MEETING THE CHALLENGES OF ULTRA-FINE FEATURE PRINTING AND REFLOW THROUGH OPTIMIZATION OF PB-FREE SOLDER PASTE

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Outline/Agenda

- Introduction
  - Miniaturization of electronics & the need for Type 6 solder pastes
  - Challenges of Type 6 solder pastes
- Discussion Topics
  - Experimental design to challenge the solder pastes
- Results of Experiments
  - Print and pause data over time
  - Reflow data in 3 conditions
  - Voiding
  - Aging, tack force, & viscosity
- Conclusions
- Q & A

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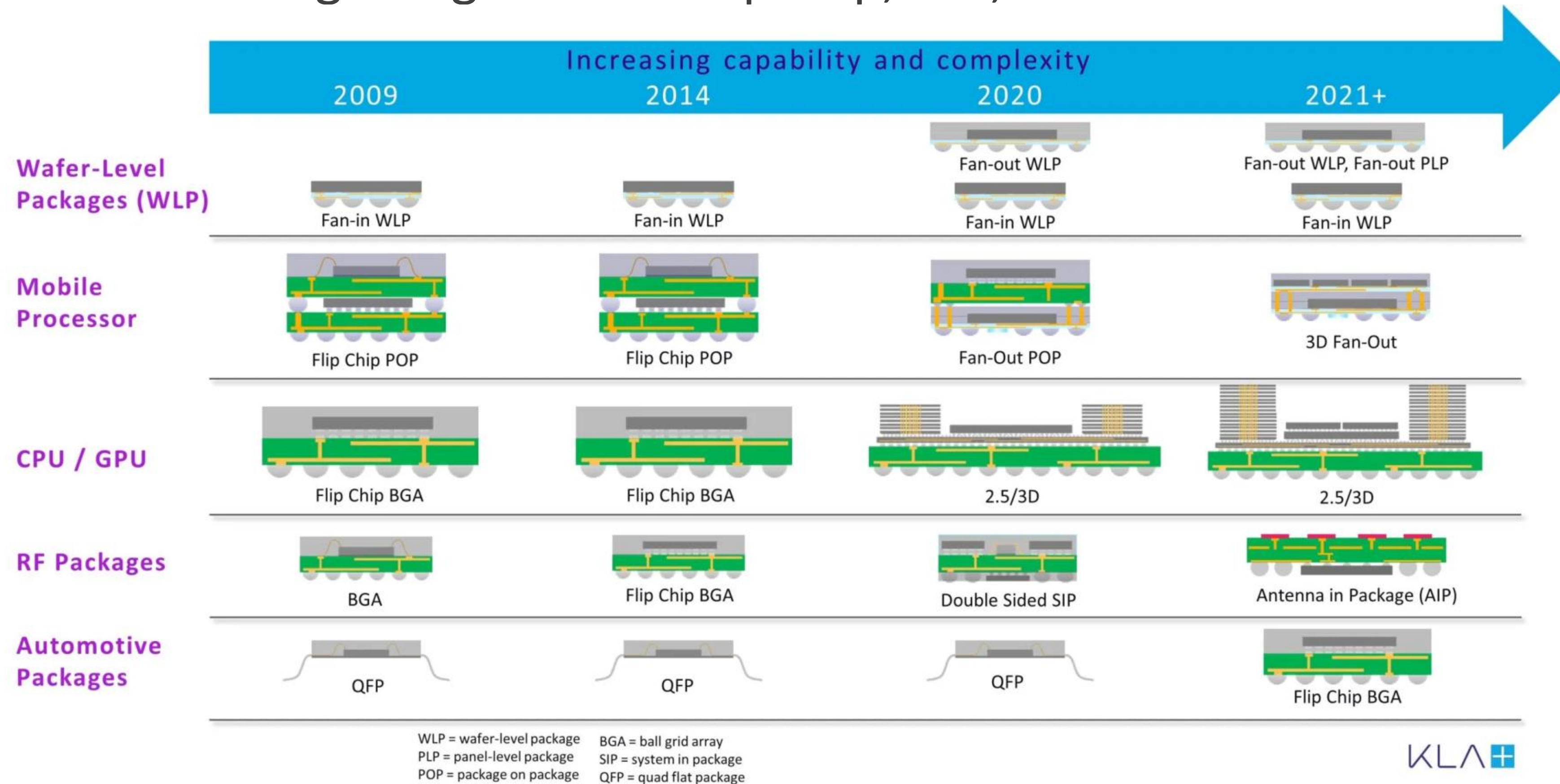
Introduction

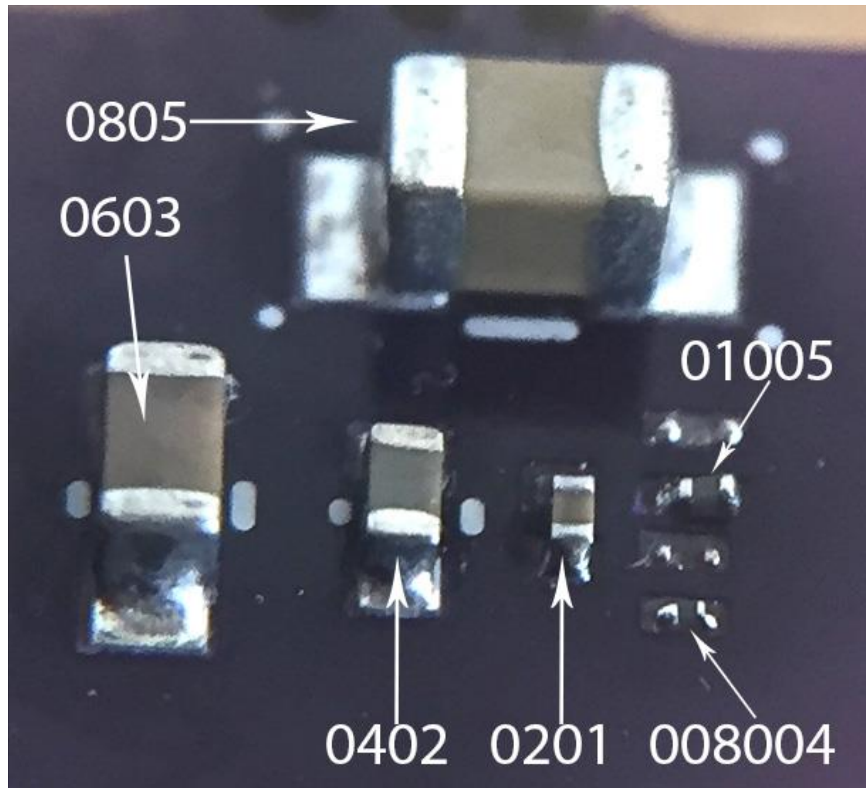
- Electronics are getting smaller: Flip chip, PoP, SiP

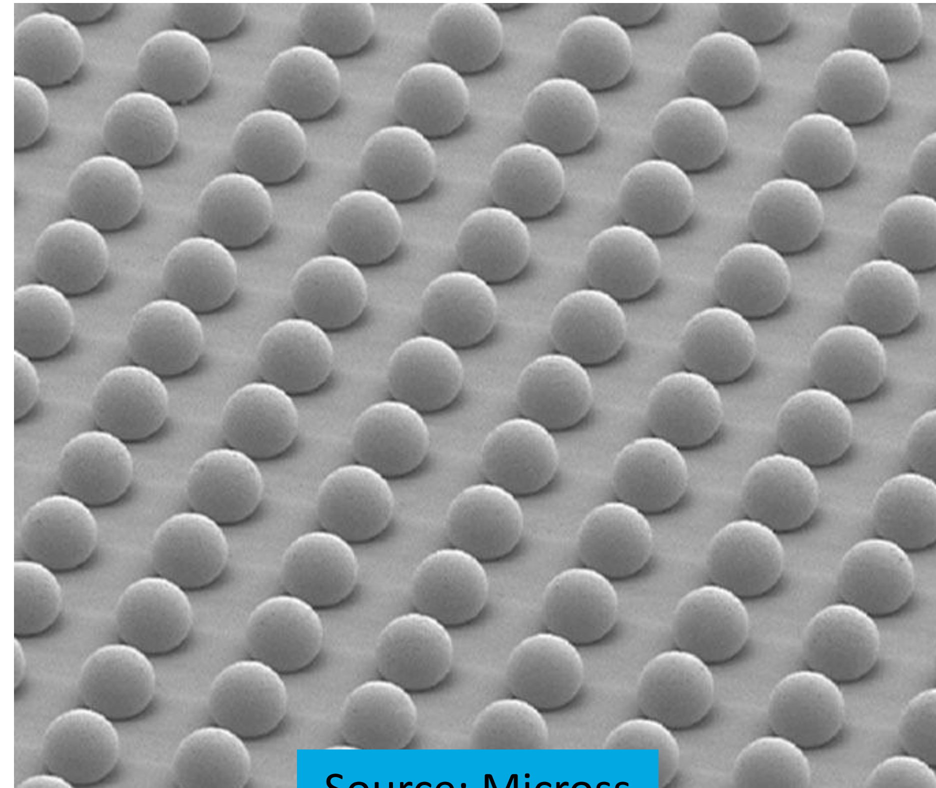


Source: KLA

Introduction

- Printing through 50-100 µm apertures requires smaller powder sizes

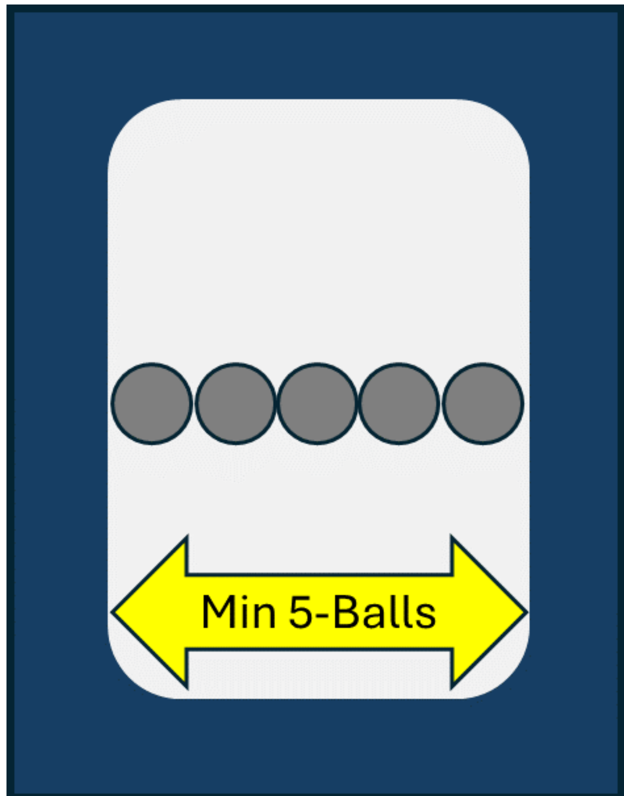




Source: Micross

Introduction

- Solder powder size and the “5-ball” rule



IPC Type	Size (µm)	Size (mils)	Smallest Aperture 5-Ball Rule (mils)	Smallest Aperture Recommended (mils)
2	45 - 75	1.8 - 3.0	15.0	16 - 17
3	25 - 45	1.0 - 1.8	9.0	10 - 11
4	20 - 38	0.8 - 1.5	7.5	9 - 10
5	15 - 25	0.6 - 1.0	5.0	6 - 7
6	5 - 15	0.2 - 0.6	3.0	4 - 5
7	2 - 11	0.1 - 0.4	2.0	3 - 4

Introduction

- Challenges of Type 6 solder pastes
  - High surface area
  - Increased activity
  - Oxidation barrier
  - Rheology tuned for application

Solder Powder Size (IPC Type)	Size Range of > 80% (µm)	Middle Surface Area of 1Kg (m^2)	Amount of Surface Area Over T3
Type 3	25 - 45	22.9	-
Type 4	20 - 38	27.7	1.2x
Type 5	15 - 25	40.2	1.7x
Type 6	5 - 15	80.3	3.5x

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Introduction

- Relative cost of solder powders
  - Significant cost jump from T5 to T6
  - Can the application allow for T5??

Type	Relative Powder Cost
3	1
4	1
5	1.1
6	4

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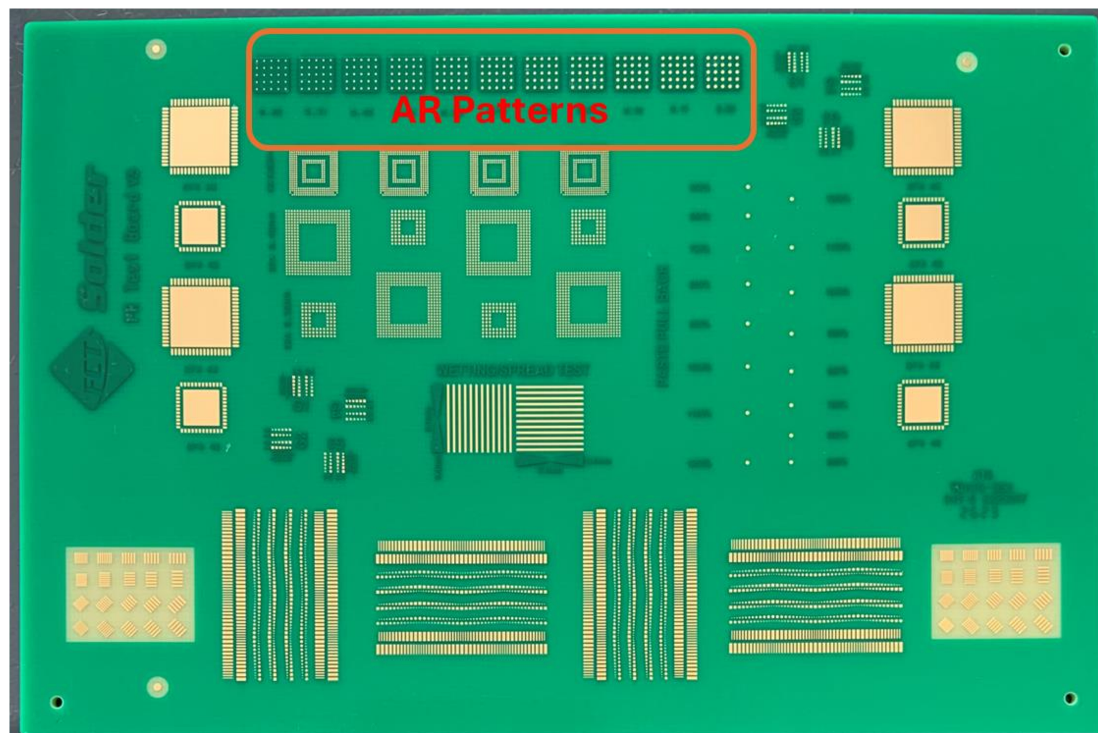
Experimental Design – Solder Pastes

Solder Paste	Flux Class (J-STD-004)
NC New	ROL0
NC New 2	ROL0
NC Old	ROL0
WS New	ORH1
WS Old	ORH1

All made with SAC305 Type 6 (5-15 µm) solder powder

Experimental Design – PR Test Board

- 75 micron (3 mil) laser cut FG stencil
- SMD pads



Area Ratio*	Aperture Size (mils)	Theoretical Vol (mils³)	# Type 6 "Balls"	Aspect Ratio*
0.30	3.40	32.1	5.7	1.13
0.35	3.96	44.5	6.6	1.32
0.40	4.54	59.3	7.6	1.51
0.45	5.12	76.0	8.5	1.71
0.50	5.70	94.9	9.5	1.90
0.55	6.29	116.1	10.5	2.10
0.60	6.88	139.4	11.5	2.29
0.65	7.47	164.8	12.5	2.49
0.70	8.06	192.3	13.4	2.69
0.75	8.65	221.9	14.4	2.88
0.80	9.25	254.1	15.4	3.08

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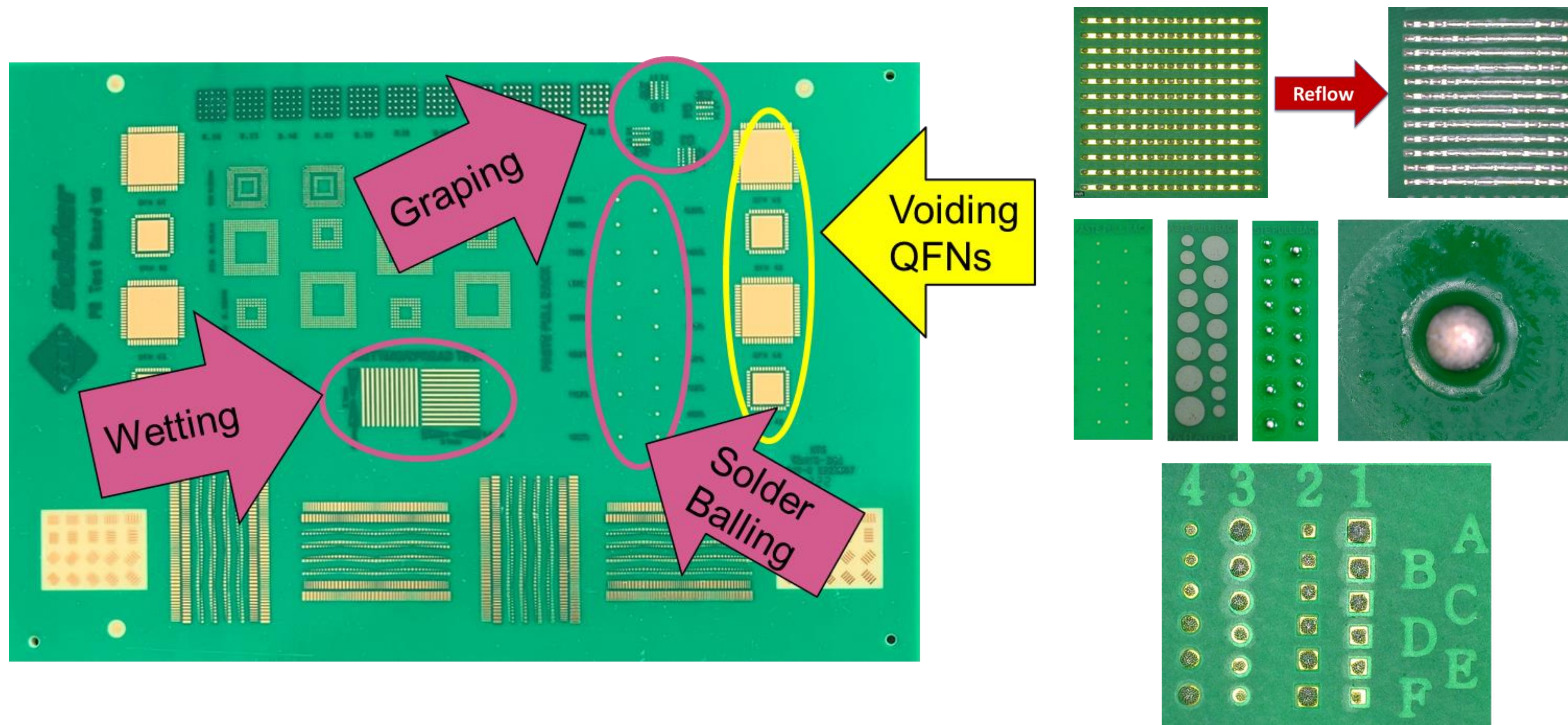
Experimental Design – PR Test Board



Experimental Design – Print & Reflow Parameters

Print Parameter	Value
Print speed (mm/sec)	30 mm/sec
Blade length (mm)	300 mm
Print pressure (kg)	5.0 – 8.0 Kg
Separation speed (mm/sec)	3 mm/sec
Separation distance (mm)	2 mm

Reflow Parameter	SAC305 Ramp to Spike (RTS)	SAC305 Long Time Above Liquid (LTAL)
Soak Time (150-200°C)	76 to 78 sec	70 to 78 sec
Time Above Liquidus (>220°C)	57 to 59 sec	134 to 138 sec
Peak Temperature	241 to 244°C	247 to 250°C
Time from 25°C to Peak	4.4 to 4.6 min	5.6 to 5.8 min

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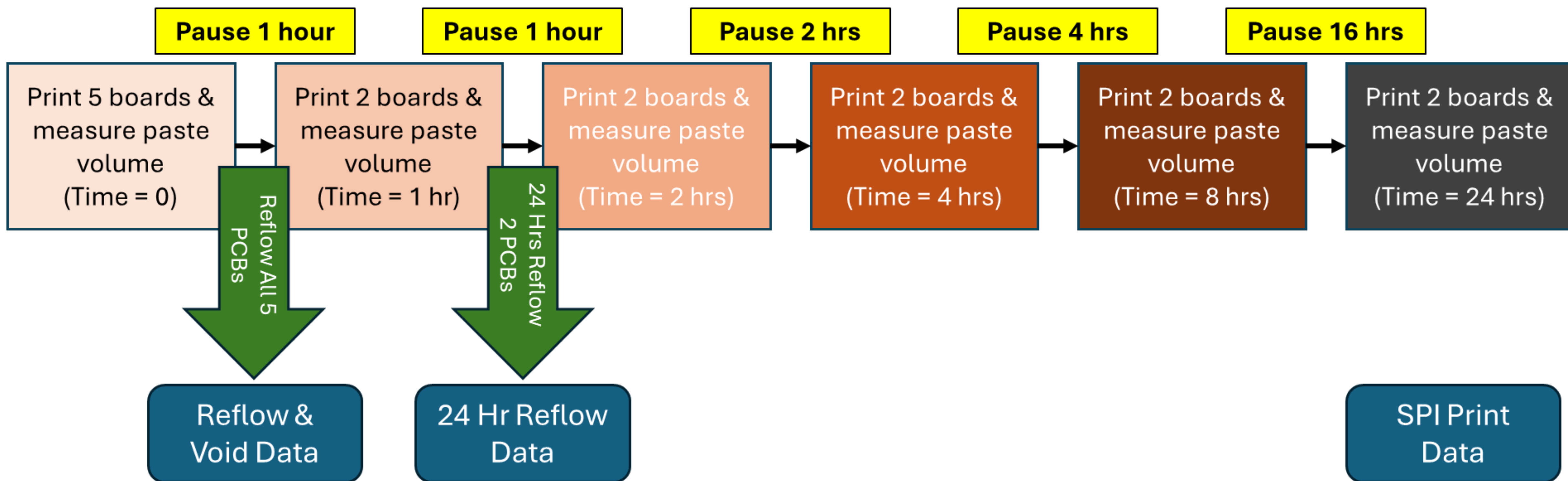
Experimental Design - Process

- 24 Hour Print & Pause



Experimental Design – Other Tests

- Reflow 5 PCBs in the LTAL profile
- Tack force initial & after 1, 2 & 3 days
  - 21-22°C (70-72°F) & 48-54% RH
- Viscosity initial
- Tack force & viscosity after heat aging
  - 34-36°C (93-97°F) for 3 days

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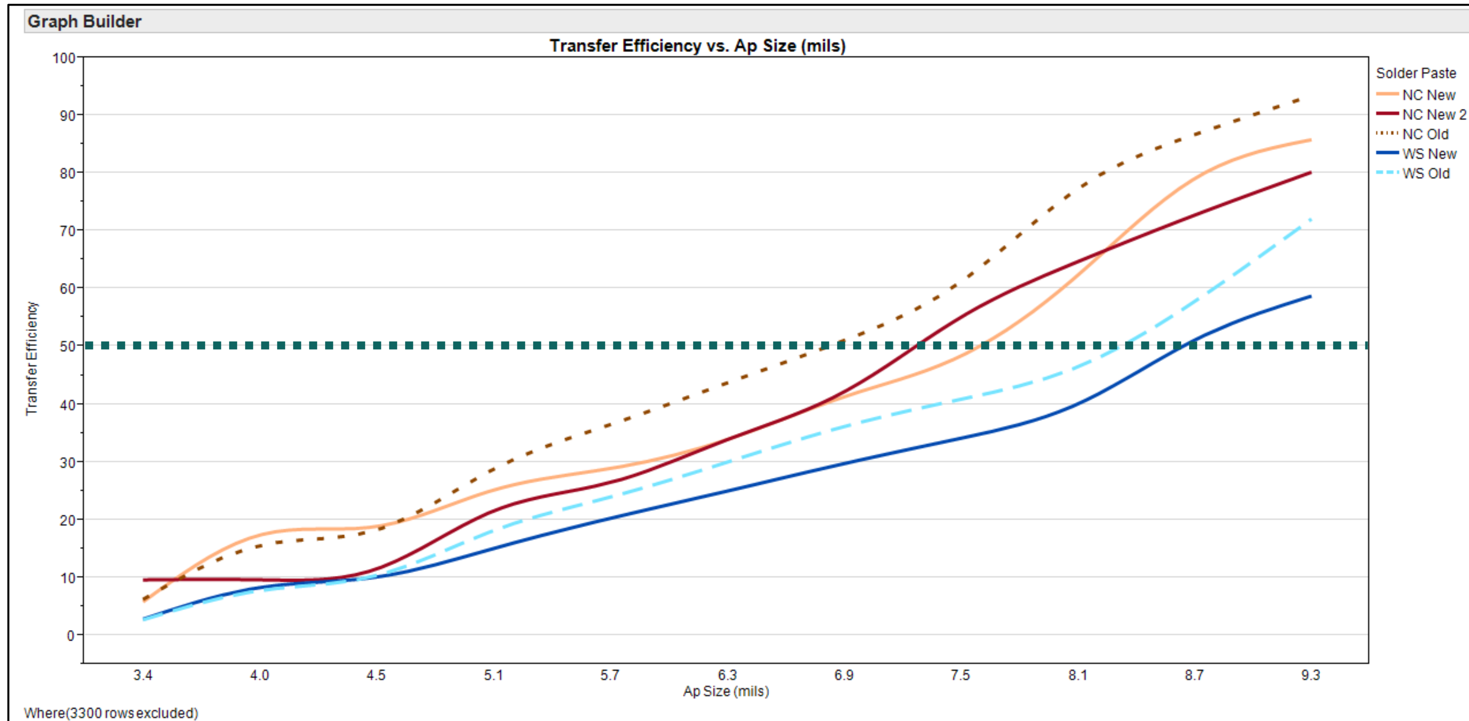
Results – Initial TE%, All ARs



Min Aperture Size and AR for > 50% TE

Solder Paste	Min Aperture Size (mils)	Min Area Ratio
NC New	7.5	0.65
NC New 2	6.9	0.60
NC Old	6.9	0.60
WS New	8.7	0.75
WS Old	8.1	0.70

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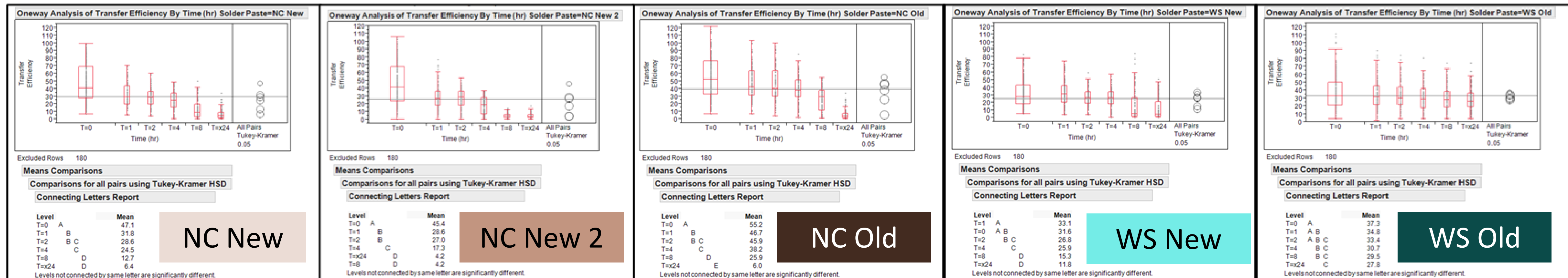
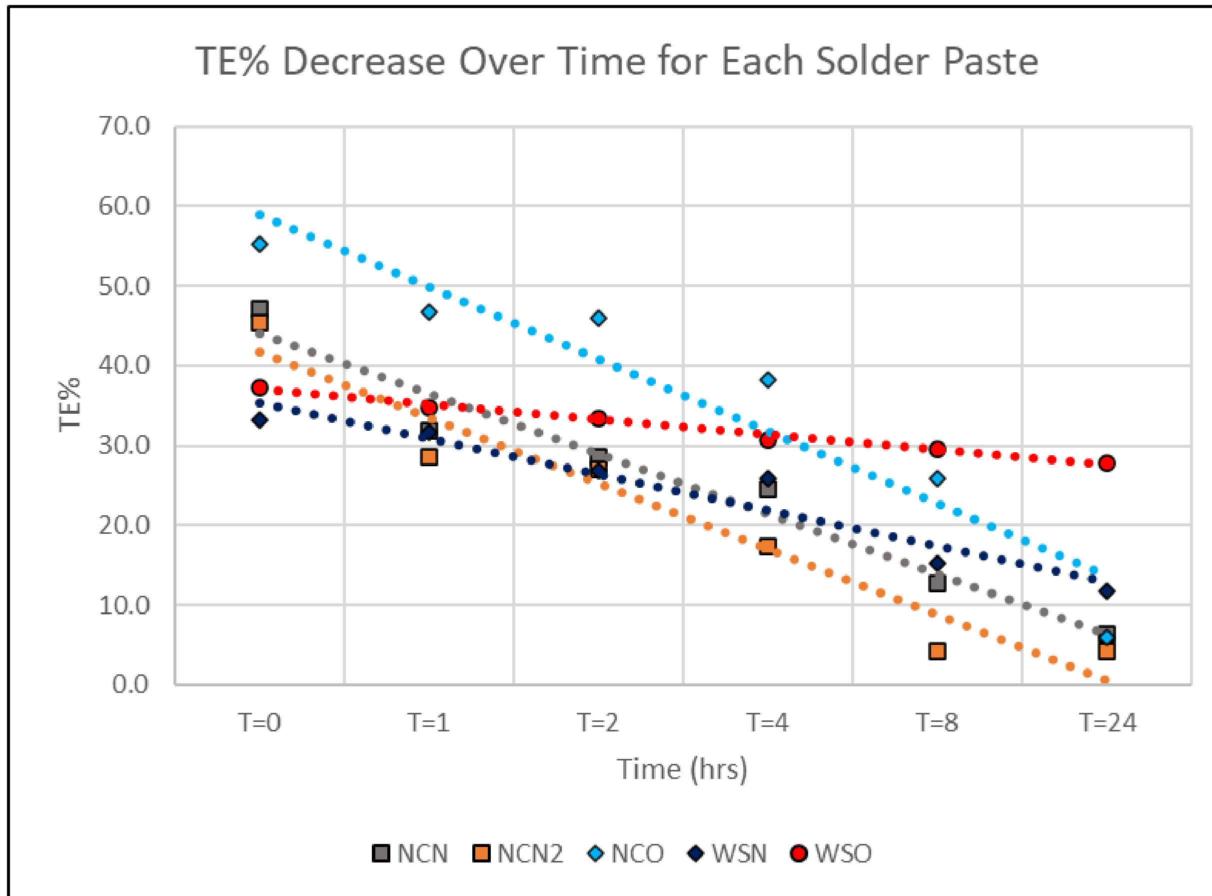
Results – Print & Pause, ARs > 0.35



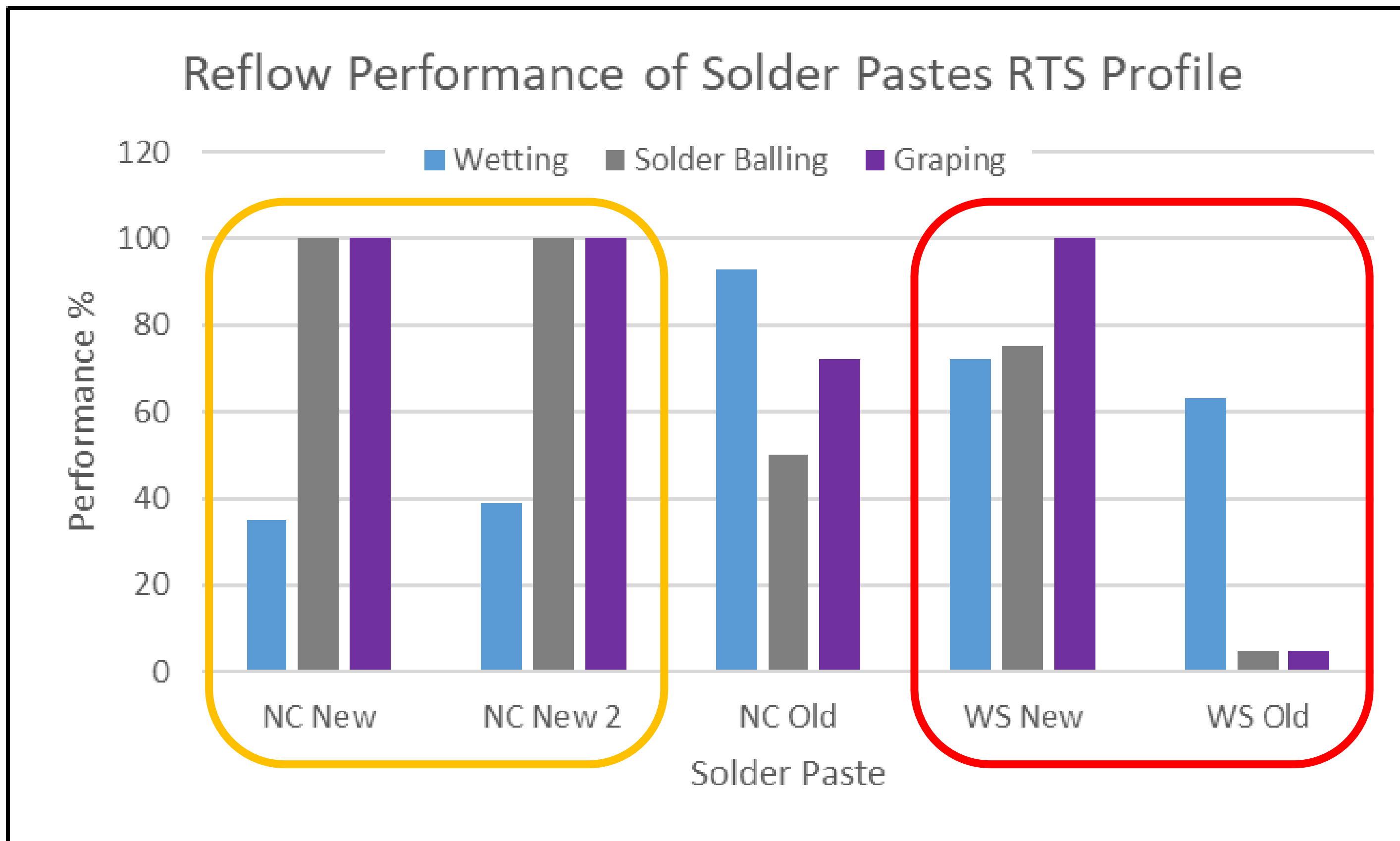
All TE% Dropped Over 24 Hrs

Results – Print & Pause, ARs > 0.35



- **NC New = slower 0.8x TE% drop vs. NC Old**
- **NC New 2 = slower 0.9x TE% drop vs. NC Old**
- **WS New = faster 2.4x TE% drop vs. WS Old**

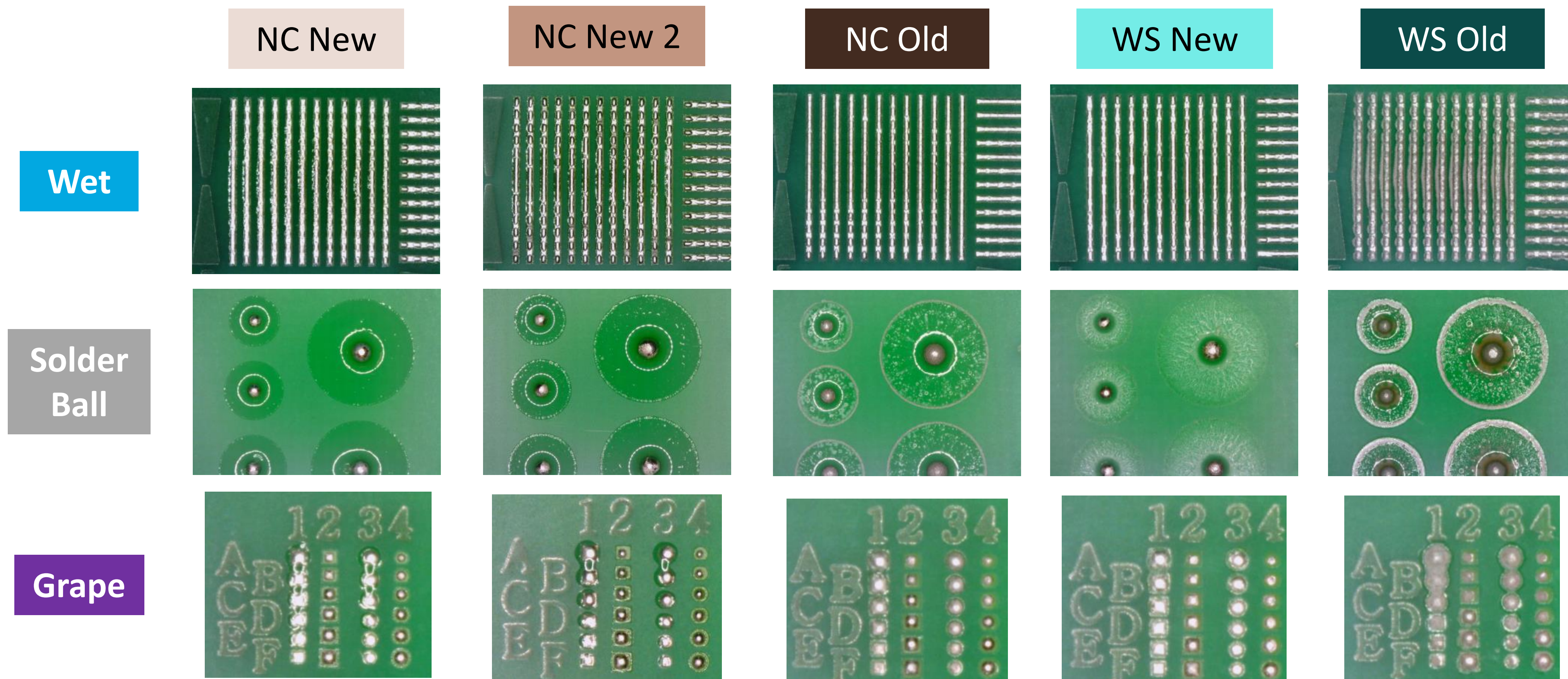
Results – Reflow Ramp to Spike (RTS)



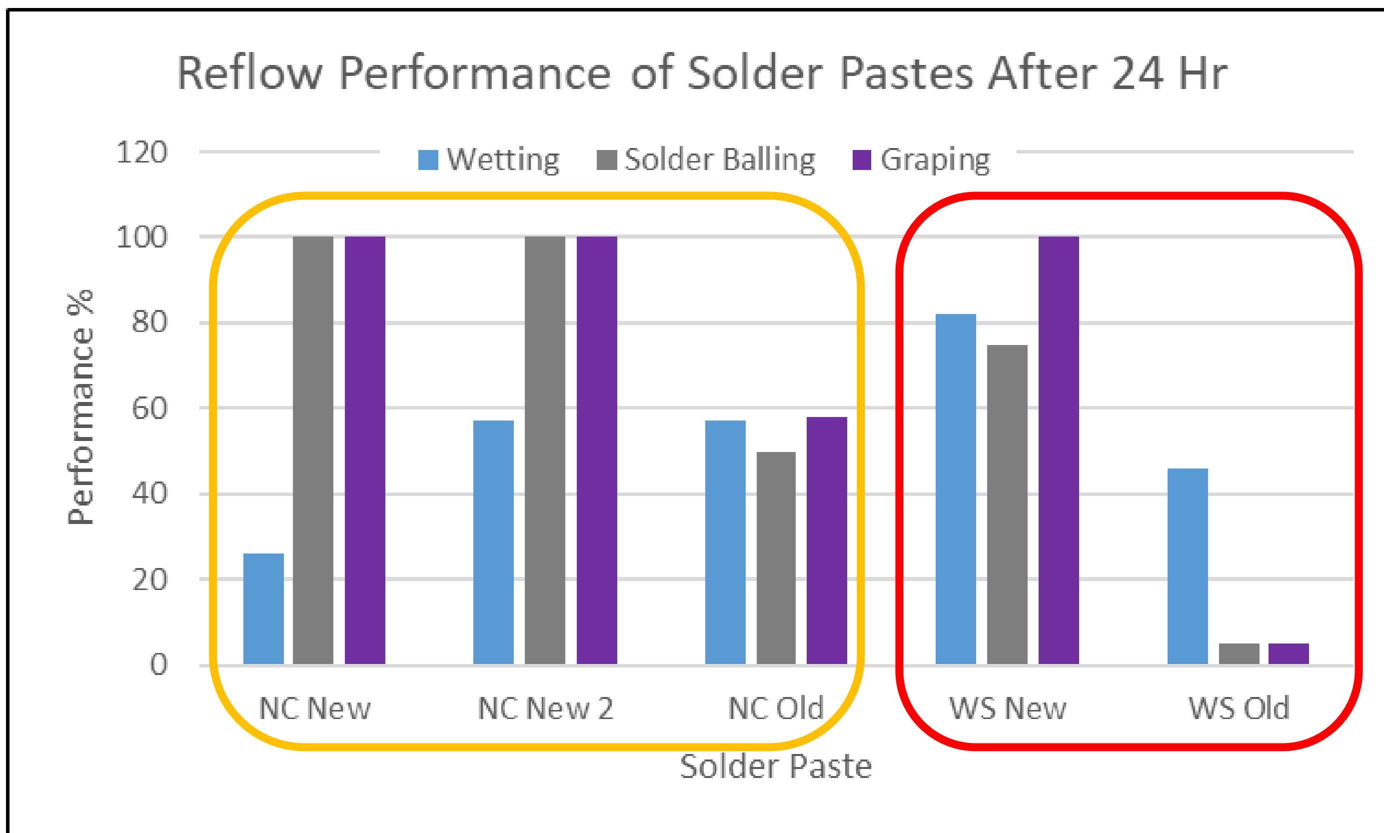
Reflow Parameter	SAC305 Ramp to Spike (RTS)
Soak Time (150-200°C)	76 to 78 sec
Time Above Liquidus (>220°C)	57 to 59 sec
Peak Temperature	241 to 244°C

- **NC New & NC New 2 ideal solder balling and graping**
- **WS New overall better reflow than WS Old**

Results – Wet, Solder Ball, Graping - RTS



Results – Reflow After 24 Hrs in Air - RTS



- **NC New & NC New 2 overall better reflow than NC Old**
- **WS New overall better reflow than WS Old**
- **Air exposure improved NC New 2 reflow**

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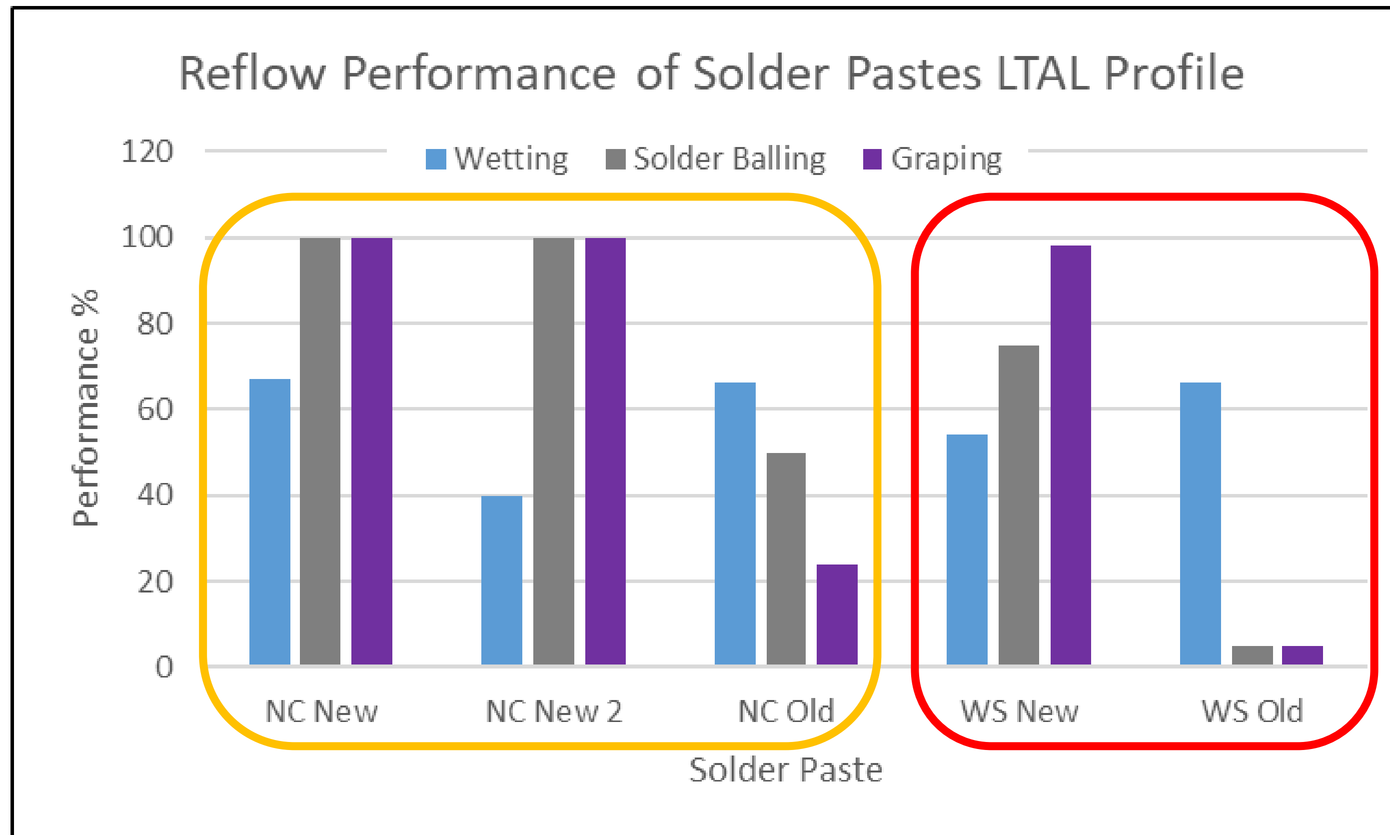
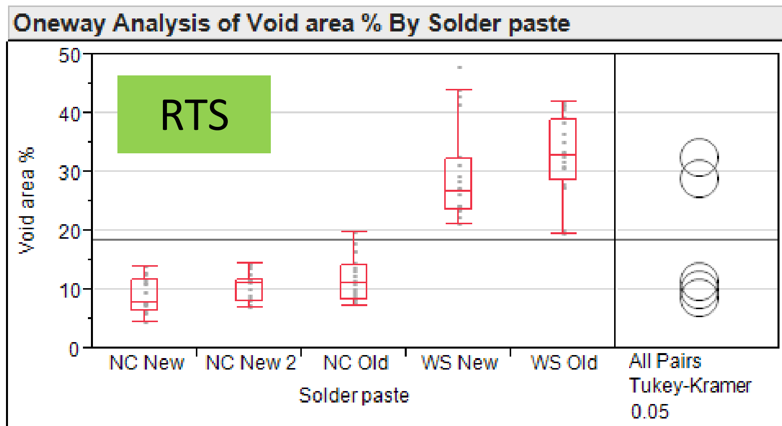
Results – Reflow Long Time Above Liquid (LTAL)



Reflow Parameter	SAC305 Long Time Above Liquid (LTAL)
Soak Time (150-200°C)	70 to 78 sec
Time Above Liquidus (>220°C)	134 to 138 sec
Peak Temperature	247 to 250°C

- **NC New & NC New 2 overall better reflow than NC Old**
- **WS New overall better reflow than WS Old**

Results – Voiding by Profile



Excluded Rows 100

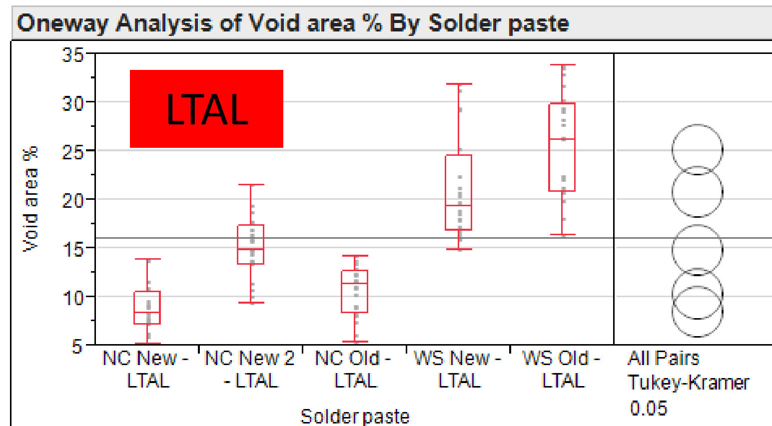
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
WS Old	A	32.9
WS New	A	29.3
NC Old	B	11.7
NC New 2	B	10.4
NC New	B	8.9

Levels not connected by same letter are significantly different.



Excluded Rows 100

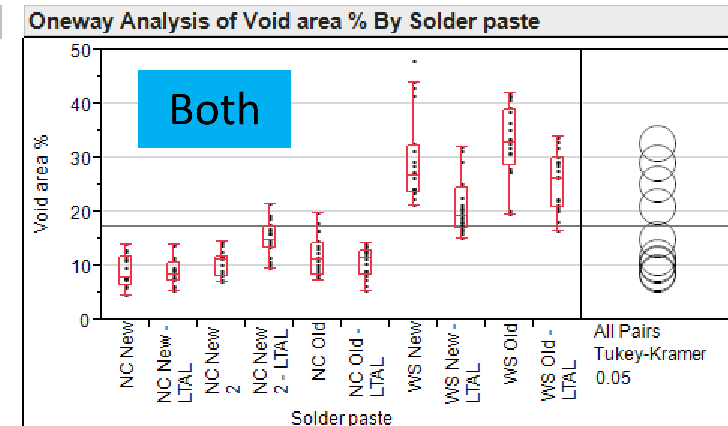
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level					Mean
WS Old - LTAL	A				25.3
WS New - LTAL		B			21.1
NC New 2 - LTAL			C		15.0
NC Old - LTAL				D	10.6
NC New - LTAL				D	8.7

Levels not connected by same letter are significantly different.



Means Comparisons

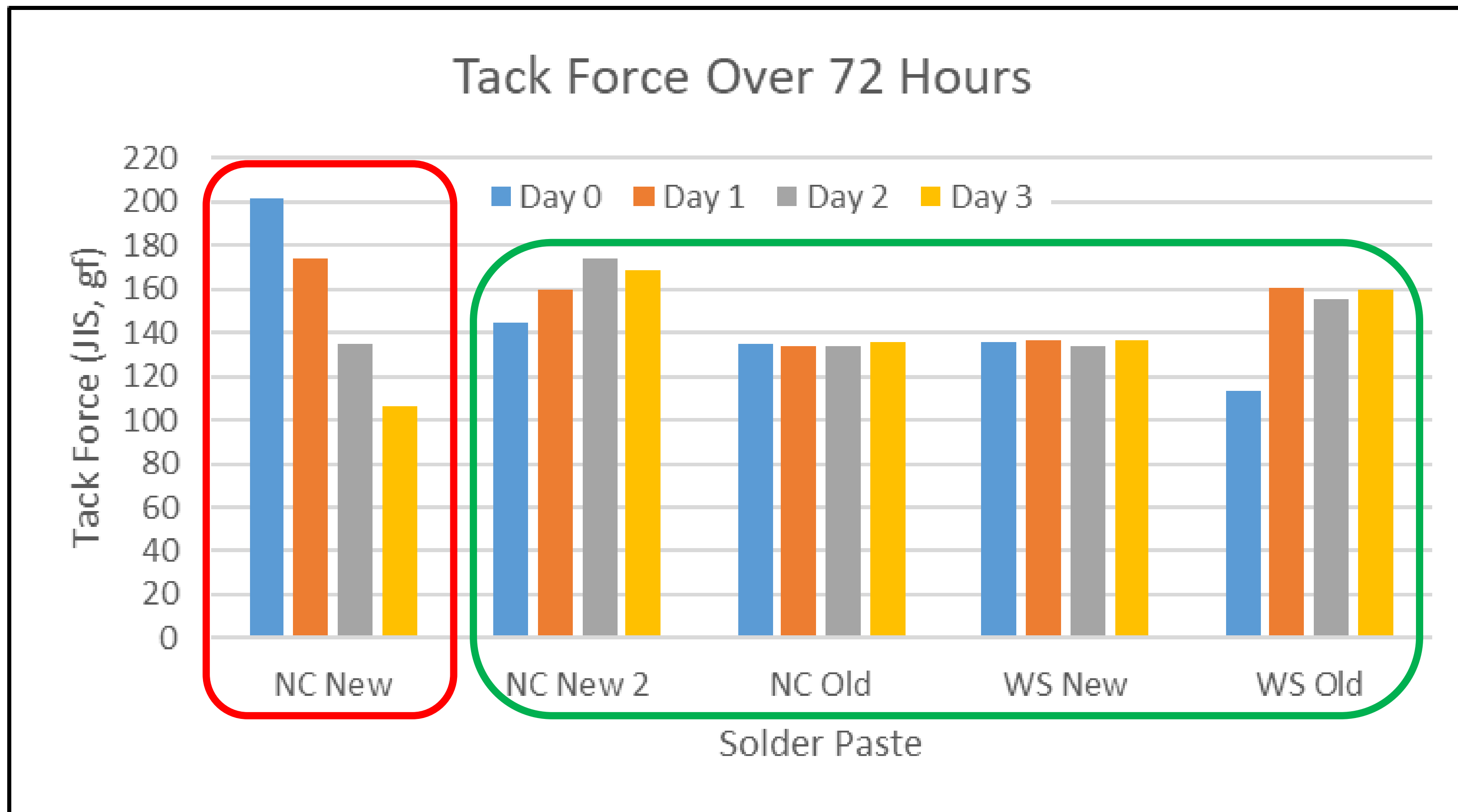
Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level						Mean
WS Old	A					32.9
WS New	A	B				29.3
WS Old - LTAL		B	C			25.3
WS New - LTAL			C			21.1
NC New 2 - LTAL				D		15.0
NC Old				D	E	11.7
NC Old - LTAL				D	E	10.6
NC New 2				D	E	10.4
NC New					E	8.9
NC New - LTAL					E	8.7

Levels not connected by same letter are significantly different.

Results – Tack Force Over 3 Days



- **NC New tack decreased significantly (unstable)**
- **All others are stable**
- **Slight increase is normal**

Results – Viscosity & Heat Aging

Solder Paste	Viscosity Initial (Kcps)	Viscosity After Heat Aging (Kcps)	Viscosity Increase (%)
NC New	1030	Not measurable	N/A
NC New 2	640	1001	56%
NC Old	430	487	13%
WS New	120	154	28%
WS Old	390	510	31%

- **NC New unstable in heat**
- **NC New 2 some increase**
- **All others are stable**

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Results – Tack Force & Heat Aging

Solder Paste	Tack Force (gf)	Tack Force After Heat Aging (gf)	Tack Force Change (%)
NC New	202	104	48% decrease
NC New 2	145	173	19% increase
NC Old	135	134	1% decrease
WS New	136	132	3% decrease
WS Old	113	138	22% increase

- **NC New unstable in heat**
- **All others are stable – similar to Viscosity**

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Conclusions

- Print initial
  - NC New 2 >50% TE at 0.60 AR (175 µm = 6.9 mils)
  - WS New >50% TE to 0.75 AR (221 µm = 8.7 mils)
  - Printable down to 0.50 AR (145 µm = 5.7 mils) with >30% TE
- Print and pause
  - NC New 2 improved print and pause over NC Old
  - WS New worse print and pause over WS Old
- Reflow
  - NC New 2 & WS New much improved reflow over NC Old & WS Old in both profiles
  - Air Exposure (24 hours) improved NC New 2 reflow

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Conclusions (cont.)

- Voiding
  - NC New 2 & WS New improved voiding over NC Old & WS Old
  - Reflow profile can be used to minimize voiding
- Tack force
  - NC New 2 & WS New had stable tack force over time
- Heat aging
  - NC New 2 had some increase in viscosity & tack
  - WS New had slightly increased viscosity & stable tack
- The new solder pastes are capable for Type 6 solder powder
  - Further optimization is ongoing

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Thank You!

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