			C	1.730000

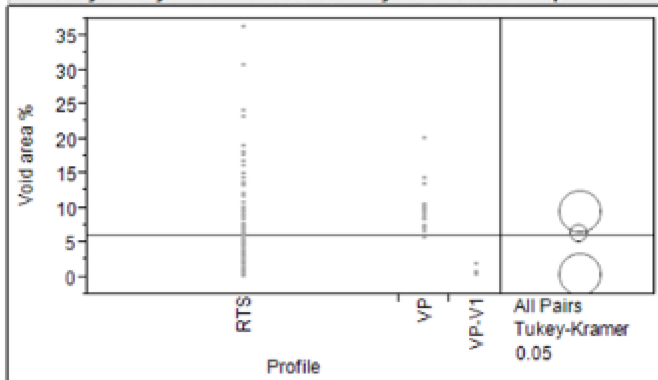
Levels not connected by same letter are significantly different.

Voiding Results – Vapor Phase



Voiding Results – Vapor Phase

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



Excluded Rows 120

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

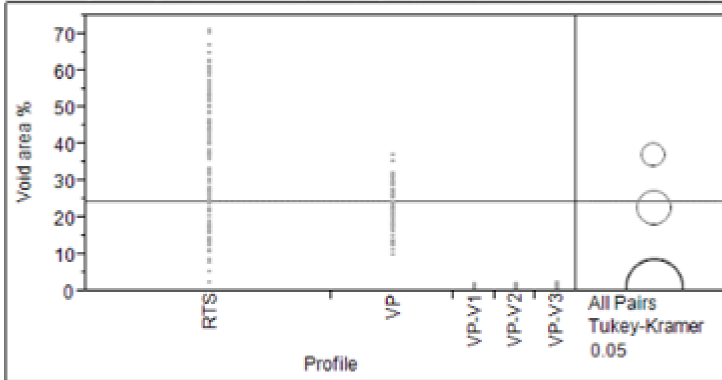
Connecting Letters Report

Level				Mean
VP	A			9.7900000
RTS		B		6.4300000
VP-V1			C	0.6350000

Levels not connected by same letter are significantly different.

A

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



Excluded Rows 760

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

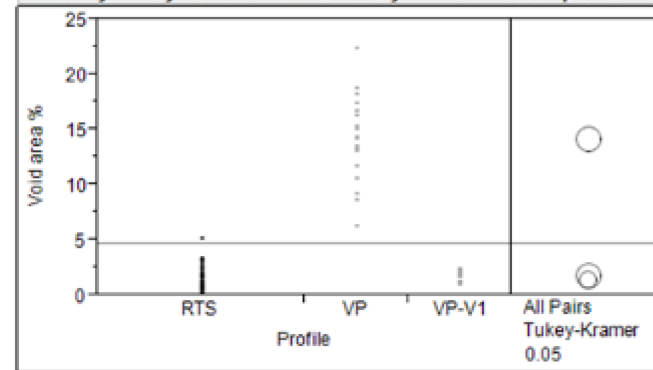
Connecting Letters Report

Level				Mean
RTS	A			37.244167
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.

B

Oneway Analysis of Void area % By Profile Solder paste=Paste C NC



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

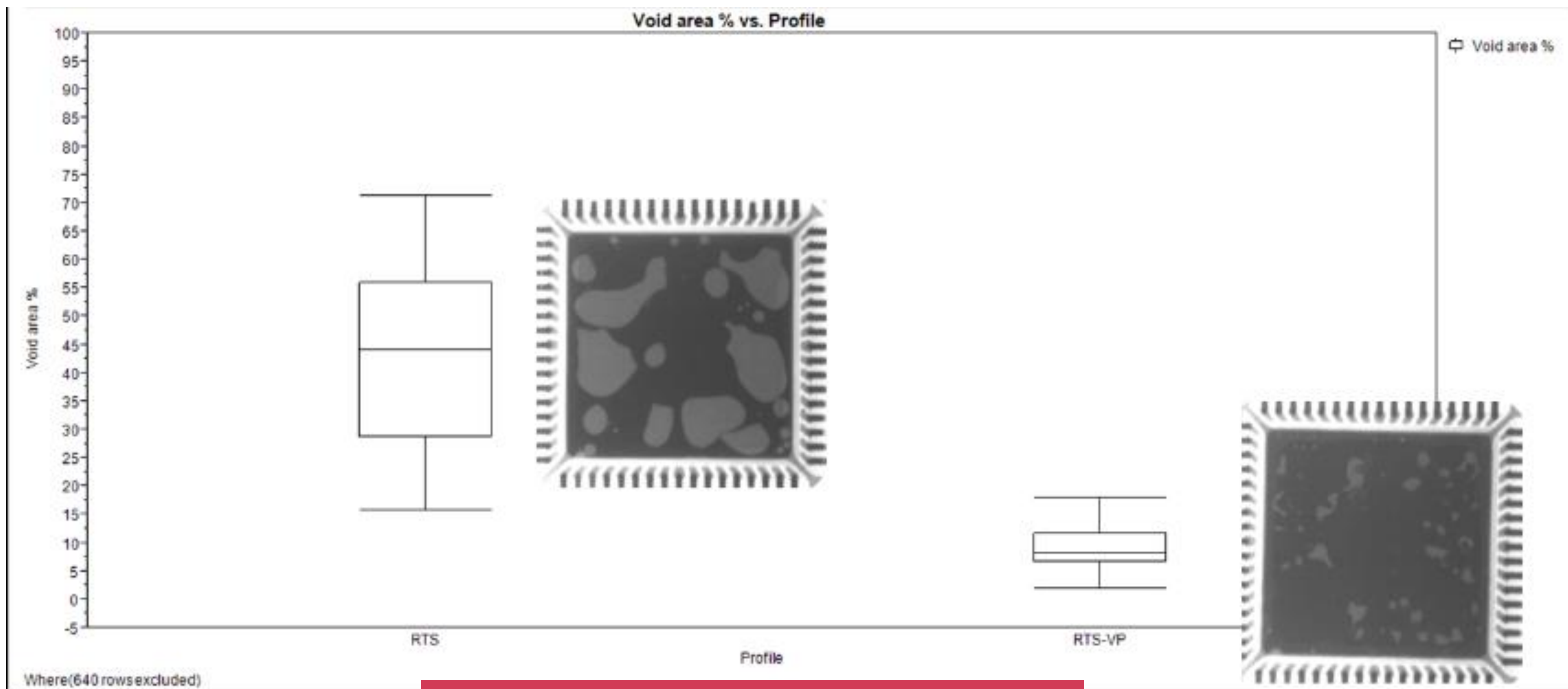
Connecting Letters Report

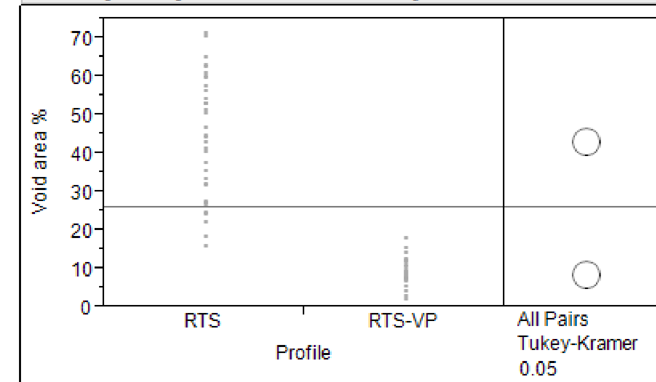
Level			Mean
VP	A		14.190000
VP-V1		B	1.780000
RTS		B	1.357500

Levels not connected by same letter are significantly different.

C

Voiding Results – VP Rework





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.

Solder Paste B SAC T3

Fill the Void

Recommendations to "Fill the Void"

- ✓ Use a solder paste that is low voiding in your process
- ✓ Use Type 4 or 5 solder powder in your paste
- ✓ Design the stencil to give gas escape routes
- ✓ Tune the reflow profile for your solder paste
- ✓ Reflow with vapor phase or nitrogen (oxygen free)
- ✓ Use a reflow system with vacuum

Future Work on Voiding

- Additional components like: LGA, LED, BGA
- More stencil designs
- Further work on solder powder size & oxide levels
- Surface finish impact
- Further work on nitrogen in convection reflow
- Voiding over the stencil life of the solder paste

Acknowledgements

We would like to thank our colleagues at A-Tek Systems for their support and help running the vapor phase reflow testing.

Thank You!