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Fill the Void IX: The Impact of Reflow on Voiding in Solder Joints

Authors

Jeff Kurish
Universal Instruments a Delta Company
Conklin, NY, USA

Piyush Kulkarni
Binghamton University
Vestal, NY, USA

Tony Lentz
FCT Assembly
Windsor, CO, USA

Agenda & Introduction

Agenda

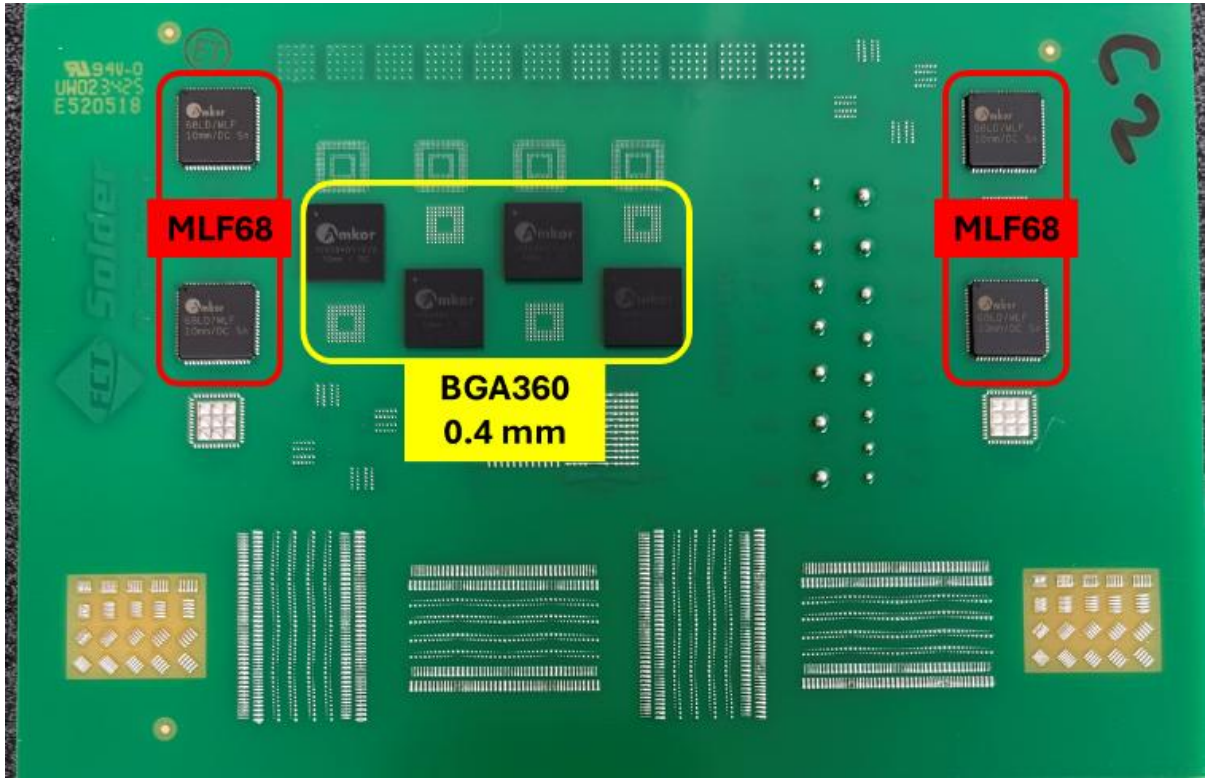
- Introduction
- Experimental Methodology
- Results
  - MLF68 Voiding Data
  - BGA360 Voiding Data
  - BGA360 Prevalence of Voids 1st & 2nd Reflow
  - BGA360 Bridging
- Conclusions

Introduction

- Voiding limits are tightening
  - BTC thermal pads <25% void area
  - BGA <15-25% void area
  - Critical applications <10% void area
- Void reduction strategies
  - Solder paste formulation and alloy
  - Print pattern and volume
  - Reflow profile adjustment
  - Vacuum in reflow
- 2nd side reflow changes void area
  - Vacuum can remove existing voids

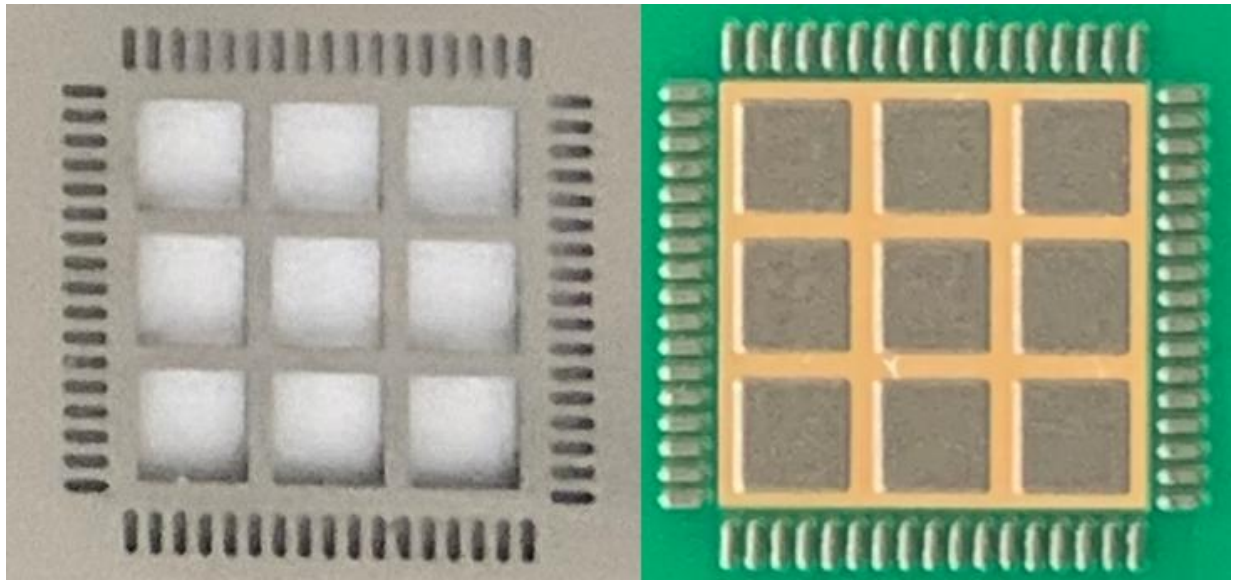
Experimental Methodology

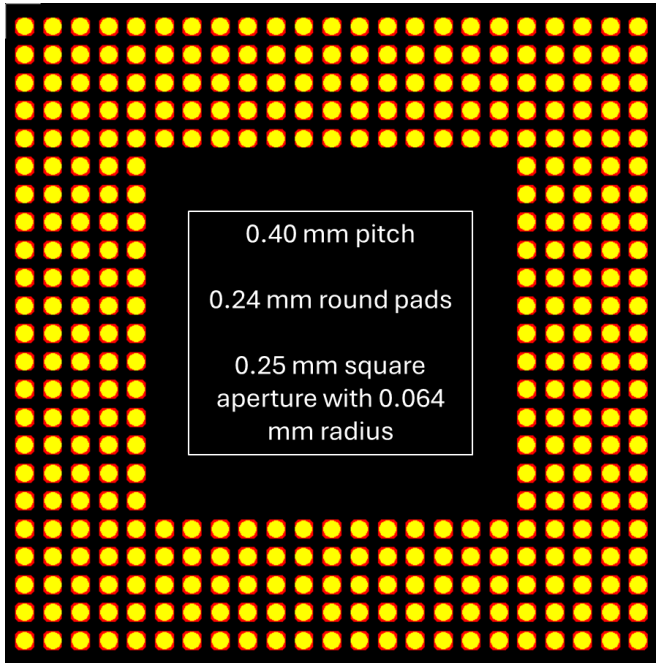
Experimental Methodology



- PR Test Board
  - Single sided FR4, SMOBC, 1.5 mm thick, 1 oz etched Cu, ENIG finish

Experimental Methodology





- Stencil Design (127 µm thick)
  - MLF68 65% area of coverage, 0.51 mm web, 2.24 mm brick
  - BGA360 0.4 mm pitch, 0.24 mm round pads, 0.25 mm square apertures

Experimental Methodology

Solder Paste	Flux Class (IPC J-STD-004)	SAC305 Content (% wt)	Relative Voiding Potential
A	ROL0	88.0	Low Voiding
C	ROL0 (Halogen containing)	87.9	High Voiding

- Solder Pastes
  - No clean, SAC305, IPC Type 4
  - Chosen from SMTA 2025 “Fill the Void VIII – Can Reflow Profiles Really Improve Voiding in Solder Joints”

Experimental Methodology

Print Parameter	Value
Print speed (mm/sec)	35 mm/sec
Blade angle (deg.)	60°
Blade length (mm)	200 mm
Print pressure (kg)	5.0 Kg
Separation speed (mm/sec)	20 mm/sec
Separation distance (mm)	1 mm
Print gap (mm)	0

- Printer (ASM DEK)

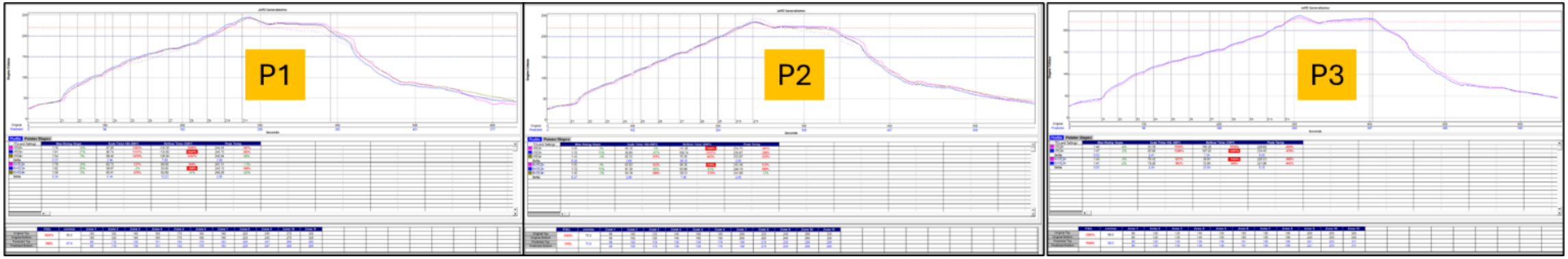
Experimental Methodology

Reflow Profile #	Conveyor Speed (cm/min)	Z2 (°C)	Z3 (°C)	Z4 (°C)	Z4 (°C)	Z5 (°C)	Z6 (°C)	Z7 (°C)	Z8 (°C)	Z9 (°C)	Z10 (°C)	Vacuum Chamber IRL (°C)	Vacuum Chamber IRC (°C)	Vacuum Chamber IRR (°C)
1	65	100	120	140	160	170	180	190	220	245	270	320	320	320
2	75	90	100	120	140	160	180	200	220	240	260	320	320	320
3	60	80	120	130	140	150	165	185	198	220	255	320	320	320

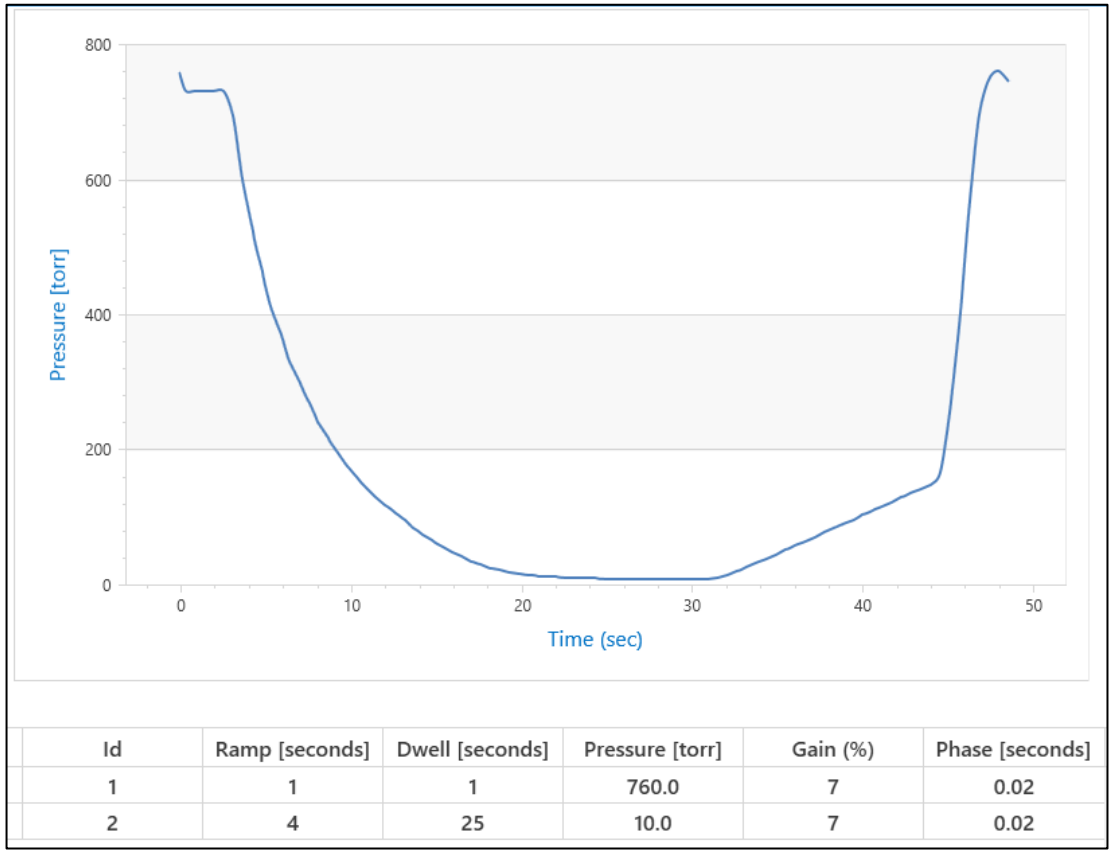
- Reflow Oven (Heller 1911-MK5-VR)
  - 10 zone, convection reflow in air
  - 3 IR heaters in vacuum chamber

Experimental Methodology

Parameter	Profile #1	Profile #2	Profile #3
Soak time 150-200°C (sec)	87 - 89	59 - 62	83 - 86
Reflow Time >220°C (sec)	127 - 135	109 - 111	100 - 108
Peak temp (°C)	243 - 246	234 - 236	229 - 234



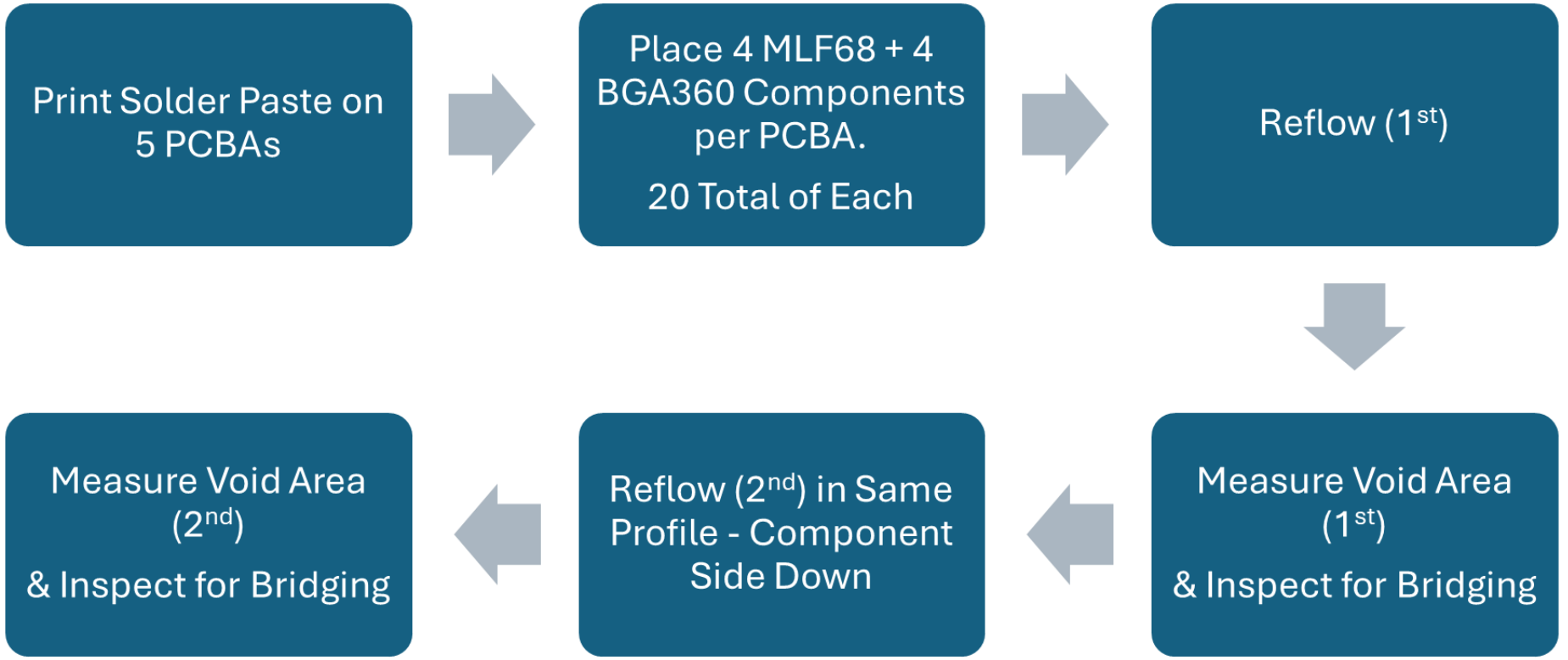
Experimental Methodology



Id	Ramp [seconds]	Dwell [seconds]	Pressure [torr]	Gain (%)	Phase [seconds]
1	1	1	760.0	7	0.02
2	4	25	10.0	7	0.02

- Vacuum Cycle
  - 10 torr for 25 sec (down from 760 torr)
  - Overall time ~45 sec

Experimental Methodology

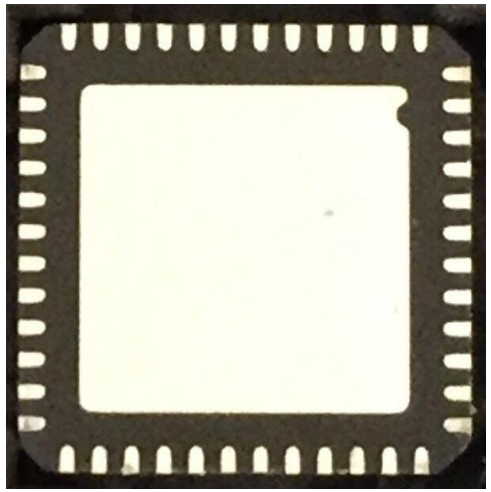


- Process
  - 1st reflow without vac then 2nd reflow with vac in same profile
  - Vice versa
  - 2nd reflow components face down

Experimental Methodology

- Codes in Data
  - Solder paste = A or C
  - Profile # = 1, 2 or 3
  - Vacuum = V
  - “-” used to separate 1st and 2nd reflow
- Example Codes
  - “C2V” = Solder paste C in reflow profile # 2 with vacuum (1st side only)
  - “A1-1V” = Solder paste A in reflow profile # 1 (1st side) followed by vacuum profile # 1 (2nd side)

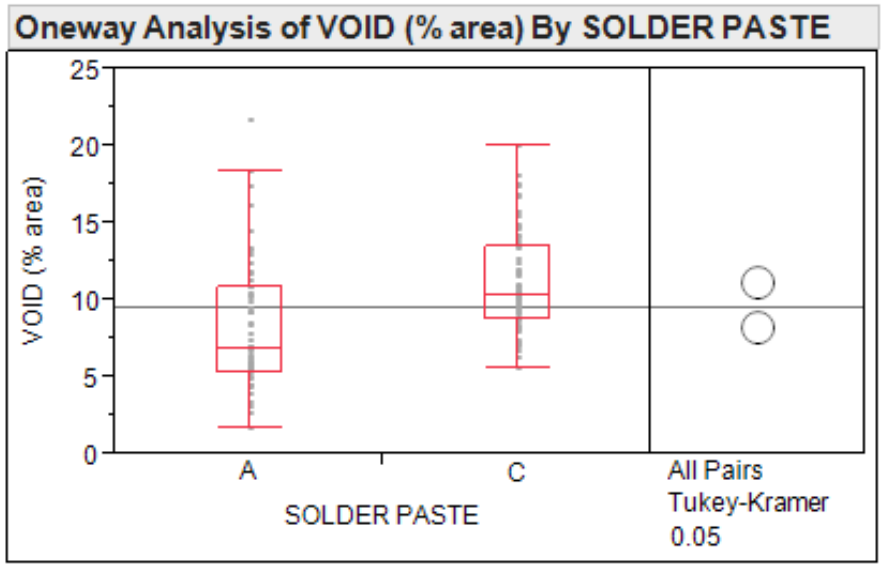
Results
MLF68



MLF68 Voiding Stats

Solder Paste	Reflow Profile	Min Void Area (%)	Mean Void Area (%)	Max Void Area (%)
A	1	2.7	7.58	18.4
A	1-1V	0.1	0.58	1.1
A	1V	0.0	0.98	1.9
A	1V-1	0.4	0.77	1.2
A	2	3.3	8.07	17.3
A	2-2V	0.5	0.97	1.5
A	2V	0.4	0.75	1.5
A	2V-2	0.5	1.31	2.0
A	3	1.7	8.96	21.7
A	3-3V	0.2	0.65	1.3
A	3V	0.2	0.56	1.9
A	3V-3	0.6	1.26	2.1
C	1	5.6	9.70	15.4
C	1-1V	0.4	1.29	2.7
C	1V	0.4	0.96	1.7
C	1V-1	0.7	1.45	5.1
C	2	7.9	12.62	20.0
C	2-2V	0.8	1.59	2.6
C	2V	0.5	1.11	2.0
C	2V-2	0.3	1.22	1.7
C	3	6.2	10.96	18.0
C	3-3V	0.3	1.19	1.9
C	3V	0.4	0.79	2.0
C	3V-3	0.3	1.04	1.6

MLF68 Voiding by Paste or Profile



Excluded Rows 360

Means Comparisons

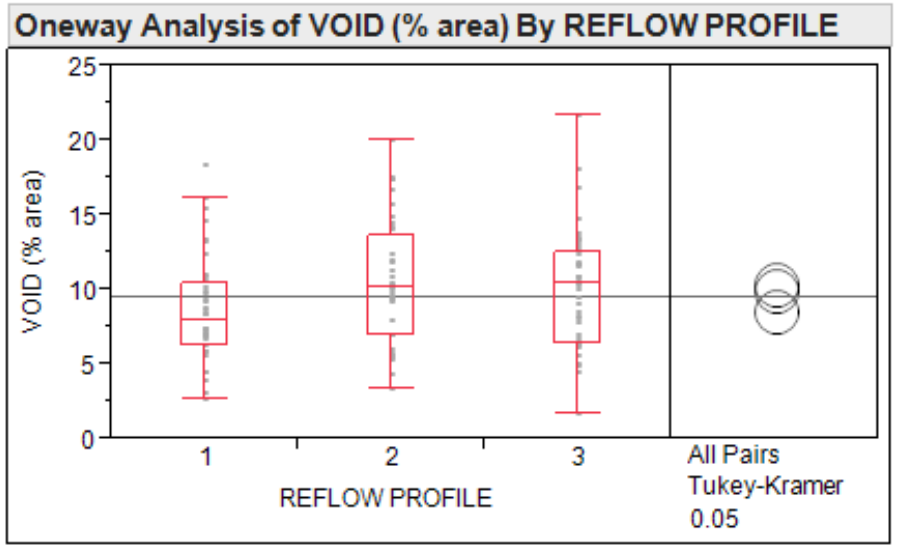
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
C	A	11.1
A	B	8.2

Levels not connected by same letter are significantly different.

Paste



Excluded Rows 360

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

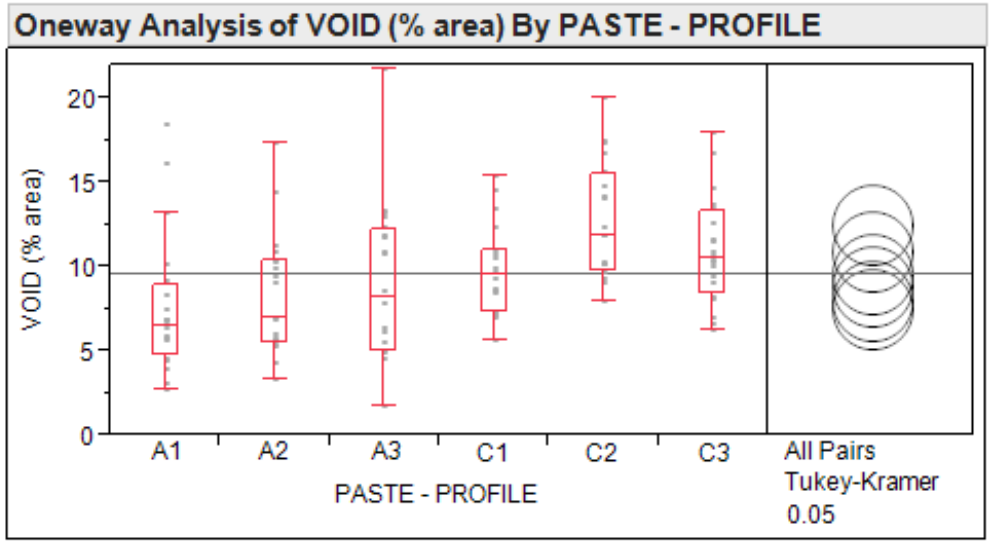
Connecting Letters Report

Level		Mean
2	A	10.3
3	A	10.0
1	A	8.6

Levels not connected by same letter are significantly different.

Profile

MLF68 Voiding by Paste & Profile



Excluded Rows 360

Means Comparisons

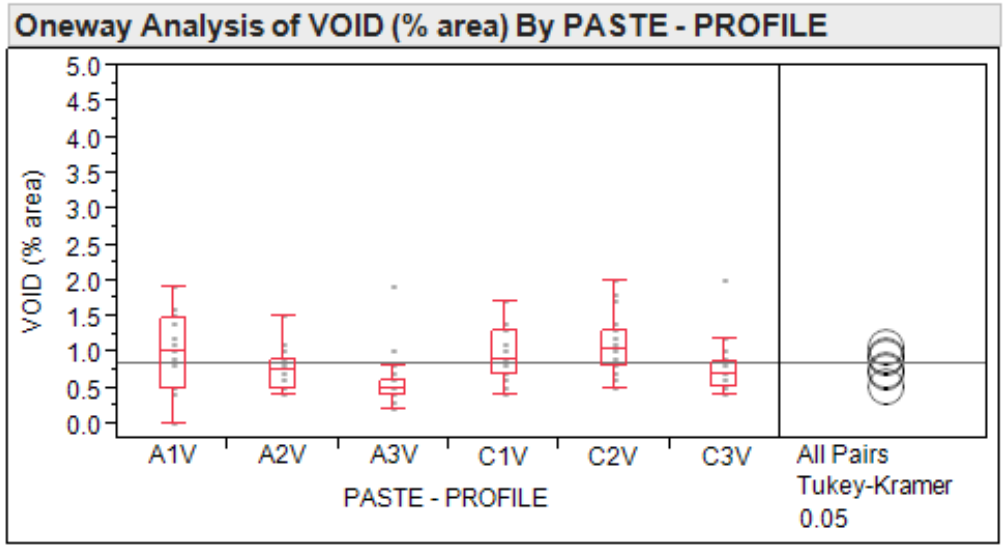
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
C2	A		12.63
C3	A	B	10.96
C1	A	B	9.70
A3		B	8.96
A2		B	8.07
A1		B	7.58

Levels not connected by same letter are significantly different.

No Vac



Excluded Rows 360

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

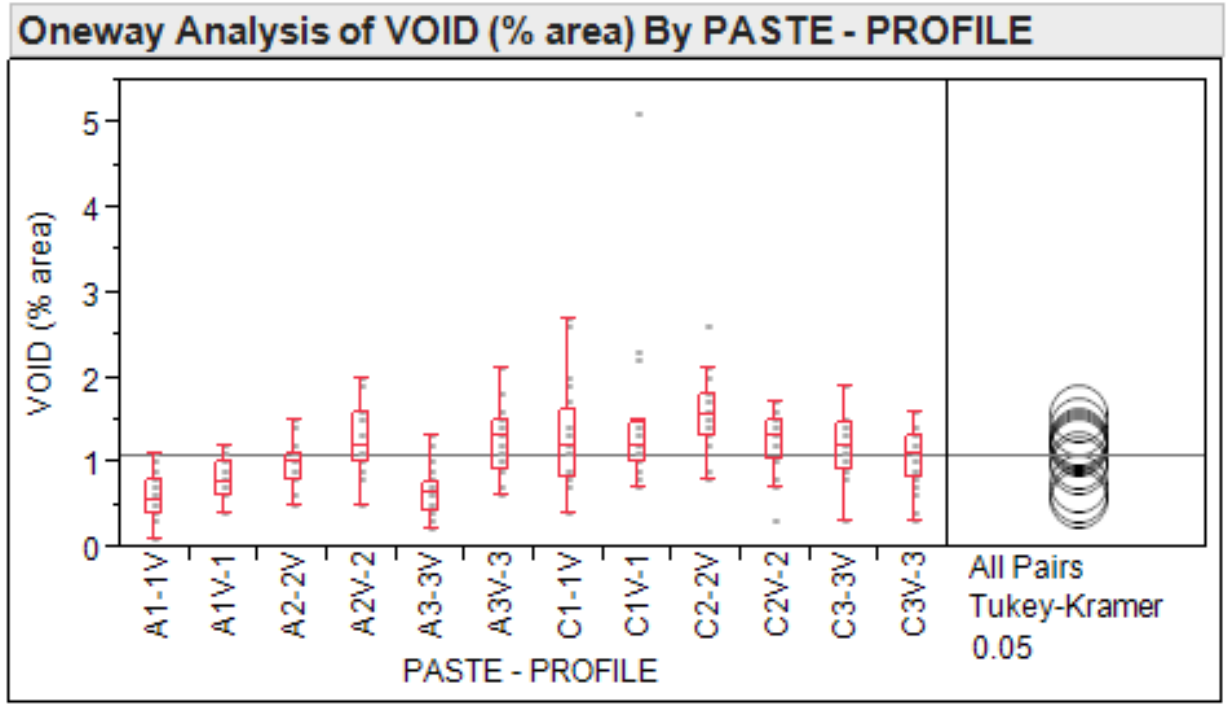
Connecting Letters Report

Level				Mean
C2V	A			1.11
A1V	A	B		0.98
C1V	A	B		0.96
C3V	A	B	C	0.79
A2V		B	C	0.75
A3V			C	0.57

Levels not connected by same letter are significantly different.

Vac

MLF68 Voiding After 2nd Side Reflow



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

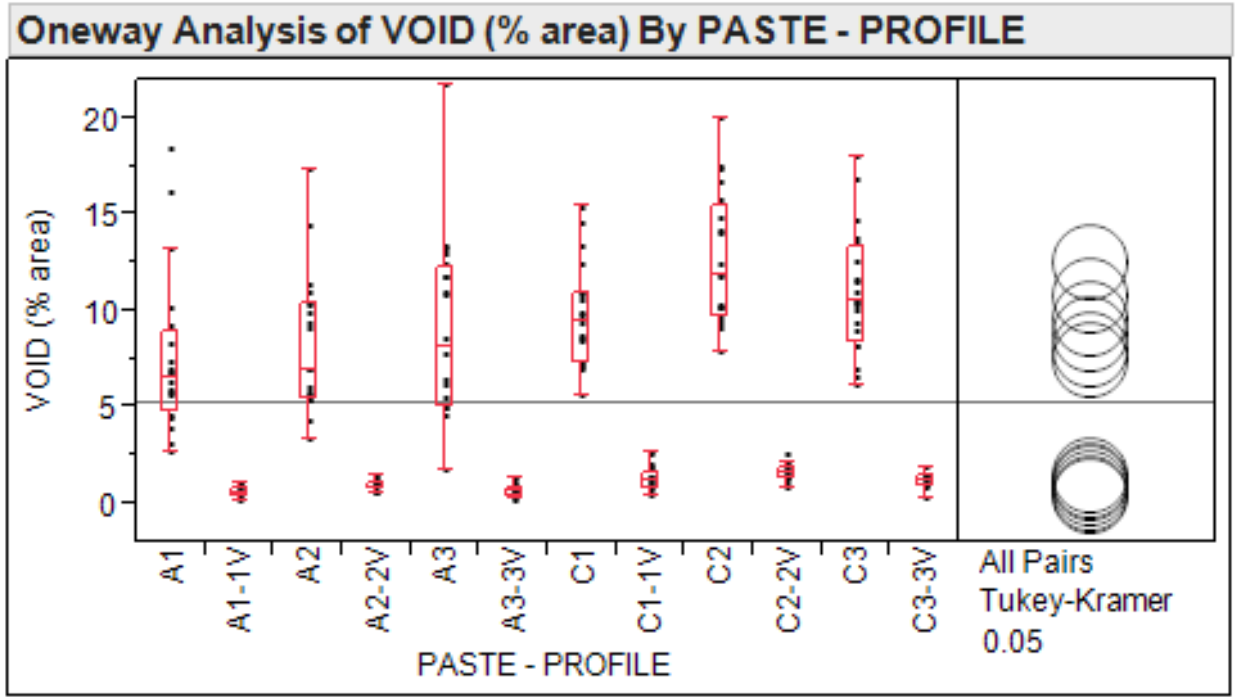
Connecting Letters Report

Level						Mean
C2-2V	A					1.59
C1V-1	A	B				1.45
A2V-2	A	B	C			1.31
C1-1V	A	B	C			1.29
A3V-3	A	B	C			1.26
C2V-2	A	B	C	D		1.23
C3-3V	A	B	C	D		1.19
C3V-3		B	C	D	E	1.04
A2-2V			C	D	E	0.97
A1V-1				D	E	0.77
A3-3V					E	0.65
A1-1V					E	0.58

Levels not connected by same letter are significantly different.

2nd Side

MLF68 Voiding 1st Side (No Vac) & 2nd Side (Vac)



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

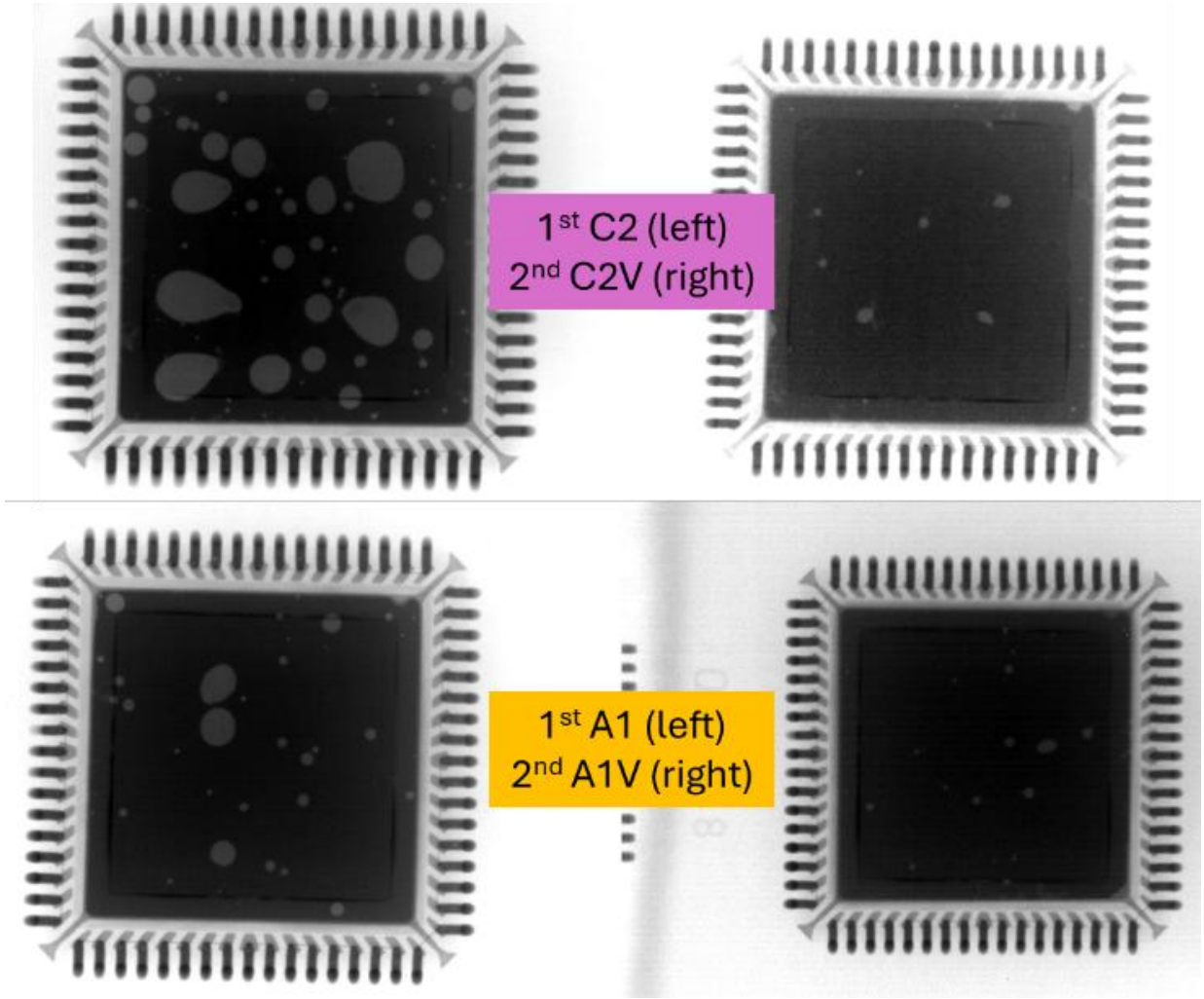
Level				Mean
C2	A			12.63
C3	A	B		10.96
C1		B	C	9.70
A3		B	C	8.96
A2			C	8.07
A1			C	7.58
C2-2V			D	1.59
C1-1V			D	1.29
C3-3V			D	1.19
A2-2V			D	0.97
A3-3V			D	0.65
A1-1V			D	0.58

Levels not connected by same letter are significantly different.

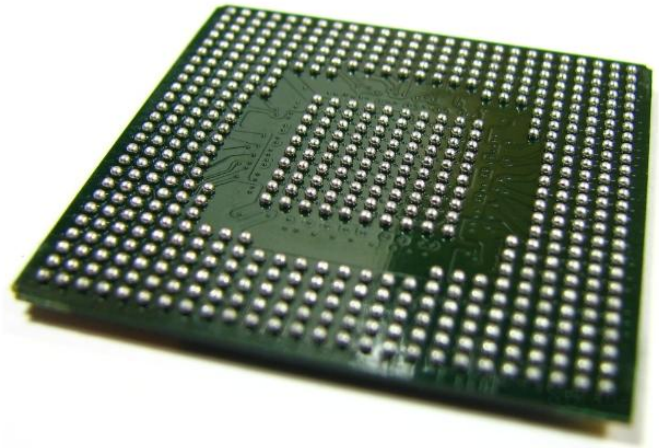
No Vac

2nd Side Vac

MLF68 Voiding 1st Side (No Vac) & 2nd Side (Vac)



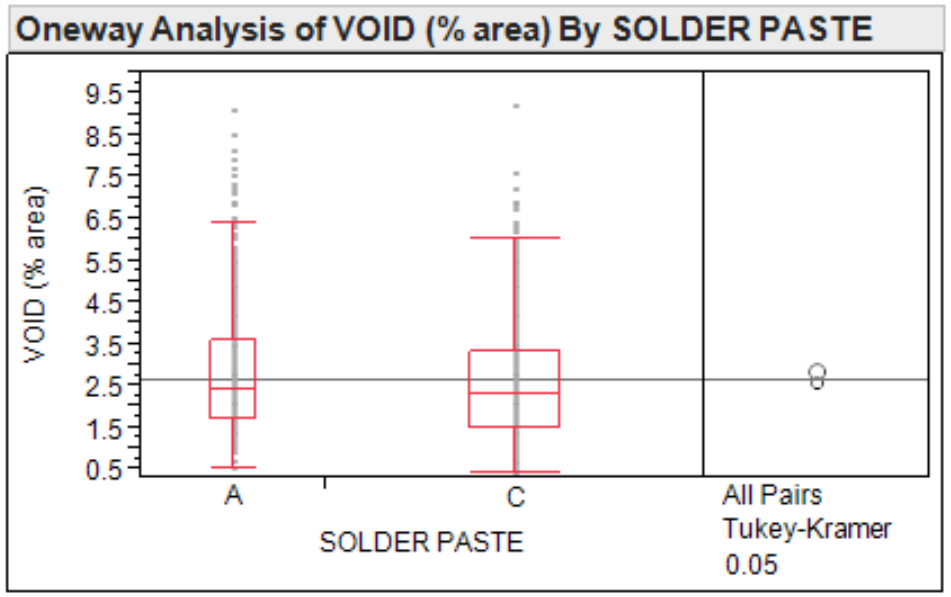
Results
BGA360



BGA360 Voiding Stats (Non-Zero)

Solder Paste	Reflow Profile	Min Void Area (%)	Mean Void Area (%)	Max Void Area (%)	Total # Non-Zero Void Data Points	Total # Zero Void Data Points
A	1	1.2	3.33	9.1	183	1106
A	1-1V	1.6	3.01	6.6	85	1290
A	1V	0.5	1.94	5.7	194	1041
A	1V-1	1.4	2.81	6.6	41	1310
A	2	0.5	2.28	7.7	178	958
A	2-2V	1.4	2.70	6.3	83	1252
A	2V	1.3	2.70	6.5	115	1146
A	2V-2	1.2	2.74	5.9	101	1255
A	3	1.6	3.16	6.5	52	869
A	3-3V	0.7	2.42	5.1	94	1222
A	3V	0.7	2.47	6.5	130	1168
A	3V-3	1.0	2.41	6.2	125	1195
C	1	0.4	2.17	9.2	384	914
C	1-1V	1.2	3.48	8.6	155	1209
C	1V	0.5	2.35	5.6	192	1103
C	1V-1	0.8	3.41	7.3	95	1280
C	2	1.1	2.86	7.6	241	978
C	2-2V	1.3	3.11	7.3	132	1274
C	2V	0.5	2.52	5.8	154	1173
C	2V-2	1.3	3.11	7.3	132	1274
C	3	0.7	2.93	7.2	219	1145
C	3-3V	1.7	3.31	5.2	22	1681
C	3V	1.3	2.83	8.0	111	877
C	3V-3	1.3	2.53	6.3	59	1412

BGA360 Voiding by Paste or Profile



Excluded Rows 2020

Means Comparisons

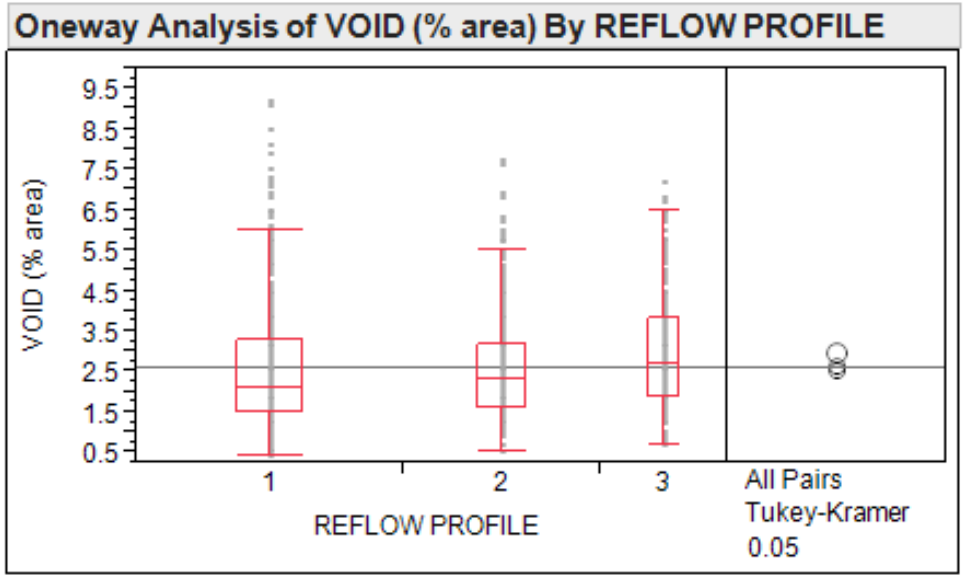
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
A	A	2.86
C	B	2.56

Levels not connected by same letter are significantly different.

Paste



Excluded Rows 2020

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

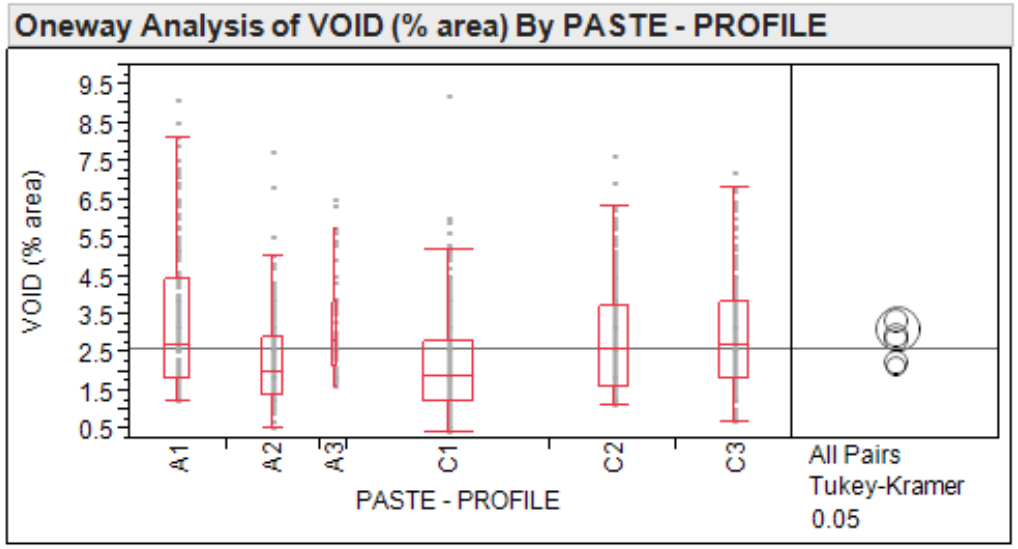
Connecting Letters Report

Level		Mean
3	A	2.98
2	B	2.61
1	B	2.54

Levels not connected by same letter are significantly different.

Profile

BGA360 Voiding by Paste & Profile



Excluded Rows 2020

Means Comparisons

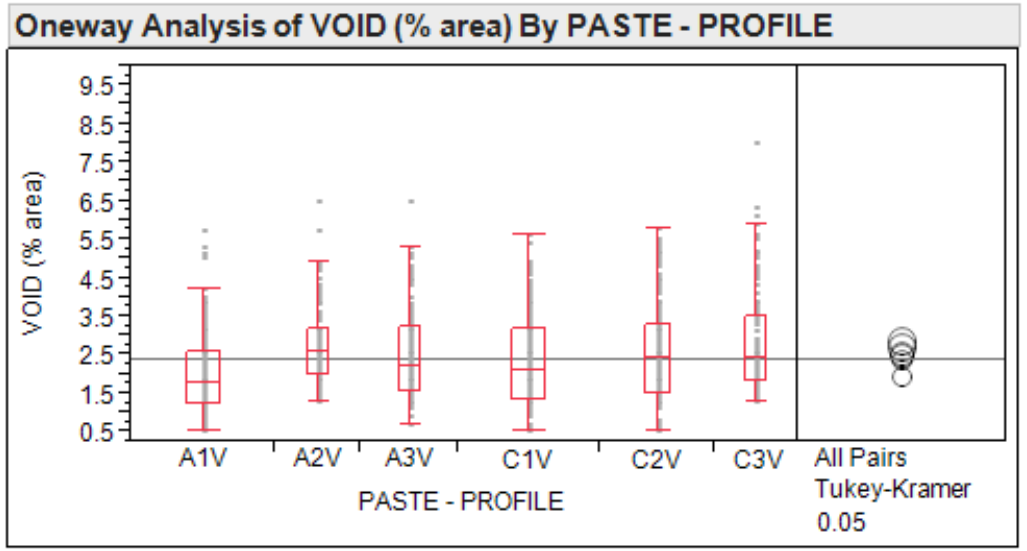
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
A1	A			3.33
A3	A	B		3.16
C3		B		2.93
C2		B		2.86
A2			C	2.28
C1			C	2.17

Levels not connected by same letter are significantly different.

No Vac



Excluded Rows 2381

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

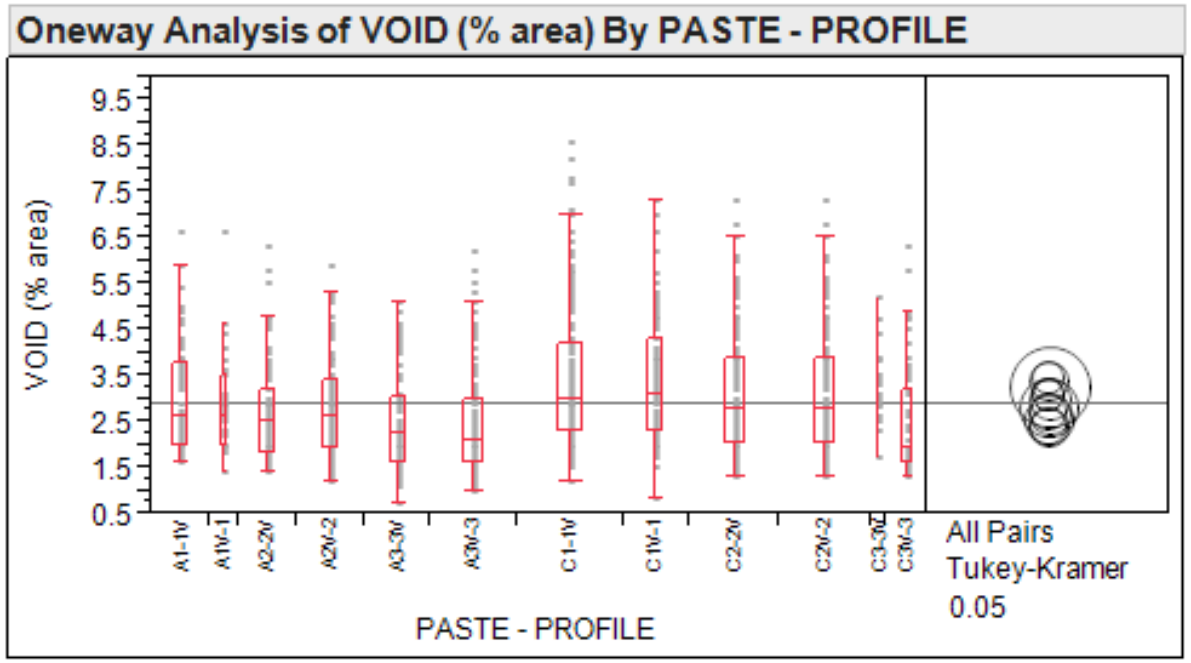
Connecting Letters Report

Level				Mean
C3V	A			2.83
A2V	A	B		2.70
C2V	A	B		2.52
A3V	A	B		2.47
C1V		B		2.35
A1V			C	1.94

Levels not connected by same letter are significantly different.

Vac

BGA360 Voiding After 2nd Side Reflow



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

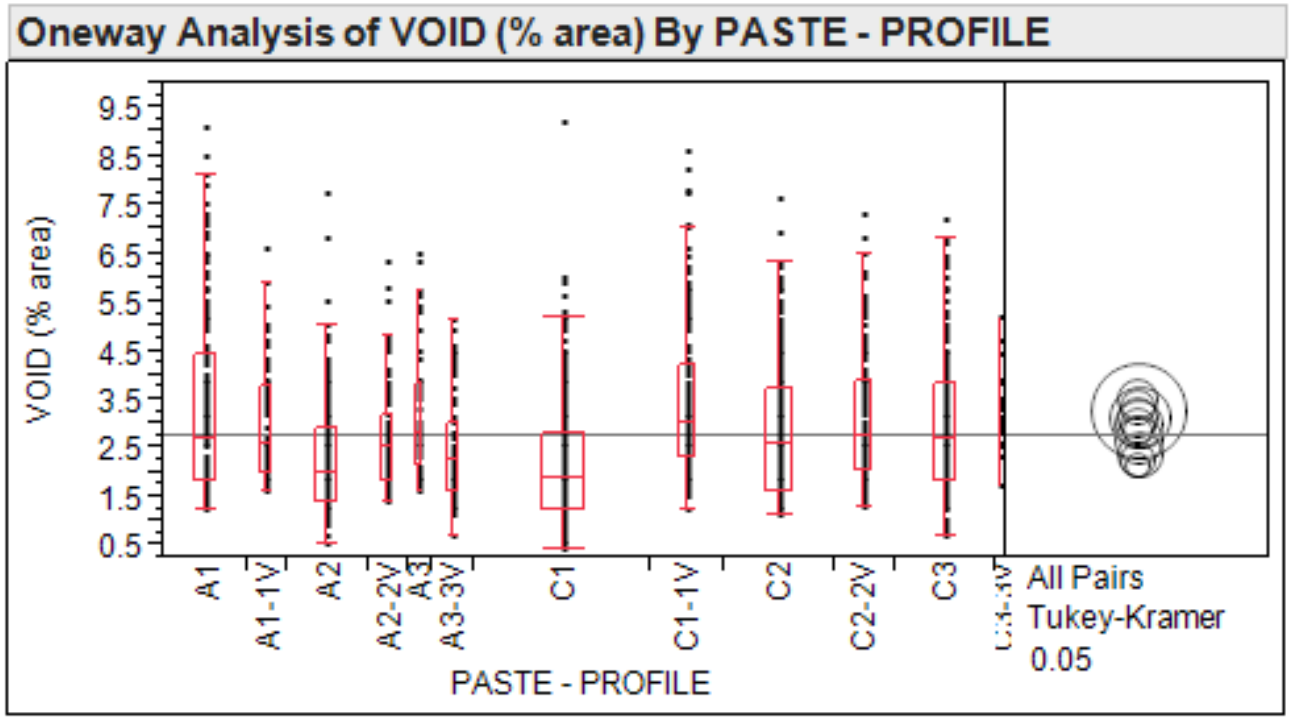
Connecting Letters Report

Level					Mean
C1-1V	A				3.48
C1V-1	A				3.41
C3-3V	A	B	C	D	3.31
C2-2V	A	B			3.11
C2V-2	A	B			3.11
A1-1V	A	B	C		3.01
A1V-1	A	B	C	D	2.81
A2V-2		B	C	D	2.74
A2-2V		B	C	D	2.70
C3V-3		B	C	D	2.53
A3-3V			C	D	2.42
A3V-3				D	2.41

Levels not connected by same letter are significantly different.

2nd Side

BGA360 Voiding 1st Side (No Vac) & 2nd Side (Vac)



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

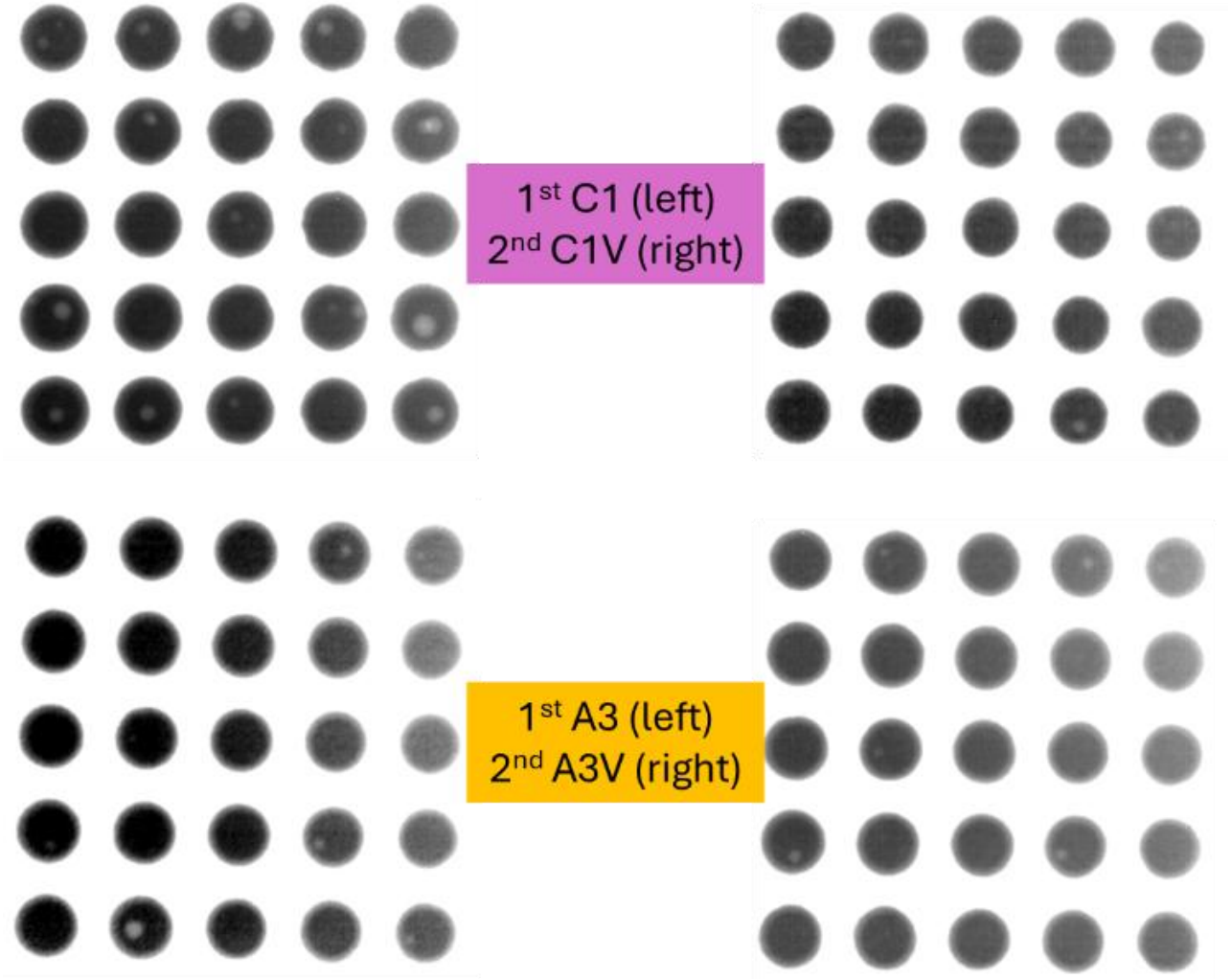
Connecting Letters Report

Level						Mean
C1-1V	A					3.48
A1		A	B			3.33
C3-3V		A	B	C	D	3.31
A3		A	B	C	D	3.16
C2-2V		A	B	C		3.11
A1-1V		A	B	C	D	3.01
C3			B	C	D	2.93
C2				C	D	2.86
A2-2V				C	D	E 2.70
A3-3V					D	E 2.42
A2						E 2.28
C1						E 2.17

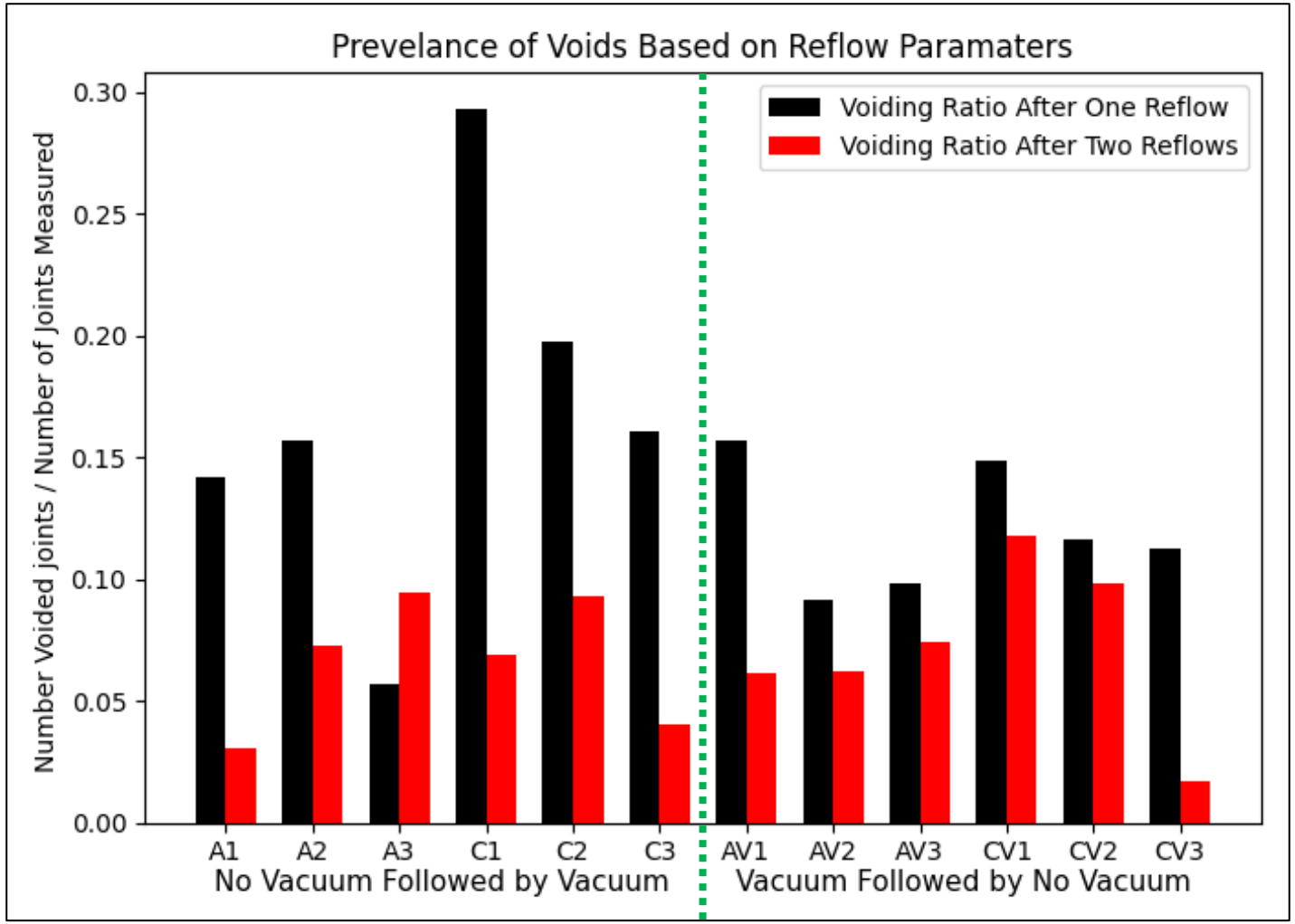
Levels not connected by same letter are significantly different.

Some No-Vac Lower Voiding than Vac

BGA360 Voiding 1st Side (No Vac) & 2nd Side (Vac)

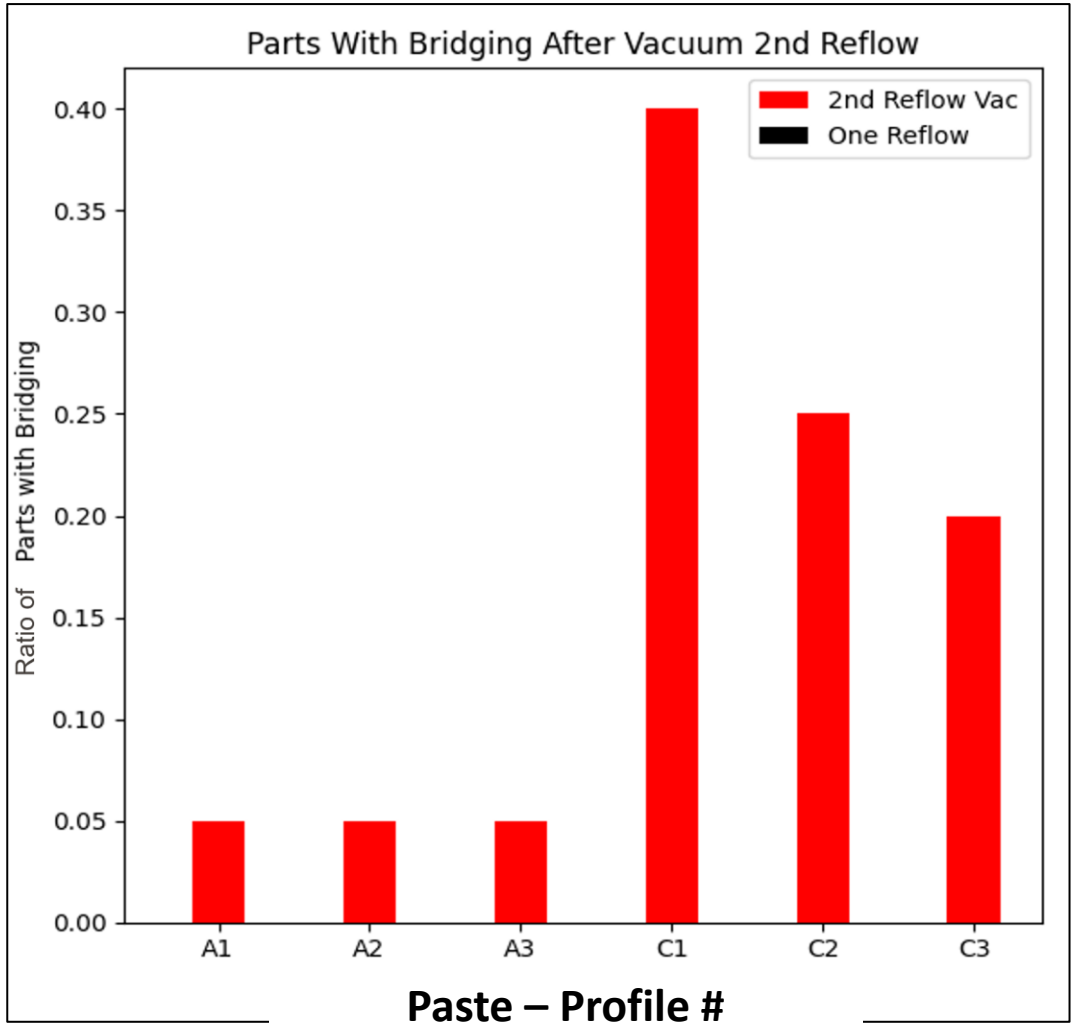


BGA360 Ratio of Joints with Voids After 1 & 2 Reflows



More Zero-Void Joints After 2nd Reflow

BGA Ratio of Parts with Bridging – 1st Side No Vac, 2nd Side Vac



No Bridging After 1 Reflow (No-Vac)

Conclusions

Conclusions

- Solder paste A and reflow profile #1 gave lower QFN voiding
- Solder paste C with profile #1, & paste A with profile #2 gave lower BGA voiding
- Vacuum reflow substantially reduced voiding in BGA and QFN solder joints
  - Similar results with 1st or 2nd side vacuum reflow
- Vacuum reflow on 2nd side reduced voids created during 1st side reflow
  - Created bridging in the BGA arrays
  - No bridging in QFN I/O pads
  - Might be minimized through vacuum setting changes
- 2nd side reflow increased the # of solder joints with zero-voids in the BGAs

Questions?