TECHNOLOGY'S FUTURE COMES TOGETHER

SAN DIEGO CONVENTION CENTER, CA, USA

Size Matters - The Effects of Solder Powder Size on Solder Paste Performance

Tony Lentz
FCT Assembly
tlentz@fctassembly.com

Table of Contents

Introduction

Solder Powder Size and Printing

Solder Powder Size and Reactivity

Test Methodology

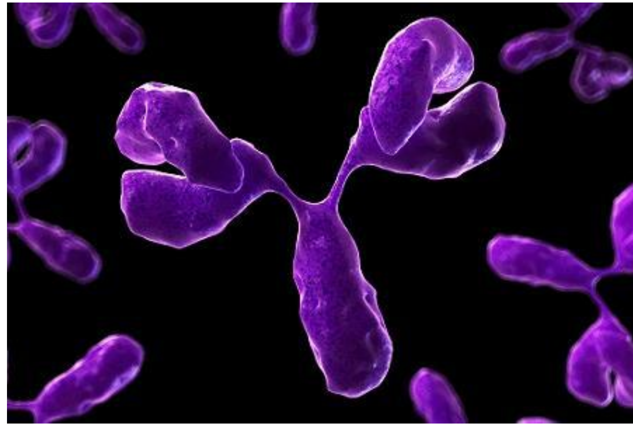
Data (some data removed for brevity)

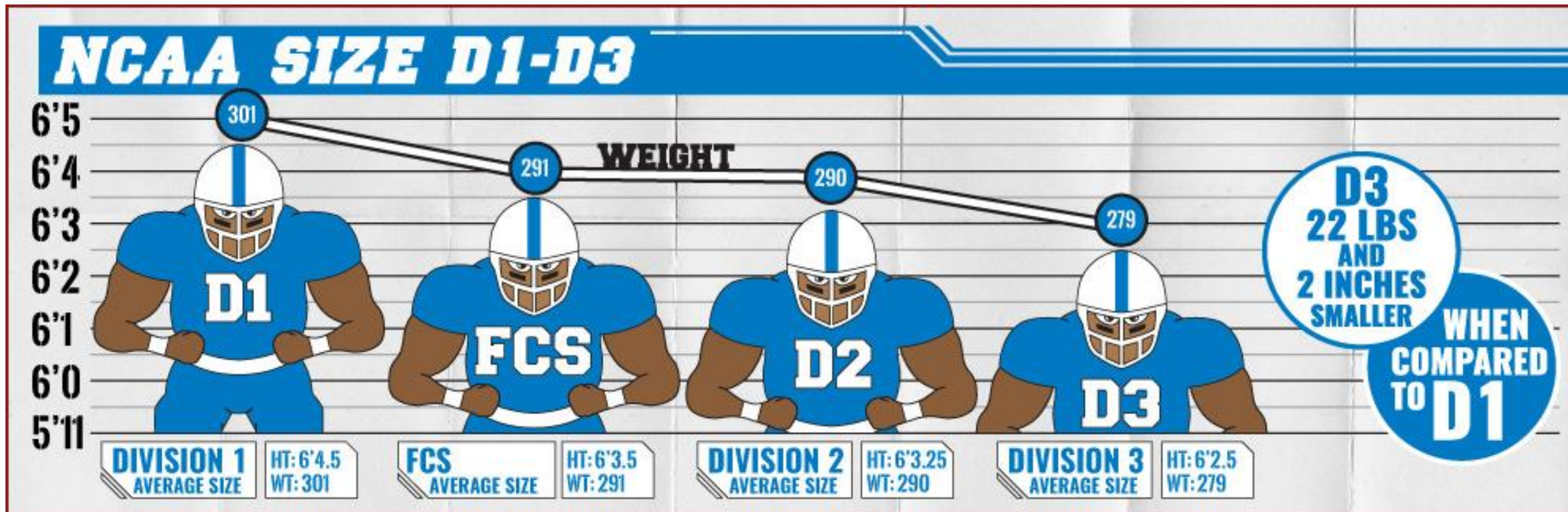
Summary & Conclusions

Questions?

Introduction

Size Matters in Many Ways





Solder Powder Size Matters

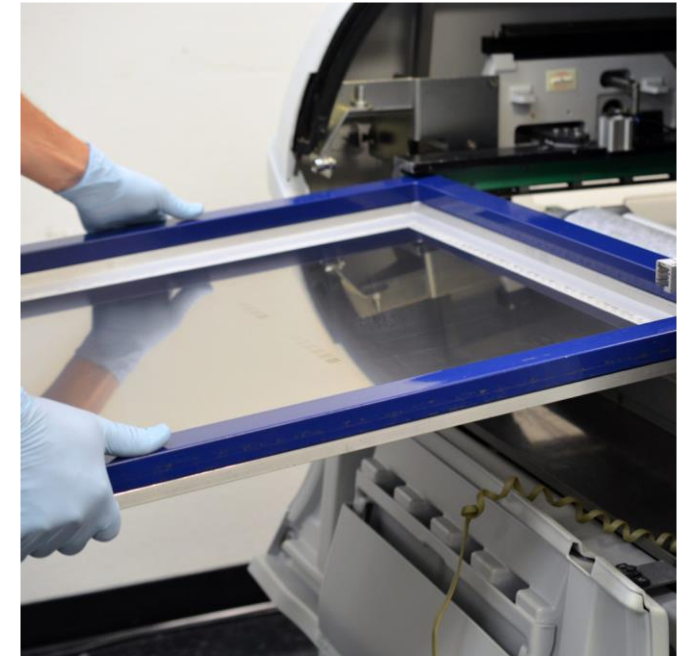
Type 3
25-45 µm

Type 4
20-38 µm

Type 5
15-25 µm

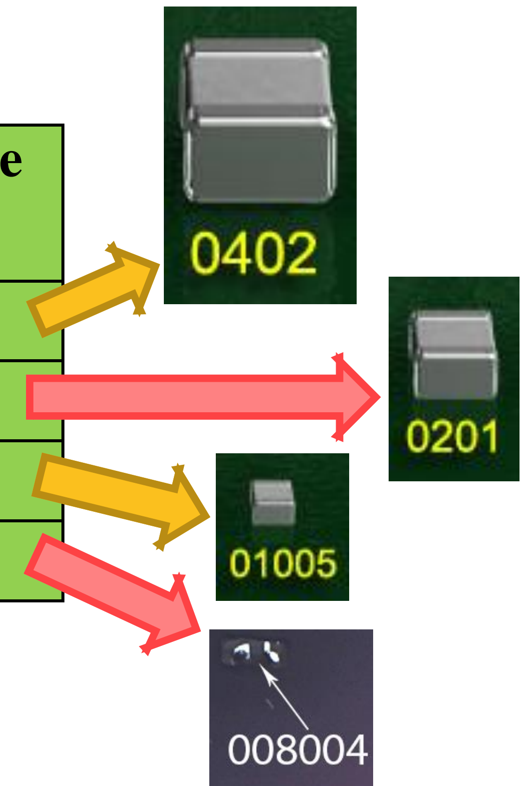
Type 6
5-15 µm

Solder Powder Size and Printing

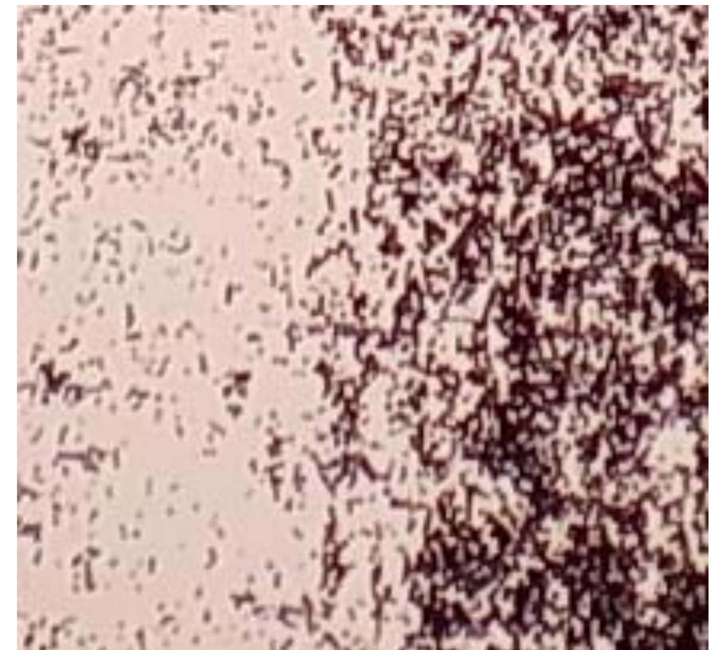


Solder Powder Size and Stencil Aperture Size (5-Ball Rule)

IPC Type	Size Range (µm)	Size Range (mil)	Minimum Aperture Size (mil)
T3	25 - 45	1.0 - 1.8	9
T4	20 - 38	0.8 - 1.5	7.5
T5	15 - 25	0.6 - 1.0	5
T6	5 - 15	0.2 - 0.6	3

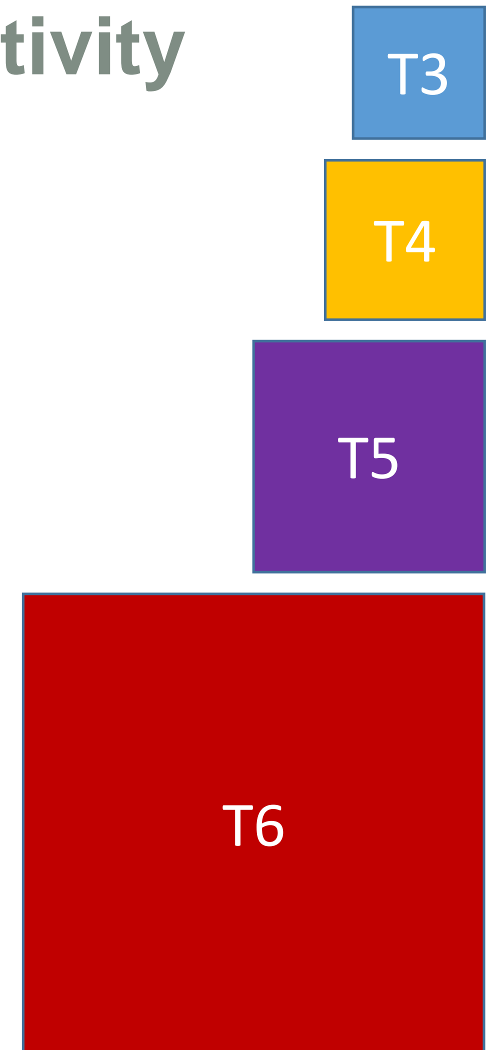


Solder Powder Size and Reactivity



Solder Powder Surface Area and Reactivity

IPC Type	Middle Surface Area of 1Kg (m^2)	Normalized Area	Amount of Surface Area Over T3 (%)
T3	22.9	1.00	-
T4	27.7	1.21	21
T5	40.2	1.75	75
T6	80.3	3.50	350

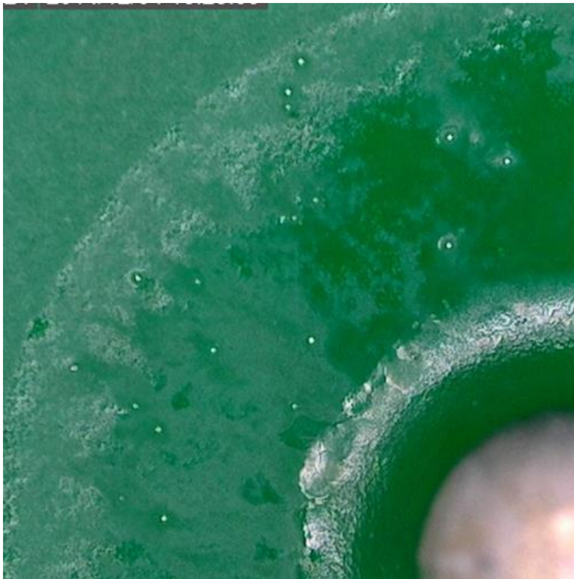


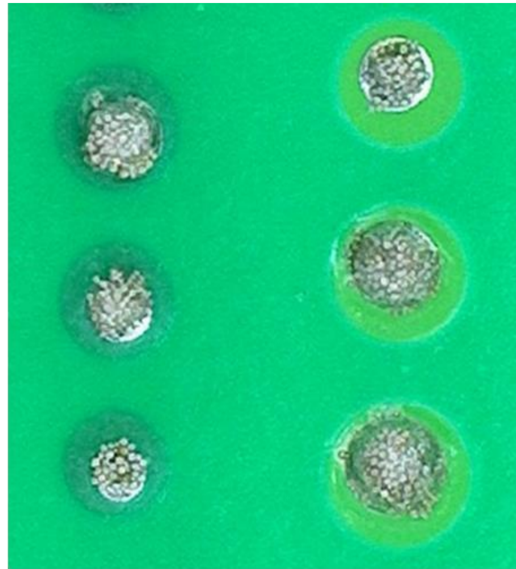
Surface Area and Reactivity

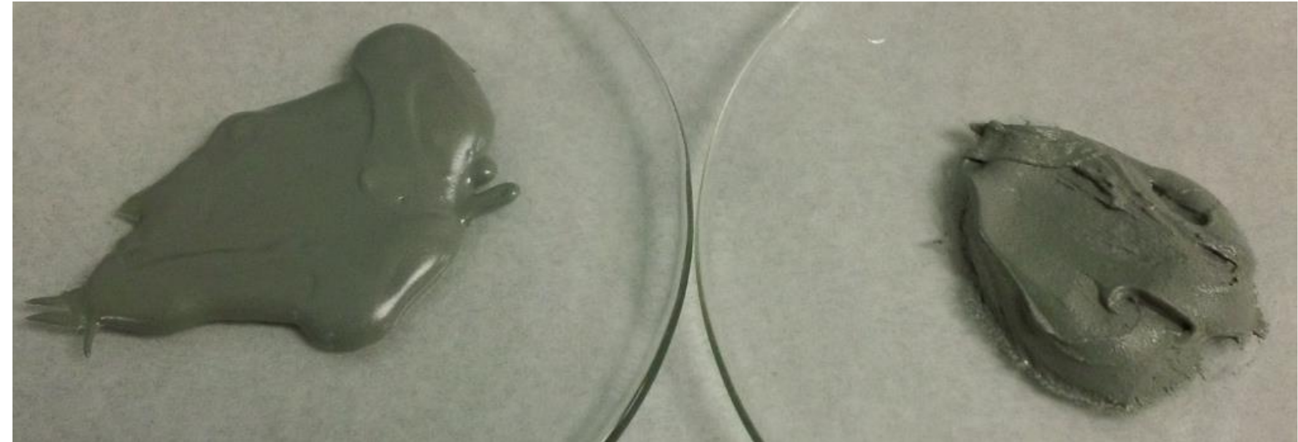
After 1 min mix

After 1 min mix

Smaller Solder Powders are Susceptible to Issues





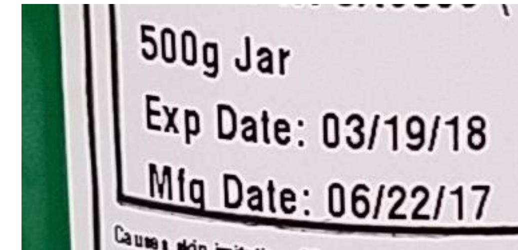


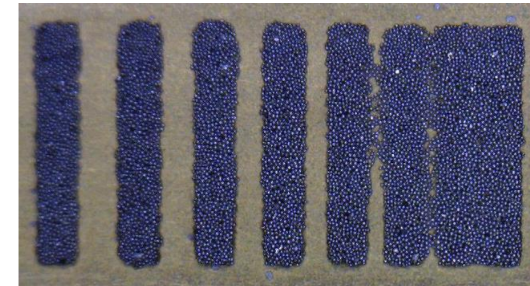
Fresh

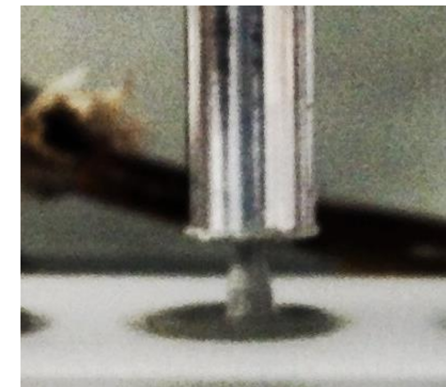
Aged

Solder Powder Size Effects on Solder Paste

- Shelf Life and Stencil Life
- Viscosity, Slump, and Solder Balling
- Tack Force Over Time
- Printing and Print / Pause
- Wetting, Graping, Voiding
- Stability or Reactivity







Test Methodology

PR Test Board

Print AR Limit

0.30 0.35 0.40 0.45 0.50

Reflow Graping

Print 0.4 mm Pitch BGA

Voiding QFNs

Reflow Wetting

Reflow Solder Balling

Solder Pastes

IPC Type	No Clean Metal Content (% wt)	Water Soluble Metal Content (% wt)
T3	88.5	88.5
T4	88.3	88.3
T5	88.0	88.0
T6	87.5	87.5
	ROL0	ORH1

Print and Pause Testing

Print 5 boards & measure solder paste volume (Time = 0) → Print 2 boards & measure volume (Time = 1 hr) → Print 2 boards & measure volume (Time = 2 hrs) → Print 2 boards & measure volume (Time = 4 hrs) → Print 2 boards & measure volume (Time = 8 hrs) → Print 2 boards & measure volume (Time = 24 hrs)

Wait 1 hour

Wait 1 hour

Wait 2 hours

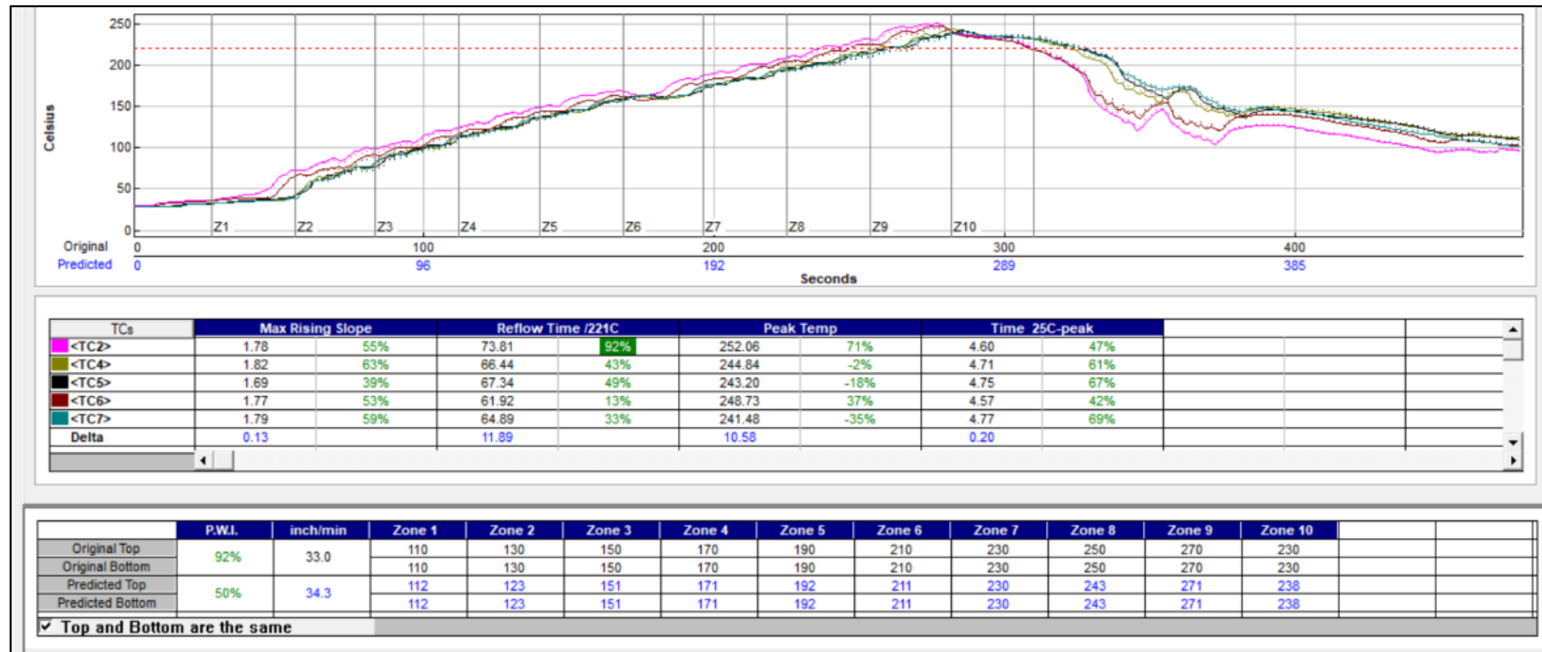
Wait 4 hours

Wait 16 hours

Reflow → Fresh Reflow

Reflow → 24 Hr Reflow

Reflow Testing



TCs	Max Rising Slope		Reflow Time /221C		Peak Temp		Time 25C-peak	
<TC2>	1.78	55%	73.81	92%	252.06	71%	4.60	47%
<TC4>	1.82	63%	66.44	43%	244.84	-2%	4.71	61%
<TC5>	1.69	39%	67.34	49%	243.20	-18%	4.75	67%
<TC6>	1.77	53%	61.92	13%	248.73	37%	4.57	42%
<TC7>	1.79	59%	64.89	33%	241.48	-35%	4.77	69%
Delta	0.13		11.89		10.58		0.20	

	P.W.I.	inch/min	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10
Original Top	92%	33.0	110	130	150	170	190	210	230	250	270	230
Original Bottom			110	130	150	170	190	210	230	250	270	230
Predicted Top	50%	34.3	112	123	151	171	192	211	230	243	271	238
Predicted Bottom			112	123	151	171	192	211	230	243	271	238

✓ Top and Bottom are the same

Setting	RTS Profile
Ramp rate	1.7 – 1.8 °C/sec
Reflow Time (>220 °C)	61 – 67 sec
Peak temperature	241 to 248 °C
Profile length (25 °C to peak)	4.70 minutes

Reflow: Freshly printed boards, and boards after 24 hours

Data: Wetting %, solder balling, graping, voiding

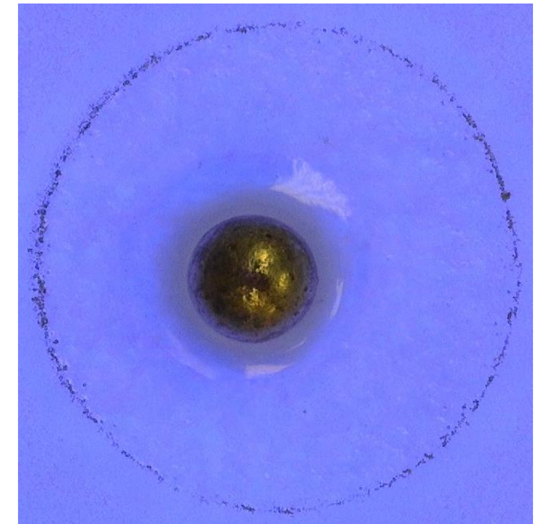
Standard Solder Paste Tests

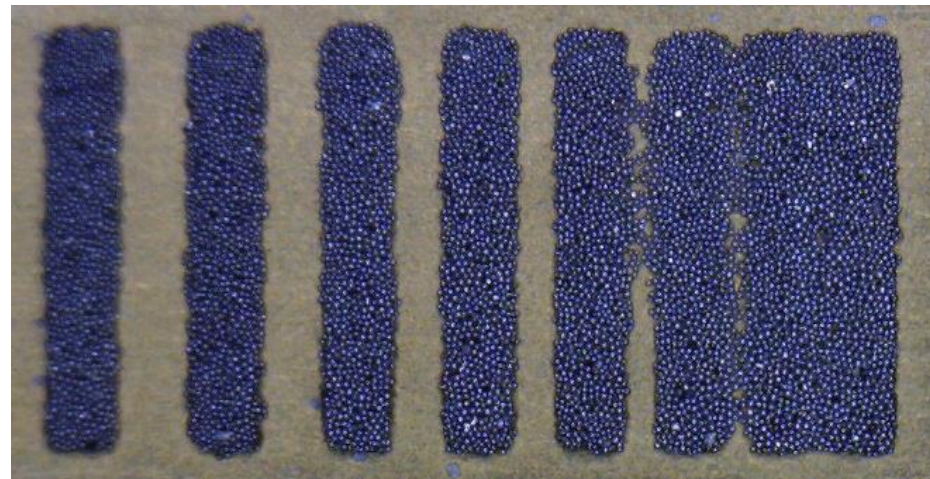
Viscosity: T-bar spindle, spiral pump

Slump (IPC J-STD-005)

Solder Balling (IPC J-STD-005)

Tack force over time: Fresh, 24, 48 and 72 hours





Aging / Stability Tests

Heat aging: 50 - 55 °C for 72 hours

Viscosity, solder balling, tack force, print, reflow

https://www.quora.com/Is-it-true-that-being-a-US-President-speeds-up-the-aging-process

Standard Solder Paste Tests

Solder Paste Viscosity

Viscosity T-Bar Spindle

Viscosity (KCps)

	SAC T3	SAC T4	SAC T5	SAC T6
No Clean	550	600	740	910
Water Soluble	730	710	700	790

Viscosity Spiral Pump

Viscosity (Pa-S)

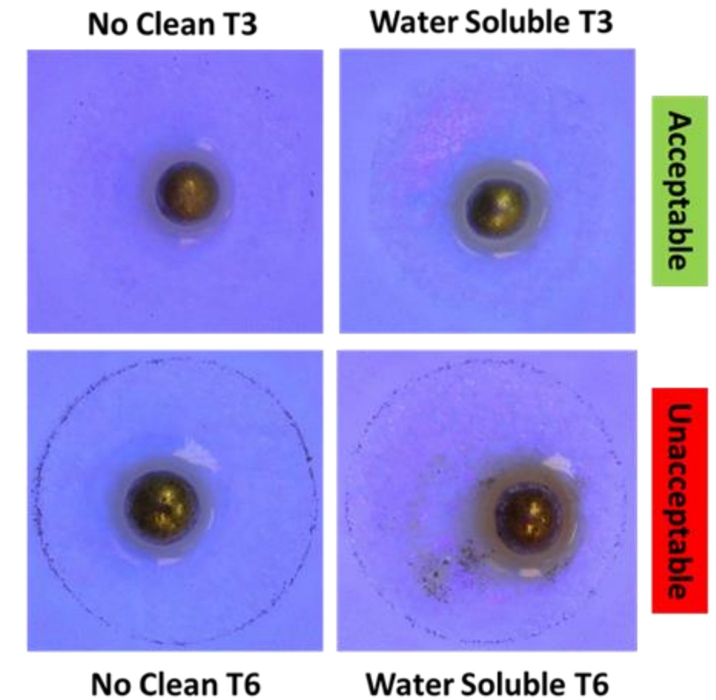
	SAC T3	SAC T4	SAC T5	SAC T6
No Clean	1164	1253	1469	1772
Water Soluble	2022	1846	1884	2294

Solder Paste Slump

	No Clean		Water Soluble	
	Cold Slump	Hot Slump	Cold Slump	Hot Slump
SAC T3	Pass	Pass	Pass	Pass
SAC T4	Pass	Pass	Pass	Pass
SAC T5	Pass	Pass	Pass	Fail
SAC T6	Pass	Fail	Pass	Fail

Solder Balling IPC

	No Clean		Water Soluble	
	Initial	After 4 Hrs	Initial	After 4 Hrs
T3	Acceptable	Acceptable	Acceptable	Acceptable
T4	Acceptable	Acceptable	Acceptable	Acceptable
T5	Acceptable	Ac - UnAc	Acceptable	Acceptable
T6	Unacceptable	Unacceptable	Unacceptable	Unacceptable



Solder Paste Printing

Solder Paste Transfer Efficiency by AR

Transfer Efficiency vs. Site

Solder Paste

NC SAC | WS SAC

Powder Size: T3, T4, T5, T6

Transfer Efficiency (0, 10, 20, 30, 40, 50, 60, 70, 80)

Site: 0.30 AR, 0.35 AR, 0.40 AR, 0.45 AR, 0.50 AR, BGA 0.50 AR (NC SAC); 0.30 AR, 0.35 AR, 0.40 AR, 0.45 AR, 0.50 AR, BGA 0.50 AR (WS SAC)

Where(10160 rows excluded)

Solder Paste Transfer Efficiency by AR

Transfer Efficiency vs. Site

Solder Paste

NC SAC | WS SAC

Transfer Efficiency: 0, 10, 20, 30, 40, 50, 60, 70, 80

Site: 0.30 AR, 0.35 AR, 0.40 AR, 0.45 AR, 0.50 AR, BGA 0.50 AR

Powder Size: T3, T4, T5, T6

Where(10160 rows excluded)

Minimum Area Ratio by Solder Powder Type

Solder Powder Size	Minimum Area Ratio No Clean	Minimum Area Ratio Water Soluble
Type 3	0.60	0.60
Type 4	0.55	0.60
Type 5	0.50	0.55
Type 6	More work needed	More work needed

Solder Paste Print and Pause

Print and Pause Test

Print and Pause Test

Print and Pause Test: TE% Drop from 8 Hrs to 24 Hrs

Solder Powder Size	Drop in TE% No Clean	Drop in TE% Water Soluble
Type 3	8	5
Type 4	10	5
Type 5	18	8
Type 6	25	6

Solder Paste Reflow

Solder Paste Wetting

Wetting Of Each Solder Paste

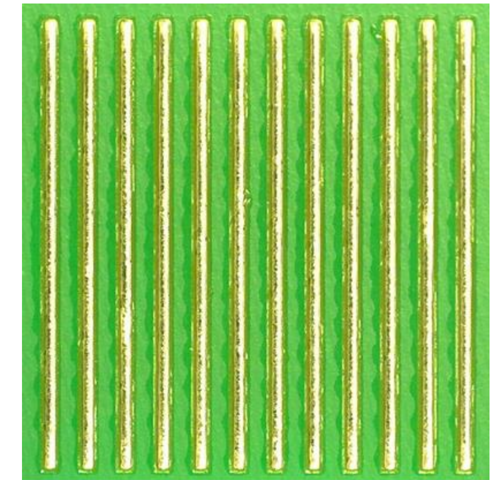
Wetting (%)

100
90
80
70
60
50
40
30
20
10
0

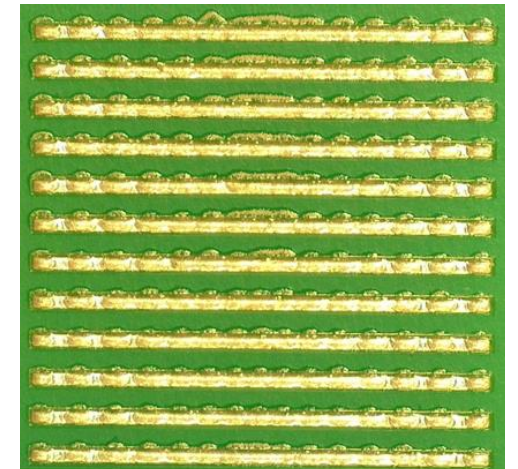
T3 T4 T5 T6

Solder Powder Size

Wetting No Clean
Wetting Water Soluble



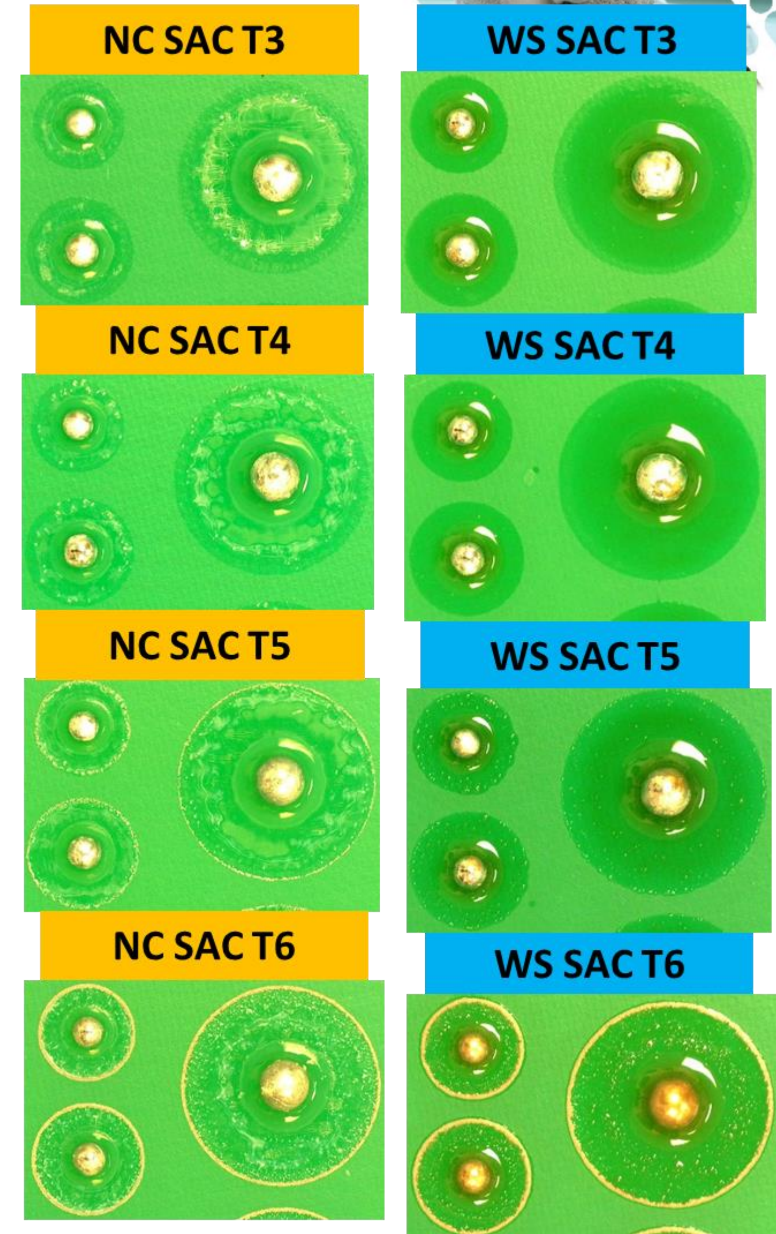
WS SAC T3



WS SAC T6

Solder Paste Solder Balling

Solder Paste	Overprint with 0 Solder Balls	Overprint with < 5 Solder Balls	Overprint with < 10 Solder Balls
No Clean T3	750%	1200%	1200%
Water Soluble T3	None	1200%	1250%
Water Soluble T4	None	500%	1200%



Solder Paste Graping

Graping Of Each Solder Paste

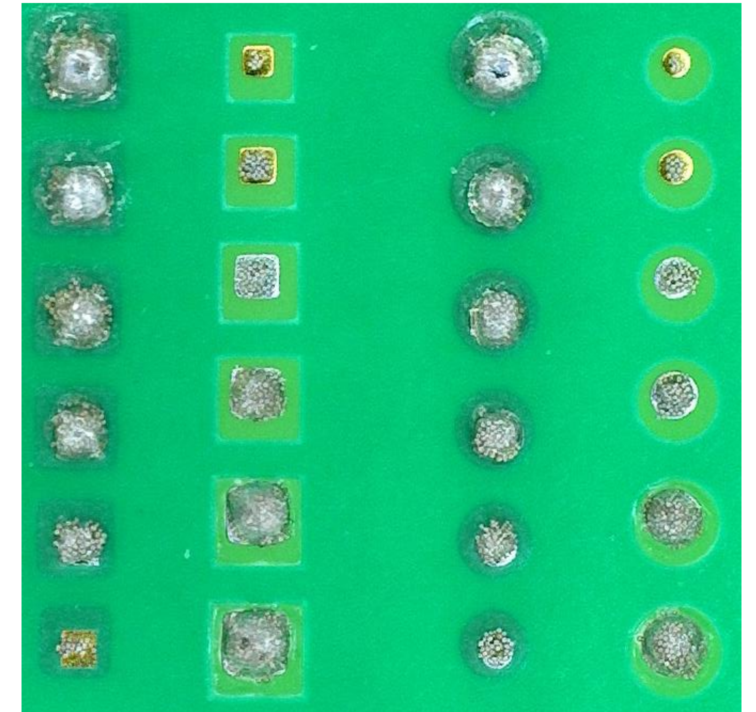
Graping (%)

100
90
80
70
60
50
40
30
20
10
0

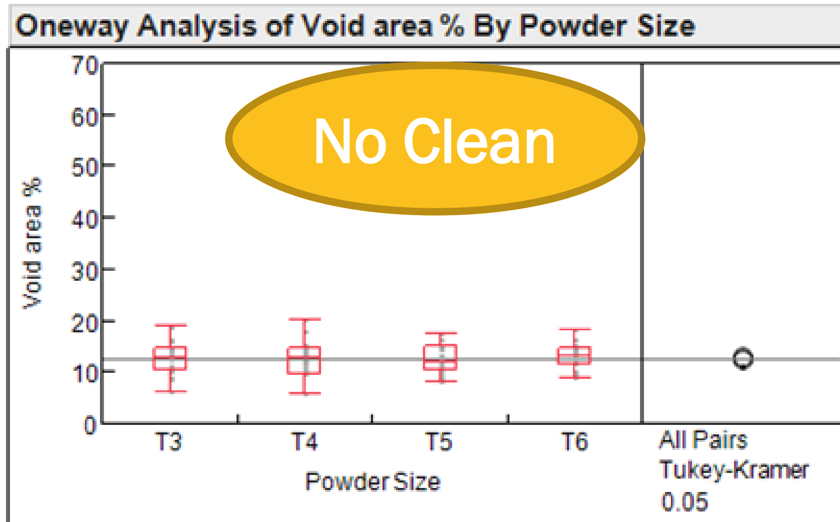
T3 T4 T5 T6

Solder Powder Size

No Clean   Water Soluble



Solder Paste Voiding



Excluded Rows 80

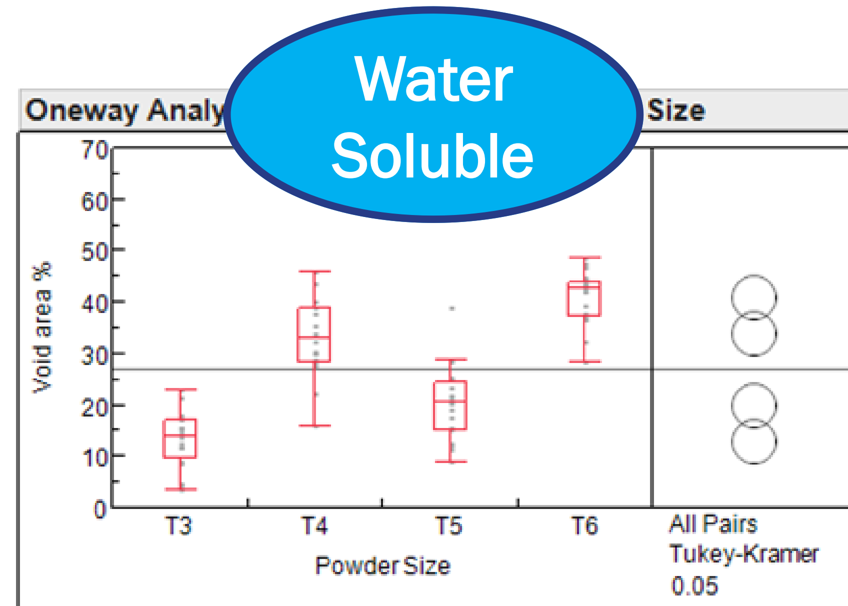
Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

Level		Mean
T6	A	13.3
T3	A	12.9
T4	A	12.7
T5	A	12.5

Levels not connected by same letter are significantly different.



Excluded Rows 80

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

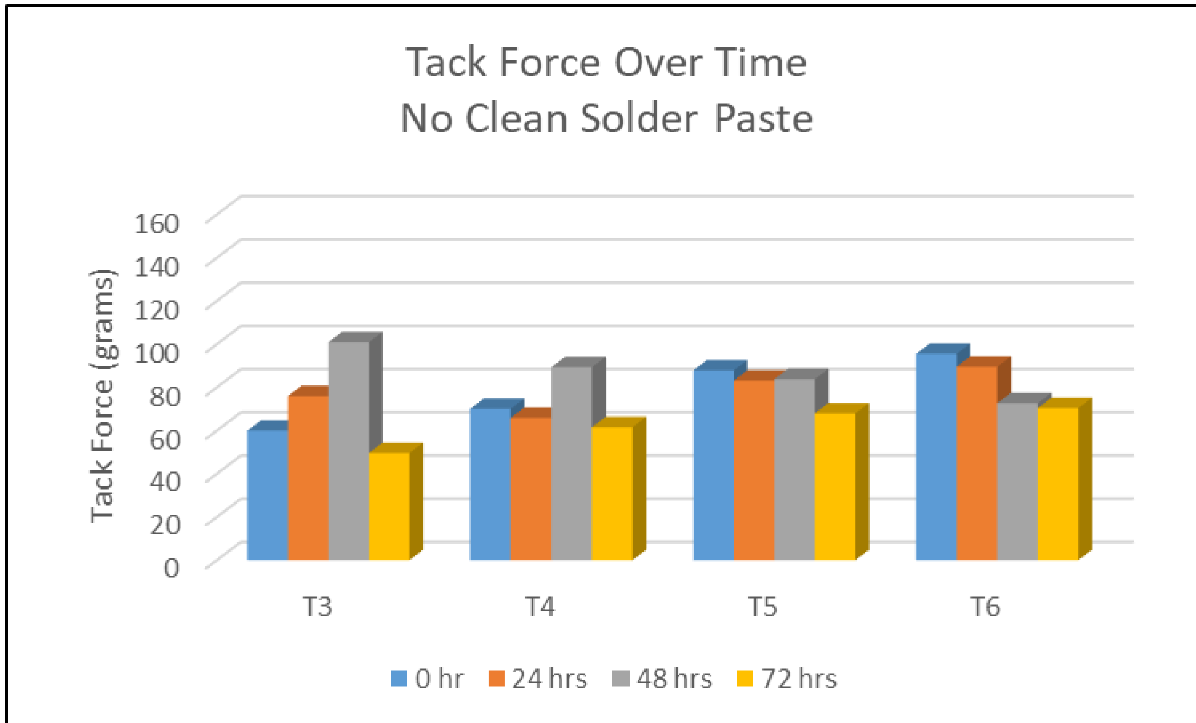
Connecting Letters Report

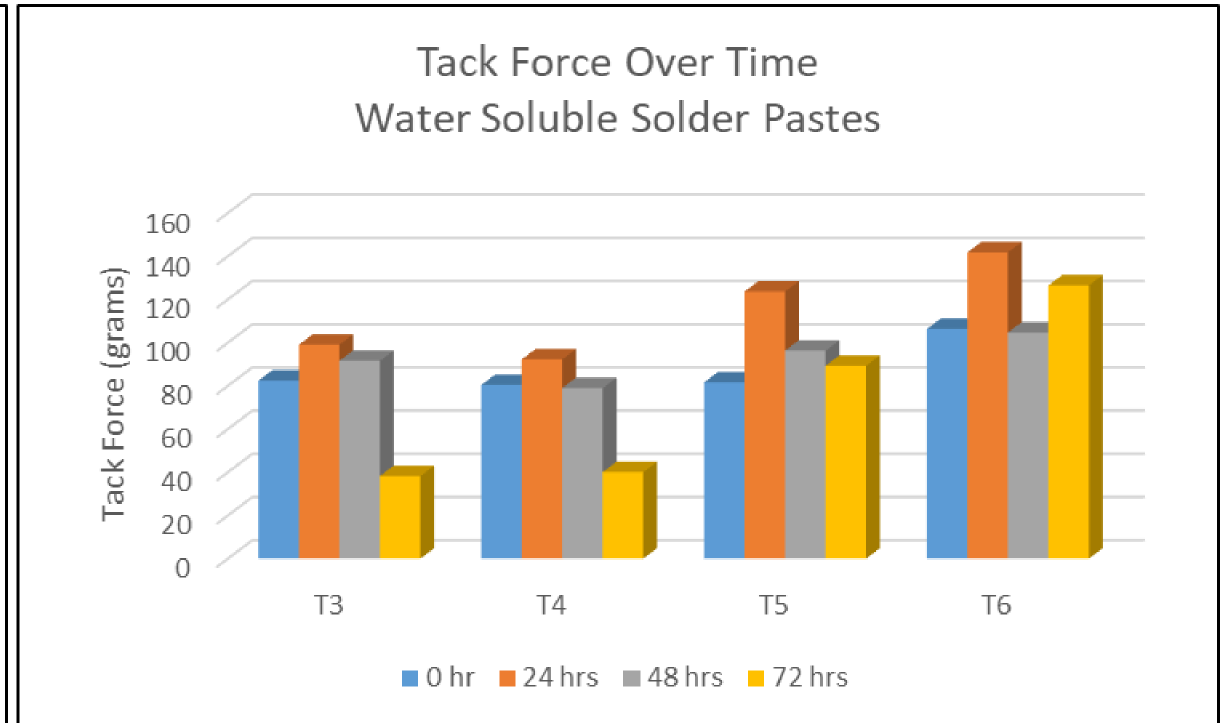
Level					Mean
T6	A				41.2
T4		B			34.3
T5			C		20.4
T3				D	13.3

Levels not connected by same letter are significantly different.

Stability of the Solder Paste

Stability: Tack Force over Time





Stability: Tack Force After Heat Aging

Stability: Viscosity Before and After Heat Aging

Viscosity T-Bar Spindle
Before and After Heat Aging

Viscosity (KCps)

2100
1900
1700
1500
1300
1100
900
700
500
300

SAC T3
SAC T4
SAC T5
SAC T6

No Clean
Water Soluble
No Clean HA
Water Soluble HA

Stability: IPC Solder Balling After Heat Aging

	No Clean		Water Soluble	
	Initial	After 4 Hrs	Initial	After 4 Hrs
T3	Acceptable	Acceptable	Acceptable	Acceptable
T4	Acceptable	Acceptable	Acceptable	Unacceptable
T5	Acceptable	Unacceptable	Acceptable	Unacceptable
T6	Unacceptable	Unacceptable	Unacceptable	Unacceptable

Stability: Printing After Heat Aging - No Clean Only

Transfer Efficiency vs. Site

Solder Paste

NC SAC | NC SAC Aged

No Clean Fresh

No Clean Aged

Transfer Efficiency: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110

Site: 0.30 AR, 0.35 AR, 0.40 AR, 0.45 AR, 0.50 AR, BGA 0.50 AR

Powder Size: T3, T4, T5, T6

Stability: Wetting After a 24 Hour Hold and Heat Aging

Wetting Fresh, 24 Hr, Heat Aged Solder Paste

Wetting (%)

100
90
80
70
60
50
40
30
20
10
0

T3 T4 T5 T6

Solder Powder Size

No Clean | NC 24 Hr | No Clean - HA | Water Soluble | WS 24 Hr

Stability: Solder Balling After 24 Hr and Heat Aging

NC SAC T3

NC SAC T4

NC SAC T5

NC SAC T6

WS SAC T4

WS SAC T5

NC T4 - 24 HR

NC T5 - 24 HR

WS T4 - 24 HR

WS T5 - 24 HR

NC T3 - HA

NC T4 - HA

NC T5 - HA

NC T6 - HA

Stability: Graping After a 24 Hour Hold and Heat Aging

Summary & Conclusions

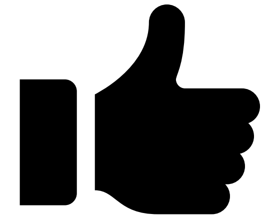
Solder Powder Size Performance Summary

CATEGORY	T3	T4	T5	T6
Slump	✓	✓	✓	✗
Solder Balling (IPC)	✓	✓	✓	✗
Printing AR Limits	0.60	0.55 - 0.60	0.50 - 0.55	??
Print and Pause	✓	✓	✓	✗
Wetting	✓	✓	✓	✓
Solder Ball / Pullback	✓	✓	✓	✗
Graping	✓	✓	✓	✗
Voiding	✓	✓	✓	WS NOK
Stability / Heat Age	✓	✓	Shorter Life	✗

Solder Powder Size Certainly Affects Performance

Positive Effects of Smaller Powder Size:

Print Smaller Area Ratios, Voiding (other studies)



Negative Effects of Smaller Powder Size:

Slump, Solder Balling, Pause in Print, Graping, Voiding (WS), Shelf Life

Solder Pastes Are Formulated to Turn Negatives into Positives!

TECHNOLOGY'S FUTURE COMES TOGETHER

SAN DIEGO CONVENTION CENTER, CA, USA

Thank You!