Process Investigation of Vacuum Reflow Within Multiple Reflow Steps

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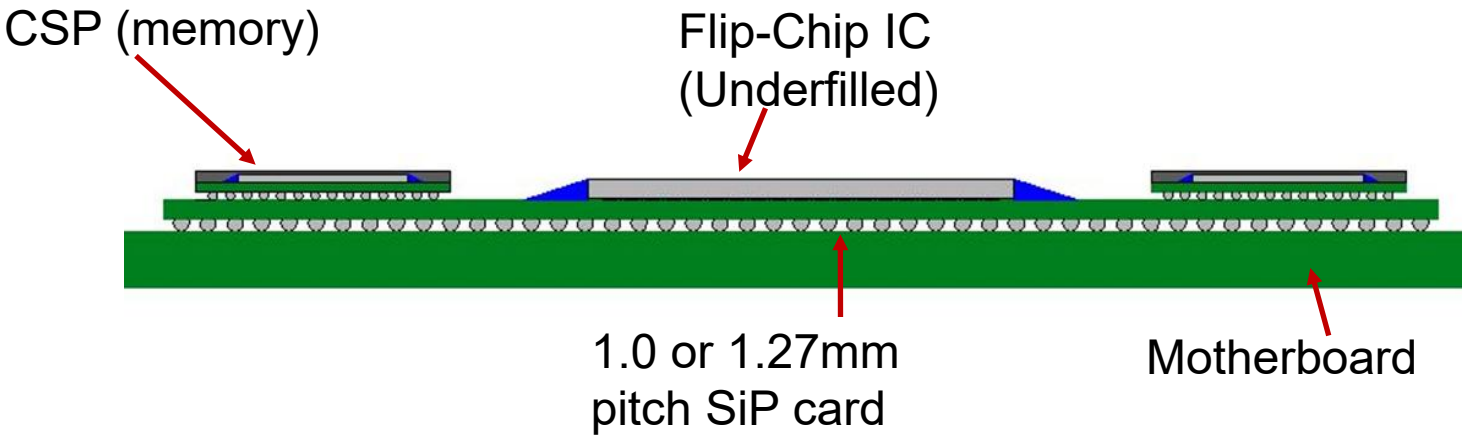
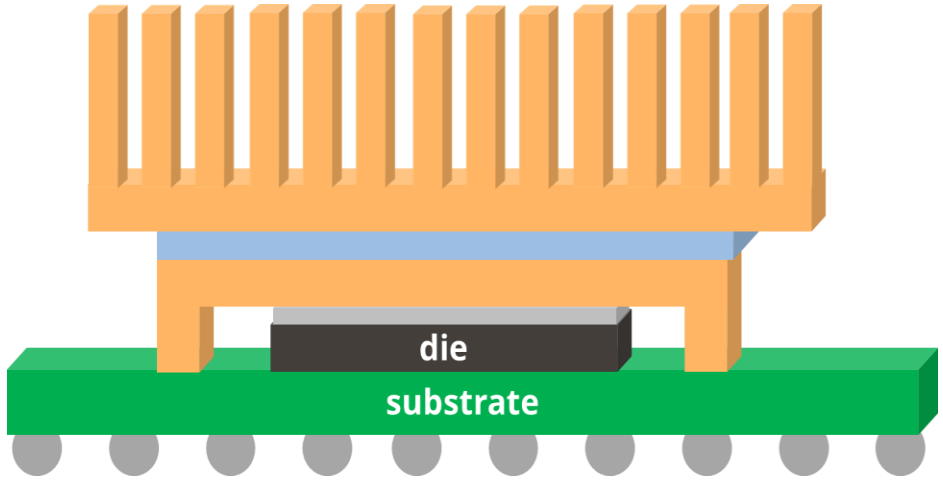
Multiple reflows are exceedingly common in modern packaging.

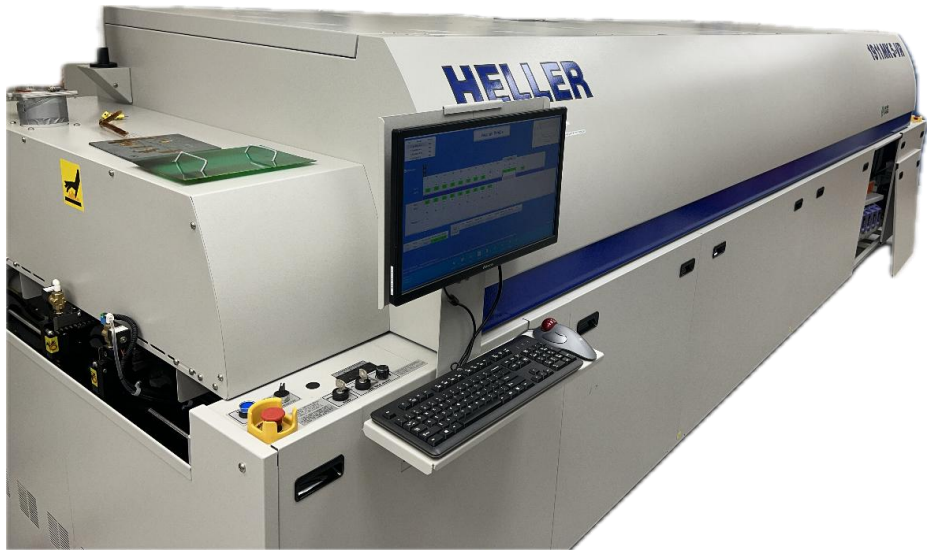


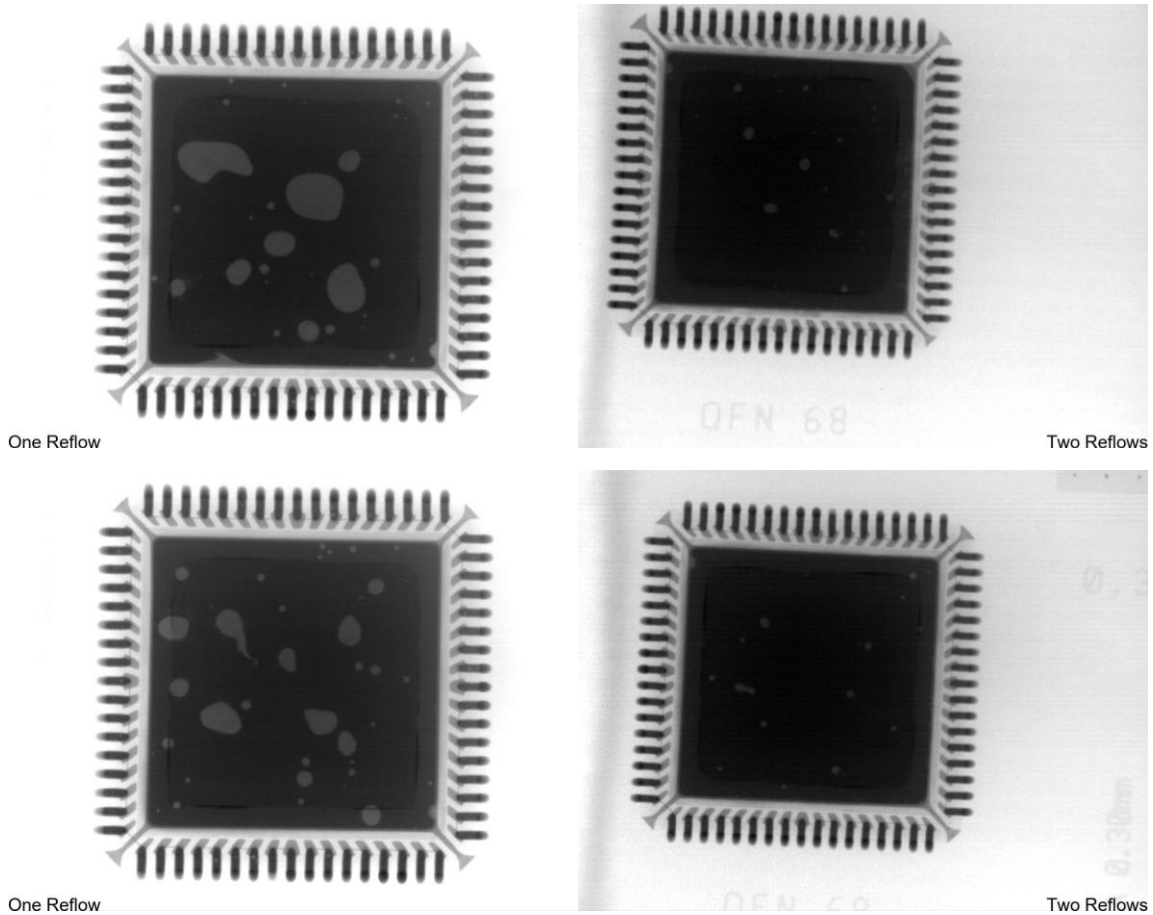
System in package parts



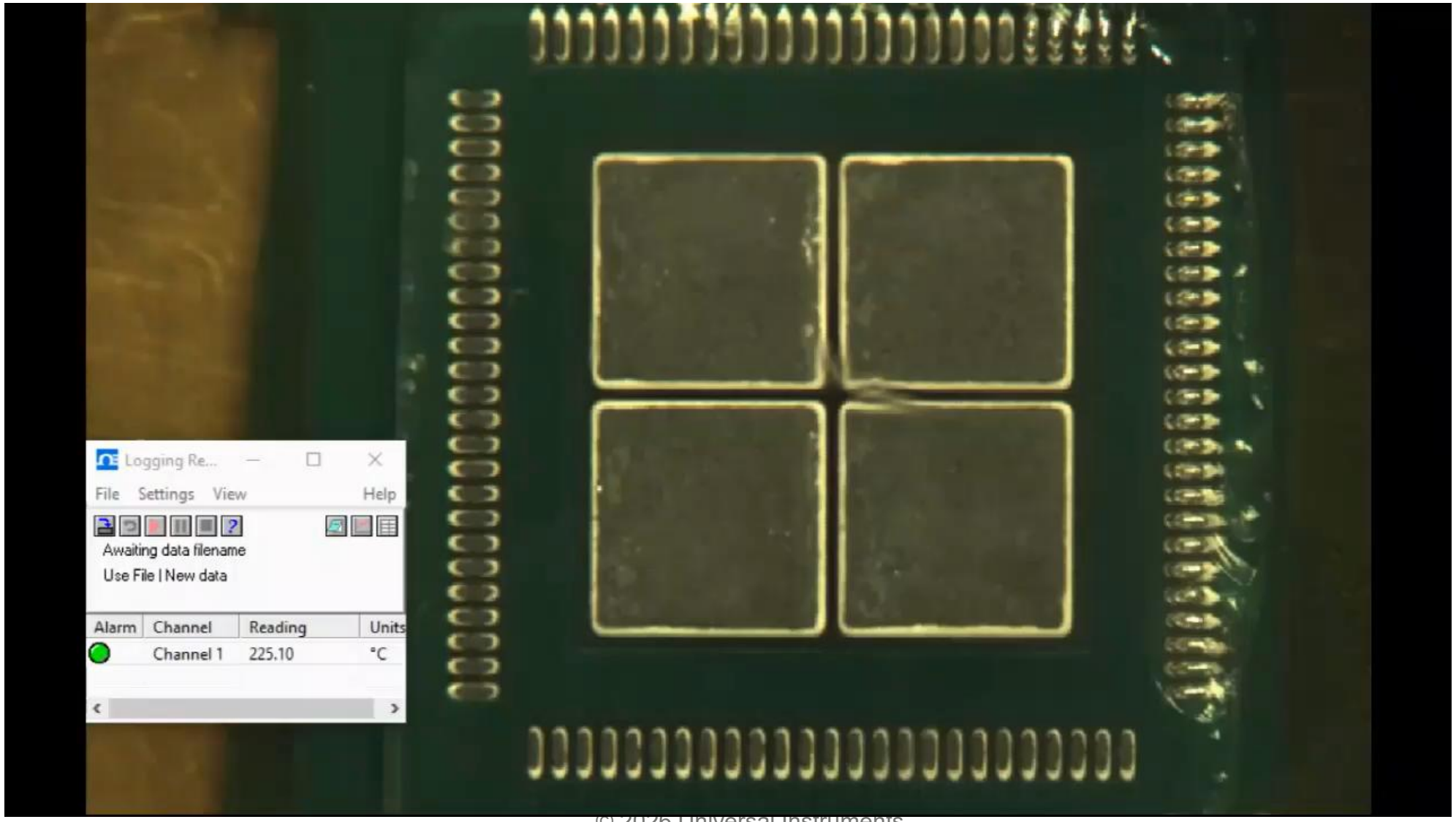
Solderable thermal interface materials

What is the effect of vacuum within a multiple reflow set?

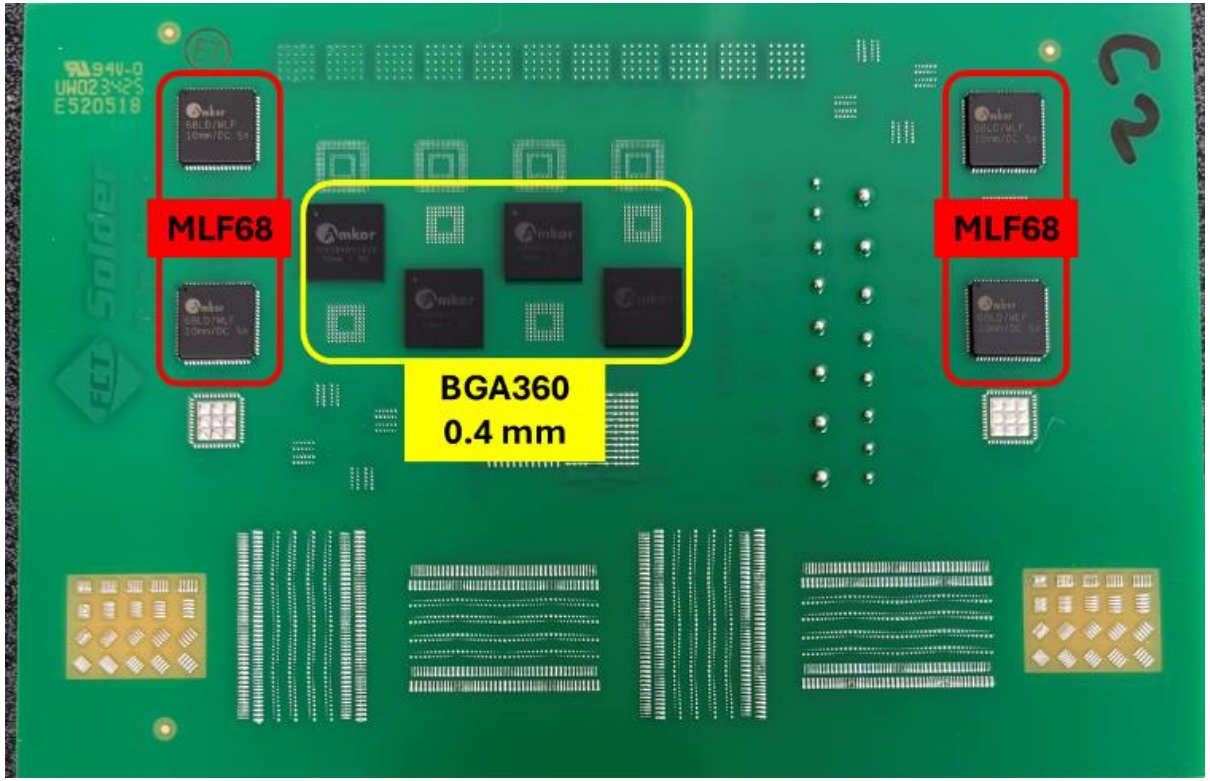




Vacuum reflow can vastly reduce voiding caused by trapped flux vapors

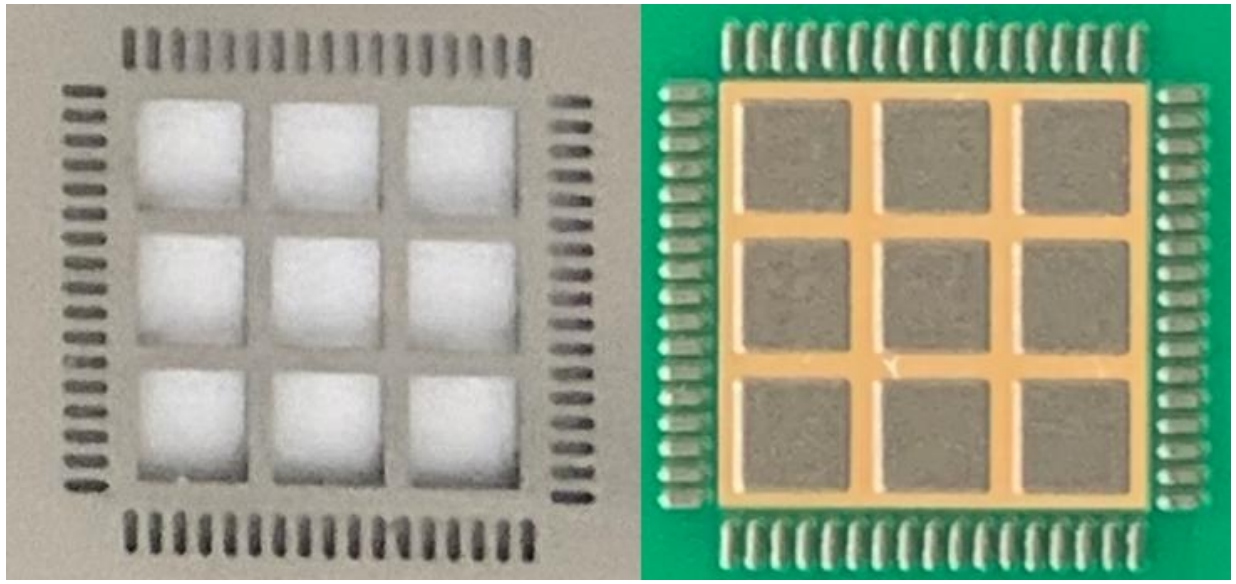


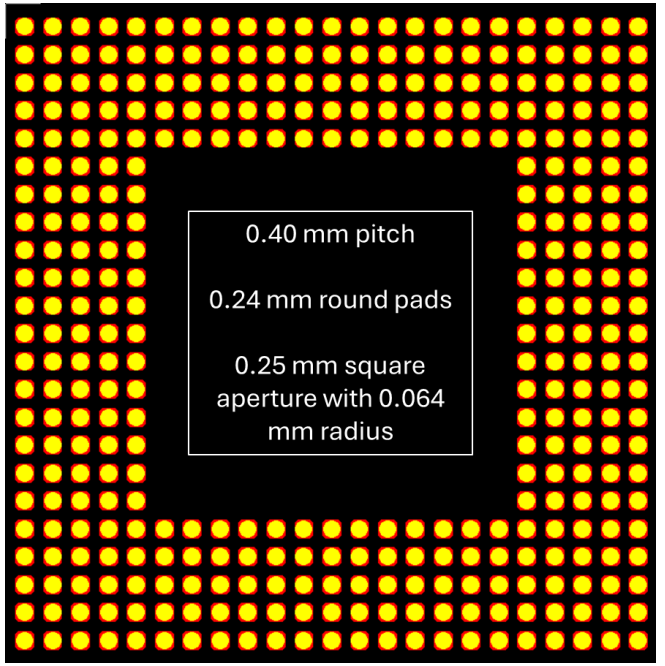
We used a FCT solder test vehicle.



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

Focus of the study was on BGA and QFN part.





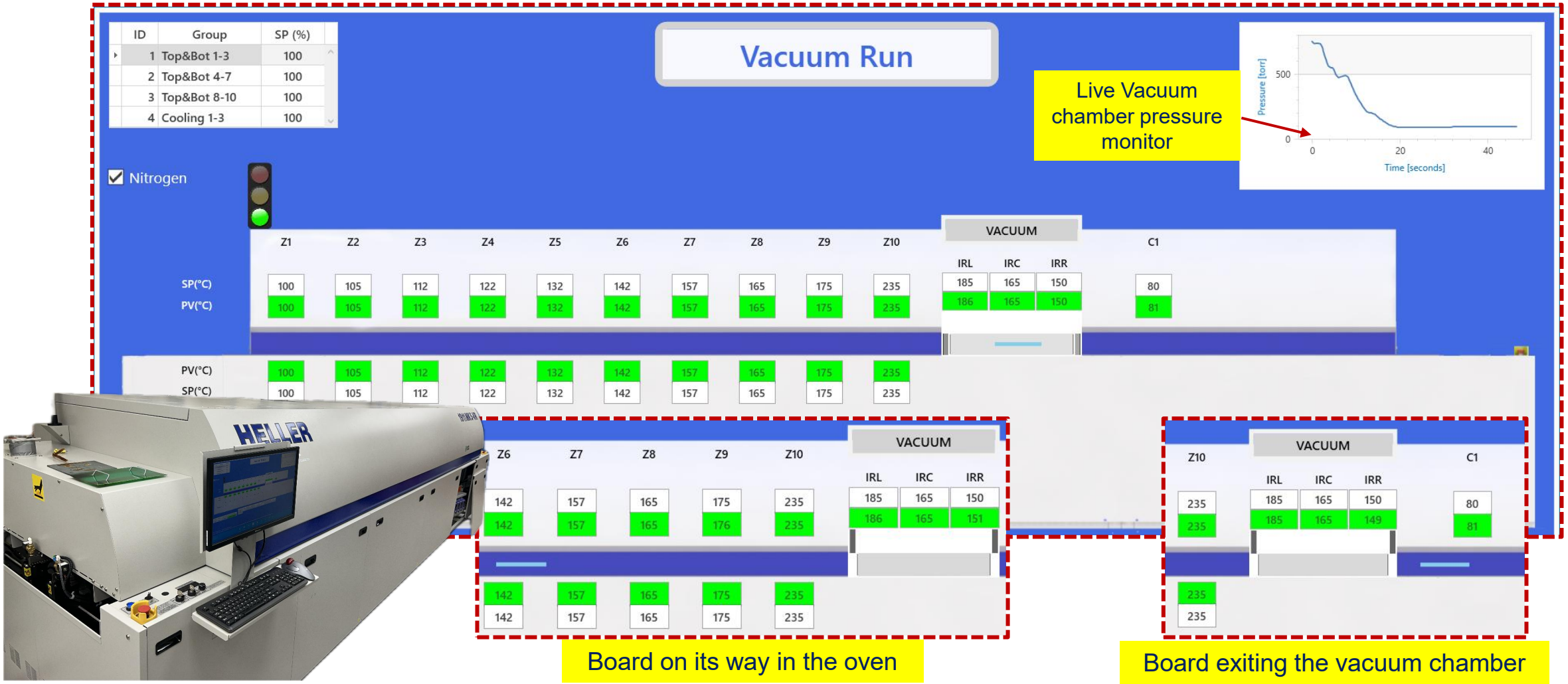
- Stencil Design (127 µm thick)
  - MLF68 65% area of coverage, 0.51 mm web, 2.24 mm brick
  - BGA360 0.4 mm pitch, 0.24 mm round pads, 0.25 mm square apertures

Solder paste choice reduces to high voiding and lower voiding.

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

– No clean, SAC305, IPC Type 4

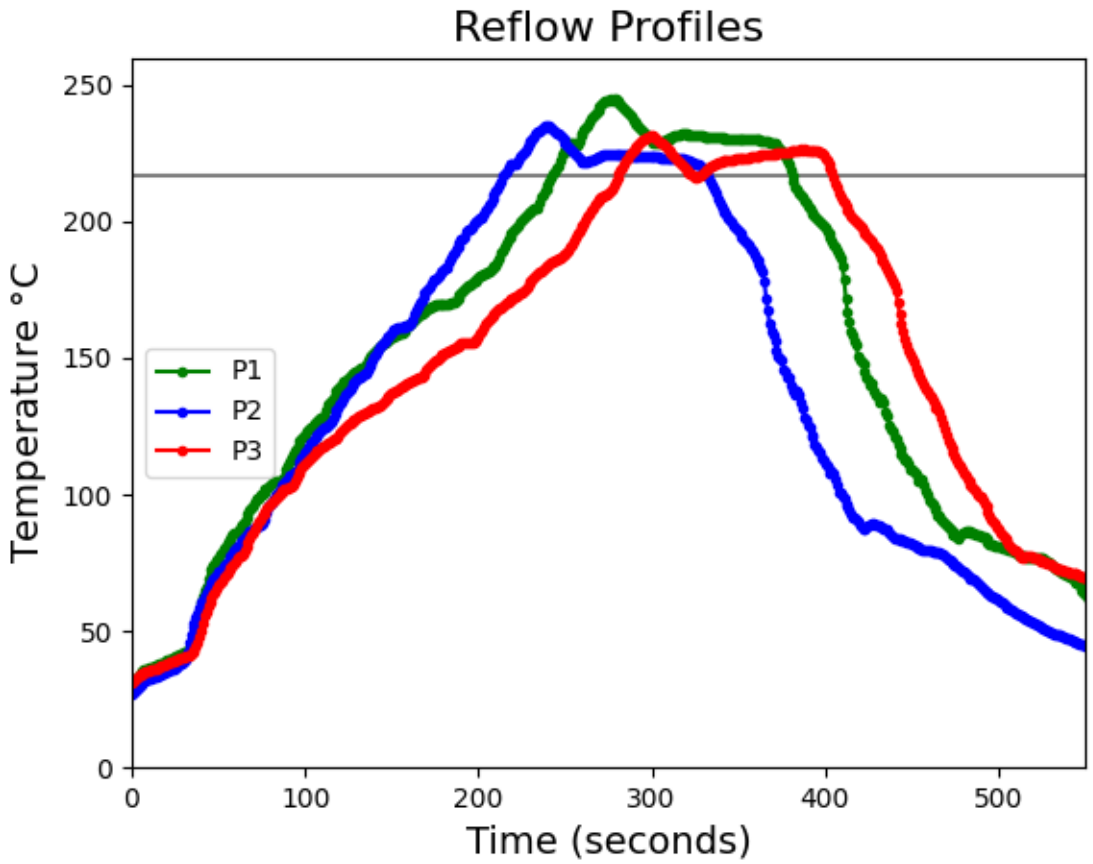
Heller 1911-MK5-VR uses 10 conventional zones and one IR heated vacuum chamber



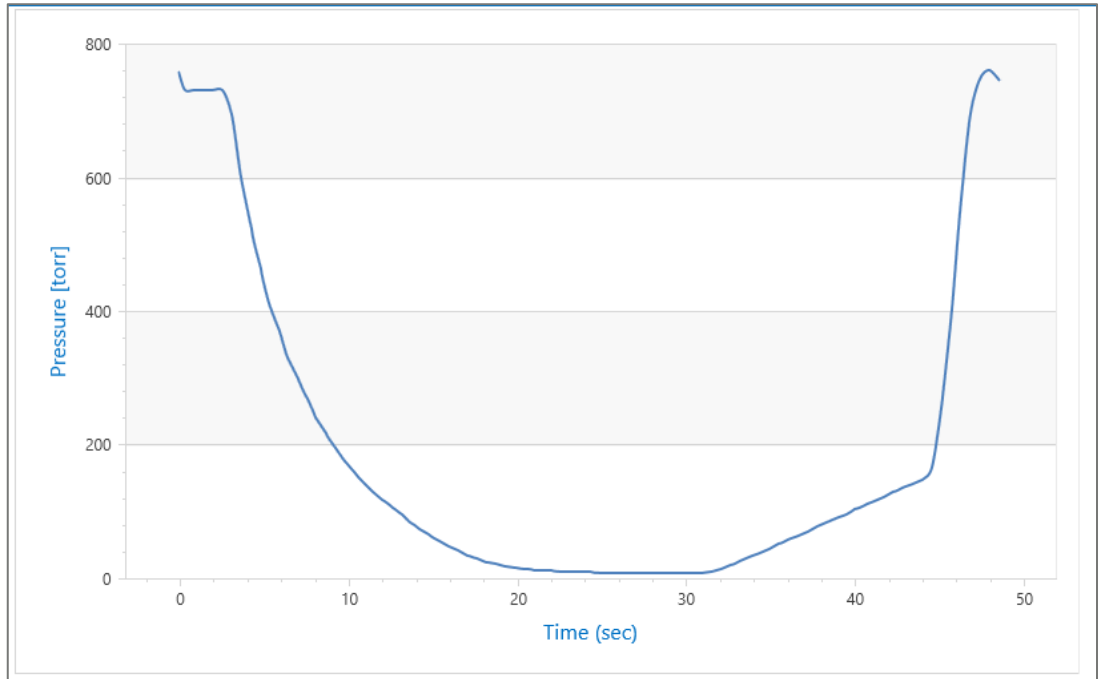
10 zone with vacuum, 3 IR heaters in vacuum chamber

Reflow profiles selected for differing peak temp and soak time.

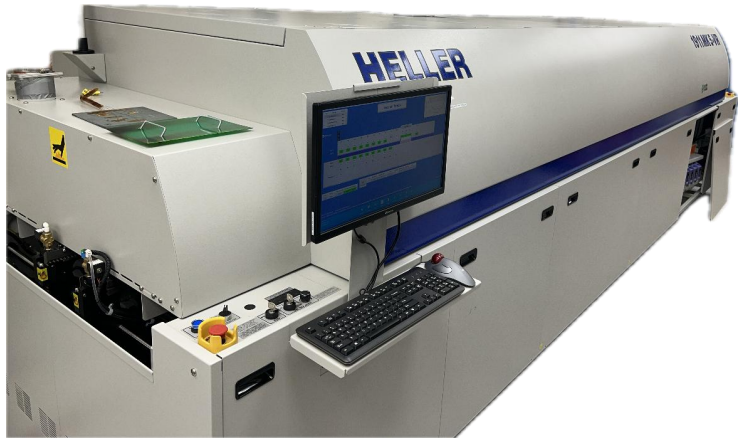
Parameter	Profile #1	Profile #2	Profile #3
Soak time 150-200°C (sec)	87 - 89	59 - 62	83 - 86
Reflow Time >220°C (sec)	127 - 135	109 - 111	100 - 108
Peak temp (°C)	243 - 246	234 - 236	229 - 234

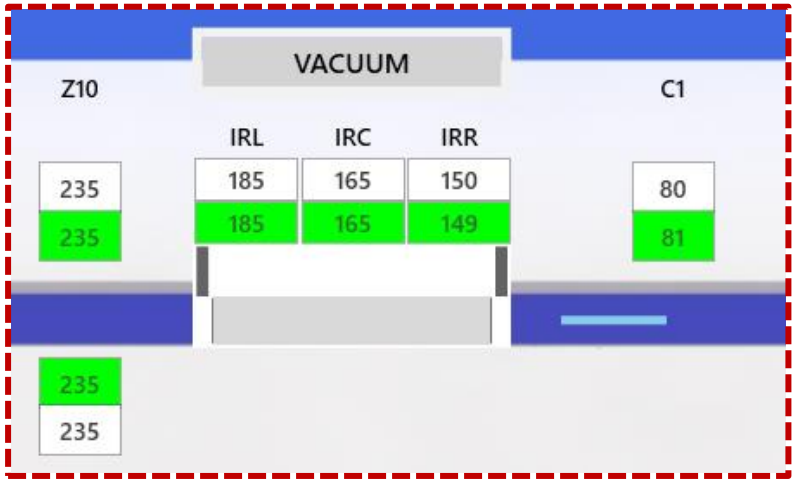


Vacuum parameters are customizable but were not investigated.



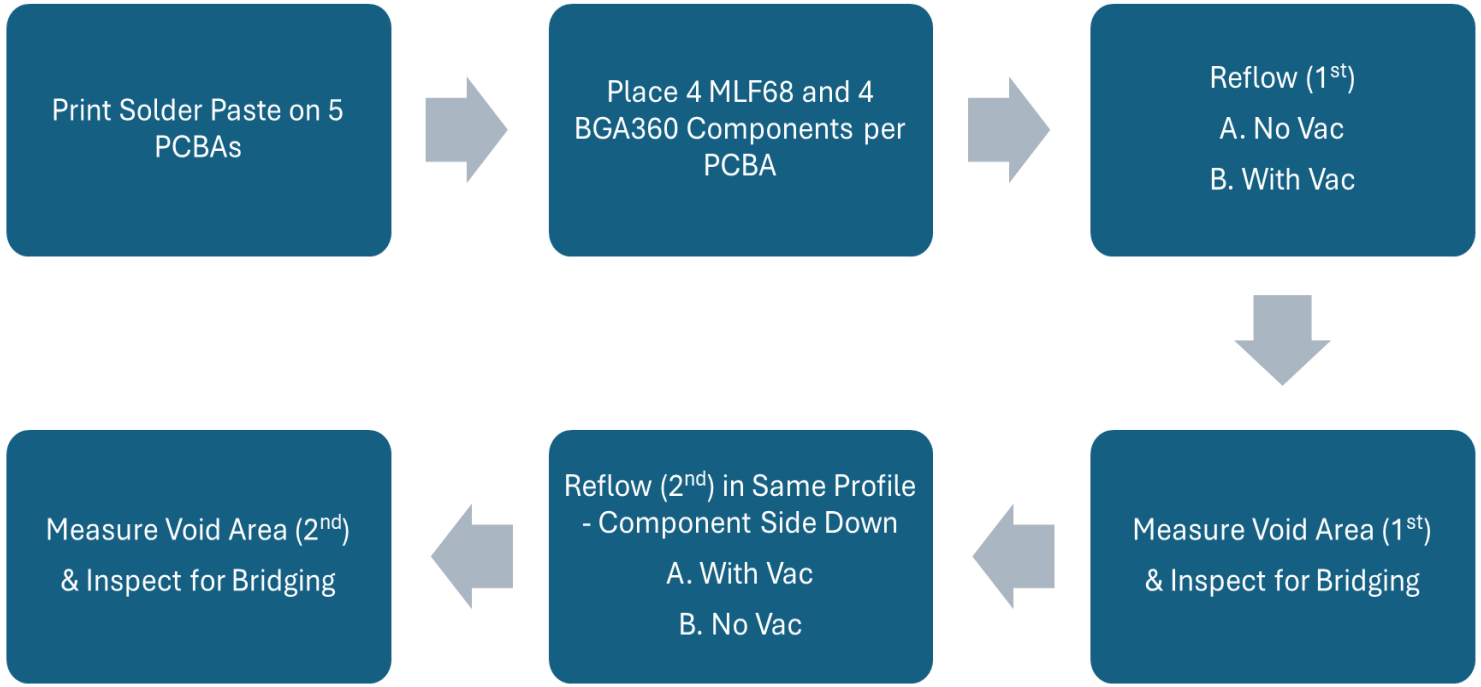
Id	Ramp [seconds]	Dwell [seconds]	Pressure [torr]	Gain (%)	Phase [seconds]
1	1	1	760.0	7	0.02
2	4	25	10.0	7	0.02





- Vacuum Cycle
  - 10 torr for 25 sec, Overall ~45 sec

Workflow for investigation included full x-ray inspection before second reflow

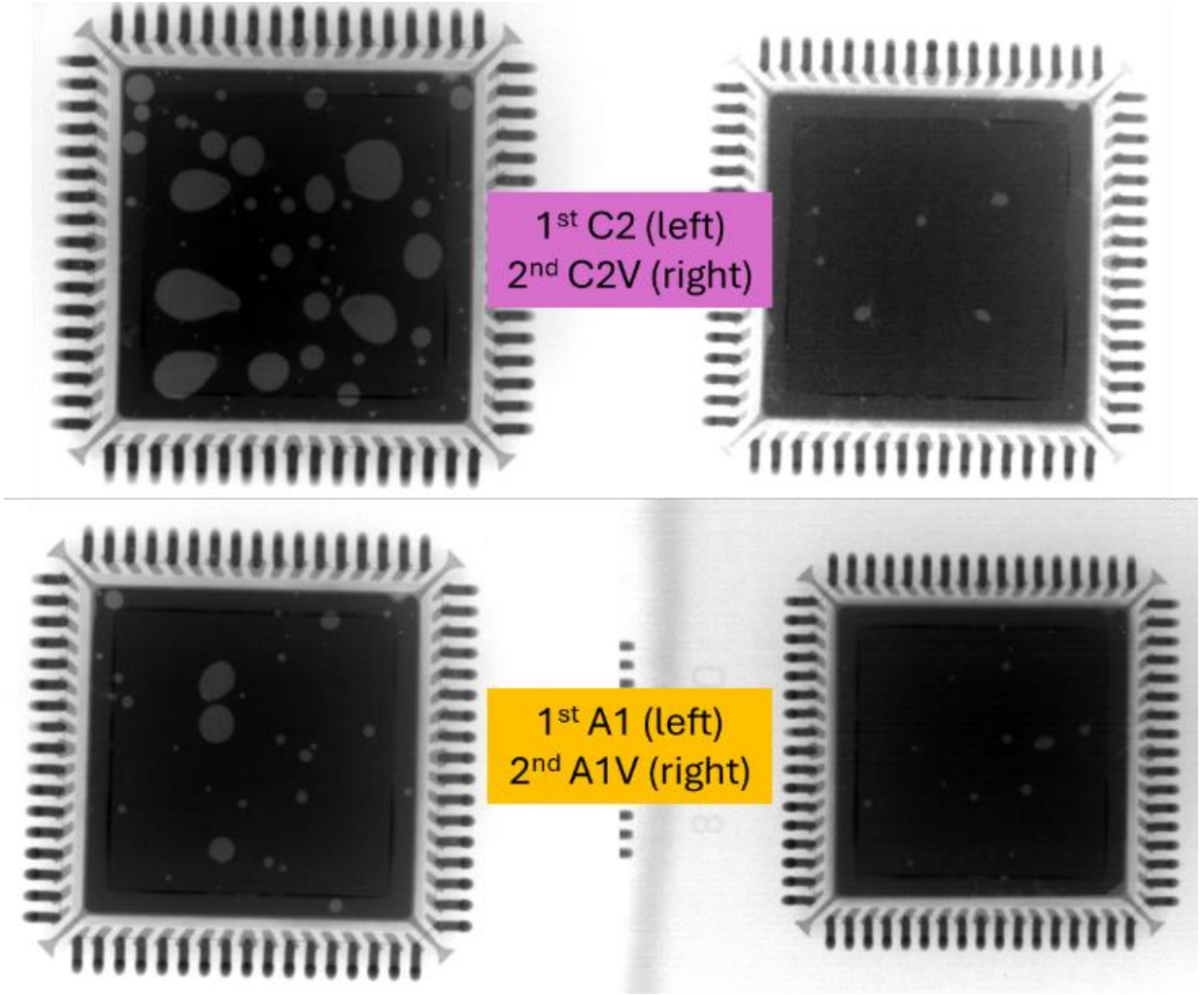


Paste	Temp Profile	First	Second	Example
A	1	Conventional	Vacuum	A1
C	2	Vacuum	Conventional	A1V
	3			

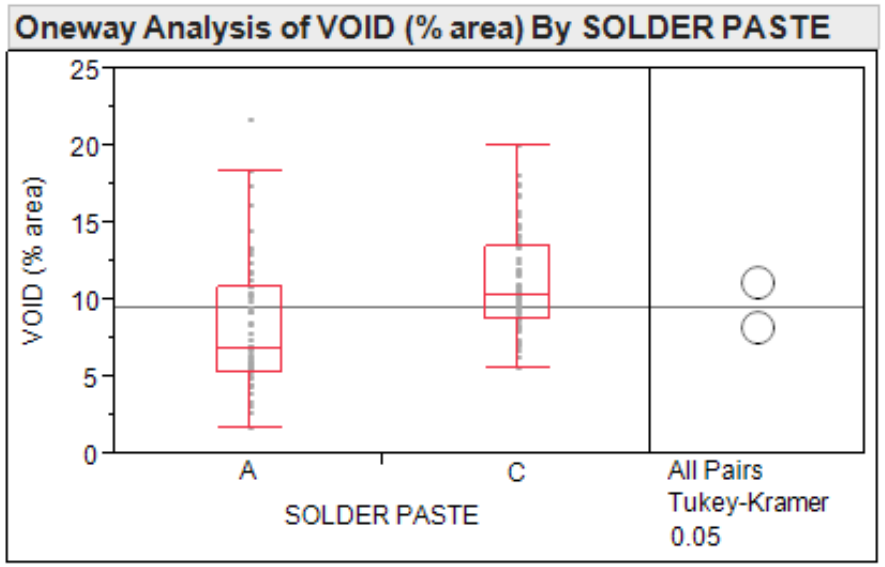
5 boards per condition
60 boards
4 (2x) placements per boards

- Process
  - 1st side reflow without vac --- 2nd side reflow with vac in same profile
  - Vice versa
  - 2nd side reflowed with components facing down

Voiding in QFNs clearly reduced by vacuum reflow.



Voiding differences existed between pastes but not profiles.



Excluded Rows 360

Means Comparisons

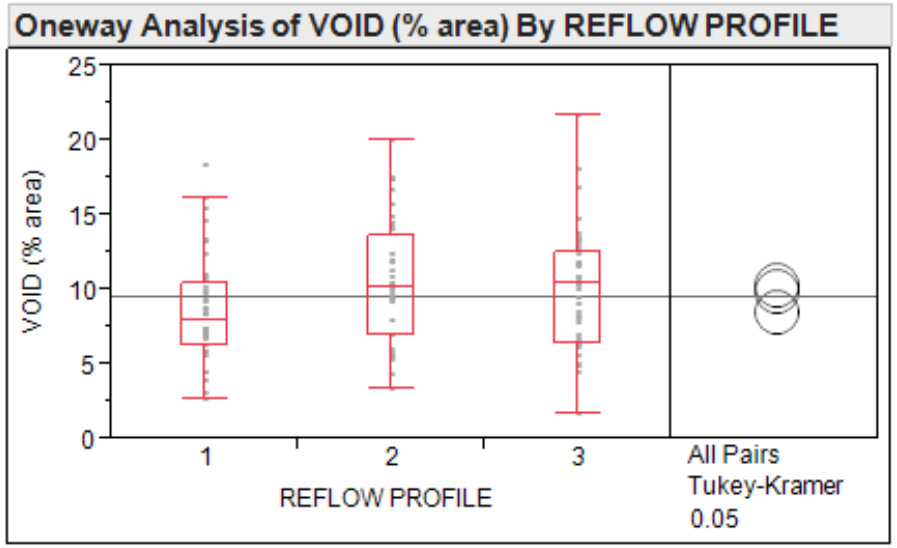
Comparisons for all pairs using Tukey-Kramer HSD

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

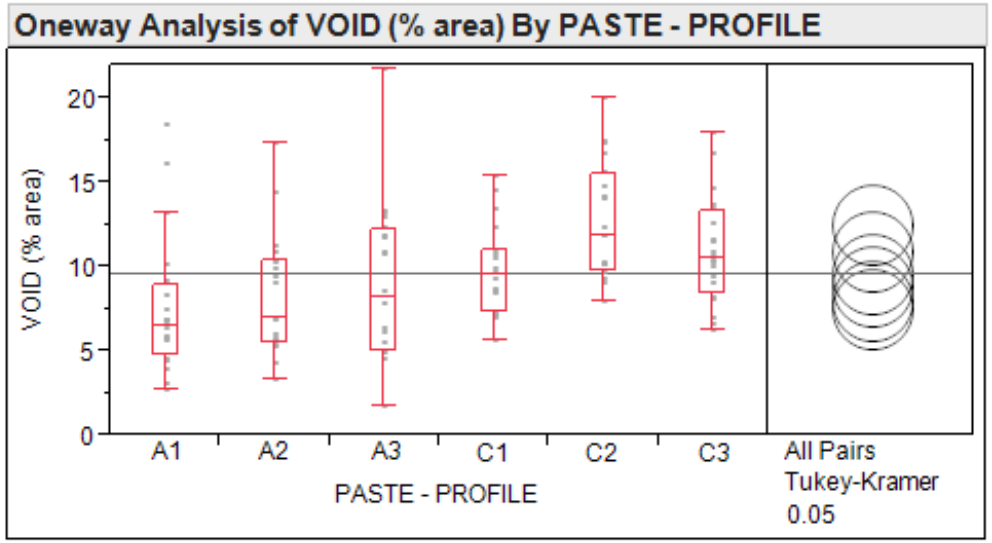
Connecting Letters Report

Level		Mean
2	A	10.3
3	A	10.0
1	A	8.6

Levels not connected by same letter are significantly different.

Profile

Vacuum reflow generates a massive reduction in voiding



Excluded Rows 360

Means Comparisons

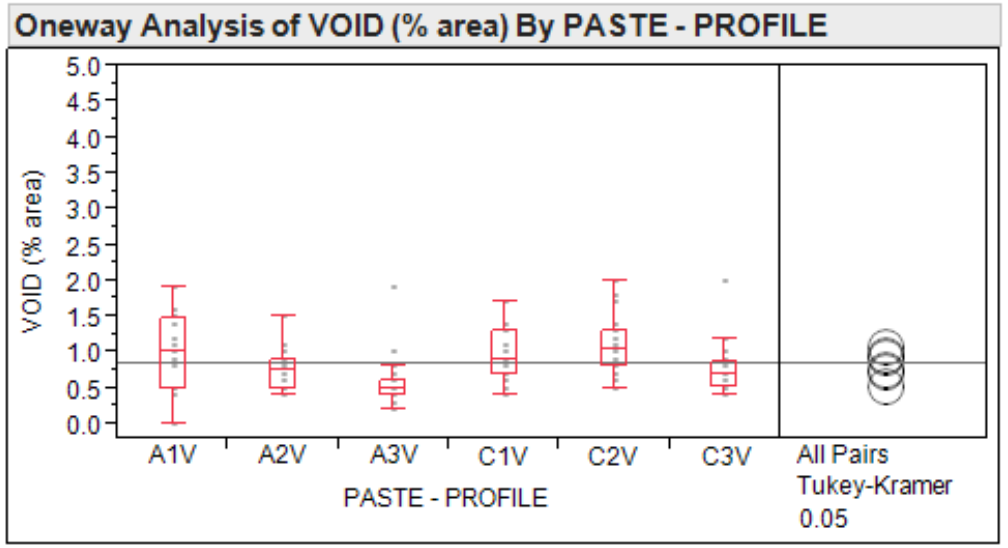
Comparisons for all pairs using Tukey-Kramer HSD

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

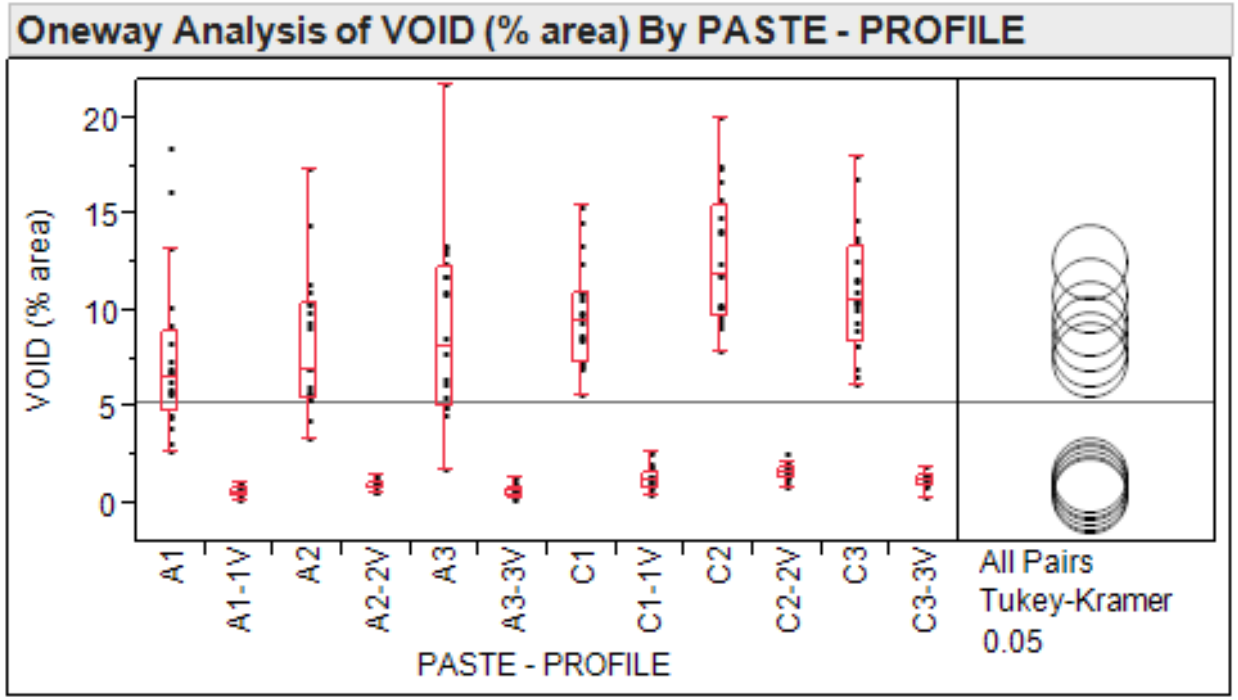
Connecting Letters Report

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

Second reflow profile having vacuum successfully reduces voiding.



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

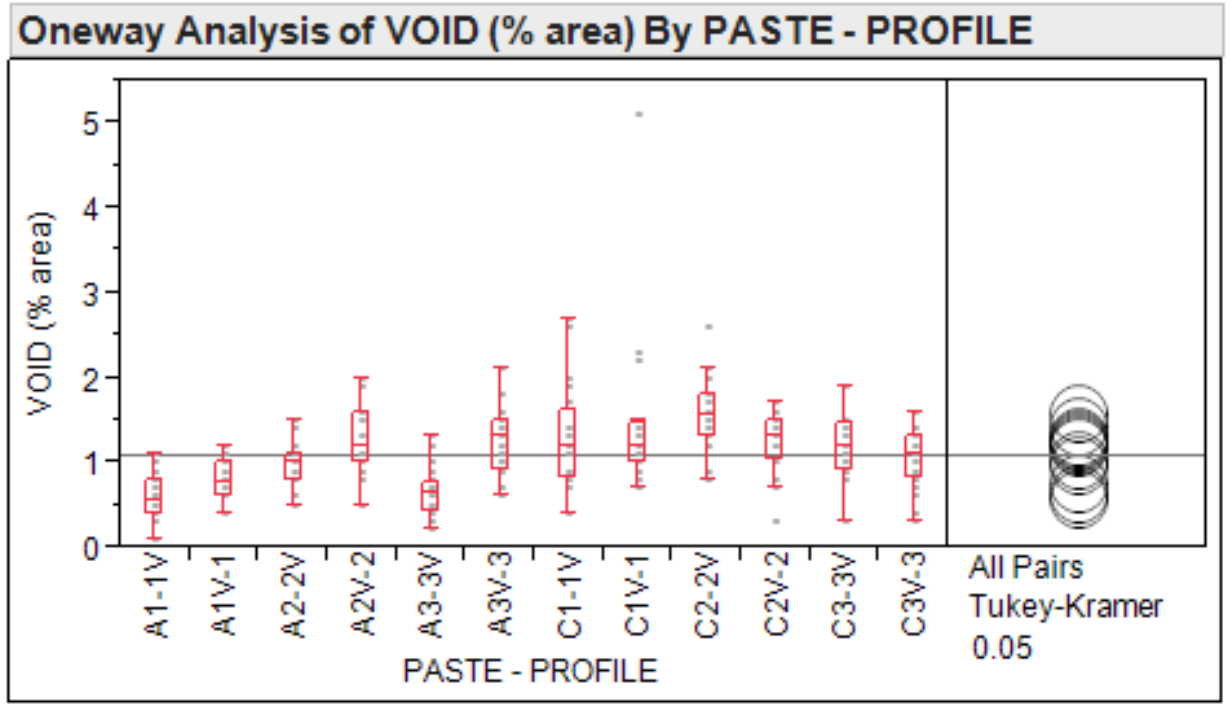
Level				Mean
C2	A			12.63
C3	A	B		10.96
C1		B	C	9.70
A3		B	C	8.96
A2			C	8.07
A1			C	7.58
C2-2V			D	1.59
C1-1V			D	1.29
C3-3V			D	1.19
A2-2V			D	0.97
A3-3V			D	0.65
A1-1V			D	0.58

Levels not connected by same letter are significantly different.

No Vac

2nd Side

Voiding after two reflows shows very little observable difference between variants.



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

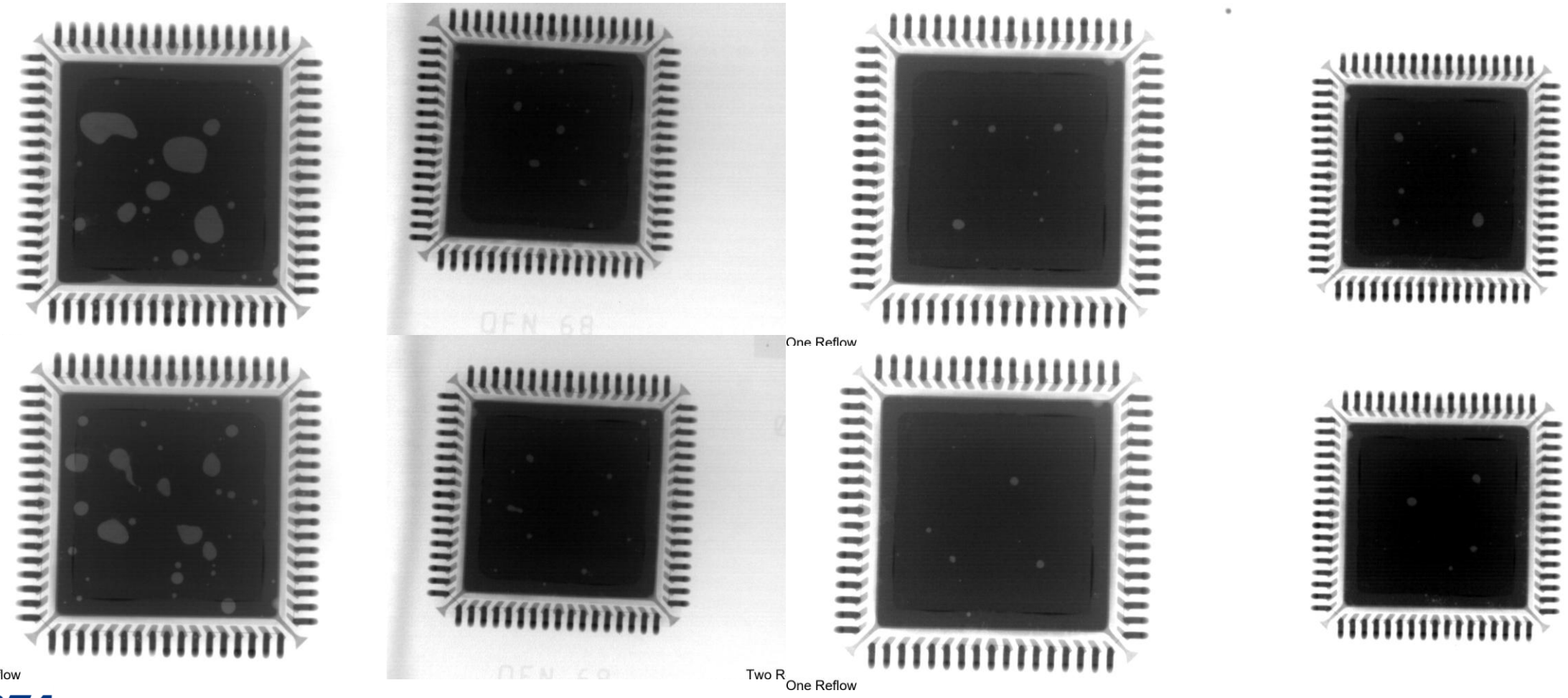
Connecting Letters Report

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

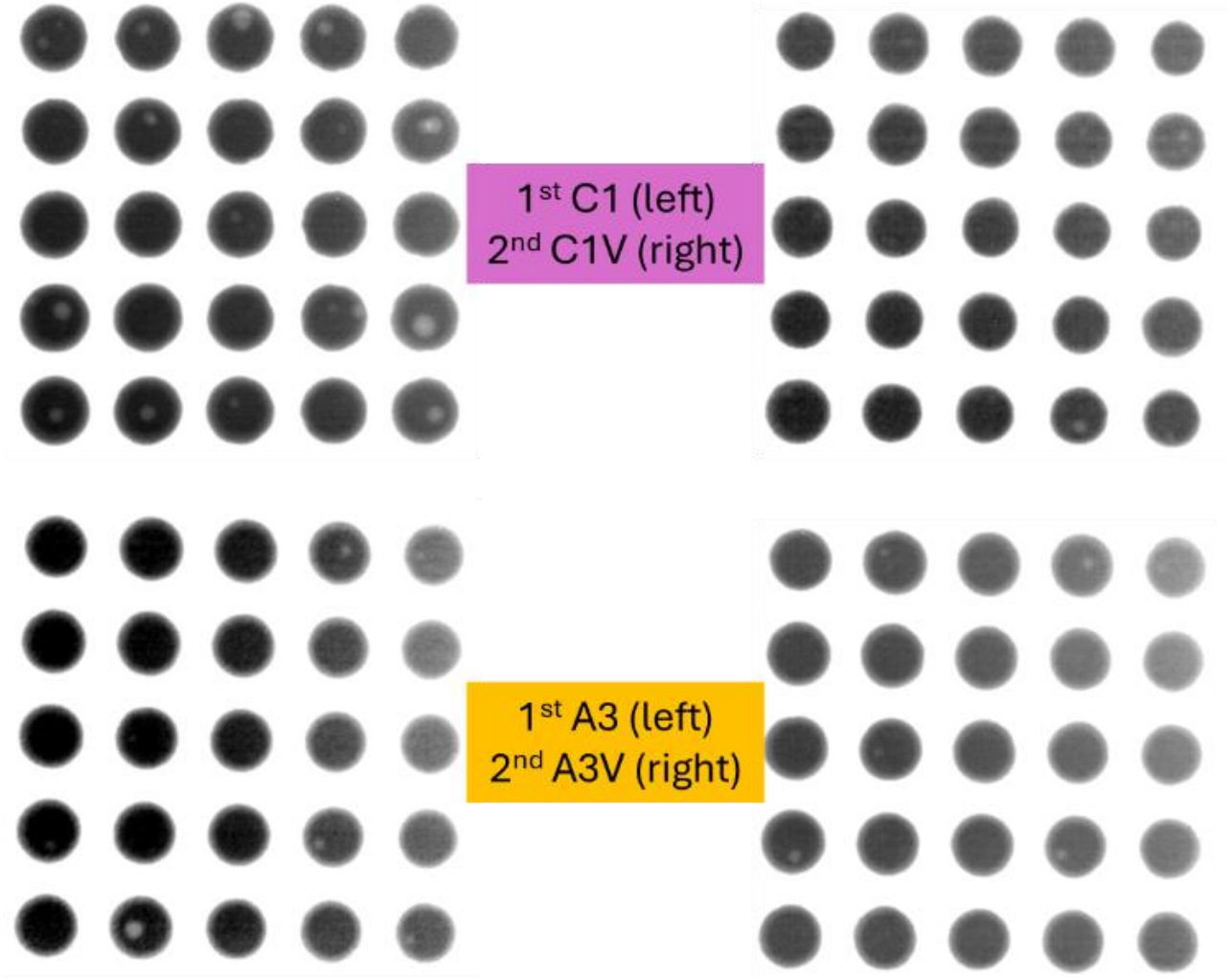
Levels not connected by same letter are significantly different.

2nd

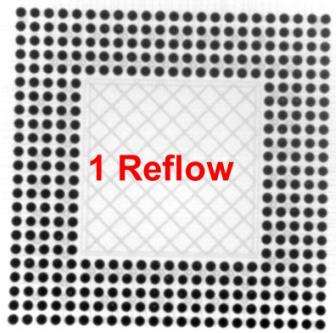
Vacuum removes voids which do not return during conventional later steps.

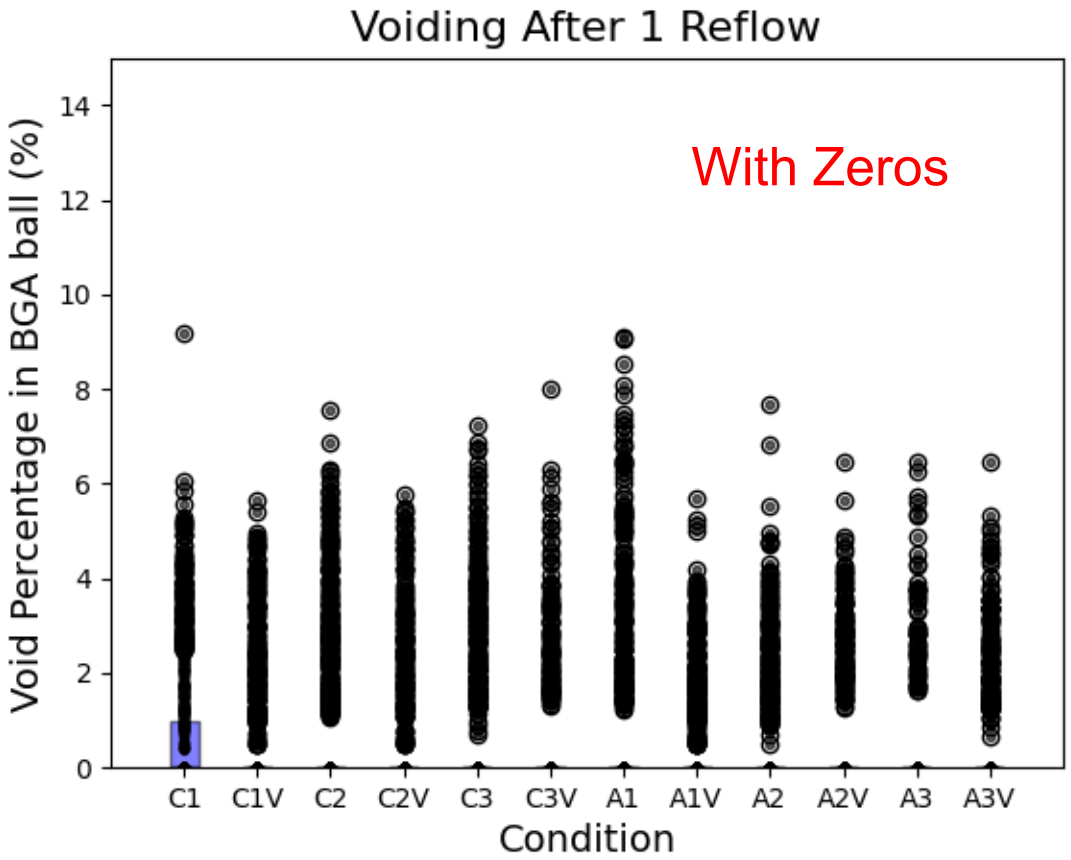


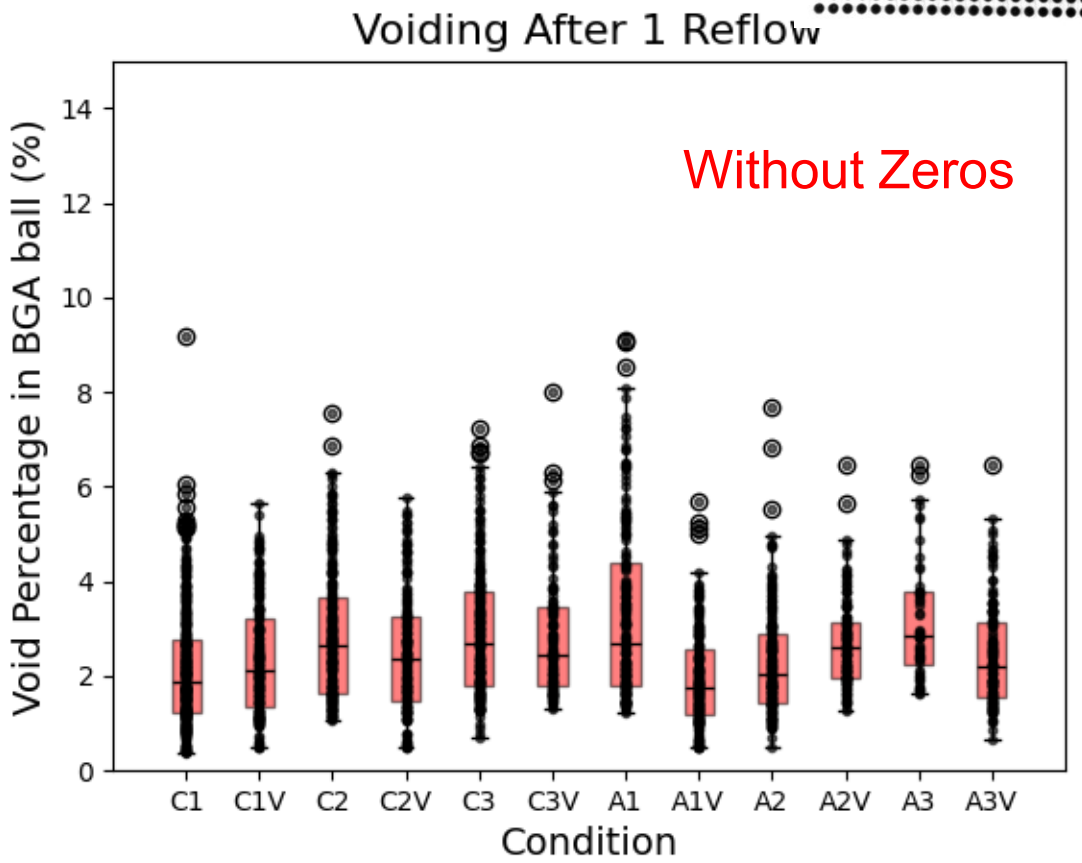
BGA voiding also reduced by vacuum reflow step



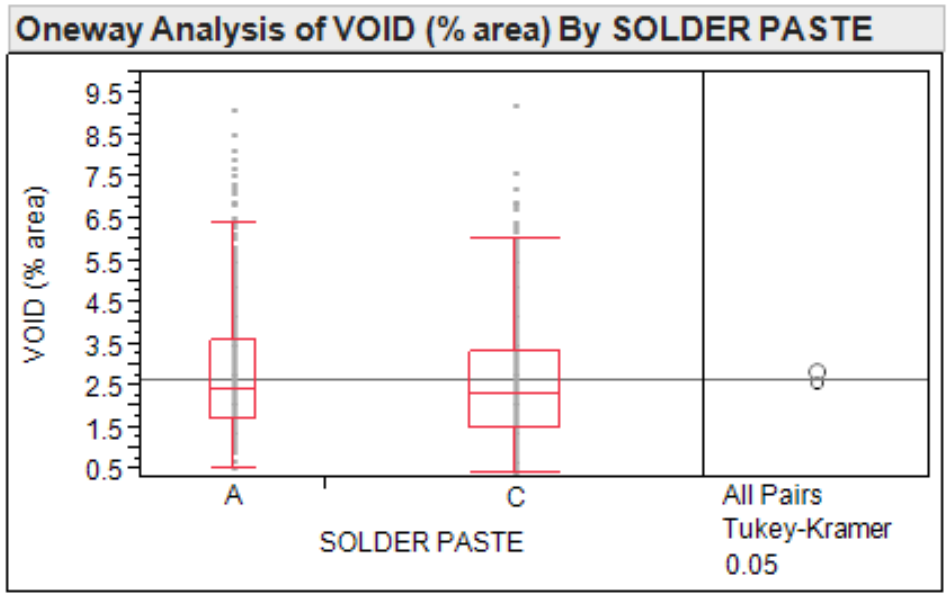
BGA joints are dominated by the non-voided







Barely any differences in voiding by paste.



Excluded Rows 2020

Means Comparisons

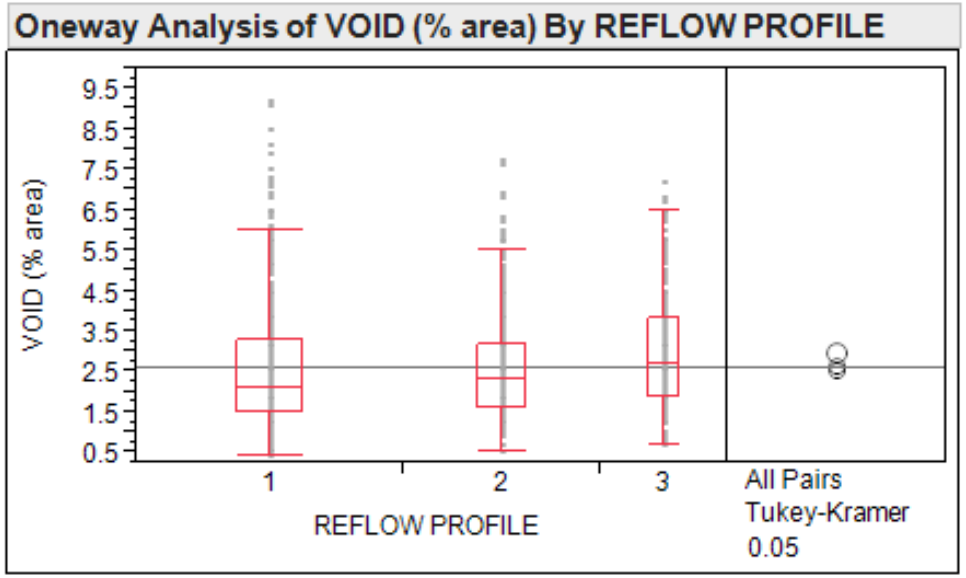
Comparisons for all pairs using Tukey-Kramer HSD

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

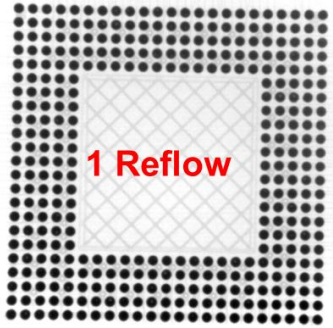
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

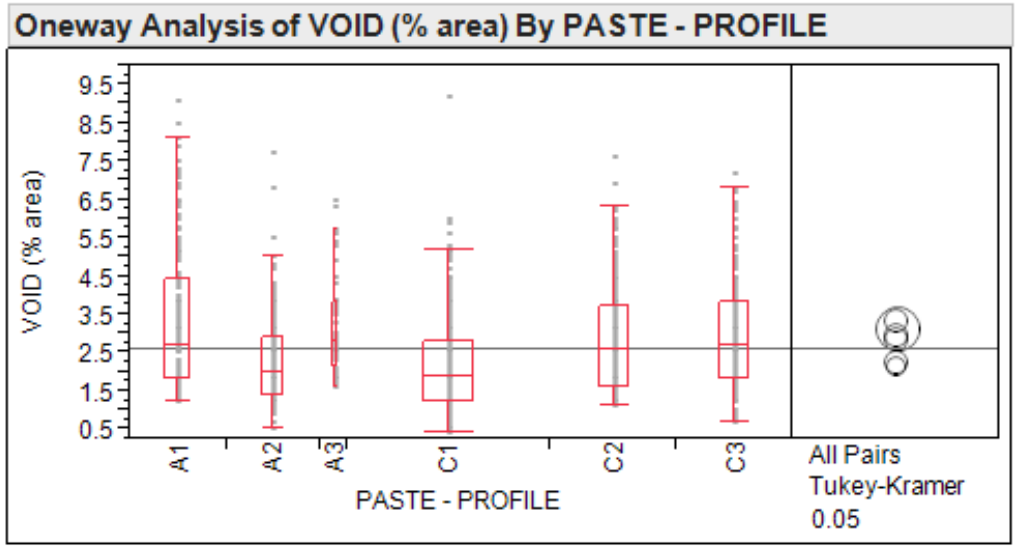
Level		Mean
3	A	2.98
2	B	2.61
1	B	2.54

Levels not connected by same letter are significantly different.

Profile



Similar voiding levels between 1st reflow types.



Excluded Rows 2020

Means Comparisons

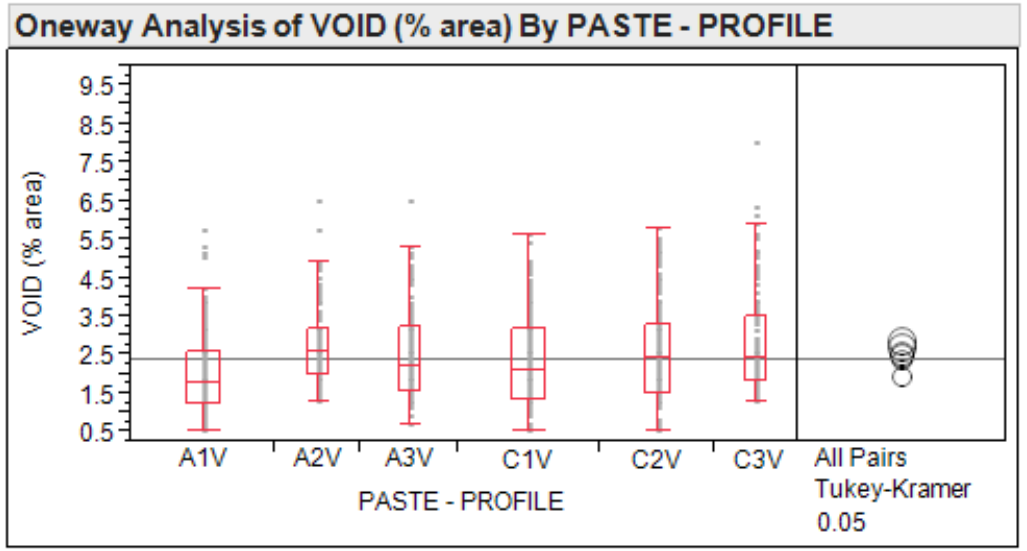
Comparisons for all pairs using Tukey-Kramer HSD

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

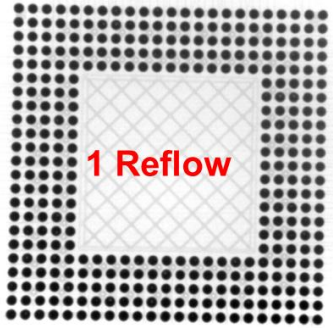
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

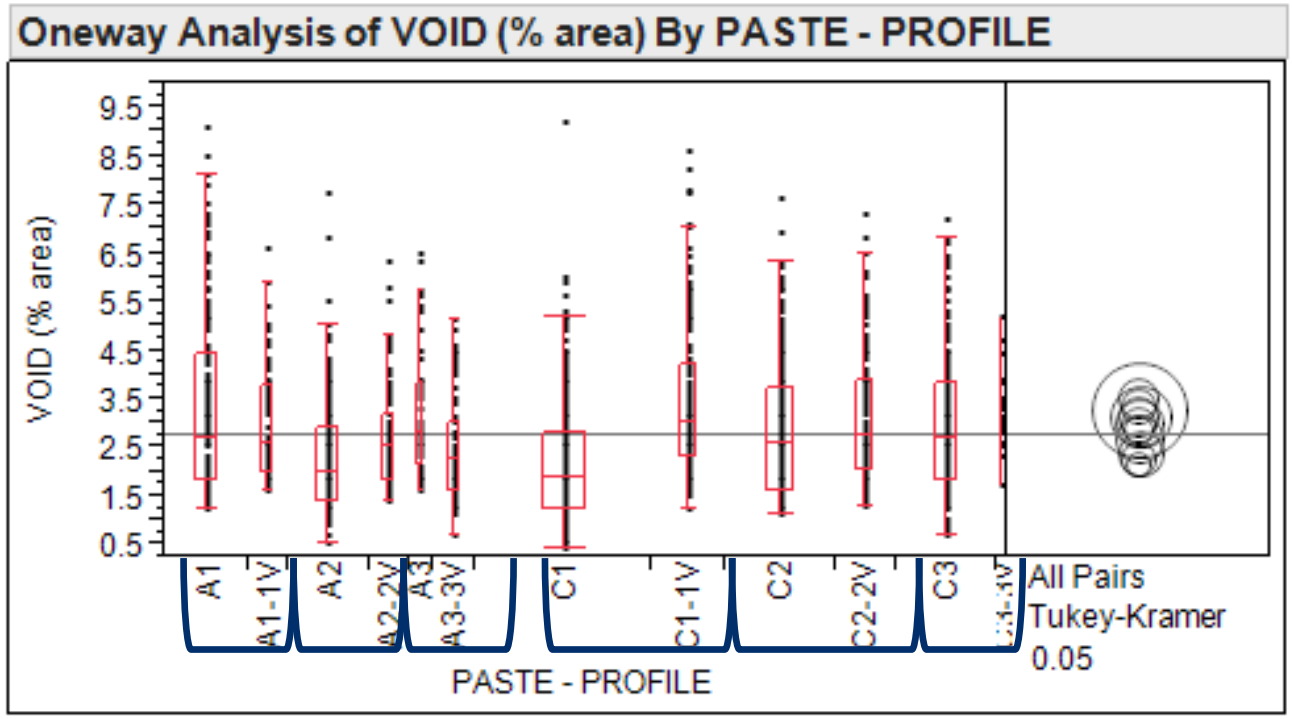
Level				Mean
C3V	A			2.83
A2V	A	B		2.70
C2V	A	B		2.52
A3V	A	B		2.47
C1V		B		2.35
A1V			C	1.94

Levels not connected by same letter are significantly different.

Vac



2nd step vacuum reflow does not substantially reduce voiding.



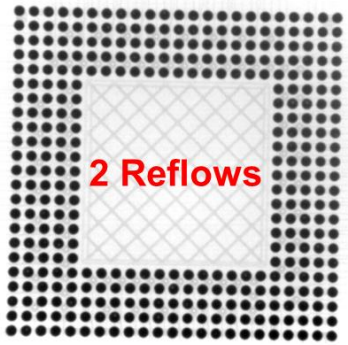
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

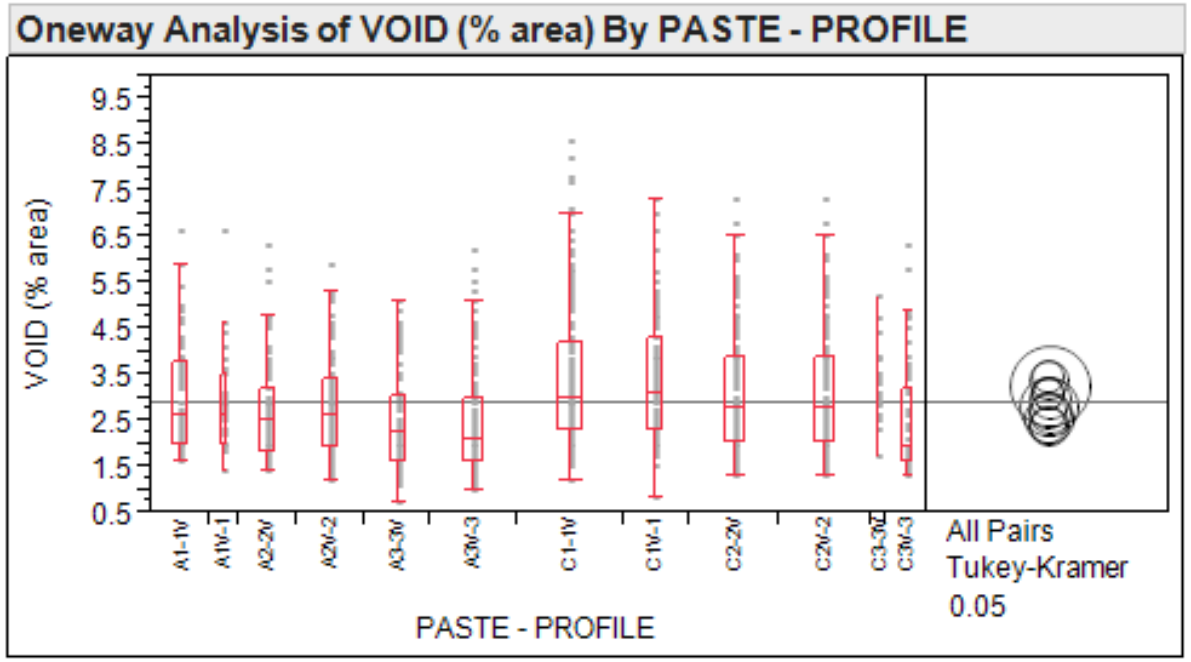
Connecting Letters Report

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 signif



1st or 2nd step vacuum reflow has roughly same void result.



Means Comparisons

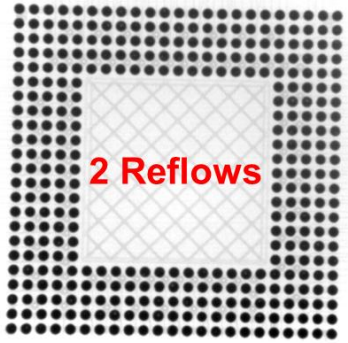
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

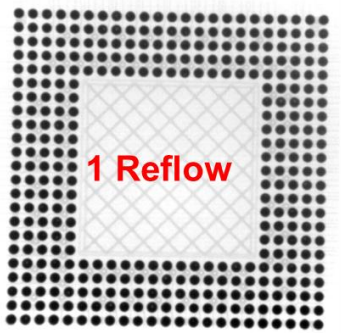
Level					Mean
C1-1V	A				3.48
C1V-1	A				3.41
C3-3V	A	B	C	D	3.31
C2-2V	A	B			3.11
C2V-2	A	B			3.11
A1-1V	A	B	C		3.01
A1V-1	A	B	C	D	2.81
A2V-2		B	C	D	2.74
A2-2V		B	C	D	2.70
C3V-3		B	C	D	2.53
A3-3V			C	D	2.42
A3V-3				D	2.41

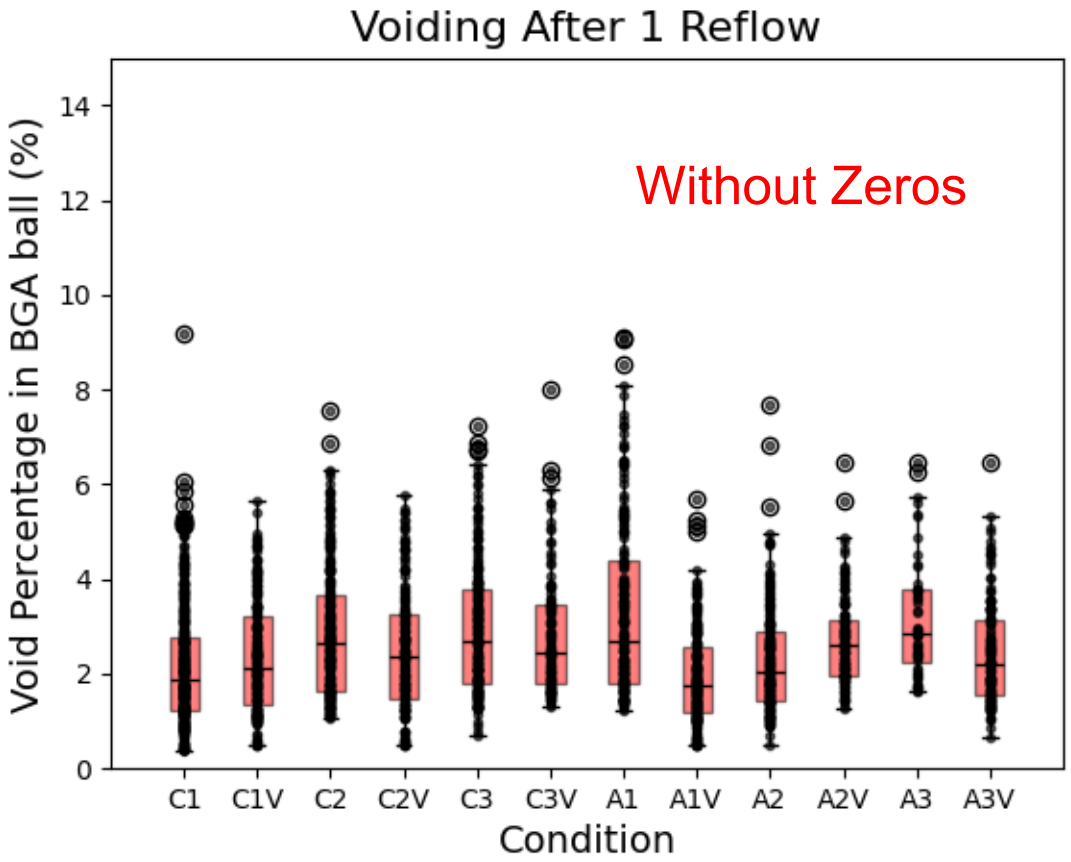
Levels not connected by same letter are significa

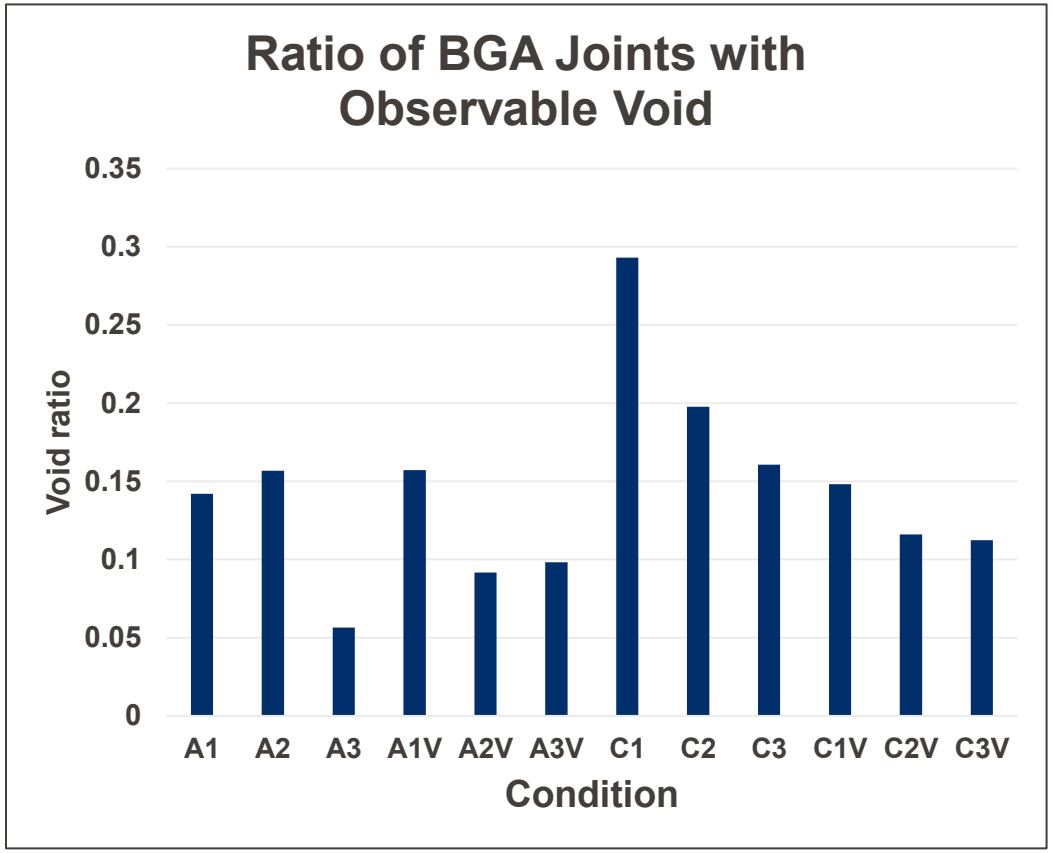
2nd



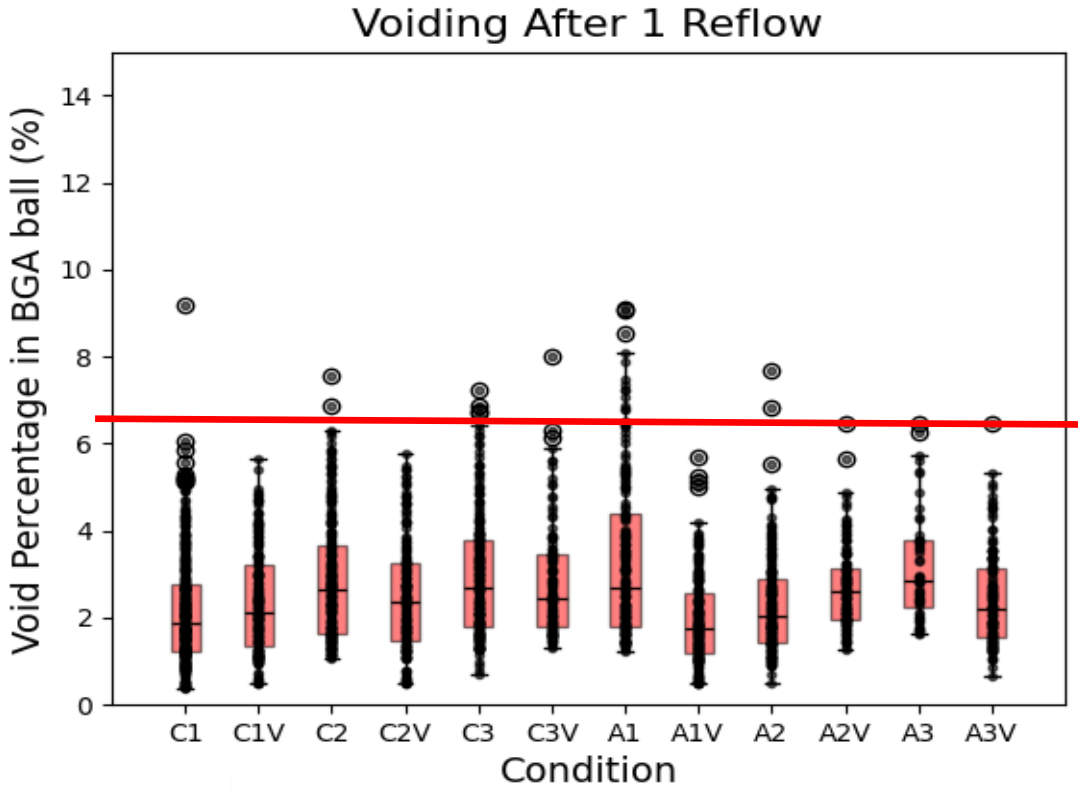
Effects of vacuum reflow are more visible in void ratio

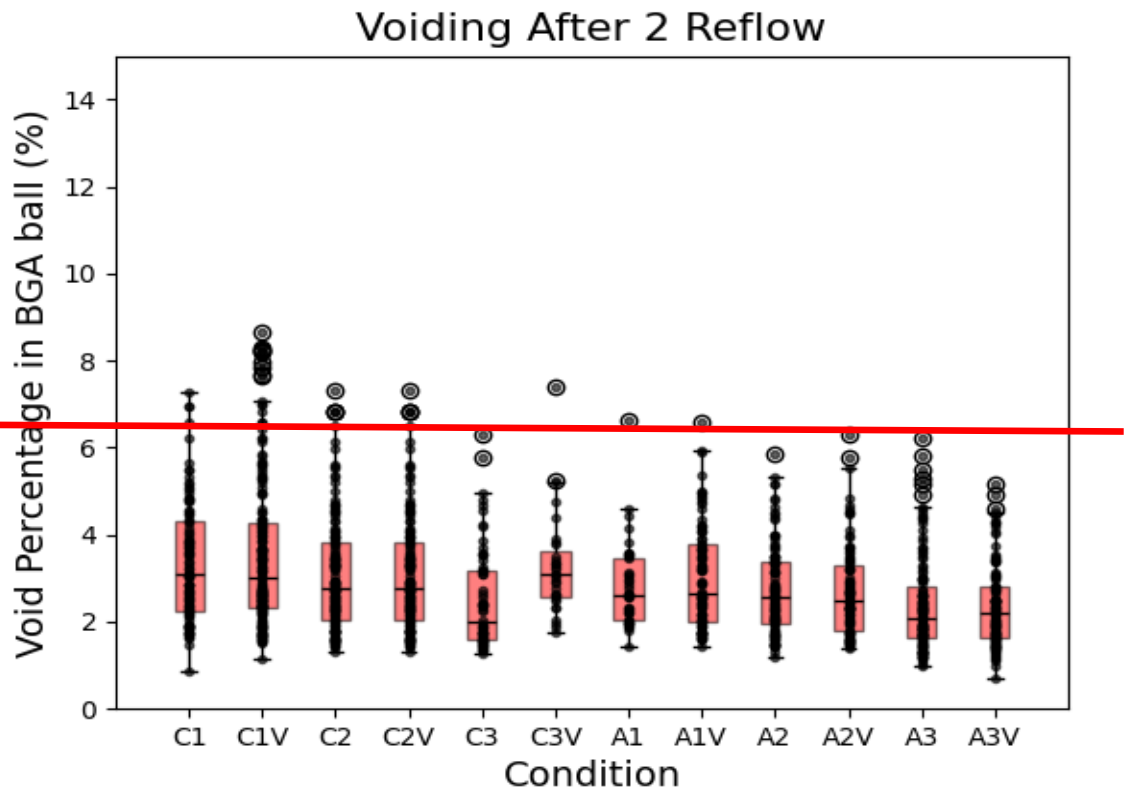


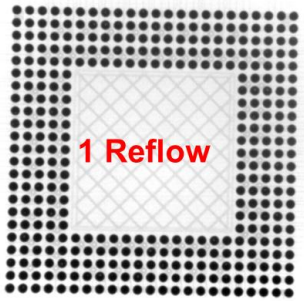


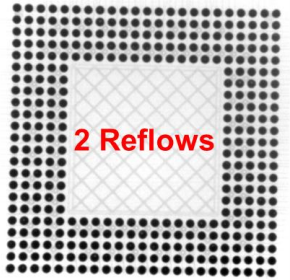


Voiding within joints with voids is not changed by multiple reflows.

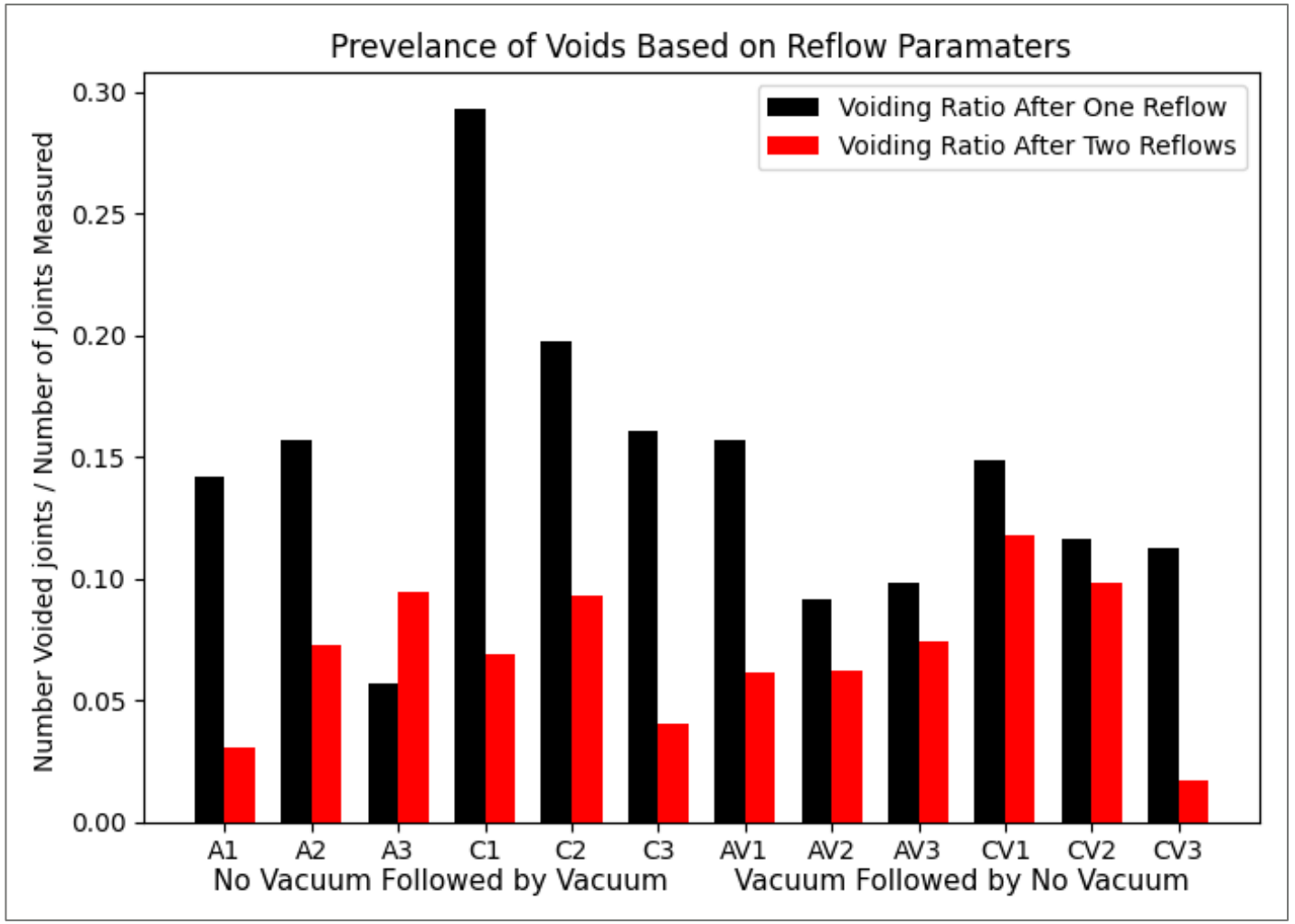




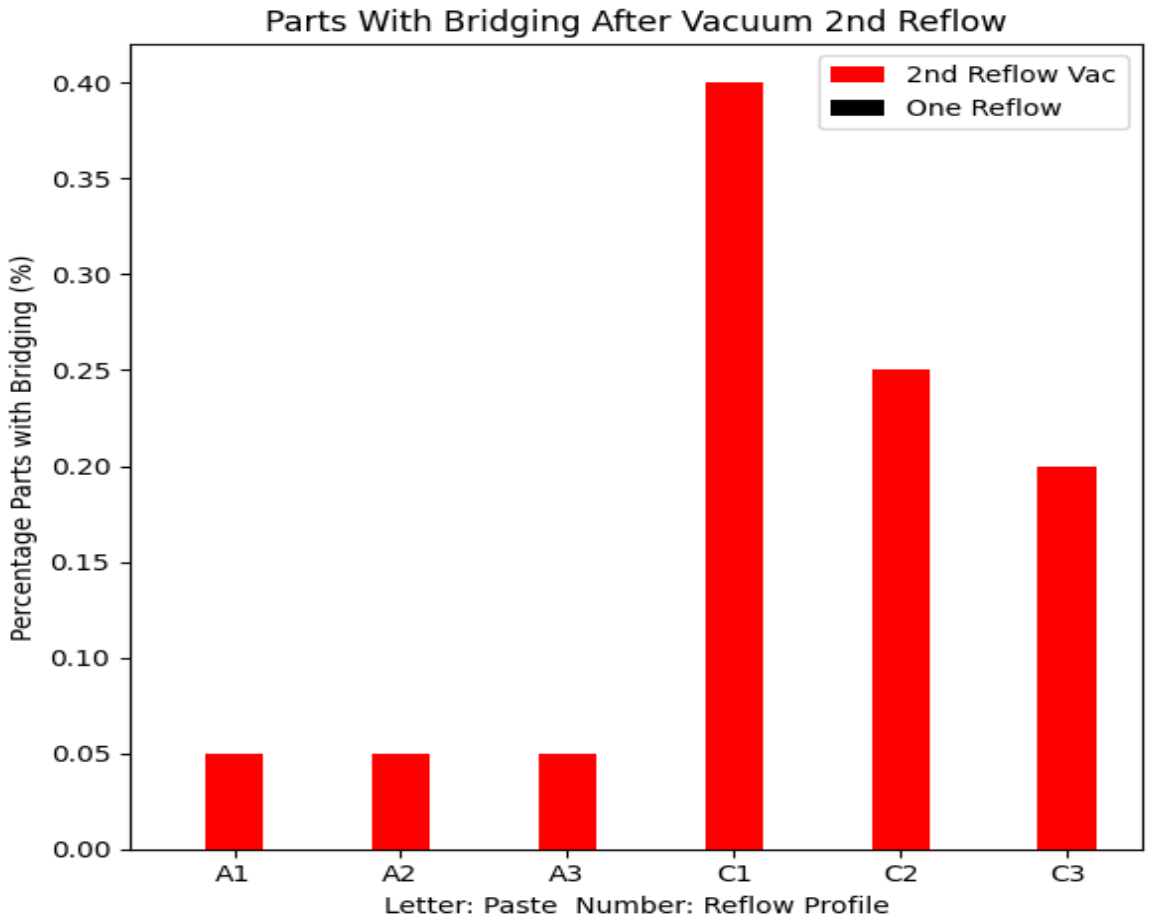


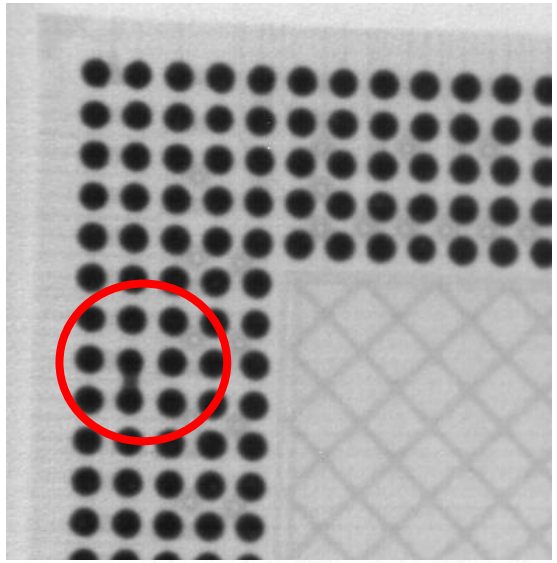


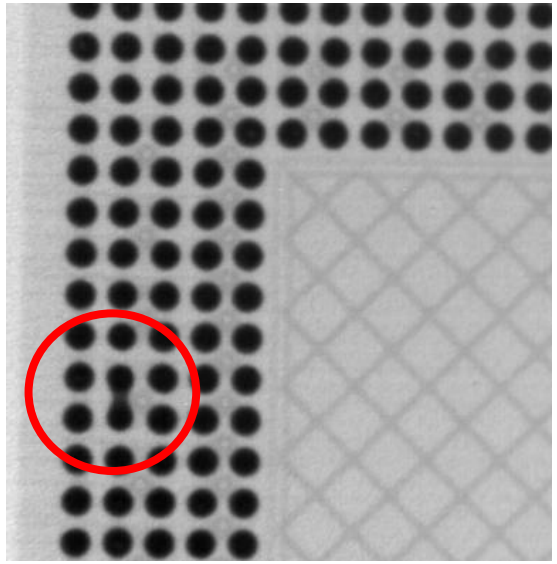
Main difference lies in voiding ratio after multiple reflows.

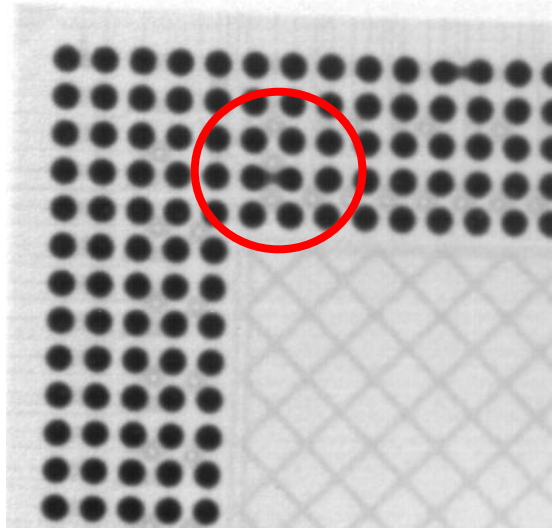


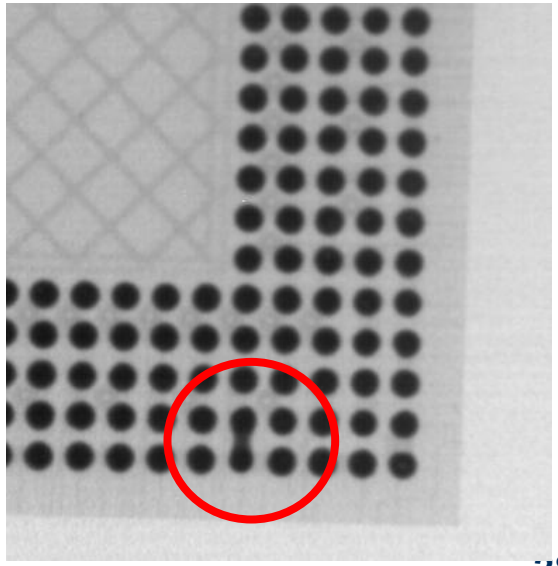
Bridging is only observed in instances where vacuum reflow occurs second.



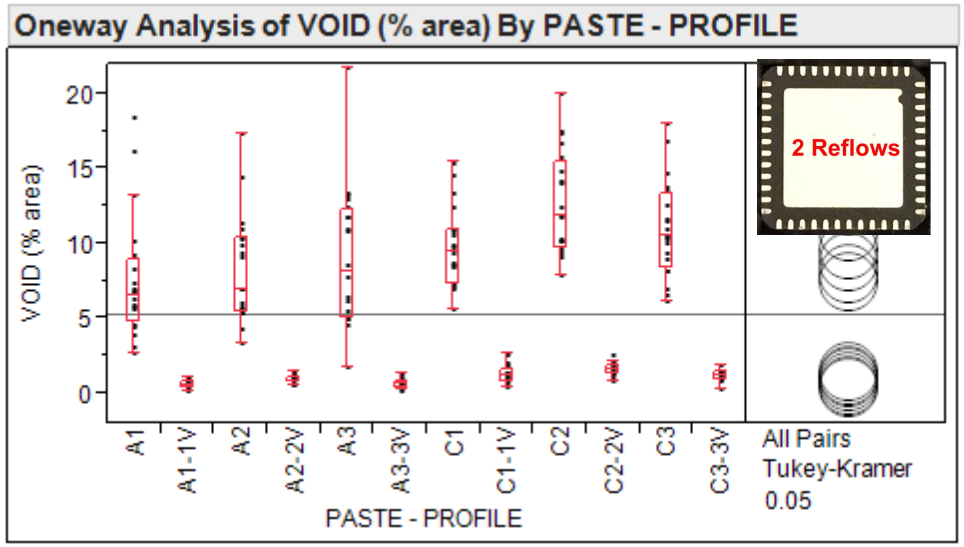


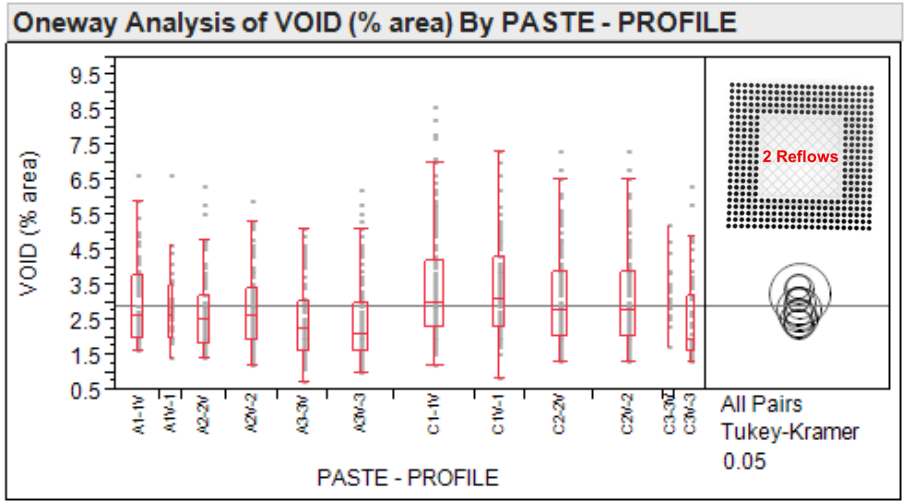


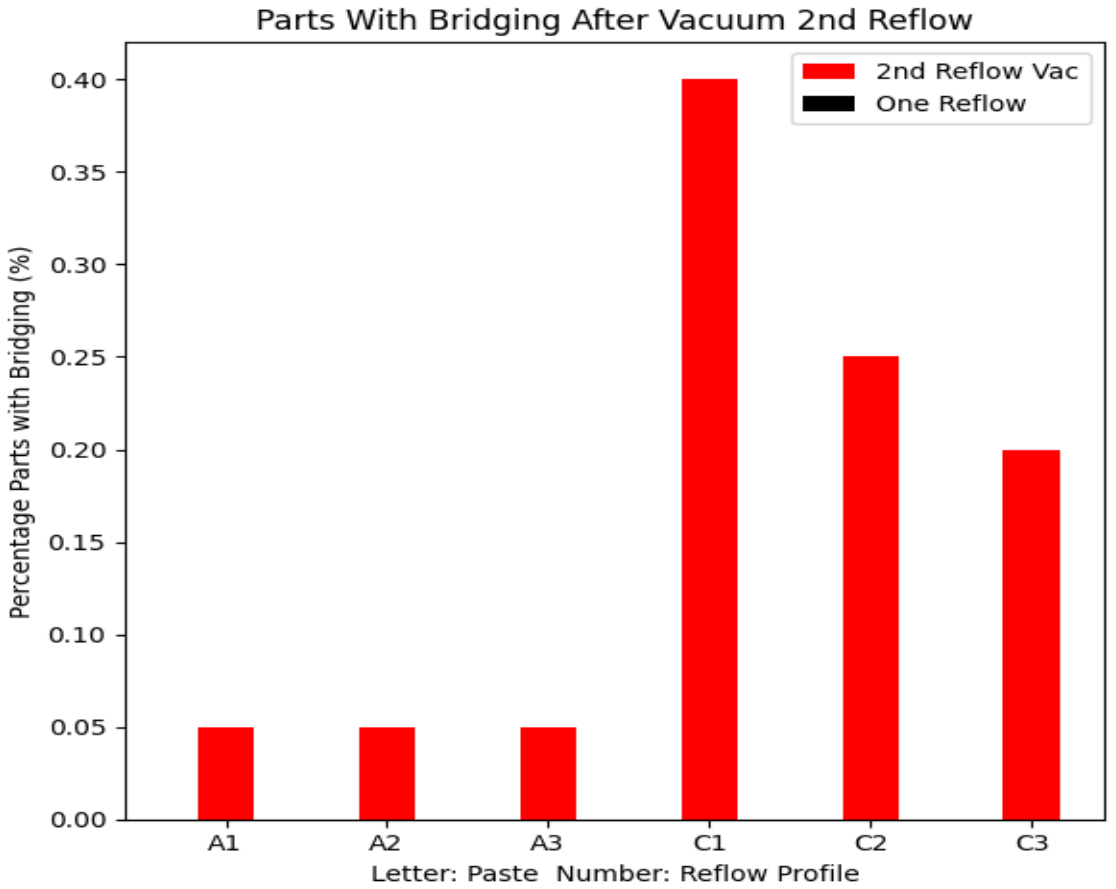




Vacuum reflow is effective for large surface area joints, less so for BGAs but may have risks.







Thanks for listening, Questions?