Fill the Void VIII "the Ocho": Can Reflow Profiles Really Improve Voiding in Solder Joints?

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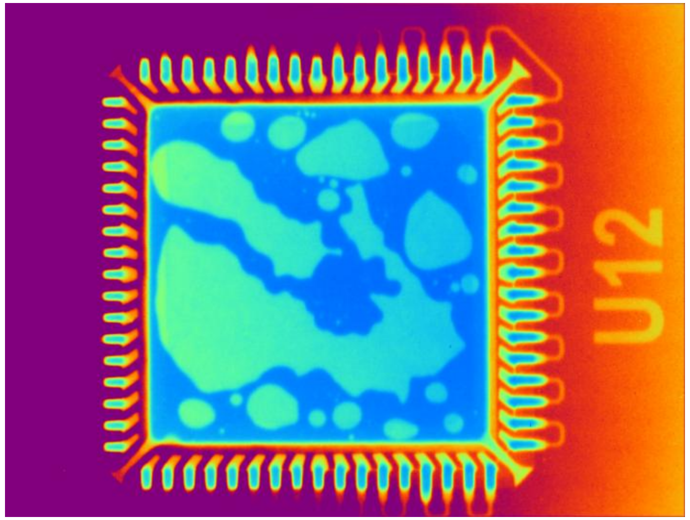
Outline/Agenda

- Introduction
  - Voiding in solder joints and why is it important?
  - How does reflow profile influence voiding?
- Discussion Topics
  - Experimental methodology
  - Solder pastes and reflow profiles
  - Process and data gathering
- Results of Experiments
  - Voiding data: solder paste, reflow profile, 2nd reflow, paste & profile combinations
- Conclusions
- Q & A

Introduction

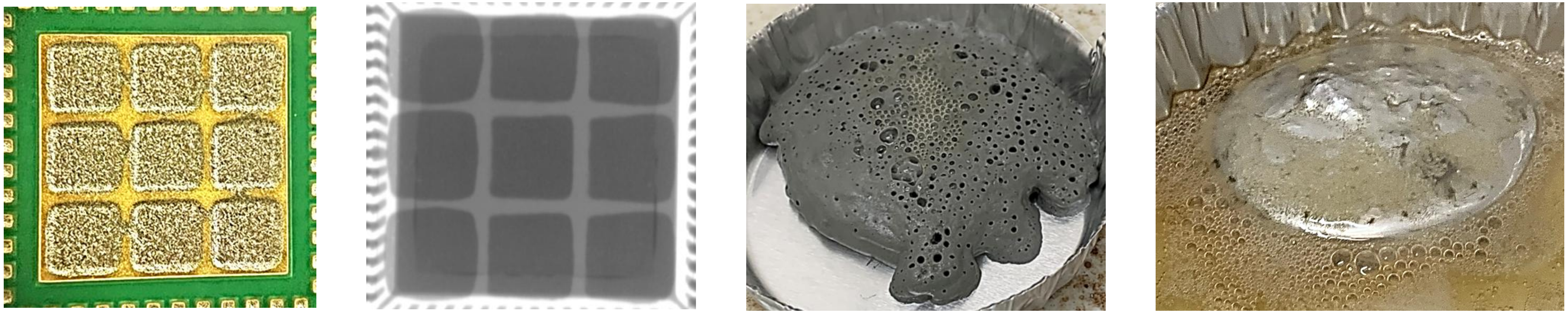
Voiding in Solder Joints: Why is it Important?

- Voiding limits have become tighter.
  - Voiding limits of 15-20% void area in BTCs and BGAs
- Rework of voids has limited effectiveness.
- This creates the need for methods to reduce voiding.
  - PCB design
  - Solder paste formulations
  - Printed solder paste volume and location
  - Use of solder pre-forms
  - Reflow with vacuum
  - Reflow profiles



How Does Reflow Profile Influence Voiding?

- Slump and flow of the solder paste
- Evaporation of volatiles
- Activation of metal surfaces to optimize wetting
- Gas escape from the molten solder



Experimental Methodology

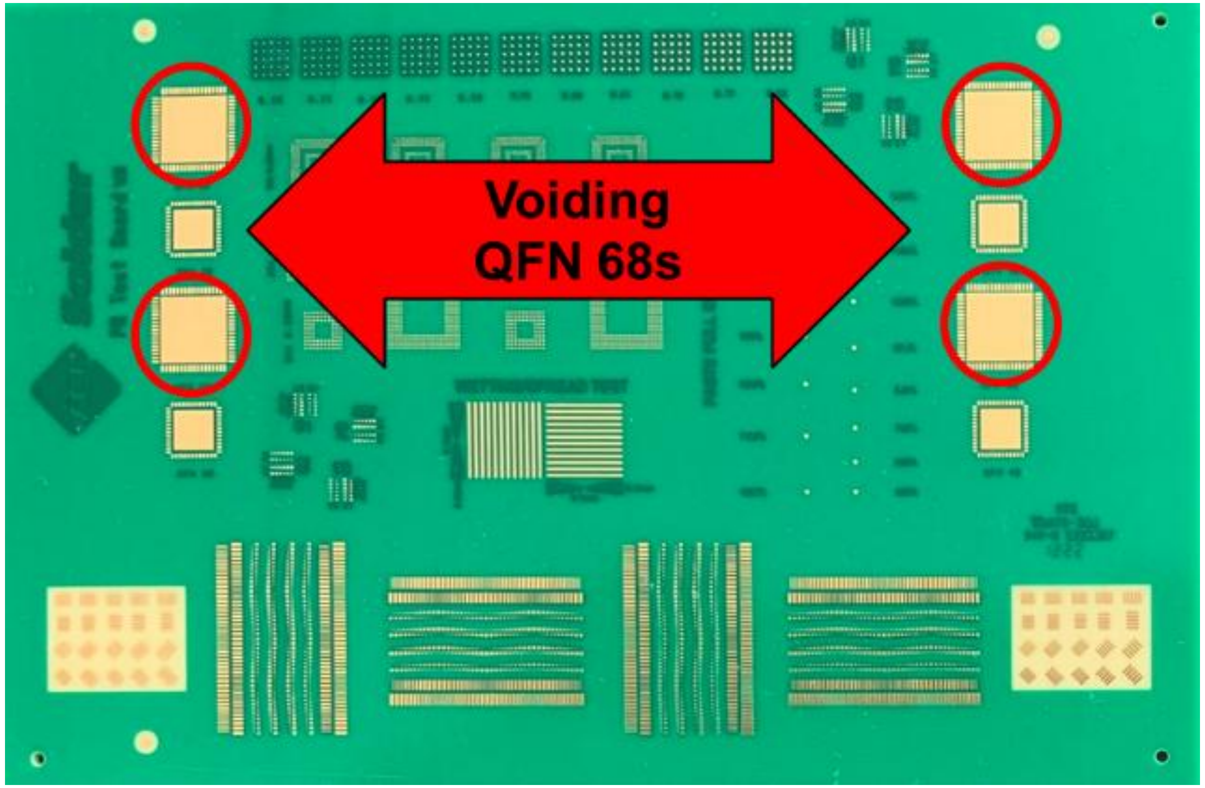
Experimental Methodology

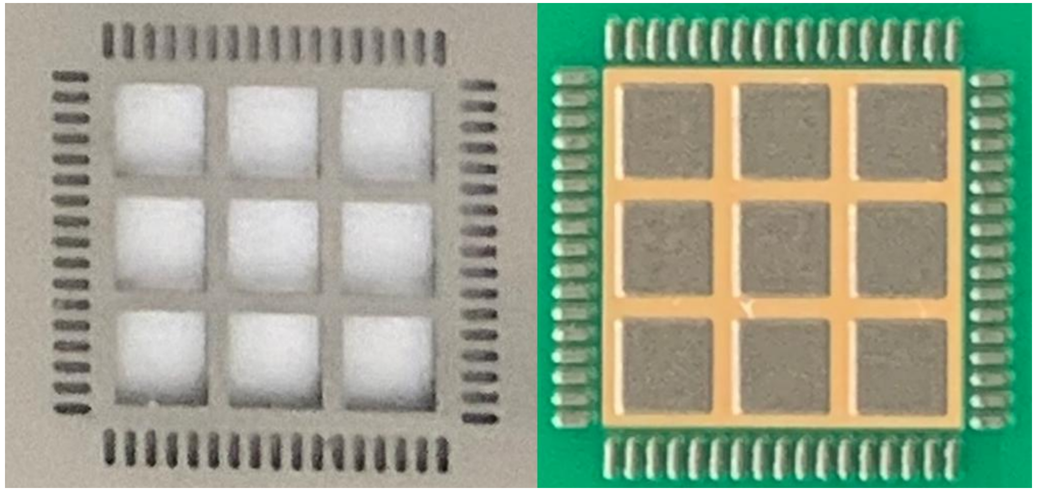
- 4 No-Clean Solder Pastes: SAC305 T4, Zero Halogen (except C)

Solder Paste	Flux Class (IPC J-STD-004)	Metal Content (% wt)
A	ROL0	88.0
B	ROL0	88.3
C	ROL0 (Halogen containing)	87.9
D	ROL0	88.2

Experimental Methodology

- PR Test Board, Single Sided, ENIG, MLF68 QFNs

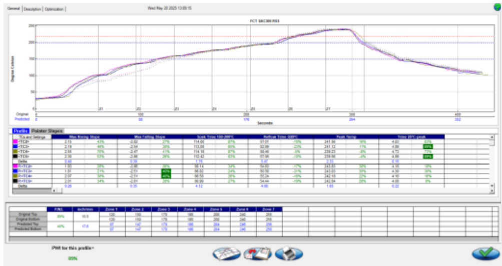


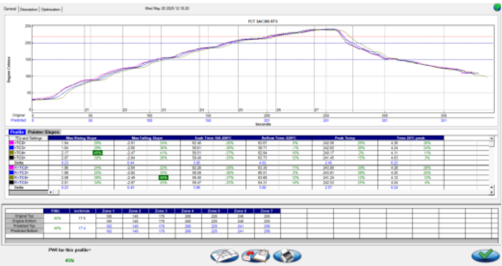


5 mil Thick Stencil. 65% Area of Coverage
20 mil Webs. 88 mil Squares

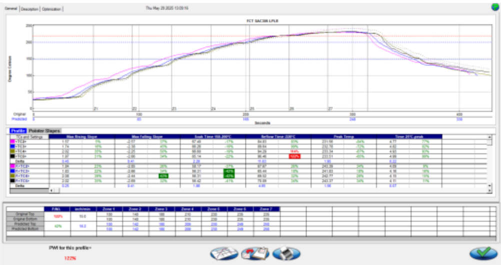
Experimental Methodology

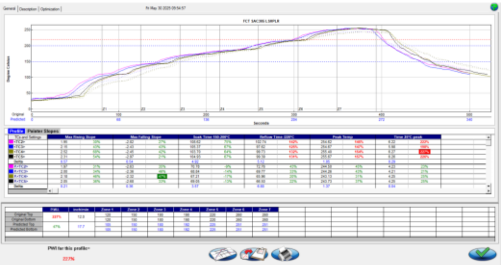
- 5 Reflow Profiles (7-Zone Convection Reflow in Air)
  - RSS = Ramp – Soak – Spike (standard soak profile)
  - RTS = Ramp – To – Spike (standard linear ramp profile)
  - LPSR = Low Peak – Short Reflow
  - LPLR = Low Peak – Long Reflow
  - LSHPLR = Long Soak – High Peak – Long Reflow


RSS


RTS


LPSR


LPLR


LSHPLR

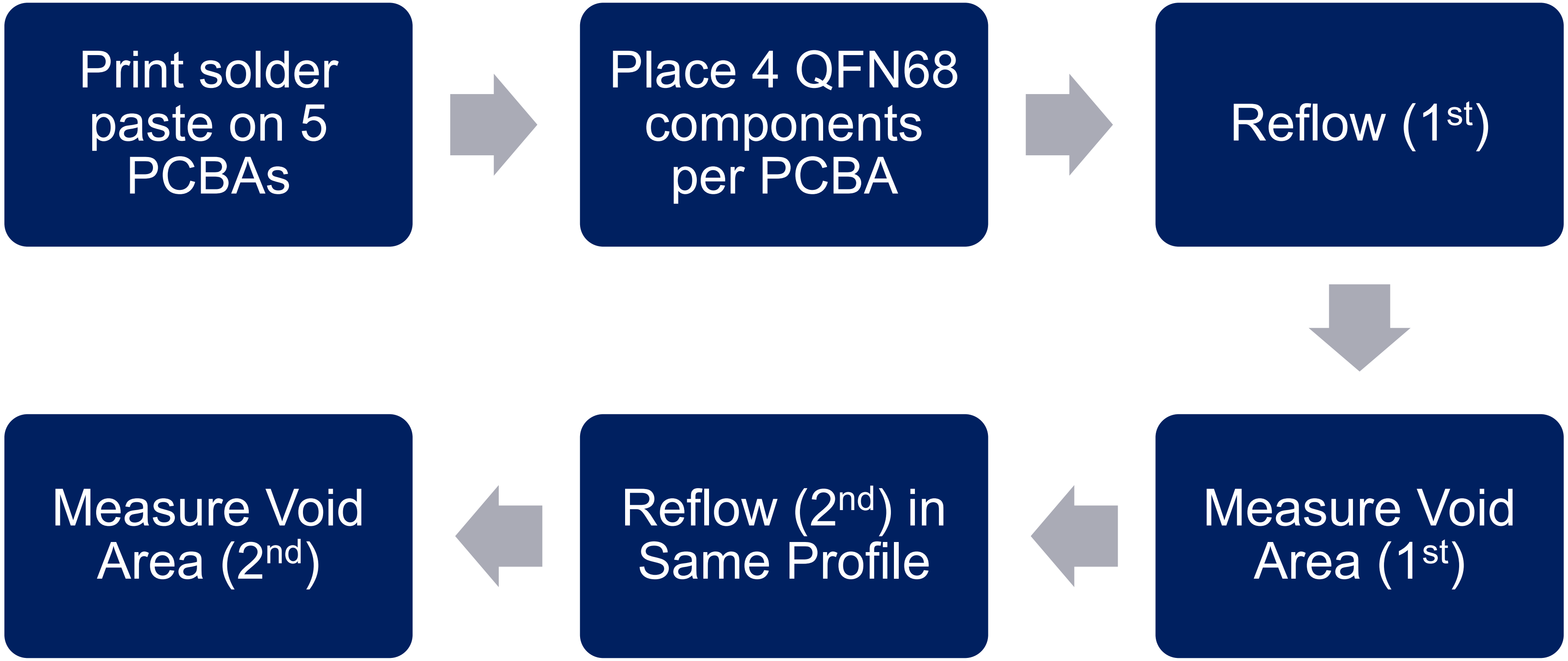
Experimental Methodology

- 5 Reflow Profiles (Measured Values)

Parameter (Measured)	SAC305 RTS	SAC305 RSS	SAC305 LPSR	SAC305 LPLR	SAC305 LSHPLR
Soak time 150-200°C (sec)	58-62	112-114	62-64	65-67	104-109
Peak temp (°C)	240-243	239-242	231-233	232-233	255-256
Reflow Time >220°C (sec)	60-64	53-58	40-45	85-96	98-103
Time from 25°C to Peak Temp (min)	4.0-4.3	4.7-4.9	3.6-3.9	4.8-5.0	6.0-6.3

Experimental Methodology

- Process Used for Voiding Measurement



Print solder paste on 5 PCBAs

Place 4 QFN68 components per PCBA

Reflow (1st)

Measure Void Area (1st)

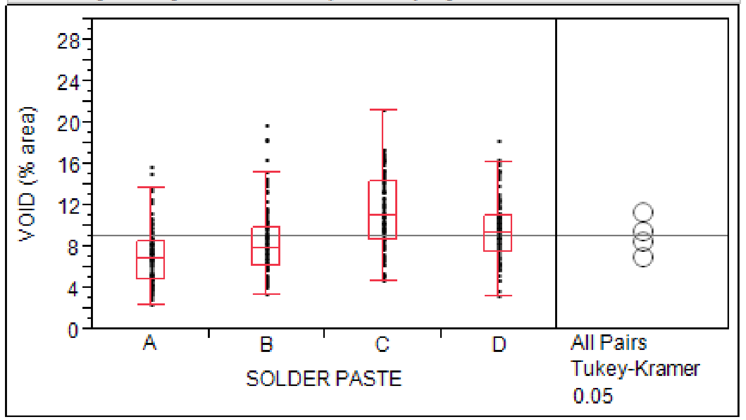
Reflow (2nd) in Same Profile

Measure Void Area (2nd)

Results

Results: Voiding by Solder Paste
All Profiles Averaged

Oneway Analysis of VOID (% area) By SOLDER PASTE



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

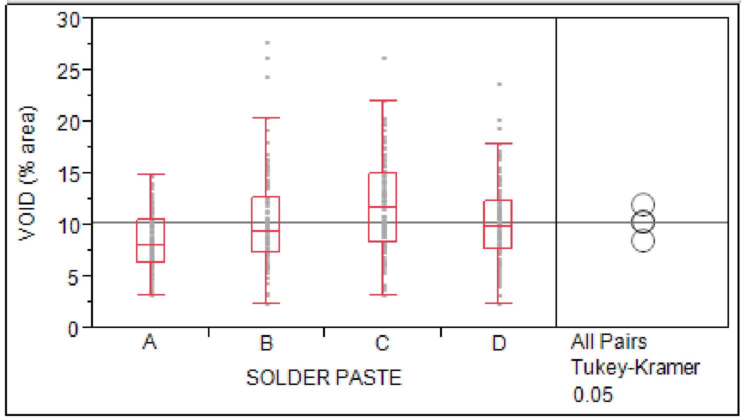
Connecting Letters Report

Level				Mean
C	A			11.4
D		B		9.4
B		B		8.5
A			C	7.1

Levels not connected by same letter are significantly different.

1st Reflow

Oneway Analysis of VOID (% area) By SOLDER PASTE



Excluded Rows 400

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

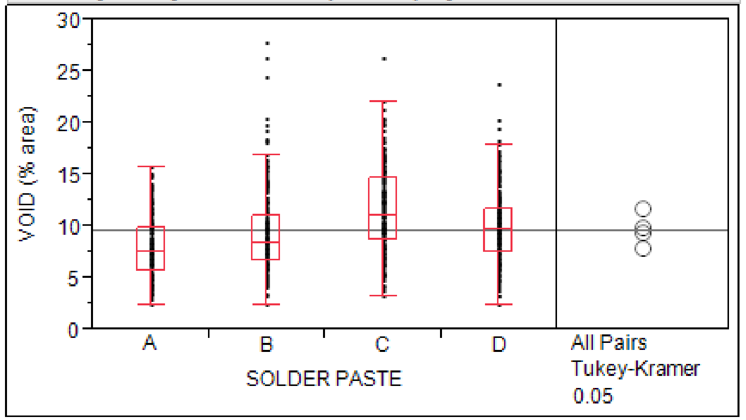
Connecting Letters Report

Level				Mean
C	A			11.9
B		B		10.3
D		B		10.3
A			C	8.5

Levels not connected by same letter are significantly different.

2nd Reflow

Oneway Analysis of VOID (% area) By SOLDER PASTE



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
C	A			11.6
D		B		9.9
B		B		9.4
A			C	7.8

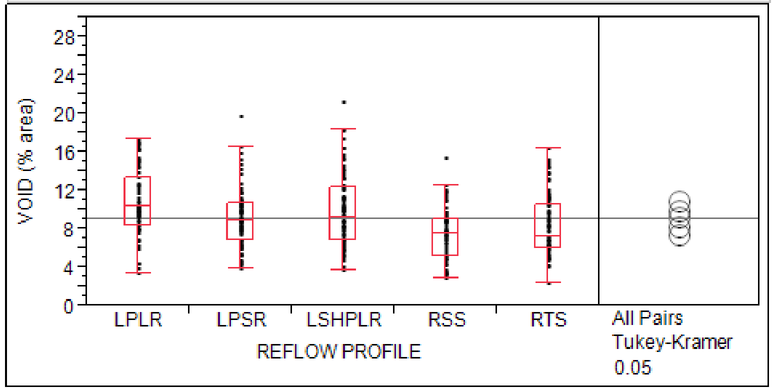
Levels not connected by same letter are significantly different.

Both Reflows

Results: Voiding by Reflow Profile

All Solder Pastes Averaged

Oneway Analysis of VOID (% area) By REFLOW PROFILE



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

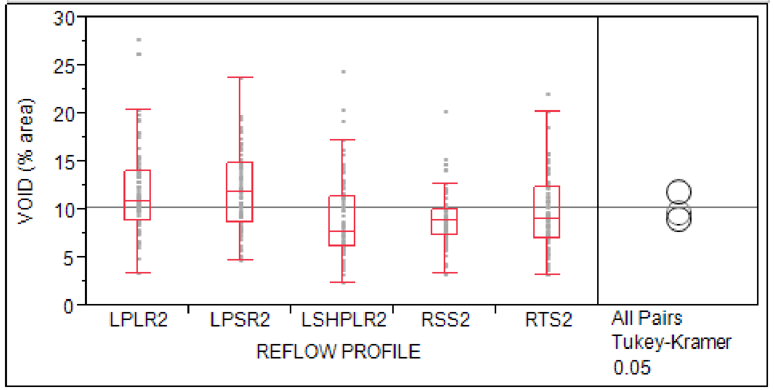
Connecting Letters Report

Level					Mean
LPLR	A				10.9
LSHPLR	A	B			9.9
LPSR		B	C		9.1
RTS			C	D	8.2
RSS				D	7.4

Levels not connected by same letter are significantly different.

1st Reflow

Oneway Analysis of VOID (% area) By REFLOW PROFILE



Excluded Rows 400

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

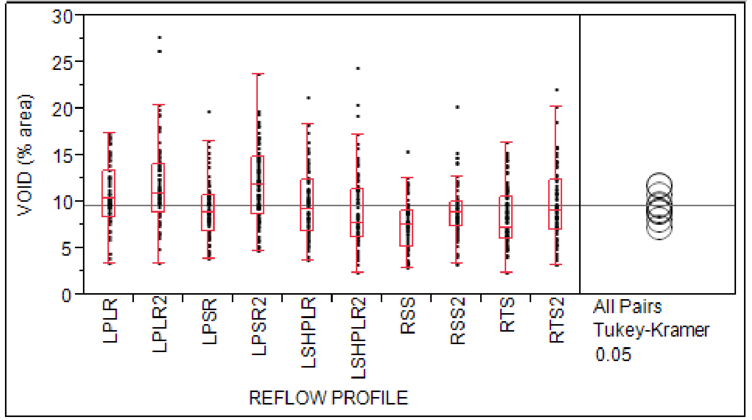
Connecting Letters Report

Level			Mean
LPSR2	A		11.9
LPLR2	A		11.8
RTS2		B	9.7
LSHPLR2		B	9.0
RSS2		B	9.0

Levels not connected by same letter are significantly different.

2nd Reflow

Oneway Analysis of VOID (% area) By REFLOW PROFILE



Means Comparisons

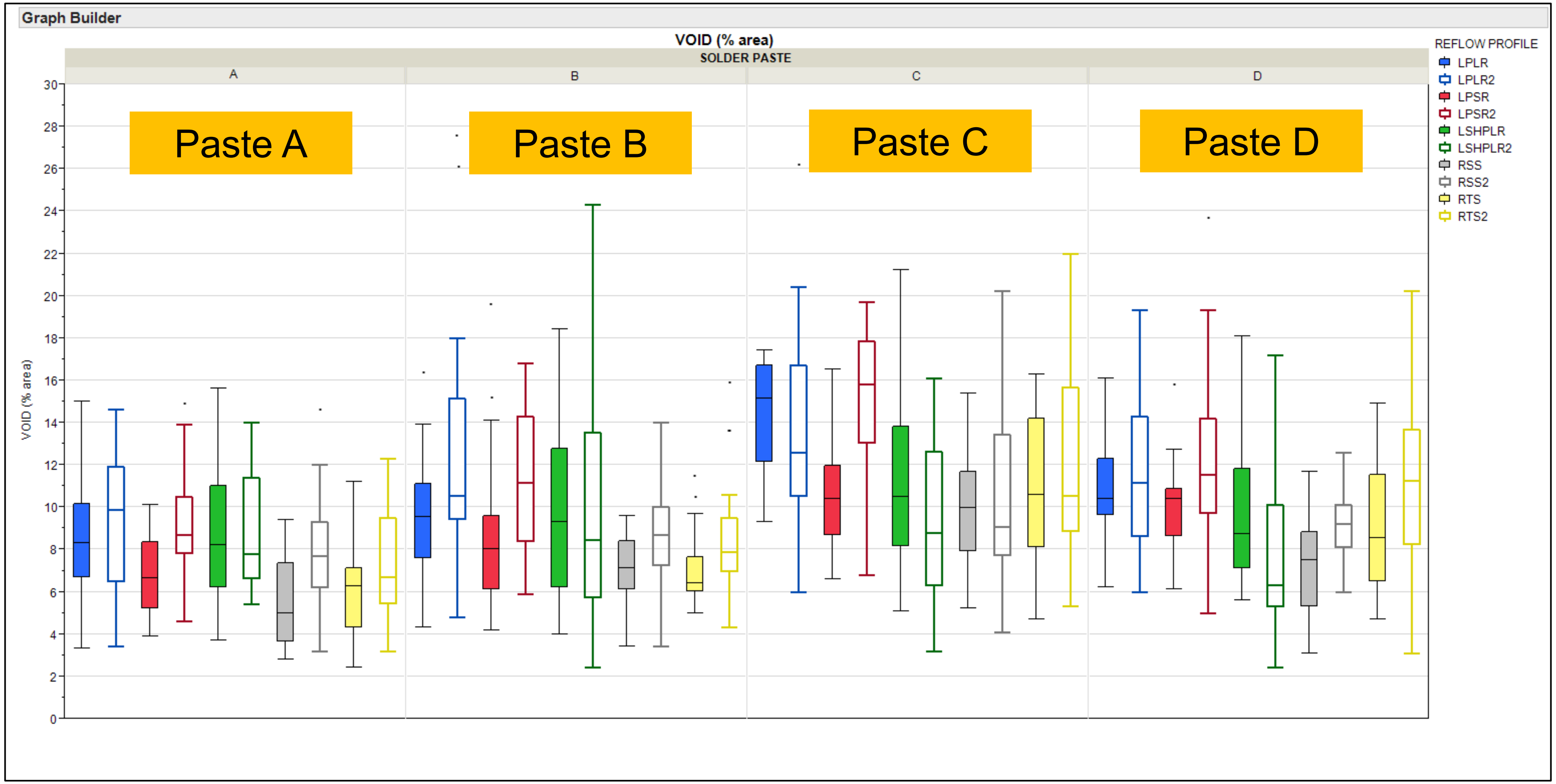
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level					Mean
LPSR2	A				11.9
LPLR2	A				11.8
LPLR	A	B			10.9
LSHPLR		B	C		9.9
RTS2		B	C		9.7
LPSR		B	C	D	9.1
LSHPLR2			C	D	9.0
RSS2			C	D	9.0
RTS			C	D	8.2
RSS				D	7.4

Both Reflows

Results: Voiding Paste by Profile

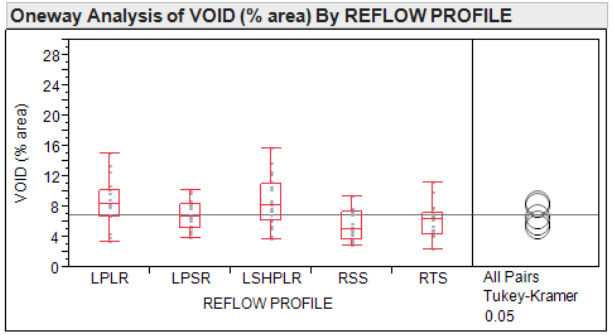


2nd Reflow (Outlines)

- Wider ranges
- Higher means

RSS (Gray) &
RTS (Yellow) Lower
voiding

Results: Voiding – Solder Paste by 1st Reflow Profile



Excluded Rows 700

Means Comparisons

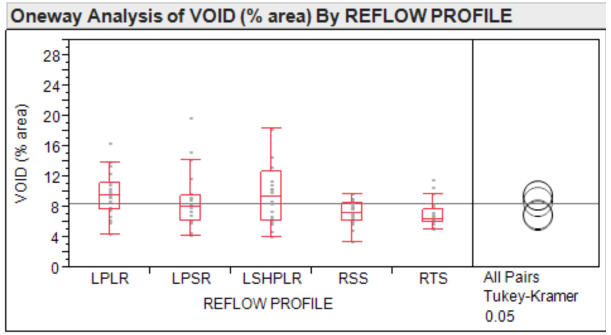
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LSHPLR	A		8.6
LPLR	A		8.4
LPSR	A	B	6.8
RTS		B	6.0
RSS		B	5.5

Levels not connected by same letter are significantly different.

A



Excluded Rows 700

Means Comparisons

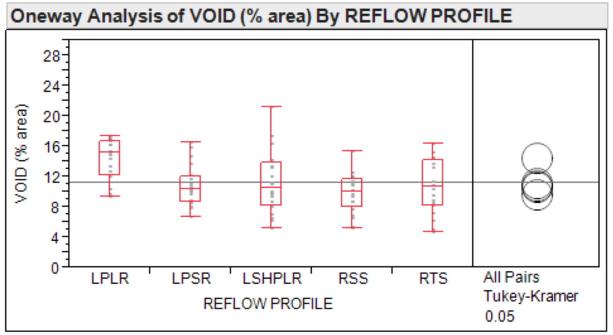
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LSHPLR	A		9.7
LPLR	A	B	9.6
LPSR	A	B	8.8
RSS	A	B	7.2
RTS		B	7.0

Levels not connected by same letter are significantly different.

B



Excluded Rows 700

Means Comparisons

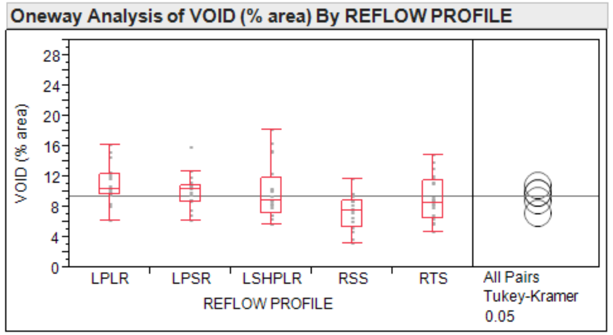
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LPLR	A		14.5
LSHPLR		B	11.2
LPSR		B	10.8
RTS		B	10.7
RSS		B	9.7

Levels not connected by same letter are significantly different.

C



Excluded Rows 700

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LPLR	A		10.9
LPSR	A		10.0
LSHPLR	A		9.9
RTS	A	B	9.1
RSS		B	7.3

Levels not connected by same letter are significantly different.

D

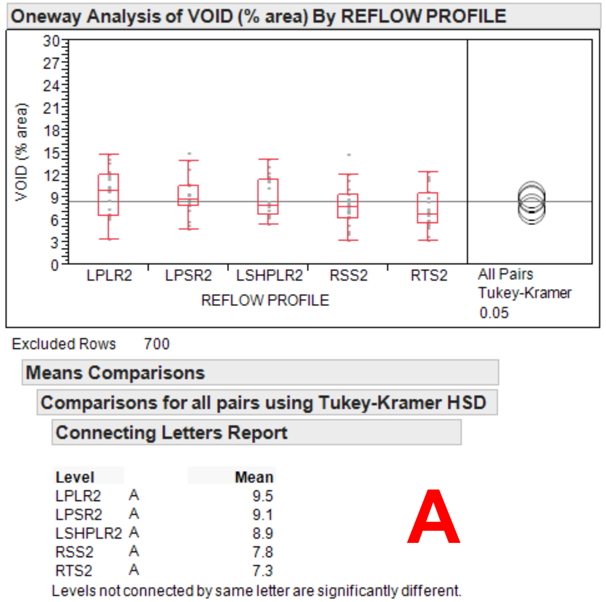
LSHPLR & LPLR Highest
RTS & RSS Lowest

LSHPLR Highest
RTS Lowest

LPLR Highest
Others Lowest

LPLR & LPSR Highest
RSS Lowest

Results: Voiding – Solder Paste by 2^{nd} Reflow Profile



Oneway Analysis of VOID (% area) By REFLOW PROFILE

Excluded Rows 700

Means Comparisons

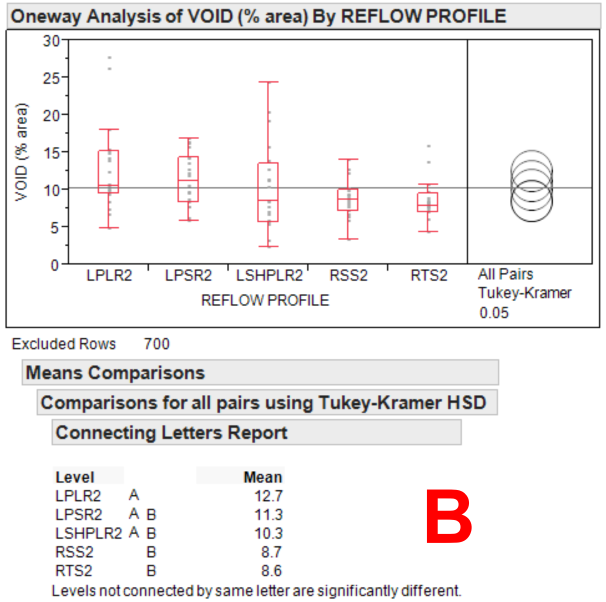
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
LPLR2	A	9.5
LPSR2	A	9.1
LSHPLR2	A	8.9
RSS2	A	7.8
RTS2	A	7.3

Levels not connected by same letter are significantly different.

A



Oneway Analysis of VOID (% area) By REFLOW PROFILE

Excluded Rows 700

Means Comparisons

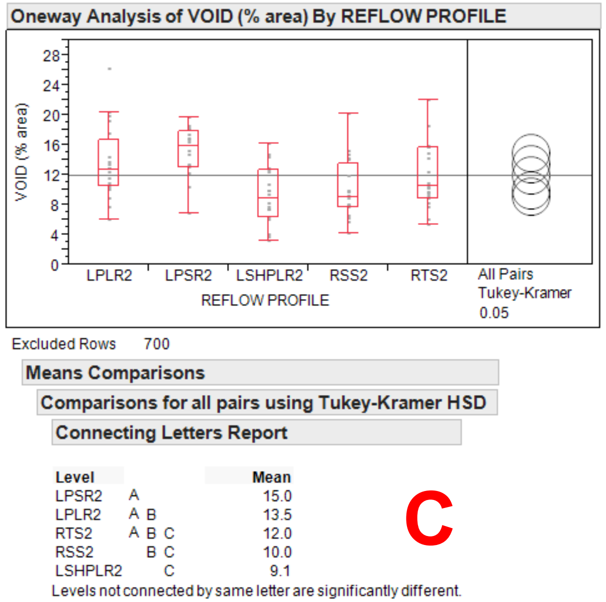
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LPLR2	A		12.7
LPSR2	A	B	11.3
LSHPLR2	A	B	10.3
RSS2		B	8.7
RTS2		B	8.6

Levels not connected by same letter are significantly different.

B



Oneway Analysis of VOID (% area) By REFLOW PROFILE

Excluded Rows 700

Means Comparisons

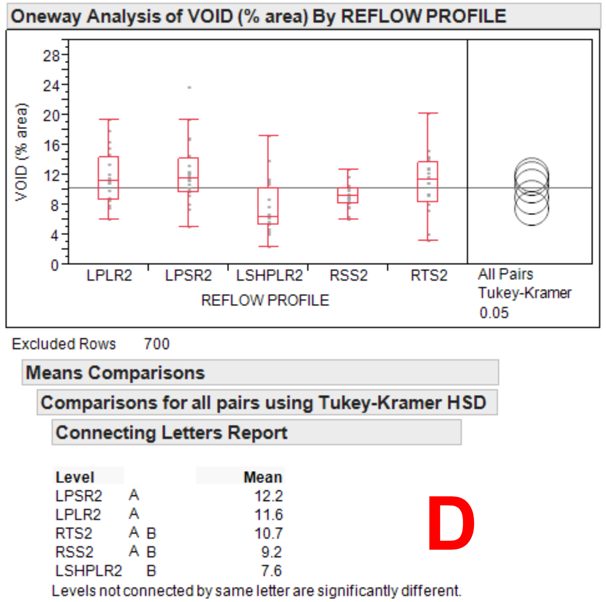
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level				Mean
LPSR2	A			15.0
LPLR2	A	B		13.5
RTS2	A	B	C	12.0
RSS2		B	C	10.0
LSHPLR2			C	9.1

Levels not connected by same letter are significantly different.

C



Oneway Analysis of VOID (% area) By REFLOW PROFILE

Excluded Rows 700

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level			Mean
LPSR2	A		12.2
LPLR2	A		11.6
RTS2	A	B	10.7
RSS2	A	B	9.2
LSHPLR2		B	7.6

Levels not connected by same letter are significantly different.

D

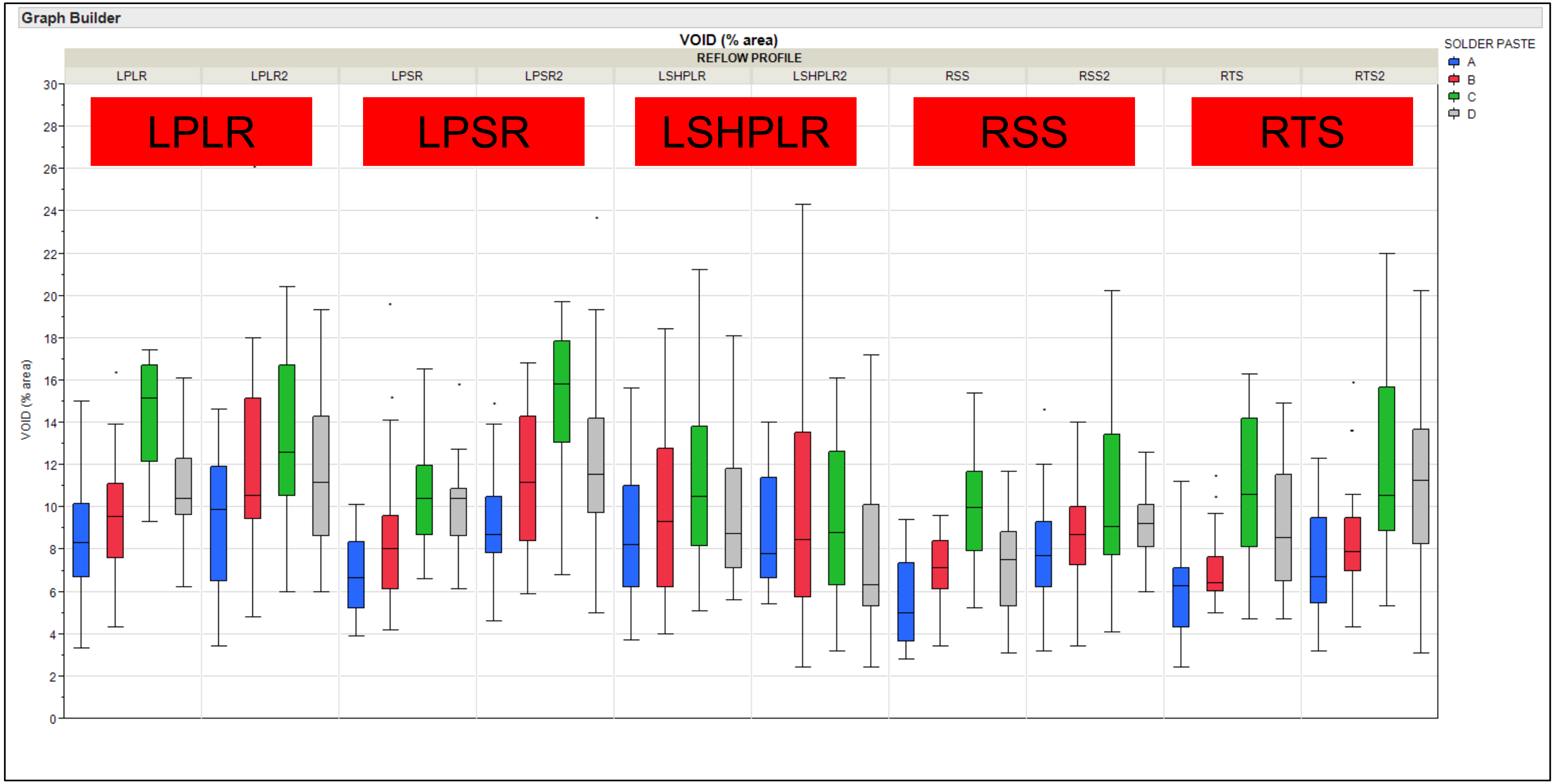
All Same

LPLR2 Highest
RSS2 & RTS2 Lowest

LPSR2 Highest
LSHPLR2 Lowest

LPSR2 & LPLR2 Highest
LSHPLR2 Lowest

Results: Voiding Profile by Paste



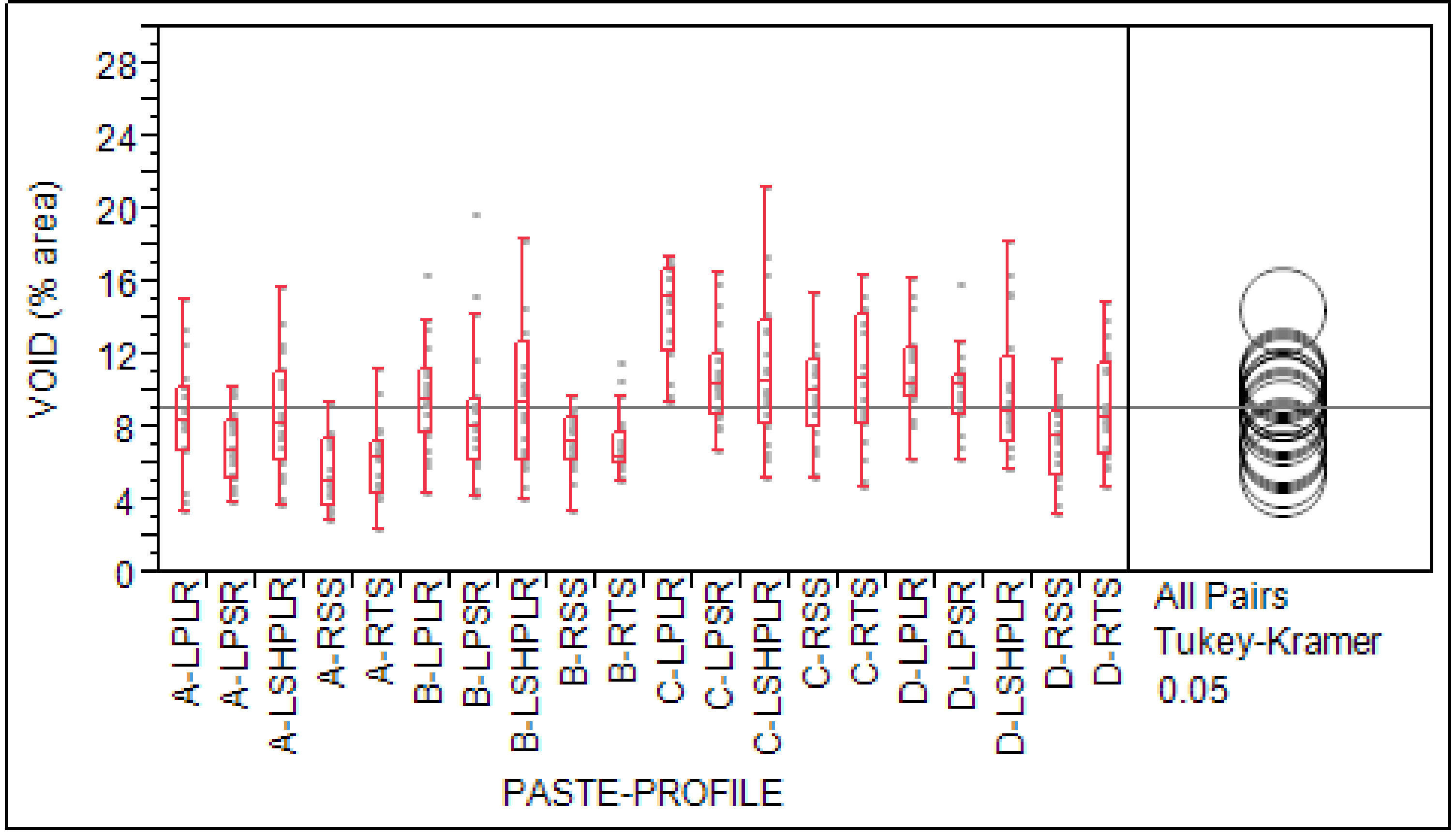
Paste A (Blue) Lower

Pastes B (Red) &
D (Gray) Middle

Paste C (Green) High

Results: Voiding Rank Paste – Reflow 1st

Oneway Analysis of VOID (% area) By PASTE-PROFILE



Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

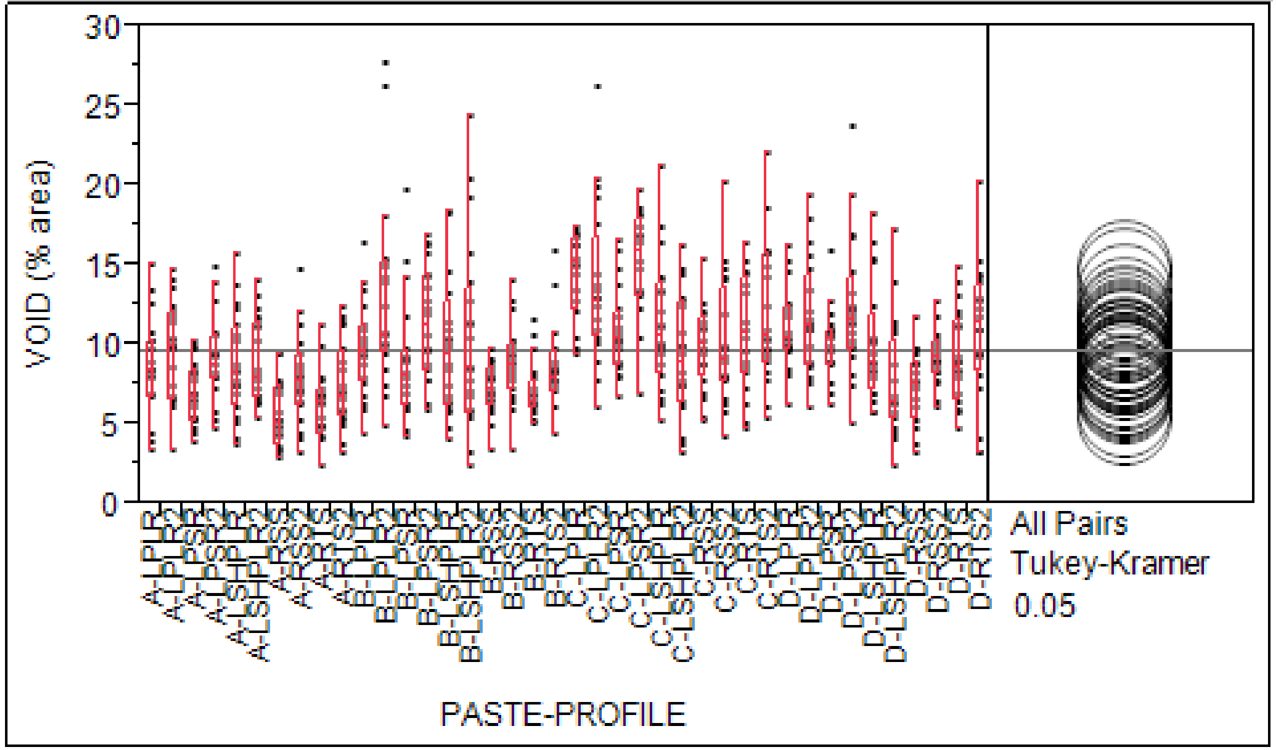
Connecting Letters Report

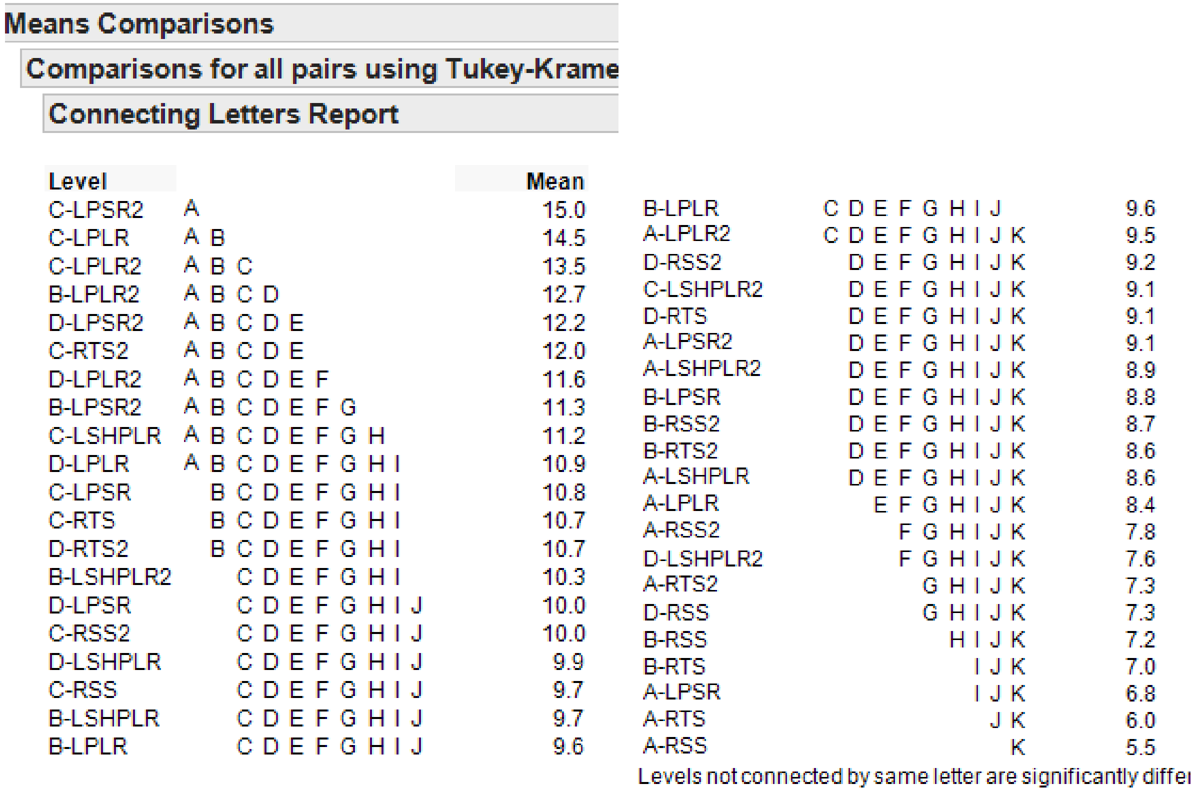
Level						Mean
C-LPLR	A					14.5
C-LSHPLR		B				11.2
D-LPLR		B				10.9
C-LPSR		B				10.8
C-RTS		B				10.7
D-LPSR		B	C			10.0
D-LSHPLR		B	C			9.9
C-RSS		B	C			9.7
B-LSHPLR		B	C			9.7
B-LPLR		B	C			9.6
D-RTS		B	C	D		9.1
B-LPSR		B	C	D		8.8
A-LSHPLR		B	C	D	E	8.6
A-LPLR		B	C	D	E	8.4
D-RSS			C	D	E	7.3
B-RSS			C	D	E	7.2
B-RTS			C	D	E	7.0
A-LPSR			C	D	E	6.8
A-RTS				D	E	6.0
A-RSS					E	5.5

Levels not connected by same letter are significantly different.

Results: Voiding Rank Paste – Reflows Both

Oneway Analysis of VOID (% area) By PASTE-PROFILE





Means Comparisons

Comparisons for all pairs using Tukey-Krame

Connecting Letters Report

Level		Mean
C-LPSR2	A	15.0
C-LPLR	A B	14.5
C-LPLR2	A B C	13.5
B-LPLR2	A B C D	12.7
D-LPSR2	A B C D E	12.2
C-RTS2	A B C D E	12.0
D-LPLR2	A B C D E F	11.6
B-LPSR2	A B C D E F G	11.3
C-LSHPLR	A B C D E F G H	11.2
D-LPLR	A B C D E F G H I	10.9
C-LPSR	B C D E F G H I	10.8
C-RTS	B C D E F G H I	10.7
D-RTS2	B C D E F G H I	10.7
B-LSHPLR2	C D E F G H I	10.3
D-LPSR	C D E F G H I J	10.0
C-RSS2	C D E F G H I J	10.0
D-LSHPLR	C D E F G H I J	9.9
C-RSS	C D E F G H I J	9.7
B-LSHPLR	C D E F G H I J	9.7
B-LPLR	C D E F G H I J	9.6
B-LPLR	C D E F G H I J	9.6
A-LPLR2	C D E F G H I J K	9.5
D-RSS2	D E F G H I J K	9.2
C-LSHPLR2	D E F G H I J K	9.1
D-RTS	D E F G H I J K	9.1
A-LPSR2	D E F G H I J K	9.1
A-LSHPLR2	D E F G H I J K	8.9
B-LPSR	D E F G H I J K	8.8
B-RSS2	D E F G H I J K	8.7
B-RTS2	D E F G H I J K	8.6
A-LSHPLR	D E F G H I J K	8.6
A-LPLR	E F G H I J K	8.4
A-RSS2	F G H I J K	7.8
D-LSHPLR2	F G H I J K	7.6
A-RTS2	G H I J K	7.3
D-RSS	G H I J K	7.3
B-RSS	H I J K	7.2
B-RTS	I J K	7.0
A-LPSR	I J K	6.8
A-RTS	J K	6.0
A-RSS	K	5.5

Levels not connected by same letter are significantly diffe

Results: 2nd Reflow Effect on Voiding

- 2nd reflow increased voids by 1.7% area

Paste – Profile 1	Mean Void Area (%)	Paste – Profile 2	Mean Void Area (%)
A-LPLR	8.4	A-LPLR2	9.5
A-LPSR	6.8	A-LPSR2	9.1
A-LSHPLR	8.6	A-LSHPLR2	8.9
A-RSS	5.5	A-RSS2	7.8
A-RTS	6.0	A-RTS2	7.3
B-LPLR	9.6	B-LPLR2	12.7
B-LPSR	8.8	B-LPSR2	11.3
B-LSHPLR	9.7	B-LSHPLR2	10.3
B-RSS	7.2	B-RSS2	8.7
B-RTS	7.0	B-RTS2	8.6
C-LPLR	14.5	C-LPLR2	13.5
C-LPSR	10.8	C-LPSR2	15.0
C-LSHPLR	11.2	C-LSHPLR2	9.1
C-RSS	9.7	C-RSS2	10.0
C-RTS	10.7	C-RTS2	12.0
D-LPLR	10.9	D-LPLR2	11.6
D-LPSR	10.0	D-LPSR2	12.2
D-LSHPLR	9.9	D-LSHPLR2	7.6
D-RSS	7.3	D-RSS2	9.2
D-RTS	9.1	D-RTS2	10.7

Results: 2nd Reflow Effect on Voiding

- Only 3 of 40 combinations decreased voiding with 2nd reflow:

Solder Paste	Reflow Profile	Decrease in Voiding Mean (% Area)
C	LPLR	-1.0
C	LSHPLR	-2.1
D	LSHPLR	-2.3

Conclusions

Conclusions

- Solder pastes had a significant effect on voiding
  - C = Highest voiding
  - A = Lowest voiding
- Reflow profiles influenced voiding
  - LPLR (Low Peak – Long Reflow) gave higher voiding than most
  - RSS (Ramp – Soak - Spike) gave lower voiding than most
- 2nd reflow increased voiding area
- Some combinations of paste - profile gave high results & some lower results
  - Many combinations showed no significant difference

Thank You! Any Questions?

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FCT Solder