



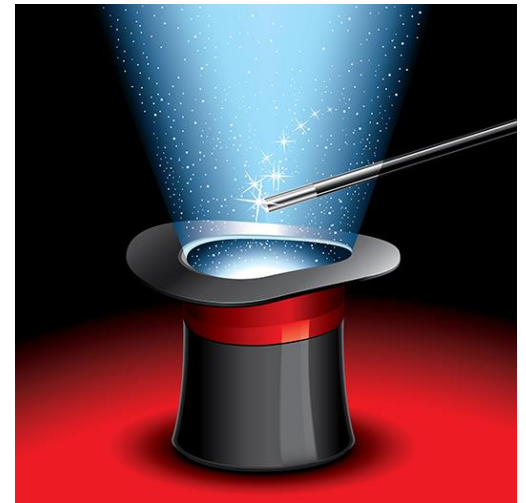
Dispelling the Black Magic of Solder Paste

Tony Lentz
FCT Assembly



Black magic (noun):

magic involving the supposed invocation of evil spirits for evil purposes





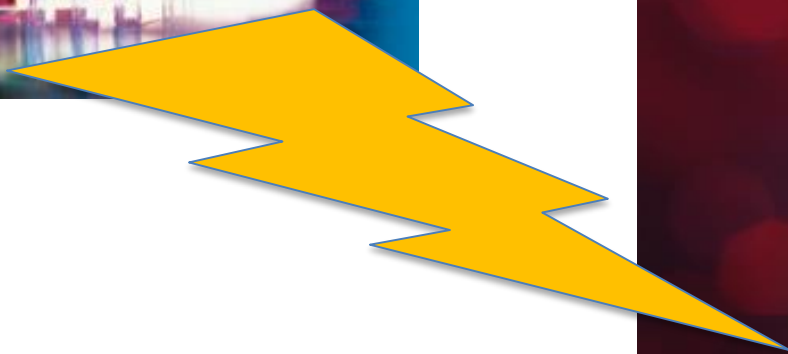
Gray magic (noun):

magic involving the secret formulation of solder paste for nefarious soldering purposes





Scientific Evaluation Dispels the Magic!



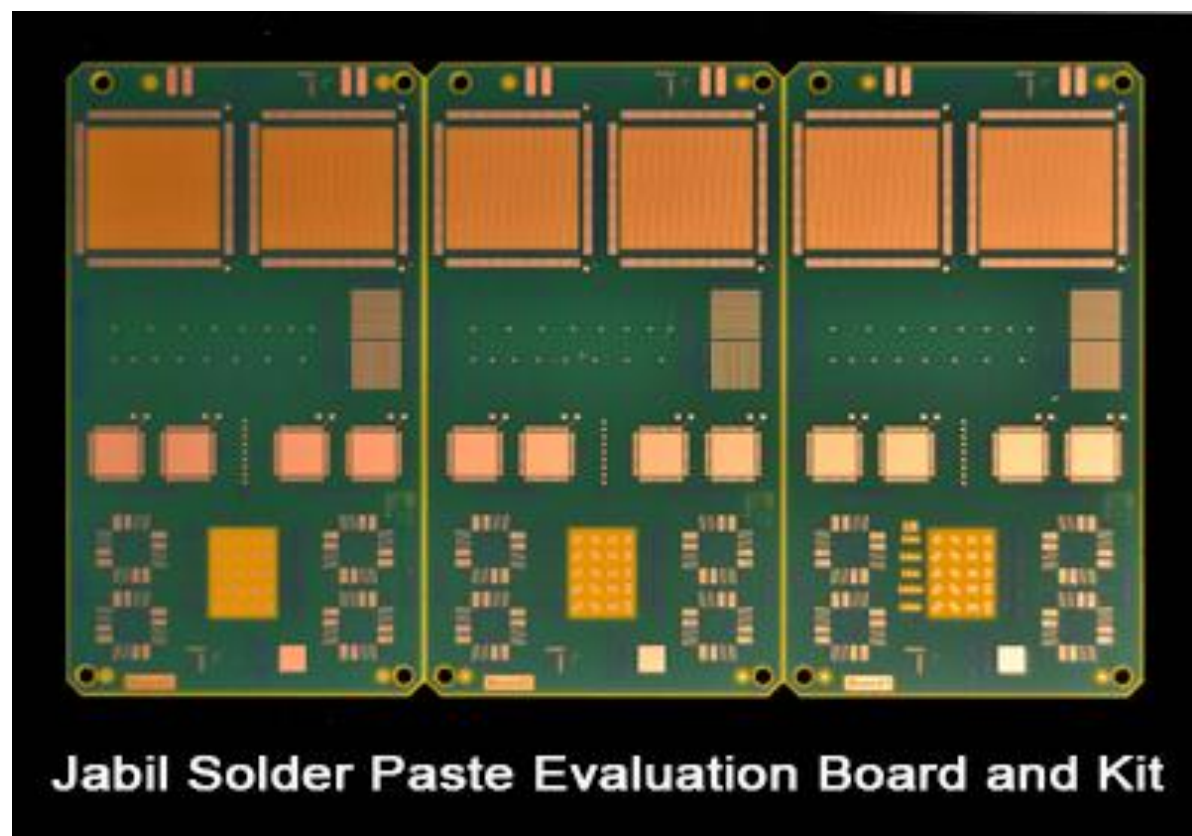


Scientific Methods for Solder Paste Evaluation

1. Quick to run
2. Use readily available equipment / materials
3. Generate meaningful quantitative data



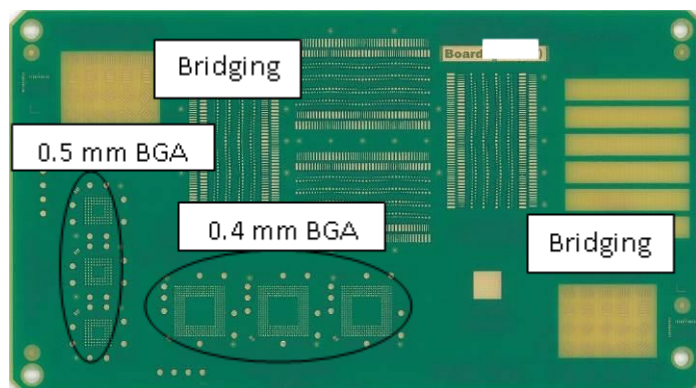
Test Circuit Boards



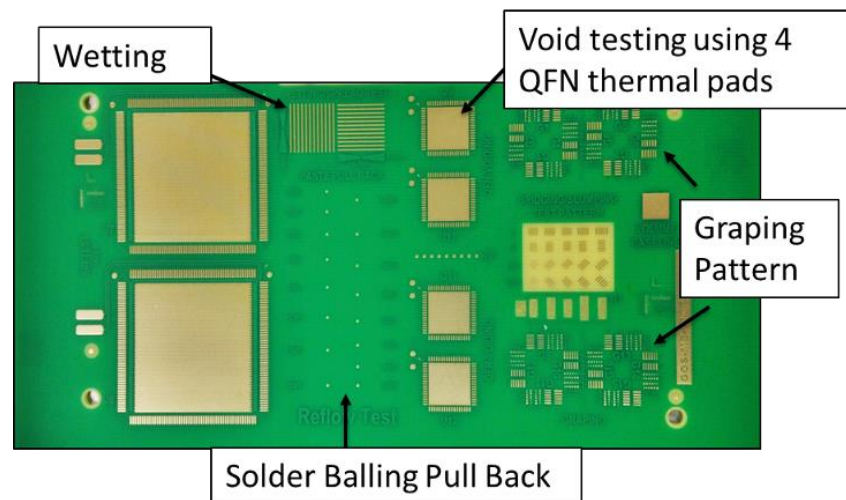
- Commercially available



Test Circuit Boards



F1 Test Board

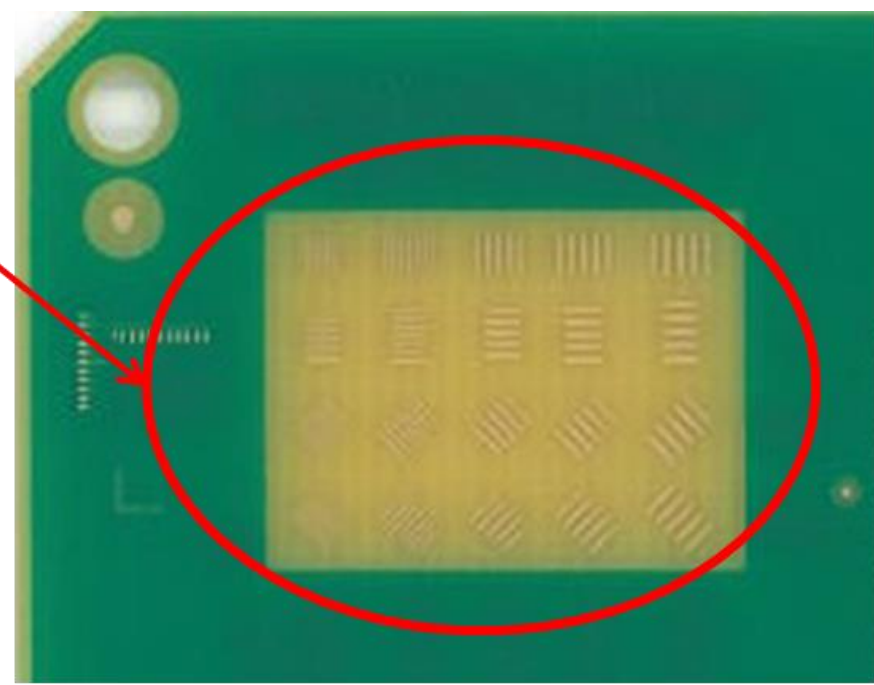
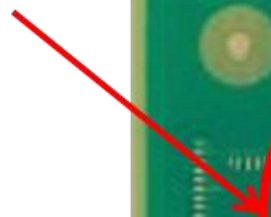


F2A Test Board



Test Circuit Boards

Bridging

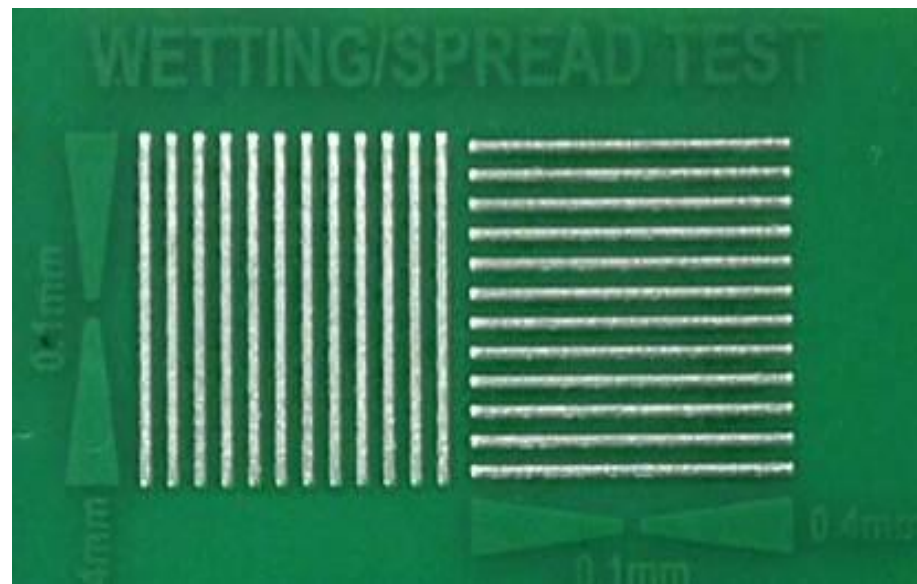
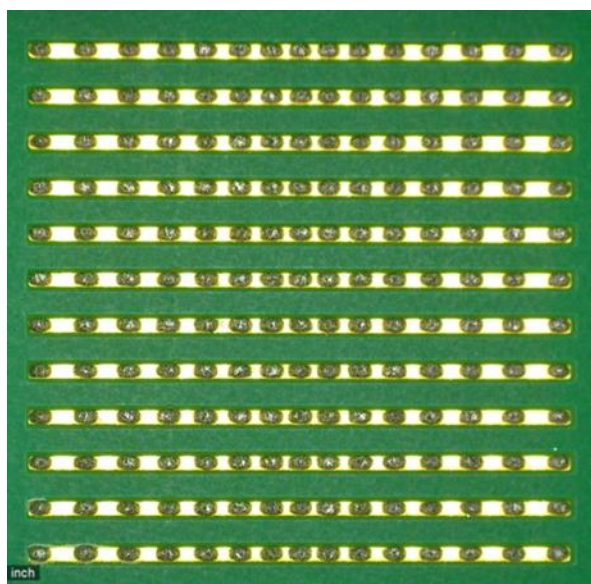


Pitch: 8, 12, 16, 18, 20 mils

F1 Bridging



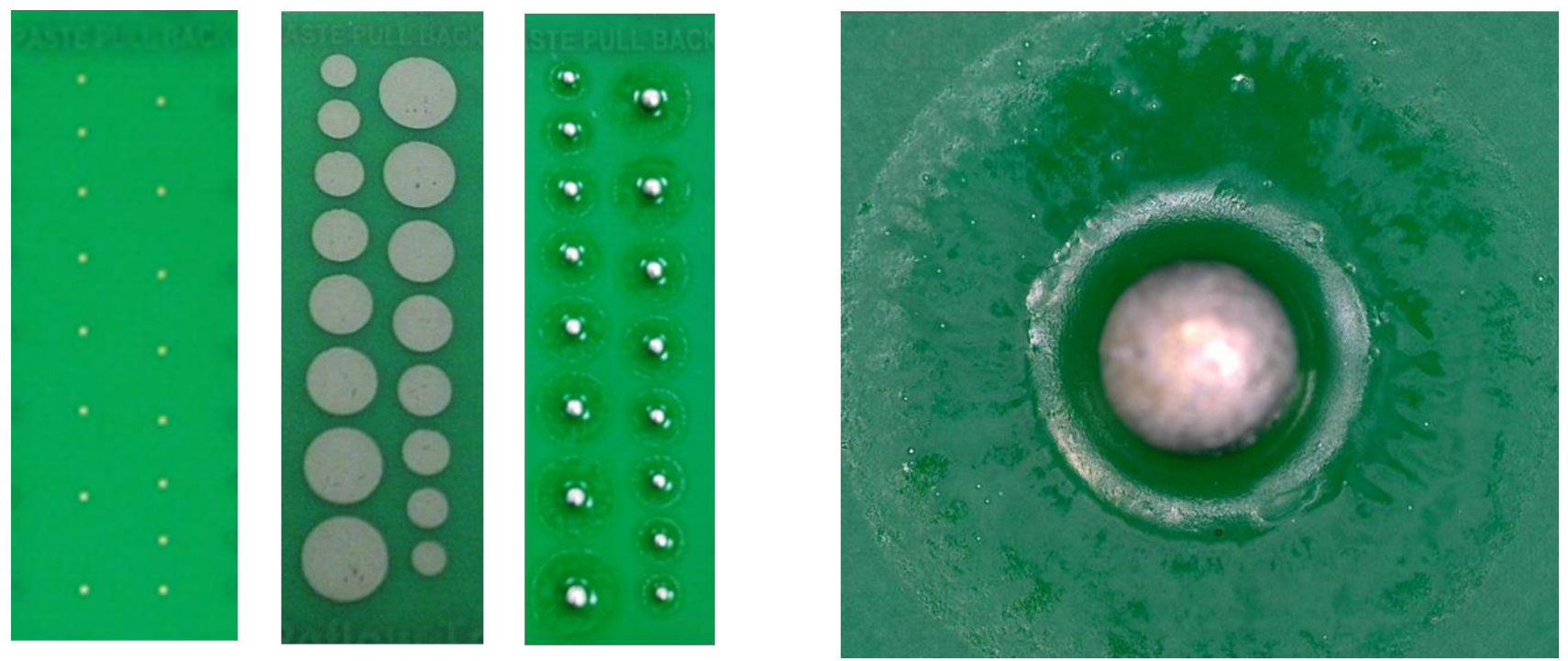
Test Circuit Boards



F2A Wetting



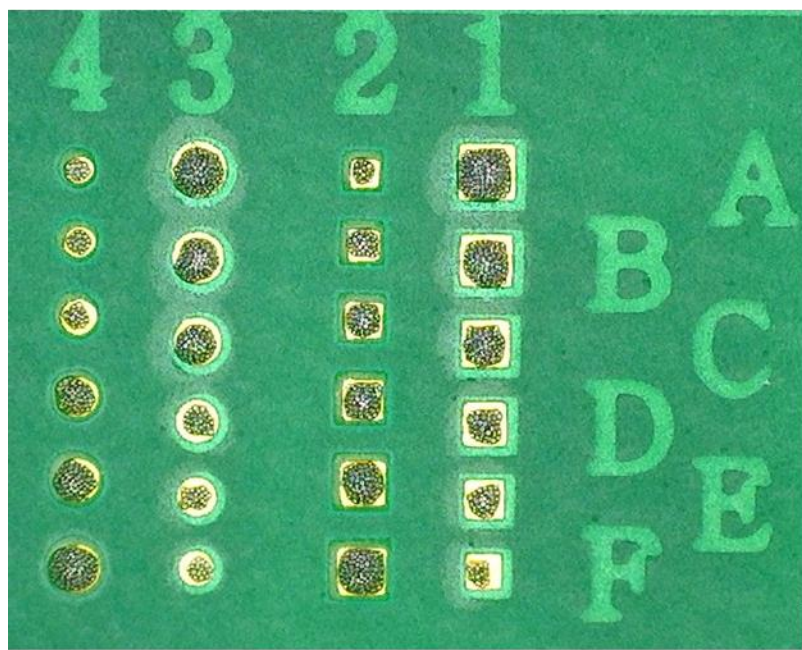
Test Circuit Boards



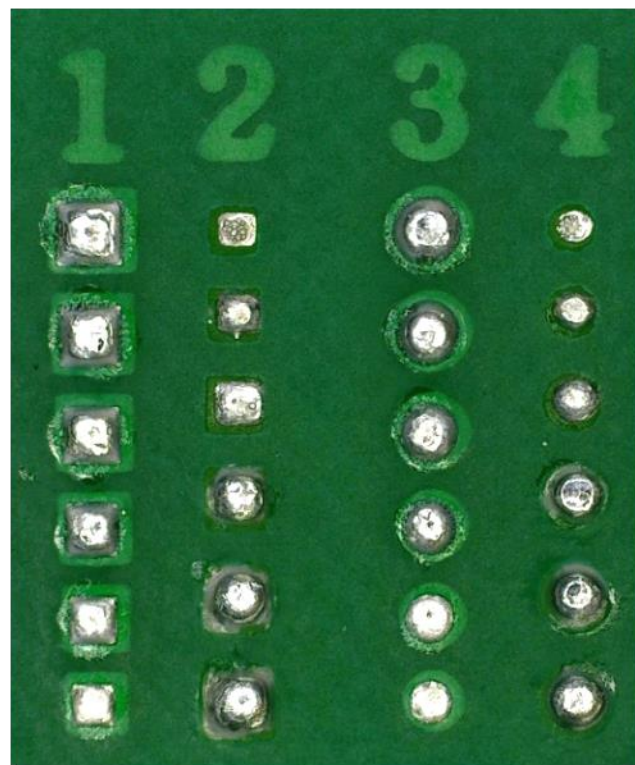
F2A Pull Back / Solder Balling



Test Circuit Boards



- 5 mil stencil
- A = 7 mil (0.35 SAR)
- B = 8 mil (0.40)
- C = 9 mil (0.45)
- D = 10 mil (0.50)
- E = 11 mil (0.55)
- F = 12 mil (0.60)

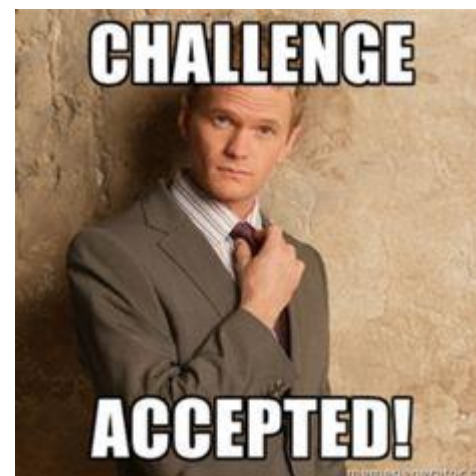


F2A Graping



Methods to Challenge Solder Paste

1. Printed volume and bridging
2. Reflow performance
3. Stencil life / Response to pause
4. Stencil life / Reflow performance
5. Open time
6. Heat aging
7. Continuous mixing
8. Water washability

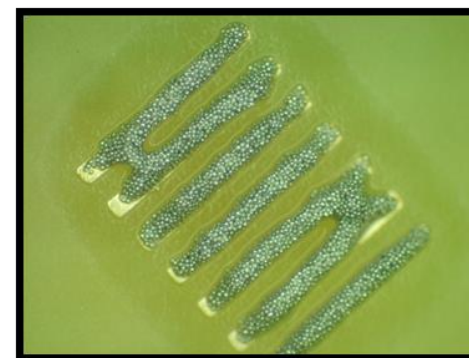




Solder Paste Volume and Bridging

Solder Paste	0.5 mm BGA Volume Avg. (mil ³)	0.5 mm BGA Volume SD (mil ³)	0.4 mm BGA Volume Avg. (mil ³)	0.4 mm BGA Volume SD (mil ³)	Bridging (%)
A	610	35	450	25	11.2
B	570	50	420	40	8.9

F1 Test Board – 10 print study





Solder Paste Volume Alternate Method





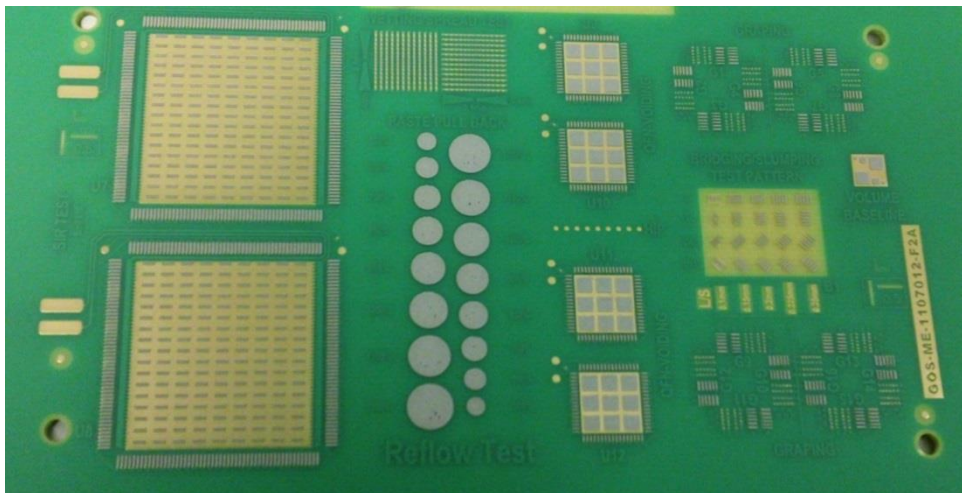
Solder Paste Volume Alternate Method

Solder Paste	Average Mass (grams)	Std. Deviation of Mass (grams)
A	0.22	0.02
B	0.18	0.05

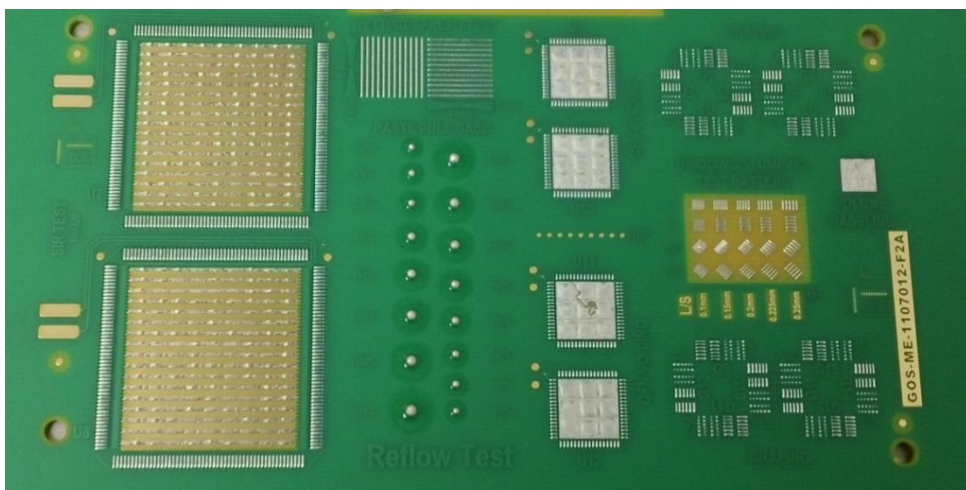
F1 Test Board – 10 print study



Solder Paste Reflow Performance



F2A Before Reflow



F2A After Reflow



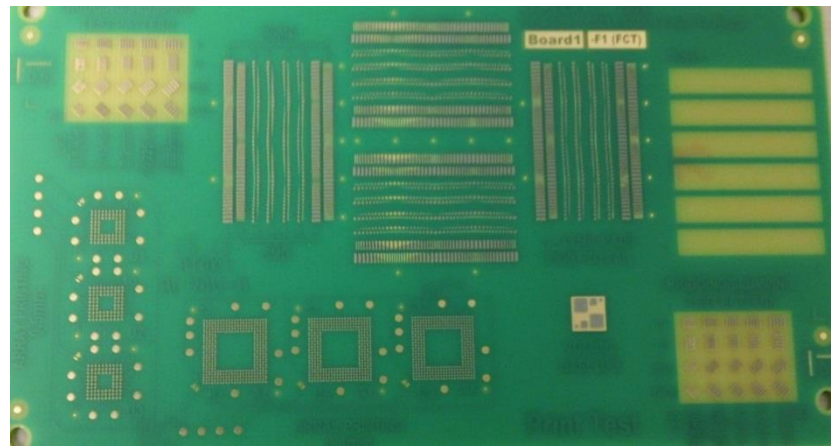
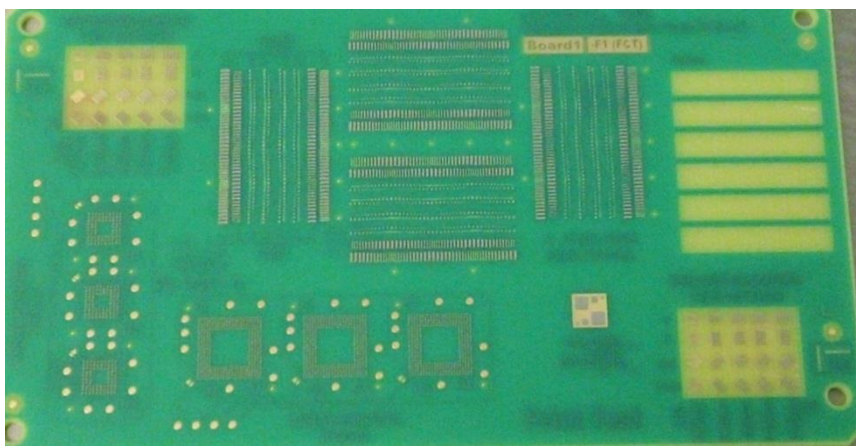
Solder Paste Reflow Performance

Solder Paste	Wetting on ENIG (% spread)	Wetting on OSP (% spread)	Solder Balling Largest 10 or less balls	Solder Balling Largest 5 or less balls	Graping (%)	Void (Area %)
A	96	22	1250%	1200%	8.6	10.2
B	89	17	1100%	950%	20.4	9.5

F2A Test Board both ENIG and OSP surface finish



Stencil Life / Response to Pause



T = 0 (left) and T = 8 hours (right)



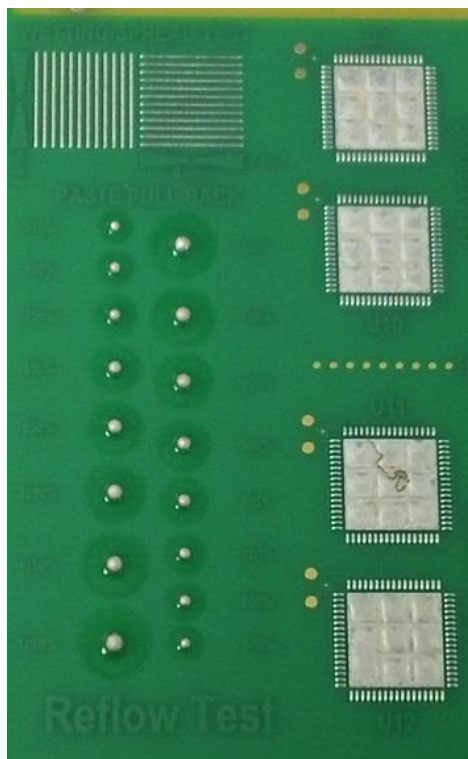
Stencil Life / Response to Pause

Stencil Life Time	Solder Paste A 0.4 mm BGA Volume Avg. (mil ³)	Solder Paste A 0.4 mm BGA Volume SD (mil ³)	Solder Paste B 0.4 mm BGA Volume Avg. (mil ³)	Solder Paste B 0.4 mm BGA Volume SD (mil ³)
0 hours (initial)	450	25	420	40
1 hour	441	28	404	43
2 hours	454	26	382	38
4 hours	439	28	355	42
8 hours	425	25	308	45

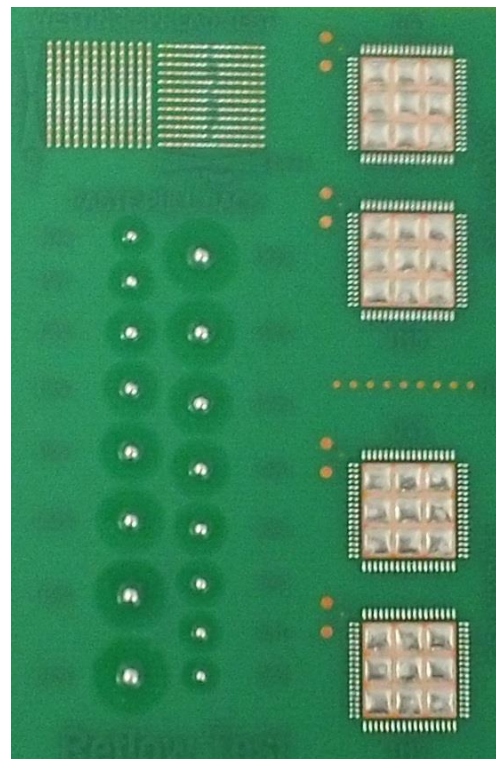
F1 Test Board or Copper Clad



Stencil Life / Reflow Performance



F2A Good Reflow



F2A Bad Reflow – 8 hrs




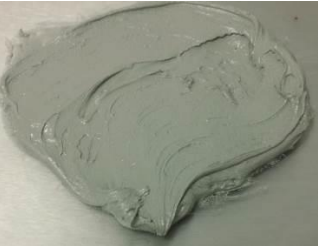

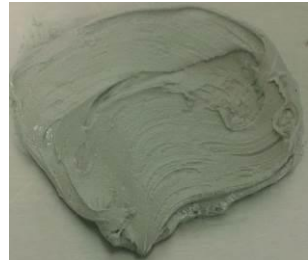

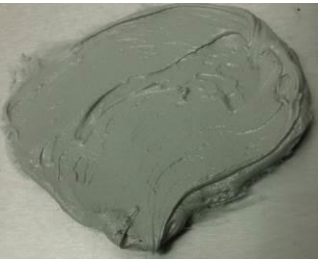
Stencil Life / Reflow Performance

Stencil Life Time	Solder Paste A Wetting (% spread)	Solder Paste A Graping %	Solder Paste B Wetting (% spread)	Solder Paste B Graping %
0 hours (initial)	96	8.6	89	20.4
1 hour	98	8.7	88	20.6
2 hours	96	8.5	85	23.5
4 hours	95	8.6	84	28.9
8 hours	94	8.8	82	32.1

F2A ENIG Test Board



Open Time / Appearance

Open Time	Solder Paste C	Solder Paste D
0 hours (initial)		
8 hours		
24 hours		



Open Time / Mass Change



Initial



After 24 hours



Open Time / Mass Change

Open Time	Solder Paste C Mass (grams)	Solder Paste C Change in Mass	Solder Paste D Mass (grams)	Solder Paste D Change in Mass
0 hours (initial)	41.85	NA	42.28	NA
8 hours	41.91	0.06g (0.14%) increase	42.29	0.01g (0.02%) increase
24 hours	42.00	0.15g (0.36%) increase	42.31	0.03g (0.07%) increase



Open Time / Tack Force



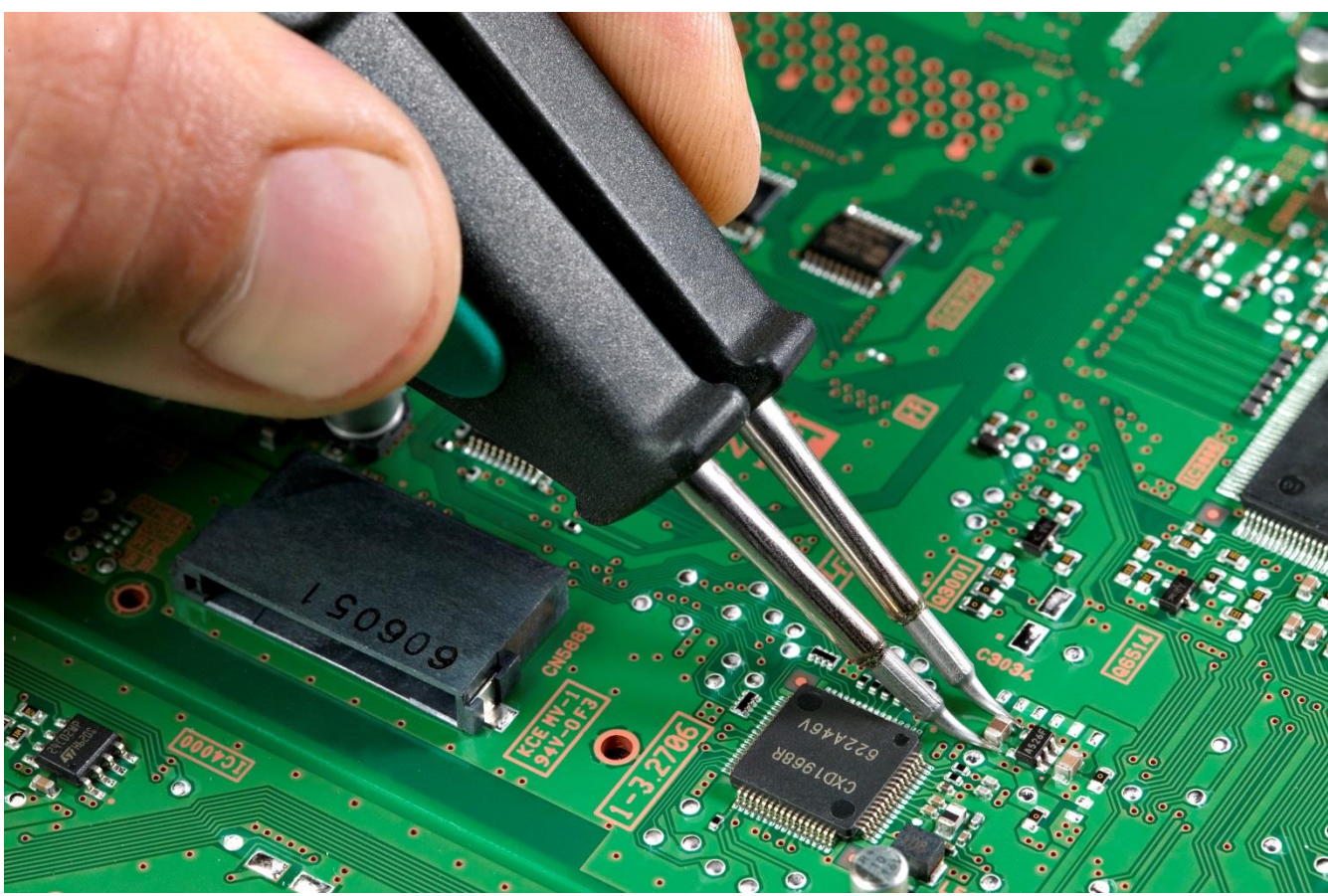


Open Time / Tack Force

Open Time	Solder Paste A Tack (gram force)	Solder Paste B Tack (gram force)	Solder Paste C Tack (gram force)
0 hours (initial)	112	95	105
1 hour	110	98	107
2 hours	115	90	104
4 hours	107	78	108
8 hours	110	55	111
24 hours	100	24	129



Open Time / Component Tack





Open Time / Component Tack

Open Time	Solder Paste A # Components on Board	Solder Paste B # Components on Board
0 hours (initial)	50	50
1 hour	50	48
2 hours	48	46
4 hours	45	40
8 hours	44	29
24 hours	40	18









Heat Aging



Heat aged 110F for 72 hours



Continuous Mixing

Mix Time	Solder Paste E	Solder Paste F
0 hours (initial)		
8 hours		
8 hours (next day)		

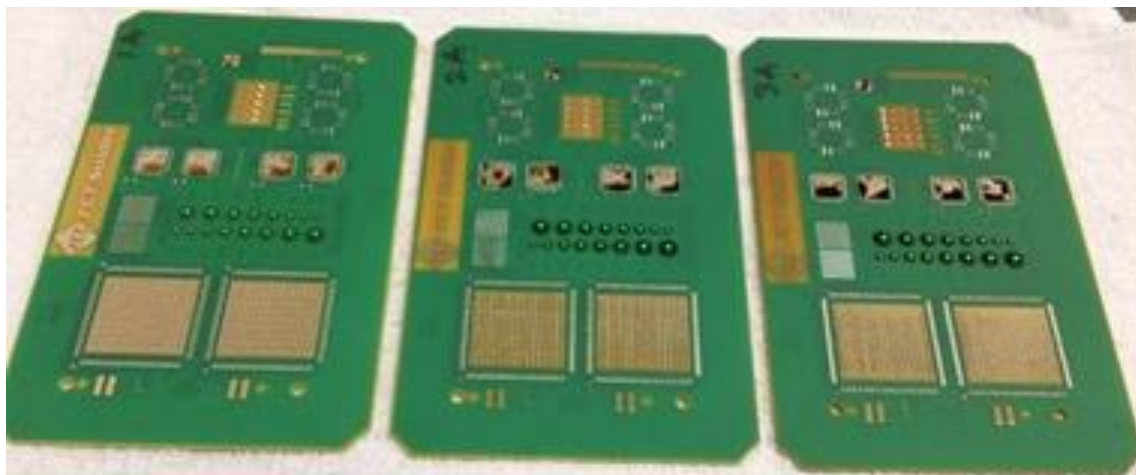


Water Solubility / Raw Paste

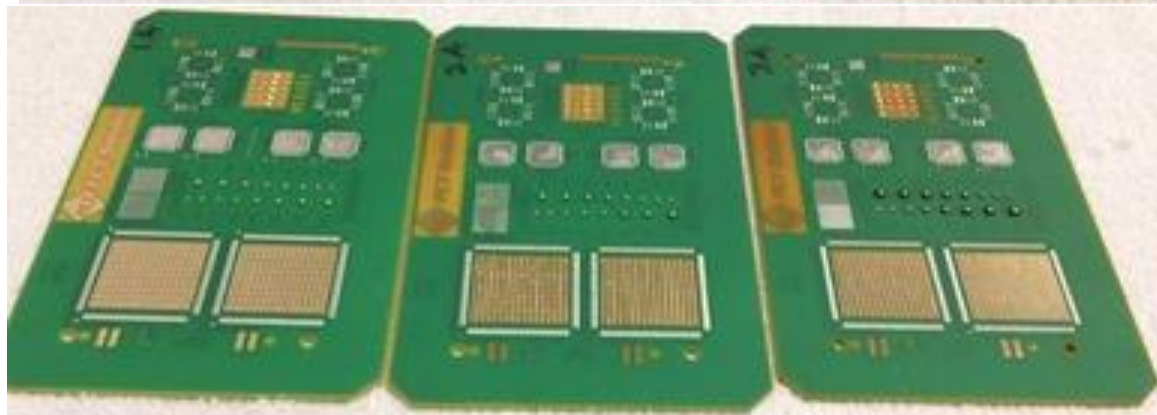




Water Solubility / After Reflow



Poor
solubility



Good
solubility



Time Requirements

Method	Property Evaluated	Time Required per Solder Paste
Solder paste volume avg. & std. deviation SPI measurement	Printability of solder paste through small area ratio apertures	60 minutes
*Alternate volume avg. & std. deviation Mass measurement	Printability of solder paste overall	30 minutes
Bridging at print	Bridging potential for solder paste, and brick definition	10 minutes Concurrent with volume
Reflow performance on ENIG	Wetting, solder balling, graping, and voiding	30 minutes
*Alternate reflow performance on OSP Run in addition to ENIG	Wetting, solder balling, graping, and voiding on OSP	20 minutes
Stencil life / Response to pause	Change in printability of a solder paste over time, as it sits on the stencil	60 minutes Spread out over 8 hours
Stencil life / Reflow performance	Change in reflow performance as the solder paste sits on the stencil	150 minutes Spread out over 8 hours
Open time / Mass change	Environmental effect on solder paste	15 minutes Spread out over 24 hours
Tack force over time Tack tester	Ability of solder paste to retain tack force when open to air	1 hour 45 minutes Spread out over 24 hours
*Alternate tack force over time Component movement	Ability of solder paste to hold components in place at 90° angle	20 minutes Spread out over 24 hours
Heat aging	Gives information about shelf life and potential reactivity of solder paste	10 minutes plus methods used after aging
Continuous mixing	Ability of solder paste to tolerate repeated printing, and potential reactivity with air	15 minutes plus methods used after mixing
Water solubility of raw solder paste	Water solubility of raw paste	15 minutes
Water solubility of reflowed flux residue	Water washability of flux after reflow	45 minutes plus Ionic contamination methods



Scoring System

1. Rank importance of the methods
2. Run the solder pastes through each method
3. Score the solder pastes in each method
4. Calculate performance metrics



Rank of Importance

Method	Rank of Importance (3=highest, 2=moderate, 1=lowest)
Solder paste volume avg. & std. deviation SPI measurement	3
*Alternate volume avg. & std. deviation Mass measurement	NA
Bridging at print	3
Reflow performance on ENIG	3
*Alternate reflow performance on OSP Run in addition to ENIG	NA
Stencil life / Response to pause	1
Stencil life / Reflow performance	1
Open time / Mass change	2
Tack force over time Tack tester	NA
*Alternate tack force over time Component movement	NA
Heat aging	NA
Continuous mixing	2
Water solubility of raw solder paste	NA
Water solubility of reflowed flux residue	NA



Score for Each Paste

Method	Score Solder Paste G	Score Solder Paste H
Solder paste volume avg. & std. deviation (SPI measurement)	3	1
Bridging at print	1	2
Reflow performance on ENIG	3	1
Open time / Mass change	3	2
Continuous mixing	3	1
Stencil life / Response to pause	2	3
Stencil life / Reflow performance	1	2

Scoring System

3 = Best performance

2 = Moderate

1 = Worst



Performance Metric

Method	Importance Rank	Score Solder Paste G	Score Solder Paste H	Performance (Rank x Score) Solder Paste G	Performance (Rank x Score) Solder Paste H
Solder paste volume avg. & std. deviation (SPI measurement)	3	3	1	9	3
Bridging at print	3	1	2	3	6
Reflow performance on ENIG	3	3	1	9	3
Open time / Mass change	2	3	2	6	4
Continuous mixing	2	3	1	6	2
Stencil life / Response to pause	1	2	3	2	3
Stencil life / Reflow performance	1	1	2	1	2
TOTAL PERFORMANCE METRIC				36	23



Conclusions

- Black magic of solder paste can be dispelled!
- Challenging methods differentiate
- Data is used to rank performance

Don't trust your gut
Use data!





Acknowledgements

We appreciate the support of Jabil Circuit who allowed us to use their test board designs.

Also appreciated is the hard work of the lab staff at FCT Assembly who aided in the development and testing of the methods.



Thank you for your attention!



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