MEETINGS & COURSES: February 1-6
CONFERENCE & EXHIBITION: February 4-6
SAN DIEGO CONVENTION CENTER | CA

FILL THE VOID V - MITIGATION OF VOIDING FOR BOTTOM TERMINATED COMPONENTS

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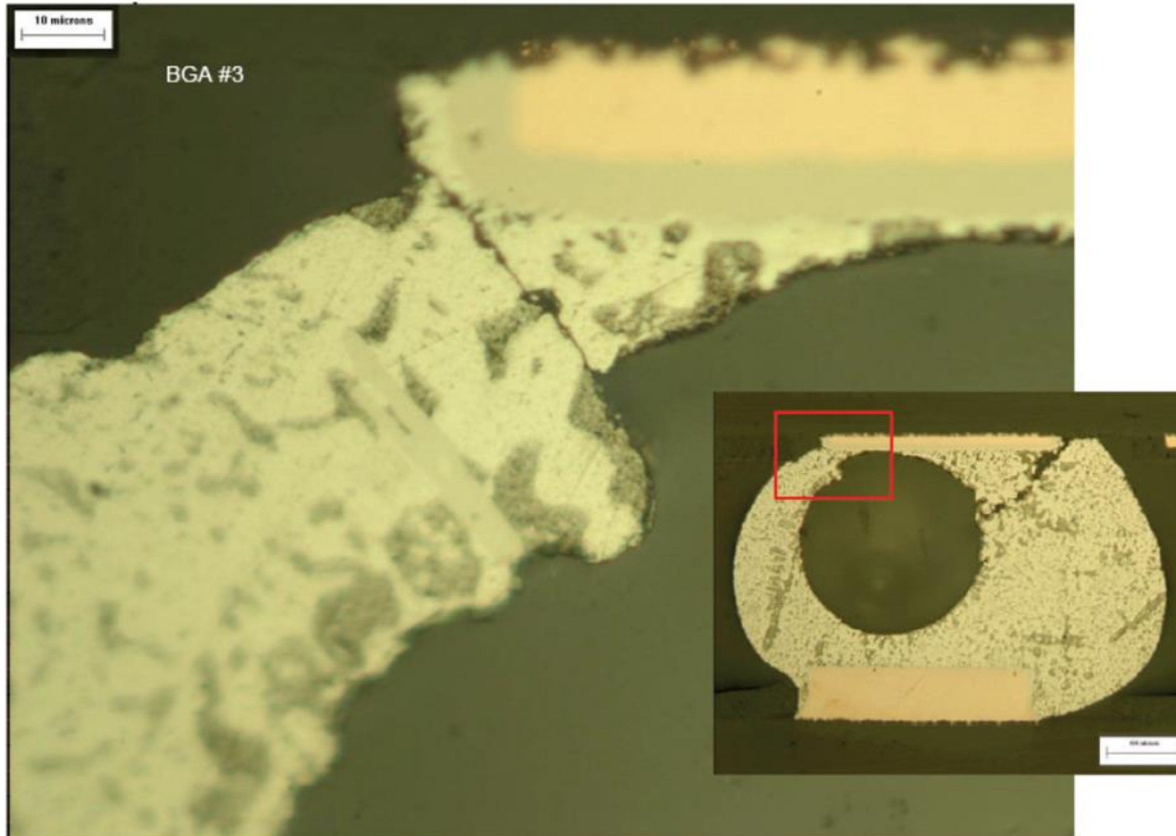
Originally presented at IPC APEX 2020.

Outline / Agenda

- Introduction
  - *Voiding - Why all the Fuss?*
  - *Causes of Voiding*
- Methodology
- Results and Discussion
  - *Voiding by Stencil Thickness*
  - *Voiding by Area of Coverage*
  - *Voiding by Component*
  - *Voiding by I/O Pad Toe Adder*
- Conclusions and Recommendations

Introduction
Voids - What is All the Fuss About?



- Mechanical Failure (Cracks)
- Overheating Failure
- Electric Signal Degradation (Noise)
- Hard to Rework!

Introduction
Voiding Causes

Print/ Dispense
Temp/ Humidity
Volume
Storage condition

Reflow
Soak Temp
Peak Temp
Soak Time
TAL
Atmospheric Pressure
BLT
Atmosphere
Ramp Rate

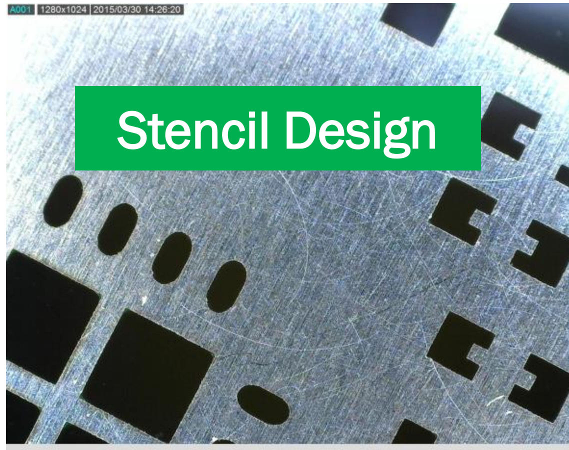
Void

Substrates / Components
Storage Condition
Surface Finish
Mounting Alignment
Oxidation Level
Soldering area
Surface Roughness

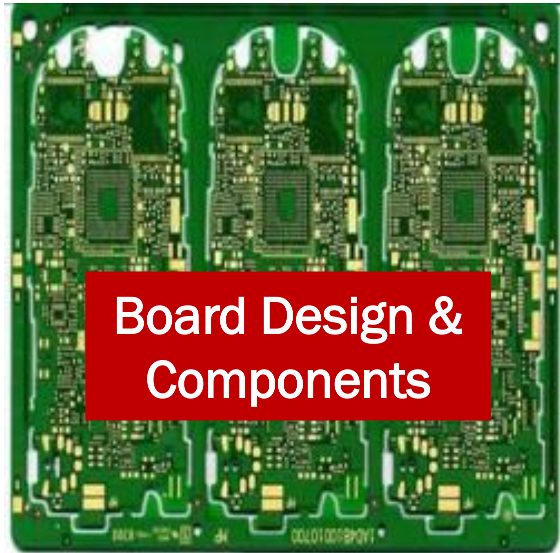
Solder Paste
Surface Tension of molten solder
Flux Activity
Powder Size/ Oxidation Level
Melting Temp Range
Storage Condition
Flux Vaporization Behavior

Introduction
Voiding Causes - What Can We Change?

Easy to Change

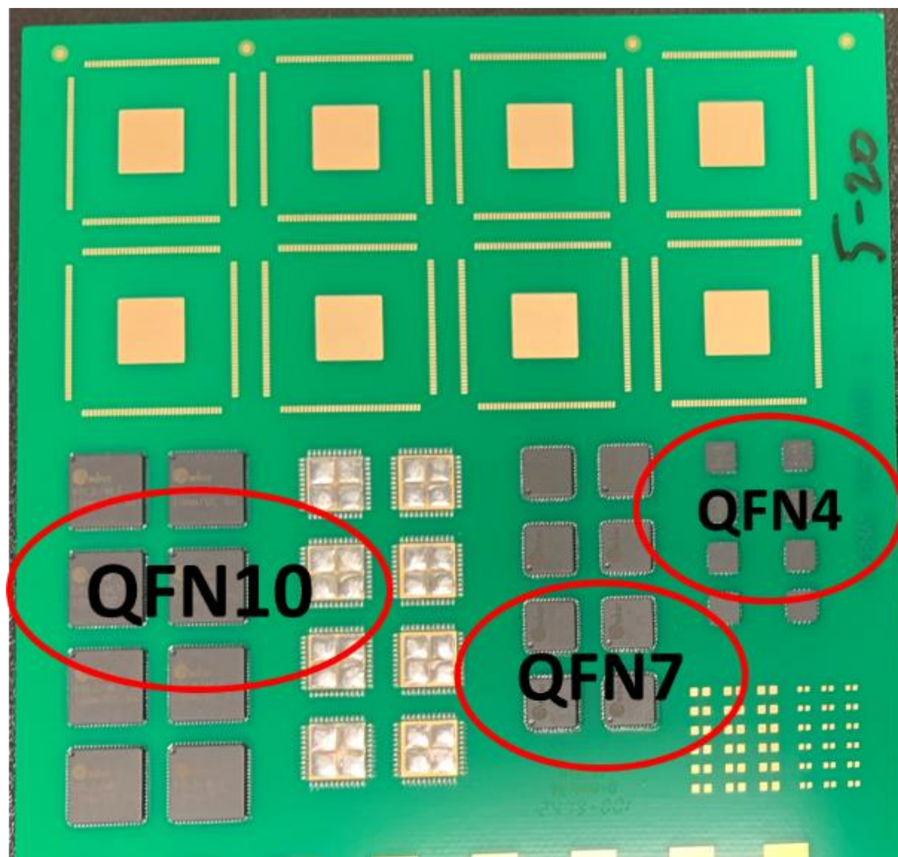


Harder to Change



Methodology

Methodology
Circuit Board and Stencil Design



70% 60% 70% 60% 70% 60% 70% 60%

1:1 Cu

+5 Toe

+10 Toe

+20 Toe

QFN10

QFN9 - Not used

QFN7

QFN4

QFN 10 mm, 7 mm, 4 mm

FR4, 0.062”, 1 oz Cu, ENIG

Thermal 70 & 60% Area of Coverage

I/O Pad Toe Adder: 0, 5, 10, 20 mils

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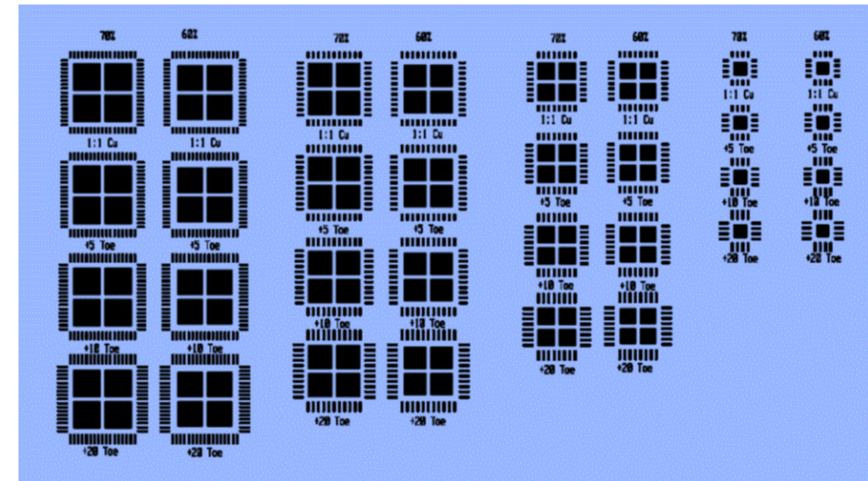
Methodology
Stencil Design Details

Two Stencil Thicknesses:
4 and 5 mil

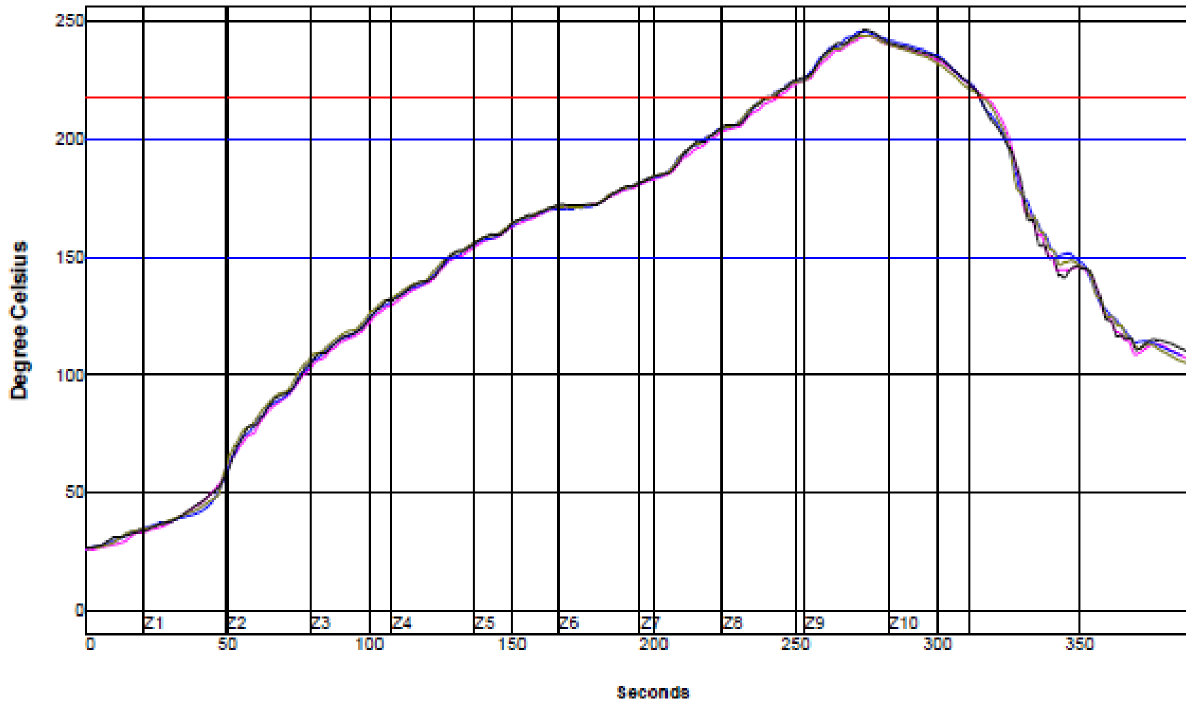


Component	Thermal Paste Area (%)	Thermal # Panes	Thermal Web Width (mils)	Thermal Brick Size (mils)	Perimeter Aperture Width (mils)	Perimeter Aperture Length 1:1 (mils)	Perimeter Aperture Length +5 (mils)	Perimeter Aperture Length +10 (mils)	Perimeter Aperture Length +20 (mils)
QFN 10	70	4	20	133.5	9.8	30.6	35.6	40.6	50.6
QFN 10	60	4	20	124	9.8	30.6	35.6	40.6	50.6
QFN 7	70	4	20	84	12.8	30.6	35.6	40.6	50.6
QFN 7	60	4	20	78	12.8	30.6	35.6	40.6	50.6
QFN 4	70	1	0	68.9	12.8	30.6	35.6	40.6	50.6
QFN 4	60	1	0	63.1	12.8	30.6	35.6	40.6	50.6

Methodology
Reflow Profiles Tested

Profile Name	Max Rise Slope (°C/sec)	Soak Time (150-200°C in sec)	Reflow Time (>220°C in sec)	Peak Temp (°C)	Time (25°C-peak in min)
Linear ramp to spike	1.7-2.1	89-91	73-74	244-247	4.5-4.6
Short linear ramp	2.0-2.1	65-66	66-69	245-247	3.9
Short plus soak	2.0-2.1	92-94	52-55	242-245	4.3
Long linear ramp	1.6-1.8	87-89	94-97	249-251	5.4-5.5
Long plus soak	1.5-1.8	114-116	75-80	246-248	5.8-5.9

Methodology
Reflow Profile Chosen



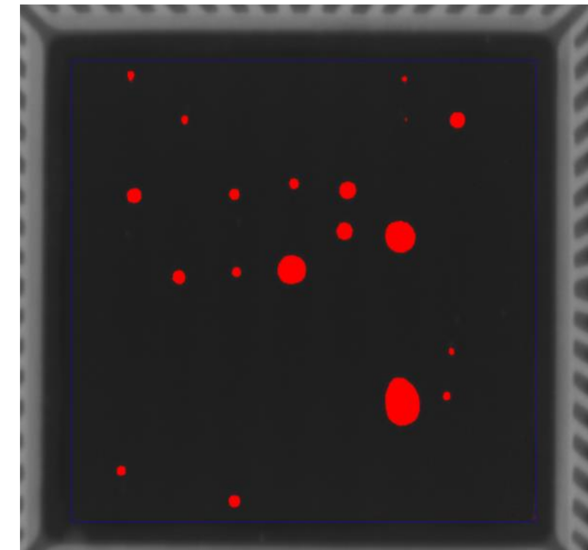
Setpoints (Degree Celsius)

Zone	1	2	3	4	5	6	7	8	9	10
Top	110	130	150	170	180	190	220	240	260	230
Bottom	110	130	150	170	180	190	220	240	260	230

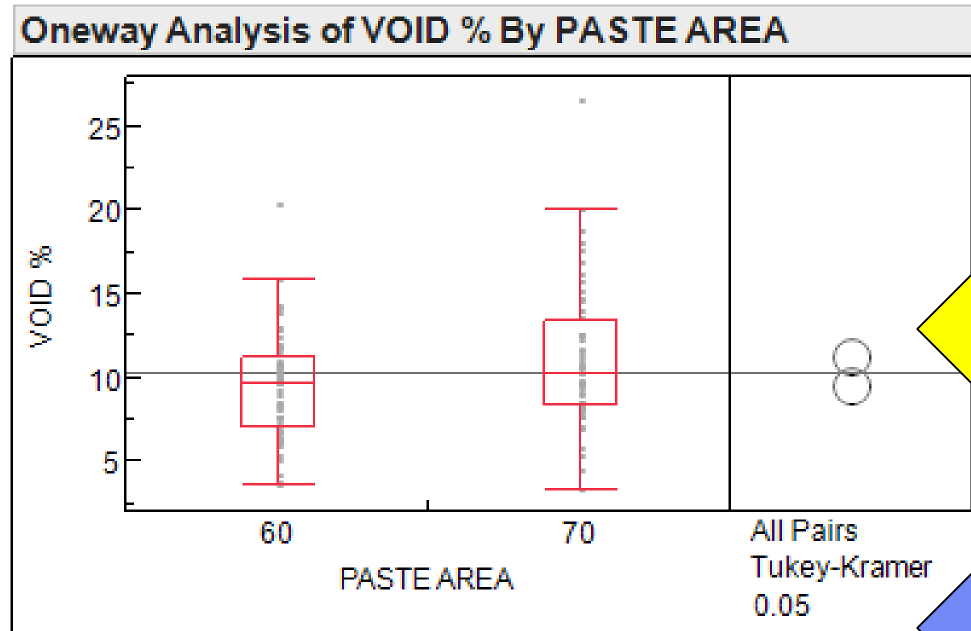
Conveyor Speed (inch/min): 33.0

PWI= 96%	Max Rising Slope		Soak Time 150-200°C		Reflow Time /218°C		Peak Temp		Time 25°C-peak	
<TC2>	1.74	16%	89.37	-2%	72.90	86%	243.73	-13%	4.57	43%
<TC3>	2.03	35%	88.64	-5%	73.28	89%	246.01	10%	4.55	40%
<TC4>	2.11	41%	90.07	0%	74.16	94%	244.17	-8%	4.57	43%
<TC5>	1.91	27%	90.73	2%	74.38	96%	246.67	17%	4.56	42%
Delta	0.37		2.09		1.48		2.94		0.02	

- Linear Ramp to Spike (RTS)
- Lowest Voiding with the Solder Paste Used



Methodology
Statistics



Excluded Rows 359

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
70	A		11.2
60		B	9.5

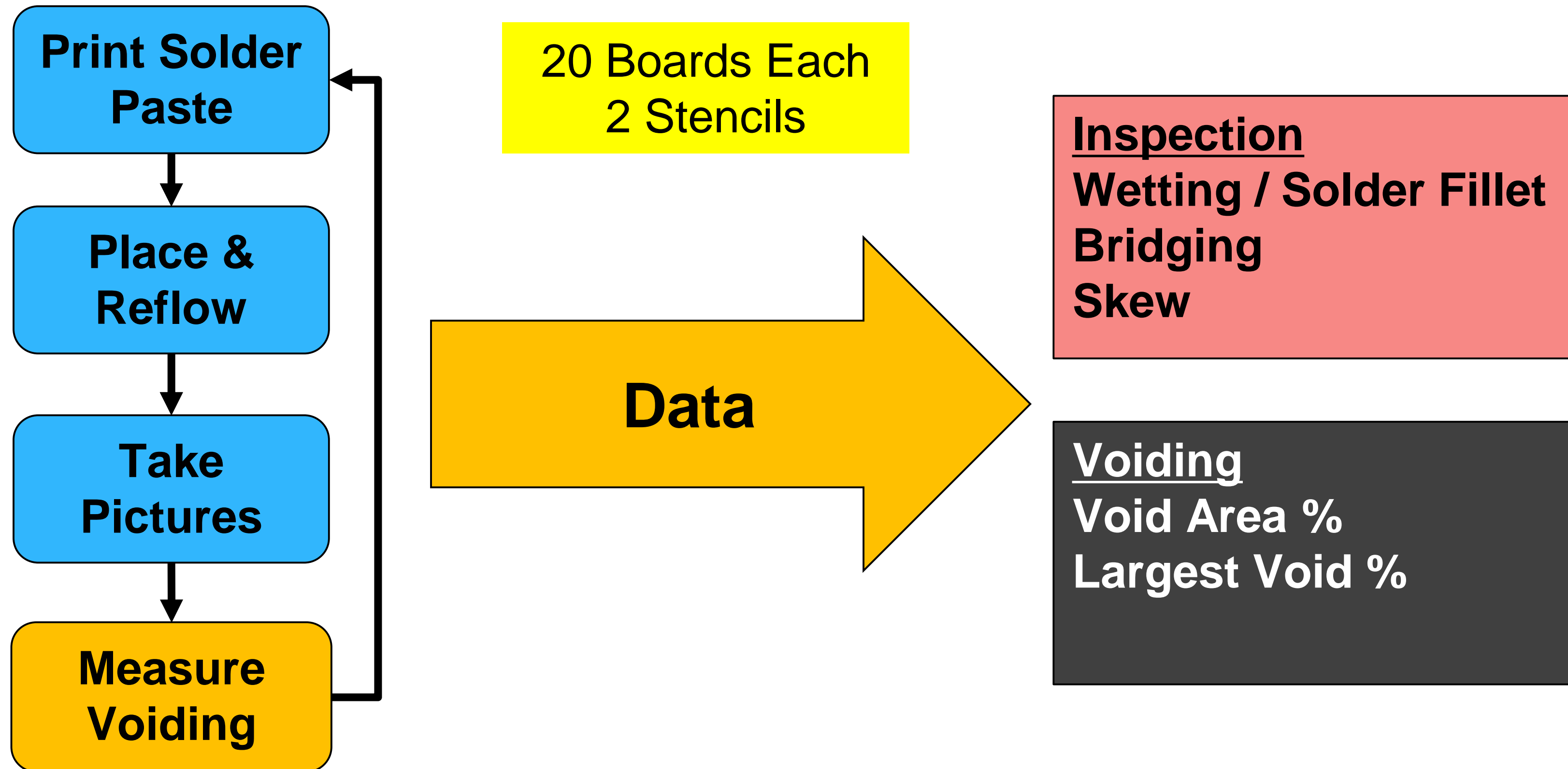
Levels not connected by same letter are significantly different.

Data sets shown as box plots & circles

95% confidence level

Connecting letters shows differences

Methodology Process



Results

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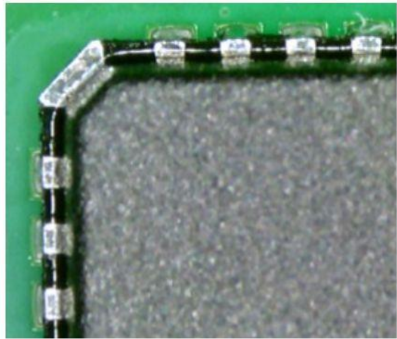
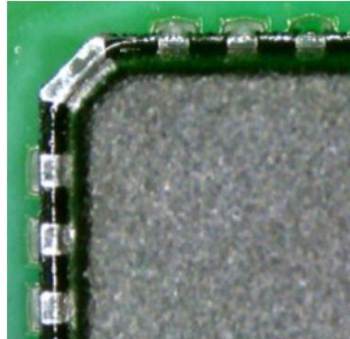
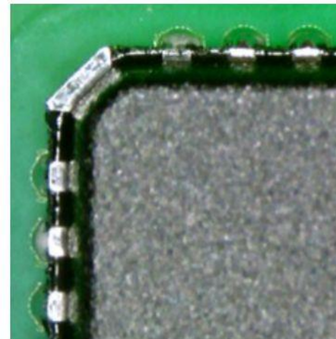
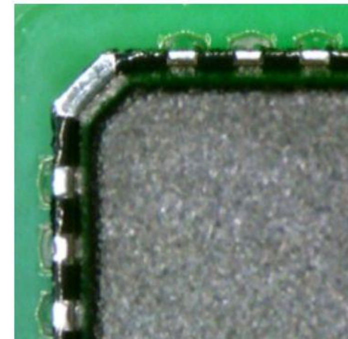
Results
I/O Solder Joints

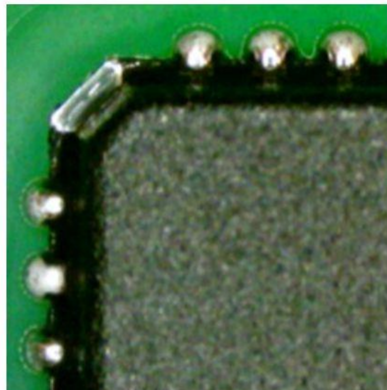
QFN 10

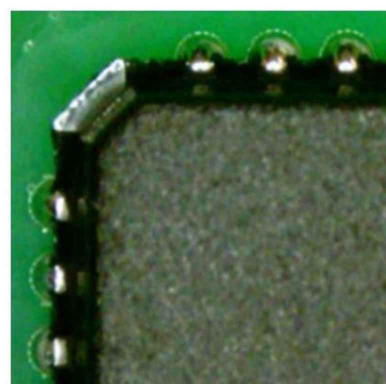

60%, +0

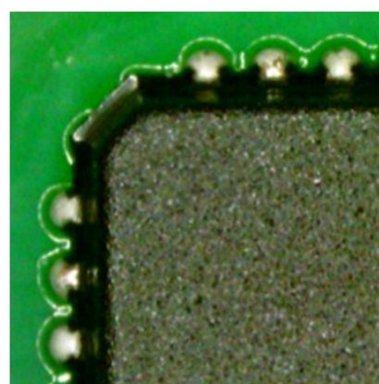

70%, +0

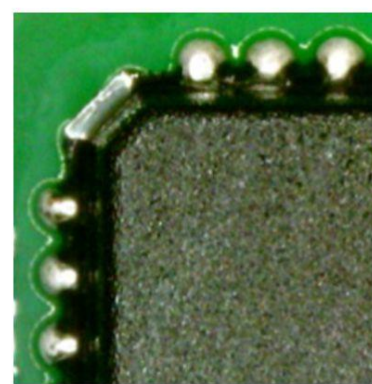

60%, +5


70%, +5


60%, +10


70%, +10


60%, +20


70%, +20

No Bridging or Skew was Observed

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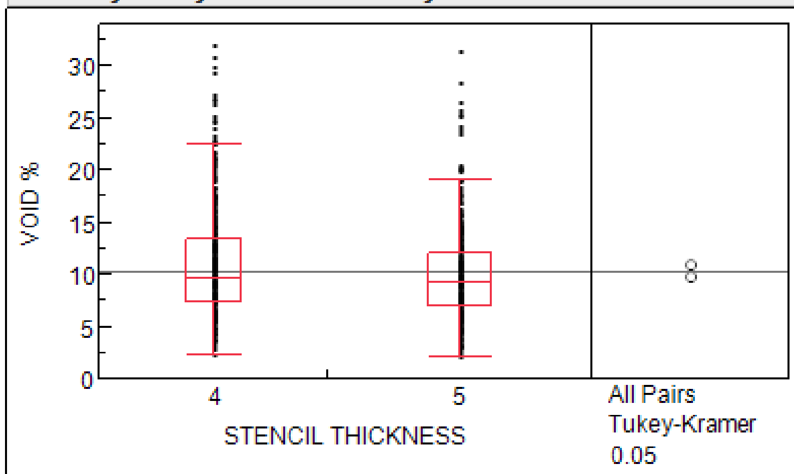
Results
Voiding by Stencil Thickness

Oneway Analysis of VOID % By STENCIL THICKNESS



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

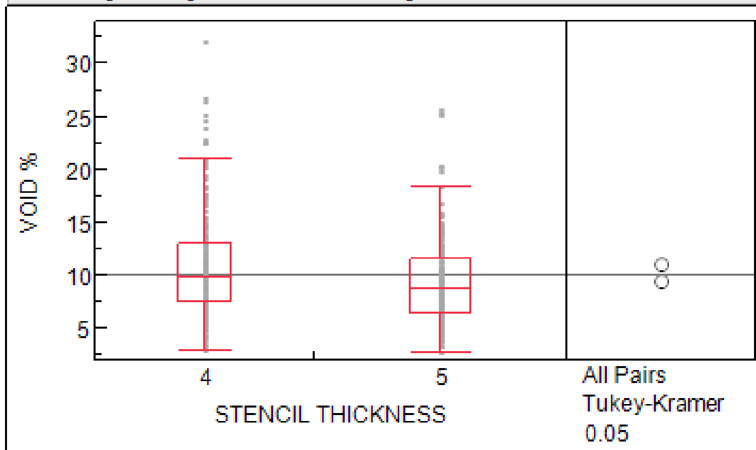
Connecting Letters Report

Level		Mean
4	A	10.9
5	B	9.8

Levels not connected by same letter are significantly different.

Overall

Oneway Analysis of VOID % By STENCIL THICKNESS



Excluded Rows 447

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

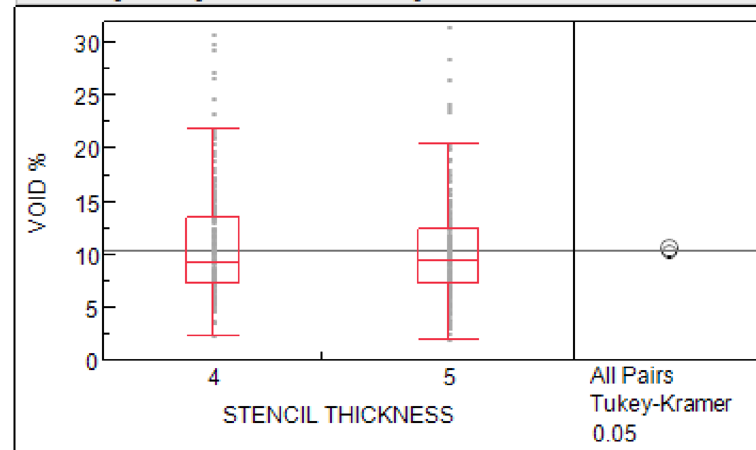
Connecting Letters Report

Level		Mean
4	A	11.0
5	B	9.4

Levels not connected by same letter are significantly different.

60% Paste Area

Oneway Analysis of VOID % By STENCIL THICKNESS



Excluded Rows 448

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

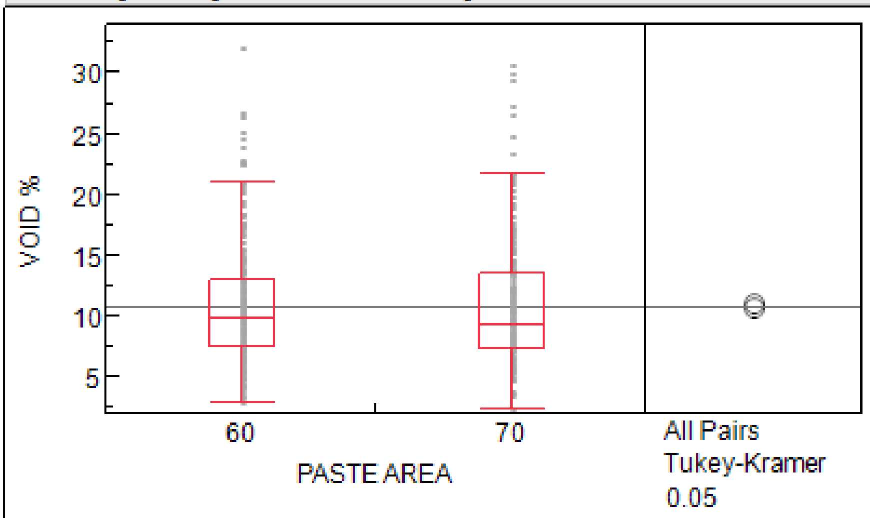
Level		Mean
4	A	10.7
5	A	10.3

Levels not connected by same letter are significantly different.

70% Paste Area

Results
Voiding by Area of Coverage

Oneway Analysis of VOID % By PASTE AREA



Excluded Rows 479

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

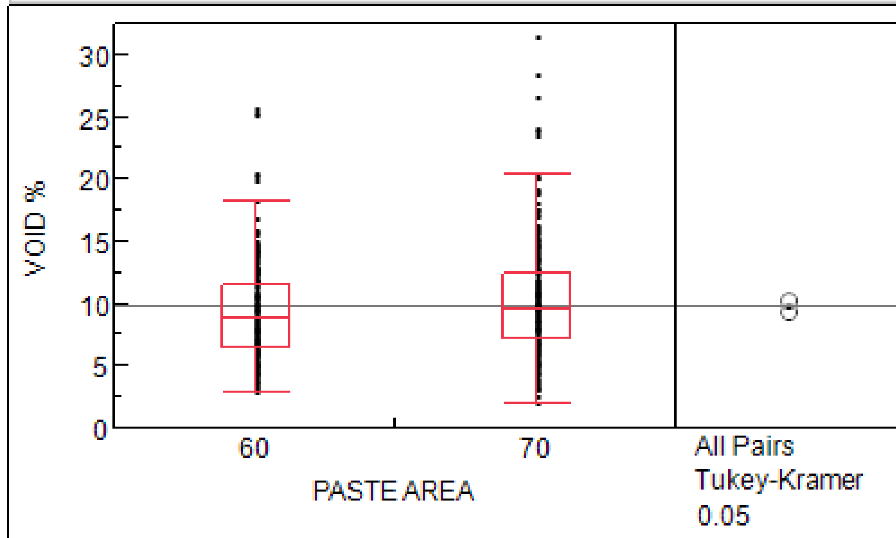
Connecting Letters Report

Level		Mean
60	A	11.0
70	A	10.7

Levels not connected by same letter are significantly different.

4 mil Stencil

Oneway Analysis of VOID % By PASTE AREA



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

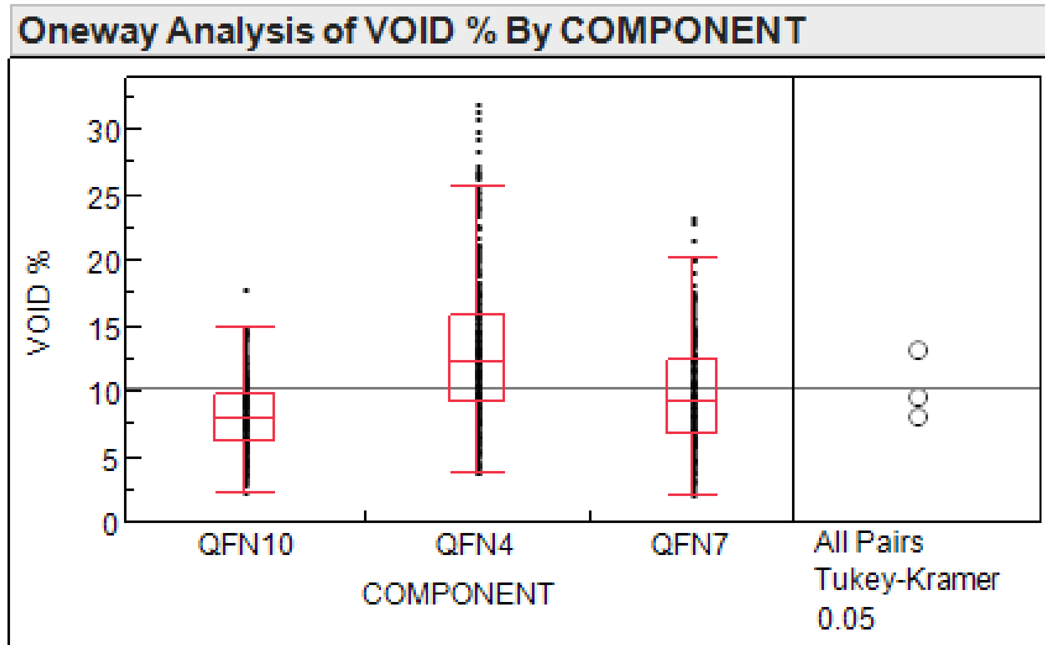
Connecting Letters Report

Level			Mean
70	A		10.3
60		B	9.4

Levels not connected by same letter are significantly different.

5 mil Stencil

Results
Voiding by Component



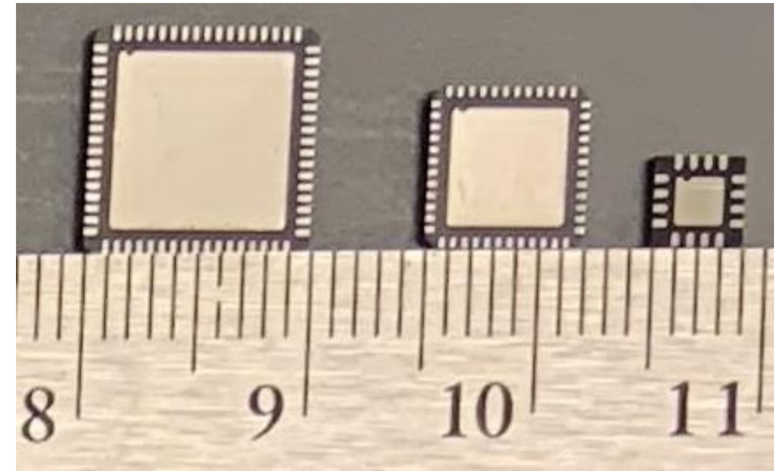
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

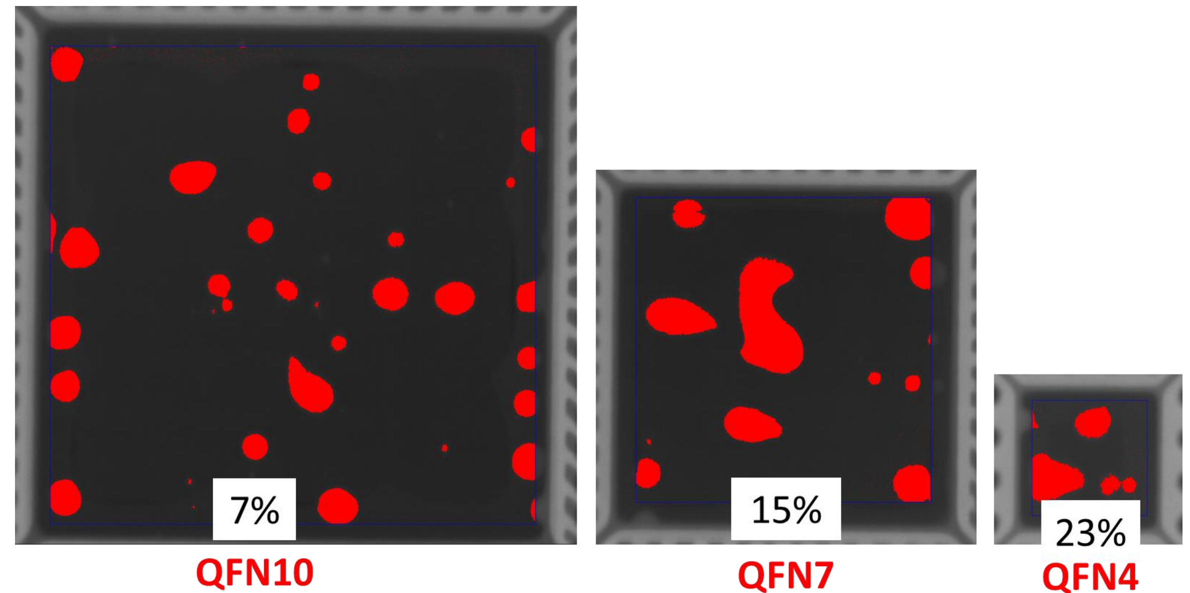
Connecting Letters Report

Level				Mean
QFN4	A			13.2
QFN7		B		9.7
QFN10			C	8.1

Levels not connected by same letter are significantly different.



Small QFN's = Higher Voiding



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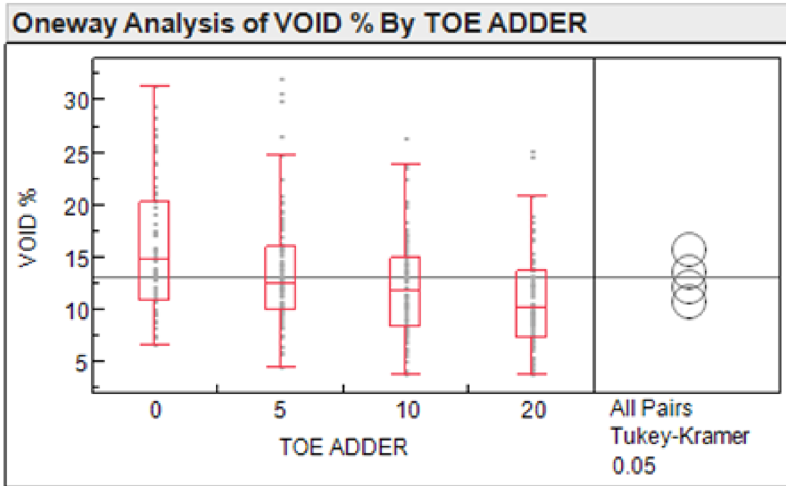
Results
Voiding by Toe Adder



Excluded Rows 592

Means Comparisons

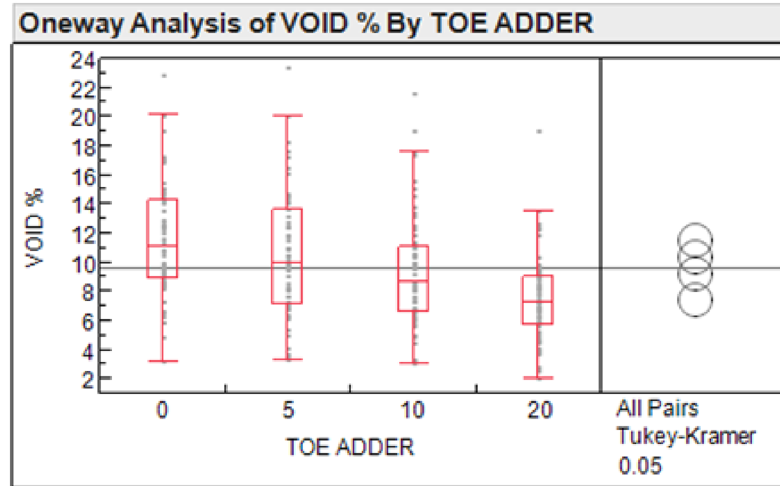
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
0	A			15.9
5	A	B		13.7
10		B	C	12.3
20			C	10.9

Levels not connected by same letter are significantly different.

QFN4



Excluded Rows 623

Means Comparisons

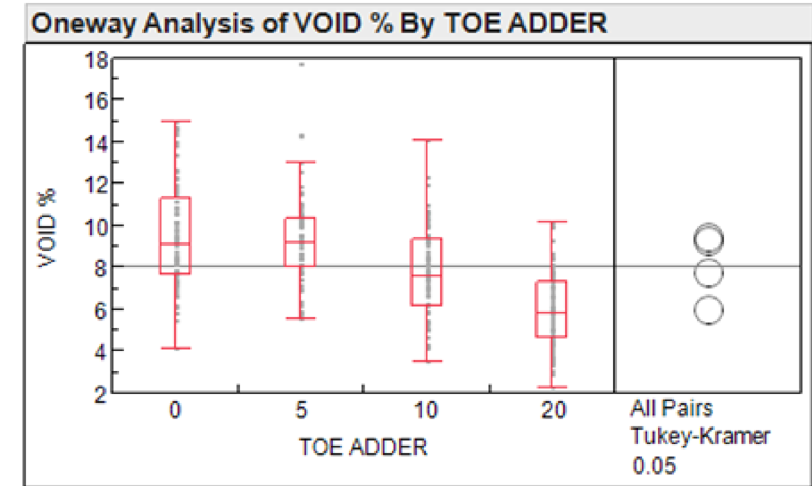
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
0	A			11.6
5	A	B		10.4
10		B		9.3
20			C	7.5

Levels not connected by same letter are significantly different.

QFN7



Excluded Rows 575

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

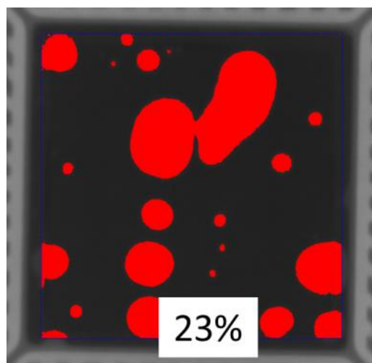
Level				Mean
0	A			9.5
5	A			9.3
10		B		7.8
20			C	6.0

Levels not connected by same letter are significantly different.

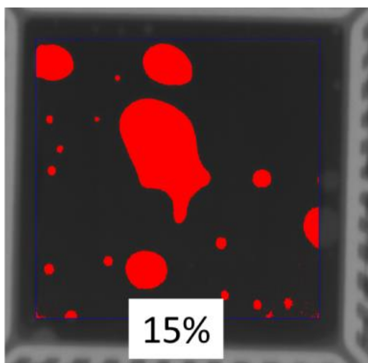
QFN10

Increasing Length of Toe Adder = Lower Voiding

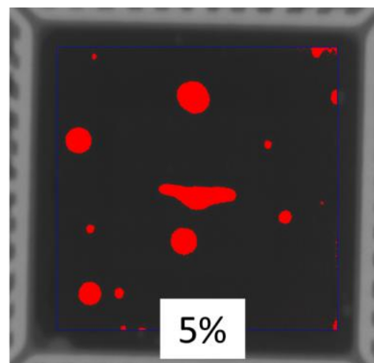
Results
Voiding by Toe Adder



QFN7 +5 Toe



QFN7 +10 Toe



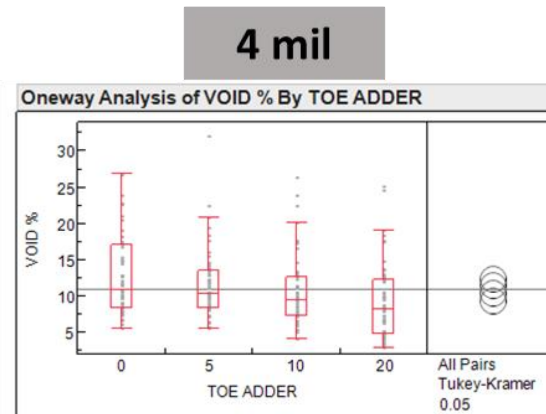
QFN7 +20 Toe

Toe Adder Affects Voiding Regardless of Paste Area or Stencil Thickness

4 mil

5 mil

60%



Excluded Rows 687

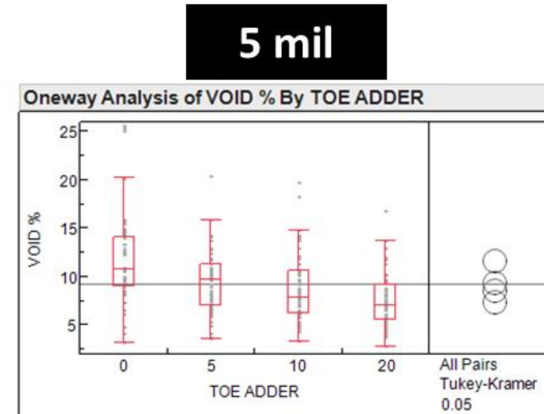
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
0	A		12.5
5	A	B	11.6
10	A	B	10.6
20		B	9.4

Levels not connected by same letter are significantly different.



Excluded Rows 239

Means Comparisons

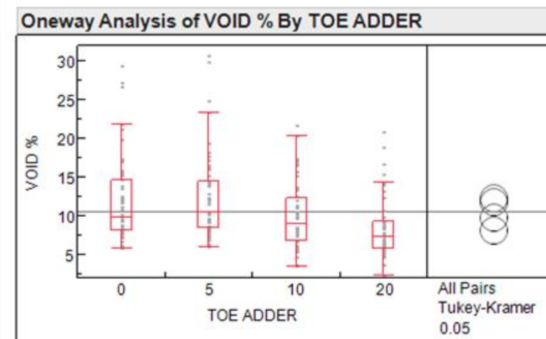
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
0	A			11.8
5		B		9.5
10		B	C	8.7
20			C	7.5

Levels not connected by same letter are significantly different.

70%



Excluded Rows 687

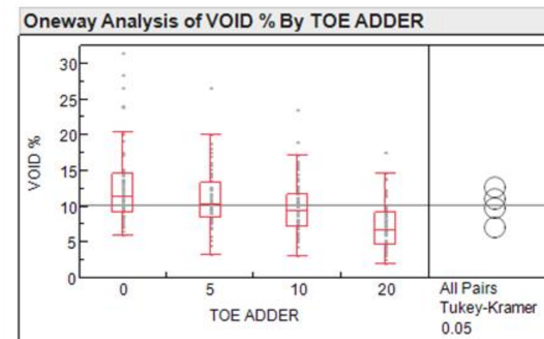
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
5	A		12.5
0	A		12.0
10	A	B	10.1
20		B	8.4

Levels not connected by same letter are significantly different.



Excluded Rows 240

Means Comparisons

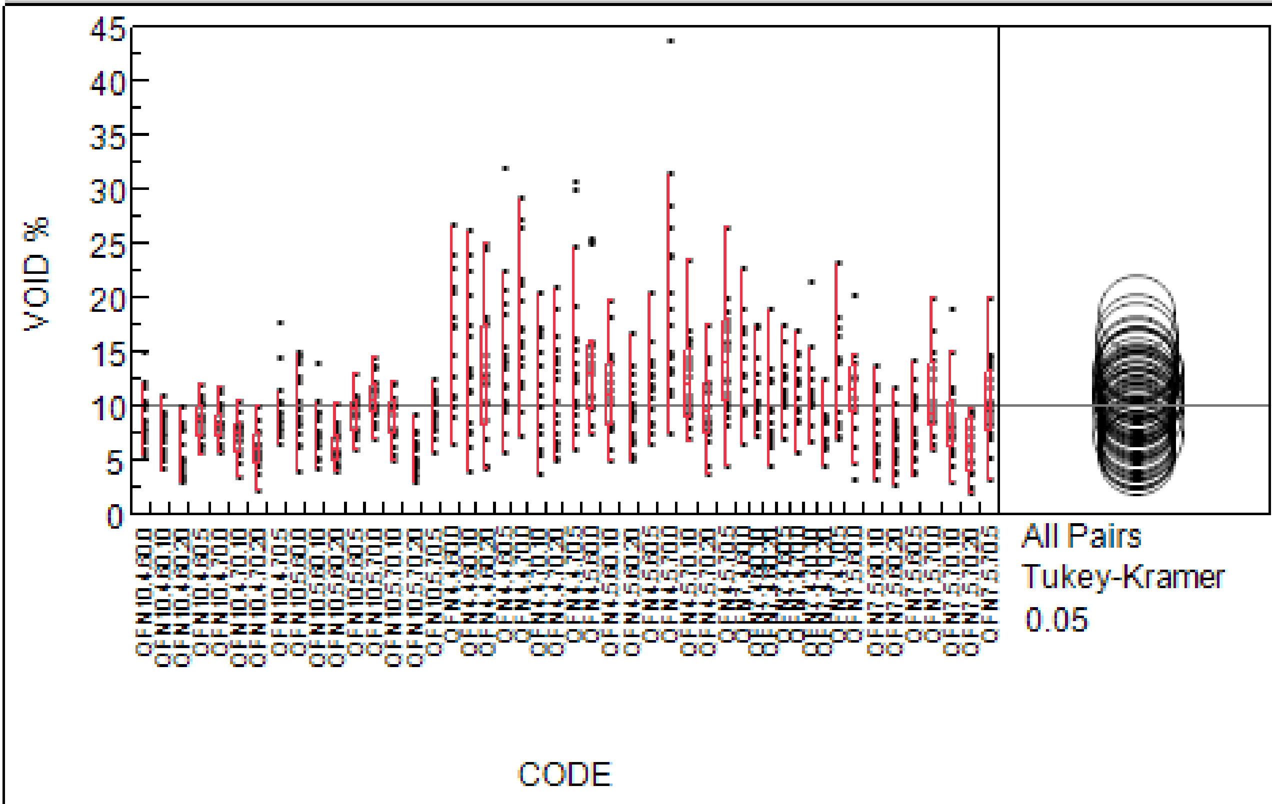
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
0	A			12.9
5	A	B		11.2
10		B		9.9
20			C	7.2

Levels not connected by same letter are significantly different.

Results
Voiding Overall



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
QFN4.5.70.0	A	18.7
QFN4.4.70.0	A B	16.6
QFN4.4.60.0	A B C	15.9
QFN4.4.70.5	A B C D	14.8
QFN4.4.60.5	A B C D E	14.6
QFN4.5.70.5	A B C D E F	14.1
QFN4.5.60.0	A B C D E F G	13.9
QFN7.4.60.0	A B C D E F G H I	13.5
QFN4.4.60.10	B C D E F G H	13.4
QFN7.4.70.5	B C D E F G H I J	13.2
QFN4.4.60.20	B C D E F G H I	12.9
QFN4.4.70.10	B C D E F G H I J K	12.3
QFN4.5.70.10	B C D E F G H I J K	12.2
QFN7.4.60.5	B C D E F G H I J K L	11.8
QFN4.5.60.5	C D E F G H I J K L	11.5
QFN7.4.70.0	B C D E F G H I J K L M N	11.4
QFN4.5.60.10	C D E F G H I J K L	11.4
QFN4.4.70.20	C D E F G H I J K L	11.4
QFN7.4.60.10	B C D E F G H I J K L M N	11.3
QFN7.4.70.10	B C D E F G H I J K L M N	11.3
QFN7.5.60.0	C D E F G H I J K L M	11.1
QFN7.5.70.0	D E F G H I J K L M N	10.8
QFN10.5.70.0	D E F G H I J K L M N	10.7
QFN10.5.60.0	D E F G H I J K L M N O	10.3
QFN7.5.70.5	D E F G H I J K L M N O	10.3
QFN4.5.70.20	D E F G H I J K L M N O	9.9
QFN10.4.70.5	D E F G H I J K L M N O	9.9
QFN7.4.60.20	D E F G H I J K L M N O	9.8
QFN4.5.60.20	E F G H I J K L M N O	9.6
QFN10.5.60.5	F G H I J K L M N O	9.4
QFN10.5.70.5	F G H I J K L M N O	9.3
QFN10.5.70.10	G H I J K L M N O	9.0
QFN10.4.60.0	H I J K L M N O	8.8
QFN10.4.60.5	H I J K L M N O	8.7
QFN7.5.70.10	H I J K L M N O	8.6
QFN10.4.70.0	I J K L M N O	8.2
QFN7.4.70.20	I J K L M N O	7.8
QFN7.5.60.5	J K L M N O	7.7
QFN10.5.60.10	K L M N O	7.6
QFN10.4.60.10	K L M N O	7.4
QFN10.4.70.10	L M N O	7.2
QFN7.5.60.10	L M N O	7.1
QFN7.5.60.20	L M N O	6.8
QFN7.5.70.20	M N O	6.3
QFN10.5.60.20	M N O	6.3
QFN10.4.70.20	N O	6.1
QFN10.4.60.20	N O	6.0
QFN10.5.70.20	O	5.5

Levels not connected by same letter are significantly different.

High Voiding
Small QFN
4 mil Stencil
+0 to 5 Toe

Low Voiding
Large QFN
5 mil Stencil
+10 to 20 Toe

Conclusions and Recommendations

Conclusions

- The linear ramp to spike (RTS) profile produced the lowest voiding with the solder paste used.
- Increasing the stencil foil thickness from 4 mils to 5 mils reduced voiding significantly.
- Increasing area of coverage from 60 to 70% did not have a significant effect.
- Overall voiding decreases as QFN component body size is increased.
- Overprinting the I/O lead toes reduces void area, regardless of the other factors.

Conclusions and Recommendations

Recommendations to Mitigate Voiding

- ✓ Use a low voiding solder paste with the appropriate reflow profile.
- ✓ Increase stencil thickness or area of coverage on thermal pads.
- ✓ Overprint to the toe of the QFN I/O pads.

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