Creation of a Novel Pb-Free Water-Soluble Solder Paste that Improves Reliability Through Low Voiding and Ease of Washability

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ABSTRACT

Voiding in bottom terminated component (BTC) solder joints and cleaning under low standoff components are common problems in the printed circuit board assembly (PCBA) process. Water-soluble solder pastes are particularly susceptible to voiding for a couple of reasons. Water-soluble solder pastes typically contain a higher volatile content than no clean solder pastes. Water-soluble solder pastes are made with hygroscopic materials that absorb moisture out of the air, which leads to an increased potential for voiding, especially in humid environments.

The prevalence of BTC usage presents a challenge not only for voiding in solder joints but also with respect to the washability of flux residues. BTCs have low standoff gaps, which make it difficult to completely remove flux residues. The cleaning process must be tuned to remove highly active water-soluble fluxes. Corrosive and electrically conductive residues may be left behind. This can lead to electro-chemical failures on the PCBA. There is a need for water-soluble solder pastes that have low voiding potential and ease of washability without compromising solder paste performance.

This paper details a new water-soluble lead-free solder paste that has dramatically improved voiding performance and washability over previous generations of solder paste. Voiding performance is tested with BTCs and multiple reflow profiles in high humidity conditions. Washability is tested with DI water vs. engineered cleaning chemistry, and the reliability of flux residues is measured using surface insulation resistance (SIR) testing. The results for the new water-soluble solder paste are summarized and compared to an older generation of solder paste. This data is presented along with recommendations for improving the reliability of PCBAs through reduced voiding and the use of an optimized wash process.

Key words: lead-free water-soluble solder paste, low stand-off components, low voiding, engineered cleaning chemistry, ease of washability, reliability of flux residues.

INTRODUCTION

Voiding in solder joints is a common issue that is faced by many PCBA manufacturers (Figure 1).

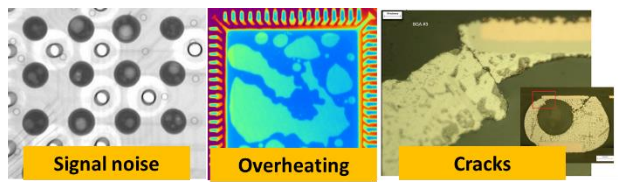

Figure 1. Voids in solder joints.

Voids in solder joints can lead to signal noise, component overheating, and potentially cracks in the solder joints. There are many ways to mitigate voiding in solder joints, including the use of a "low-voiding" solder paste.

Difficulty in removing flux residues, especially from under BTCs and other low-standoff components, is another common issue (Figure 2).

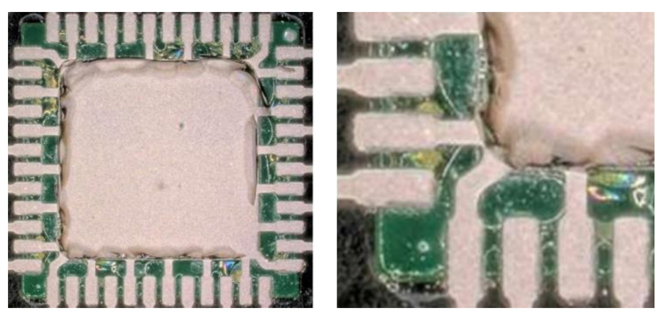

Figure 2. Flux residue under a Quad-flat no-lead component (QFN) [1].

If flux residues remain after cleaning, then corrosion and dendritic growth can occur, leading to failures of the PCBA (Figure 3).

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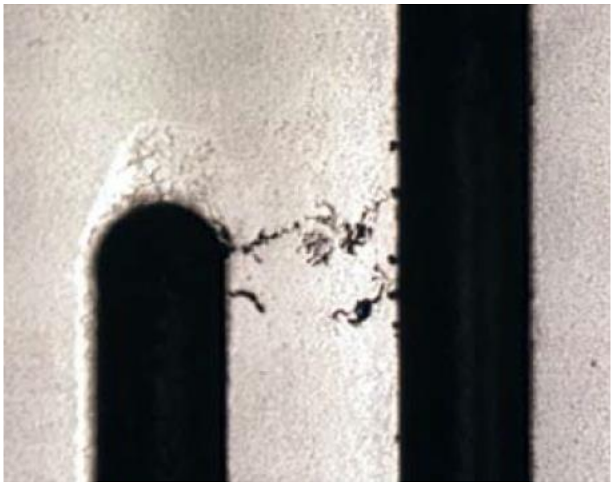


Figure 3. Dendritic growth through flux residues.

Dendritic growth can occur when three things are present: ions, moisture, and a voltage bias. Flux residues are the most likely source of ionic species. Moisture is present in the environment the PCBA is used. A voltage bias is necessary for the PCBA to operate. It is nearly impossible to completely remove the potential for moisture on a PCBA, and voltage is present when the device is powered. The best way to eliminate the potential for dendritic growth is to remove the ionic species. If fluxes and other contaminates are removed completely through a robust cleaning process, then dendritic growth cannot occur.

PRIOR WORK

Bixenman, et al., [1] described how to establish a cleanliness risk profile for PCBAs with lead-less and near-chip scale packages. Several SIR test board designs with components were detailed, and their usage was described.

Lentz [2] detailed the formulation of a new Pb-free water-soluble solder paste, and the results are summarized below.

- Three solder pastes were tested for environmental stability, stencil life, printability, wetting, solder balling, graping, and water washability.
- The new solder paste outperformed the older generations in many ways, including water washability.

Carboni, et al. [3] discuss important factors to consider when selecting a cleaning agent.

- Cleaning agents must remove the soils and residues from the process.
- Cleaning agents must be compatible with the residues being removed, the equipment, and the process.
- The user must be able to control the cleaning chemistry and the cleanliness of the PCBAs over the life of the cleaning bath.
- Cleaning agents must follow environmental, social, and governance criteria for the local area.

Tellefsen et al. [4] researched an SIR test method to reveal the effects of trapped solder paste flux residues under BTCs. Electrochemical failures were generated with existing commercial solder pastes. A new high-reliability solder paste was developed to perform well in this test method.

Lentz, et al. [5] showed the voiding differences of three water-soluble Pb-free solder pastes, and these differences were significant. Several factors besides solder paste contribute to voiding, which makes it a complex issue to solve.

It is clear from prior work that difficulty in removing flux residues and voiding in solder joints are issues that impact the reliability of PCBAs. Proper cleaning and mitigation of voiding are especially important as circuit boards become smaller and more densely packed with components. It is necessary to look to the future and provide solutions to enhance the reliability of PCBAs.

EXPERIMENTAL METHODOLOGY

The goal of this project is to test a new water-soluble Pb-free solder paste against the last generation of solder paste. The important factors are voiding in solder joints and cleanability, which ultimately affect the reliability of the PCBA. In addition, general solder paste performance was tested, and data was compared between the solder pastes.

General solder paste performance was evaluated using the PR test board v2 from FCT solder (Figure 5).

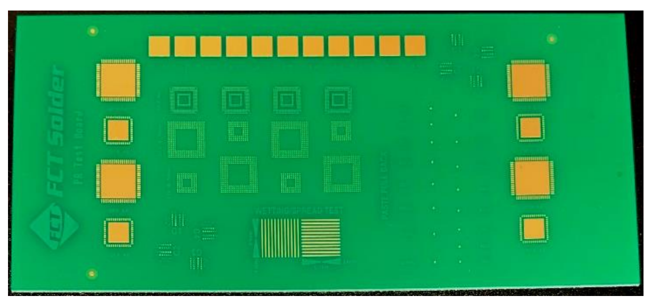


Figure 5. PR test board v2 from FCT Solder.

The PR test board v2 is made from 1.57 mm (0.062 in) thick FR-4 laminate with an ENIG surface finish. This PCB includes test patterns that generate data for the following variables: printed solder paste volume, printed area ratio limit (AR), wetting, solder balling, graping, and voiding in QFN thermal pads. The use of the PR test board v2 was detailed by Lentz [6]. The PR test board is designed to test the failure limit of solder pastes due to its challenging test patterns. The print patterns use stencil area ratios down to 0.30, which is well below the IPC recommended limit of 0.66 area ratio [7].

In addition, internal tests were used to measure the environmental stability of solder paste, including:

- Tack force over time
- Mass change over time
- Stencil life - transfer efficiency (TE%) over 8 hours

The main variables for testing electrochemical reliability are listed below:

- Two (2) solder pastes: Current and New Pb-free water-soluble solder pastes. Both were made with SAC305 Type 4 solder powder.
- Two (2) reflow profiles: Ramp-to-spike (RTS) and Ramp-soak-spike (RSS)
- Two (2) cleaning methods: In-line with DI water and In-line with engineered chemistry

These parameters were tested in accordance with the cleaning DOE test matrix (Table 1). One PCB was run with each solder paste and reflow profile combination that was not cleaned. This was SIR tested to show the worst case scenario.

The PCB test vehicle used was IPC B-52 Legacy 2 from Magnalytix (Figure 4). The B-52 Legacy 2 is made from 1.57 mm (0.062 in) thick FR-4 laminate with an ENIG surface finish. Electrical connections allow for testing of SIR within each of the four quadrants. This IPC B-52 Legacy 2 PCB includes the following components:

- BGA-244 with Center Lug: 1.0 mm pitch
- QFN-48 (4x): 0.5 mm pitch
- QFP-160: 0.65 mm pitch
- Passive capacitors (10x each): 0805, 0603, 0402, and 0201 Imperial sizes

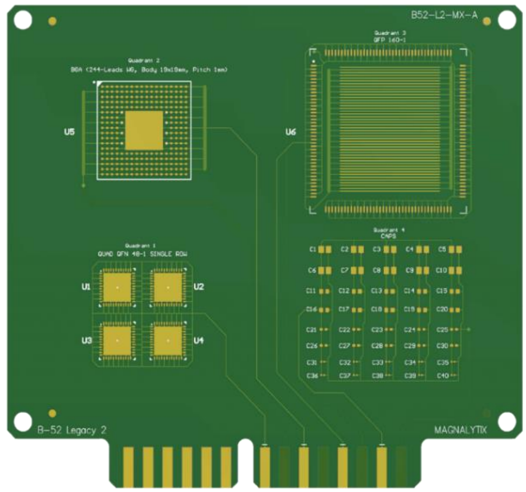


Figure 4. IPC B-52 Legacy 2 from Magnalytix.

Table 1: Cleaning DOE Test Matrix

Test #	Test Board	Solder Paste #1	Solder Paste #2	Solder Profile Ramp to Spike	Solder Profile Soak Profile	Inline - DI Water	Inline - Eng. Aq.	SIR [40°C/90% RH/ 5V / 168-Hours]
		WS #1		x		No-Clean	No-Clean	x
1	MGX B52 Legacy 2	WS #1		x		x		x
2	MGX B52 Legacy 2	WS #1		x		x		x
3	MGX B52 Legacy 2	WS #1		x			x	x
4	MGX B52 Legacy 2	WS #1		x			x	x
		WS #1			x	No-Clean	No-Clean	x
5	MGX B52 Legacy 2	WS #1			x	x		x
6	MGX B52 Legacy 2	WS #1			x	x		x
7	MGX B52 Legacy 2	WS #1			x		x	x
8	MGX B52 Legacy 2	WS #1			x		x	x
			WS#2	x		No-Clean	No-Clean	x
1	MGX B52 Legacy 2		WS#2	x		x		x
2	MGX B52 Legacy 2		WS#2	x		x		x
3	MGX B52 Legacy 2		WS#2	x			x	x
4	MGX B52 Legacy 2		WS#2	x			x	x
			WS#2		x	No-Clean	No-Clean	x
5	MGX B52 Legacy 2		WS#2		x	x		x
6	MGX B52 Legacy 2		WS#2		x	x		x
7	MGX B52 Legacy 2		WS#2		x		x	x
8	MGX B52 Legacy 2		WS#2		x		x	x

Surface Insulation Resistance (SIR)

This test uses an industry-standard pattern of traces (called a “comb”) to test the conductivity of the residues by combining environmental moisture, electricity, and flux residues in a test chamber and monitoring their electrical resistance over seven days. The industry minimum for this resistance value is 100 megohms ($10^8\ \Omega$) (Figure 5).

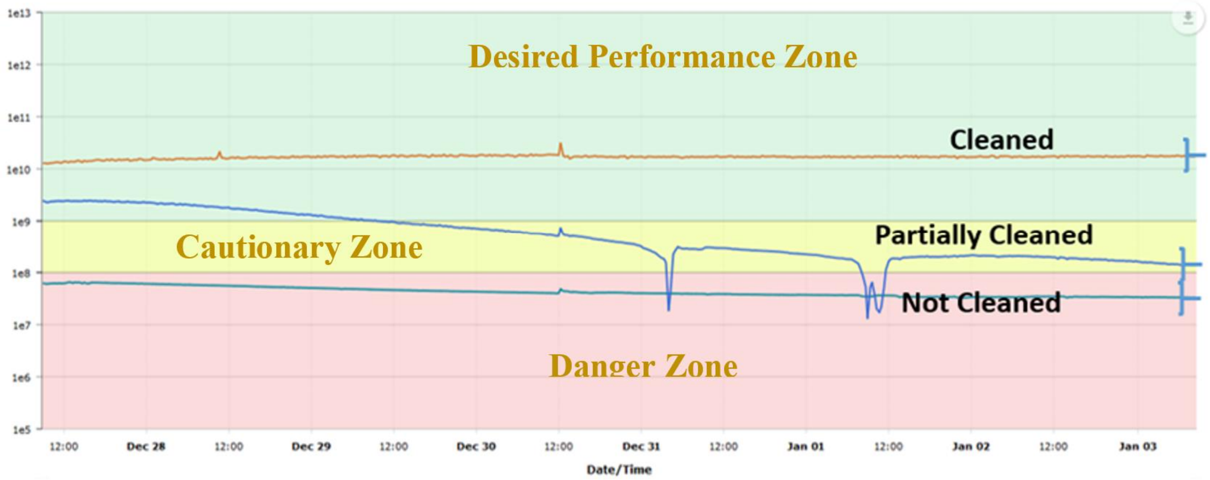


Figure 5. SIR Performance Zones and Cleanliness Levels

Readings below Log $10_8\Omega$ threshold are considered failures and coded RED. Resistance measurements between Log 10_8 and $10_9\ \Omega$s are acceptable but considered process indicators and are coded YELLOW. Resistances consistently above Log $10_9\ \Omega$ are coded GREEN, representing the desired performance range.

The printing process parameters are listed in Table 2 below.

Table 2. Printing process parameters.

Print speed (mm/sec)	25 mm/sec
Blade length (mm)	305 mm
Print pressure (kg)	6.8 kg
Separation speed (mm/sec)	1 mm/sec
Separation distance (mm)	1 mm
Stencil thickness (µm)	100 microns
Stencil material	Stainless steel with nano-coating

The reflow profiles data is in Table 3 below and the profile graphs are in Figure 6.

Table 3. Reflow profile parameters.

Parameter	Ramp-to-Spike (RTS)	Ramp-Soak-Spike (RSS)
Time above 220 °C	57-59 sec	60-67 sec
Time between 150-200 °C	75-78 sec	104-112 sec
Peak temperature	241-244 °C	243-246 °C
Time 25 °C to peak temperature	4.4-4.6 min	5.4-5.5 min

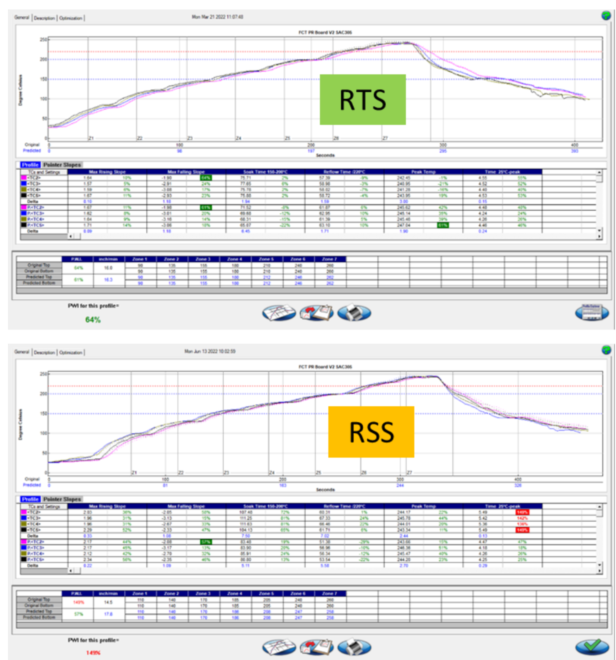


Figure 6. Reflow profiles. Linear ramp-to-spike (RTS) on the top and ramp-soak-spike (RSS) on the bottom.

Voiding was evaluated on the PR test board v2 using the 10 mm QFN thermal pad solder joints. The voiding levels from each solder paste in each reflow profile were compared.

Cleanability was evaluated using the B-52 Legacy 2 boards. The parameters for cleaning are shown in Table 4 below.

Table 4. Cleaning process parameters.

Cleaning process	In-line
Belt speed (m/min)	1.0 ft./minute
Wash temperature (°C)	60°C
Wash chemistry & concentration (% vol)	DI-Water & Eng. Aqueous diluted in DI-Water at 5%
Rinse temperature (°C)	54°C
Dry temperature (°C)	48°C

Please note that the cleaning chemistry was used on only half of the circuit boards. The other half were run with DI water alone.

After cleaning, SIR testing was run to measure the cleanliness of the 4 quadrants on the B-52 Legacy 2 boards. The resistance measurements were used to determine the effectiveness of the cleaning process for each solder paste and reflow profile combination.

RESULTS AND DISCUSSION

General Solder Paste Performance

General solder paste performance was measured for the current versus the new product. Two different environmental stability tests were used. The first environmental test involved measuring the tack force of the solder paste over a 72-hour period where the tack force coupons were stored open to the air (Figure 7).

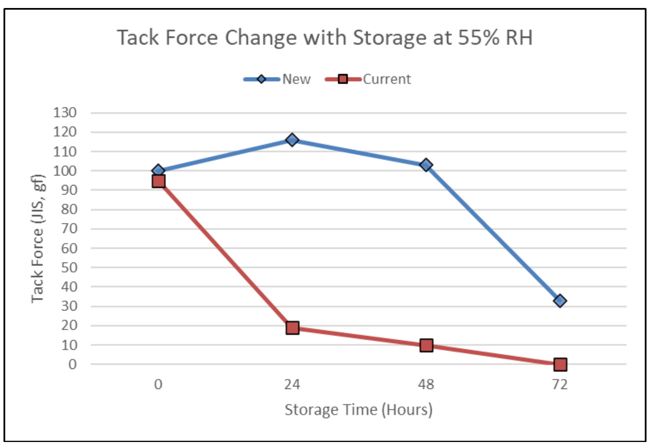


Figure 7. Tack force over 72 hours for the current and new solder pastes.

One of the weaknesses of the current solder paste is tack force loss over a long period of time. The current solder paste loses nearly all its tack force during 24 hours of storage at room temperature (RT) and 55% RH. After 72 hours of storage, the tack force of the current solder paste is close to zero (0). The new solder paste is more stable in this test and holds tack force over 48 hours.

The second environmental stability test involved storing solder paste in a dish open to the air and measuring mass change over 24 hours. When solder paste is stored open to the air, several things occur simultaneously.

- Solvents evaporate out of the solder paste, causing a mass loss.
- Air (oxygen) migrates through the flux to the solder powder surface and causes oxidation. This may result in a slight mass increase.
- Moisture from the air is absorbed into the hygroscopic materials in the flux, causing a mass increase.

Storage was done at RT at both 20% RH and 55% RH, and the results are shown below (Figure 8).

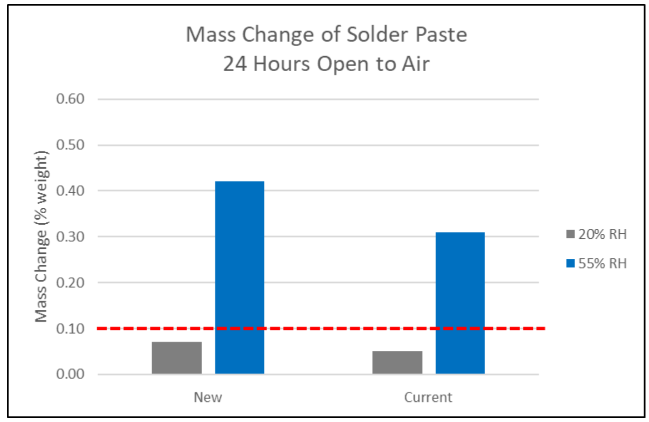


Figure 8. Mass change over time for the current and new solder pastes.

There was less than 0.1% by weight mass increase for both solder pastes when stored at 20% RH, which is negligible. Both solder pastes gained significant mass during storage at 55% RH, indicating moisture absorption. The new solder paste gained more mass than the current product, but the percentage changes were comparable to other water-soluble solder pastes.

Stencil life over 8 hours was measured using the PR test board v2 and a print and pause test with 4 PCBs run after each pause time. TE% was measured using the 0.5 mm pitch BGA's (0.50 area ratio). The stencil life results are in Figure 9 below.

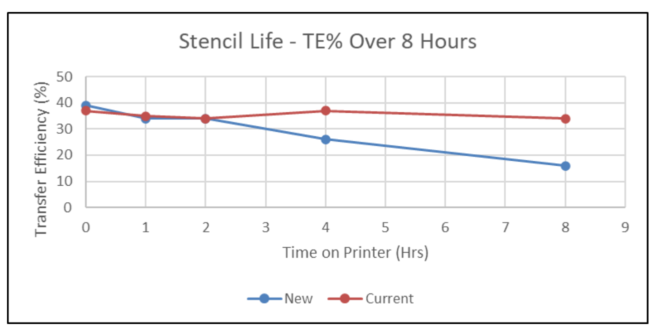


Figure 9. Stencil life of the current and new solder pastes over 8 hours in a print and pause test.

One of the strengths of the current solder paste is consistent printability over the 8-hour print and pause test. There is little to no change in TE% for the current solder paste throughout this 8-hour test. The new solder paste lost some TE% between 2 and 4 hours and again between 4 and 8 hours. The new solder paste does not last as long on the printer as the current product, but the stencil life is within normally acceptable limits.

PR Test Board v2 Performance

The PR test board measures printing area ratio limit, printability in 0.5 mm pitch BGAs, wetting, solder balling, graping, and voiding on QFN thermal pads [6].

Printability with varying print speed was measured using 0.5 mm pitch BGA arrays (0.50 area ratio) for both the current and new solder paste (Figure 10).

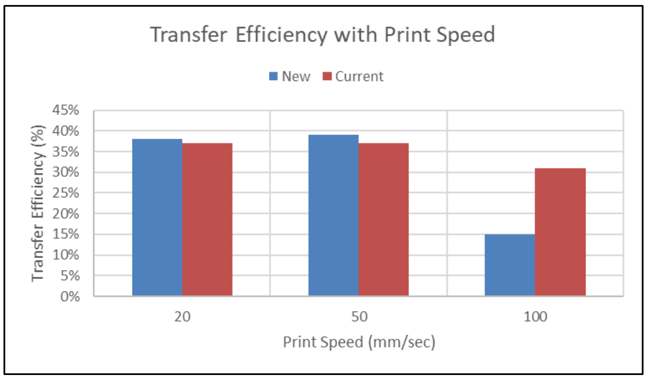


Figure 10. TE% with print speed for the current and new solder pastes.

One of the strengths of the current solder paste is consistent printing regardless of print speed. There was a slight drop in TE% for the current solder paste at a speed of 100 mm/sec, but this is insignificant. The new solder paste showed a larger drop in TE% at 100 mm/sec than the current solder paste. The new solder paste printed consistently at 20 and 50 mm/sec print speeds which are more commonly used than the 100 mm/sec print speed.

Wetting or spread % was measured on ENIG and OSP surface finishes for both solder pastes (Figure 11).

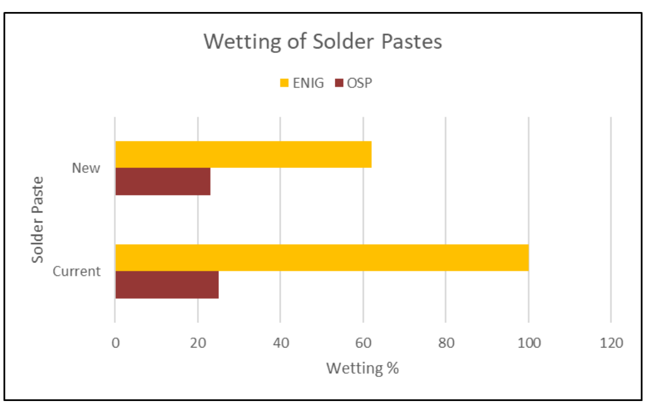


Figure 11. Wetting of the current and new solder pastes on ENIG and OSP surface finishes.

On the ENIG surface finish, the new solder paste spread less than the current solder paste. One strength of the current solder paste is exceptional spread in this test. The spread of the new solder paste is typical of most solder pastes in this test. On the OSP surface finish, both solder pastes performed as expected with nearly identical wetting. This is typical wetting for most solder pastes on OSP.

Voiding on the PR test board v2 was measured in the QFN68 thermal pad solder joints. This was done for both the current and new solder pastes, and the RTS and RSS reflow profiles (Figure 12).

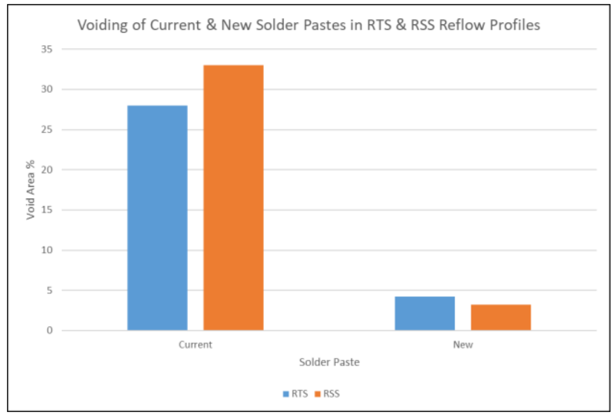


Figure 12. Voiding of the current and new solder pastes in the RTS and RSS reflow profiles.

One of the weaknesses of the current water-soluble Pb-free solder paste is the potential for high voiding on BTCs. The new solder paste was designed to reduce voiding to ultra-low levels, which is demonstrated in this test.

Hand Cleanability of the Current and New Solder Pastes

Hand cleaning of the current solder paste from the stencil is relatively difficult due to a tendency for a thin layer of the solder paste to adhere to the stencil surface. Conversely, the new solder paste was designed to improve upon this and is much easier to hand clean from the stencil.

Cleaning Effects with the B-52 Legacy 2 Boards

Water soluble solder pastes are engineered to be cleaned using a DI-Wash process. The benefit of a water-soluble solder paste is the ease of cleaning. The tradeoff is the activity level of the remaining flux residue. Water soluble flux residue is ionic and has a high risk of electrochemical migration when the electronics are exposed to climatic environments.

The B-52 Legacy 2 test board used for this study is populated with leadless and bottom terminated components. Complete removal of the flux residues under these components is critical. One of the factors studied is to compare the cleaning performance of DI-Water versus DI-Water with an engineered cleaning agent. The cleaning agent lowers surface tension and improves wetting.

The Magnalytix test boards were used to study two water-soluble solder pastes, a linear and soak reflow profile, and cleaning effects.

Figure 13 illustrates the SIR test performance of the *current* water-soluble solder paste, soak profile, and not cleaned. Heavy flux residues were present under all component terminations. All SIR channels failed SIR testing.

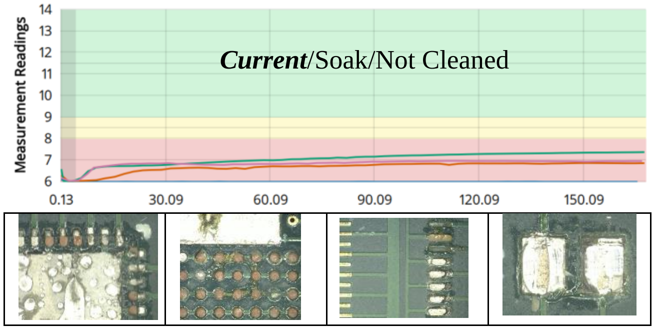


Figure 13: *Current* Solder Paste/Soak/Not Cleaned

Figure 14 illustrates the SIR test performance of the *new* water-soluble solder paste, soak profile, and not cleaned. Heavy flux residues were present under all component terminations. The new solder paste was not glossy and had a drier residue. All channels failed SIR testing.

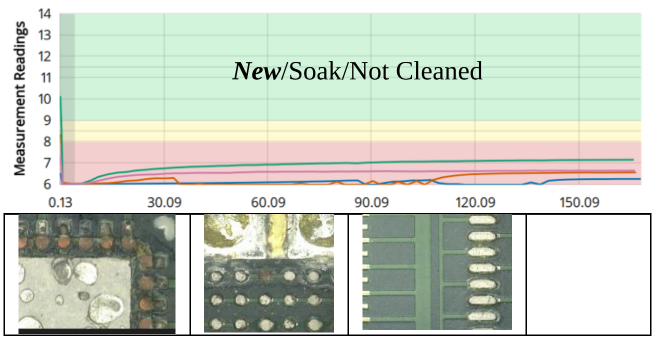


Figure 14: *New* Solder Paste/Soak/Not Cleaned

Figure 15 illustrates the SIR test performance of the *current* water-soluble solder paste, linear profile, and not cleaned. Heavy flux residues were present under all component terminations. All SIR channels failed SIR testing.

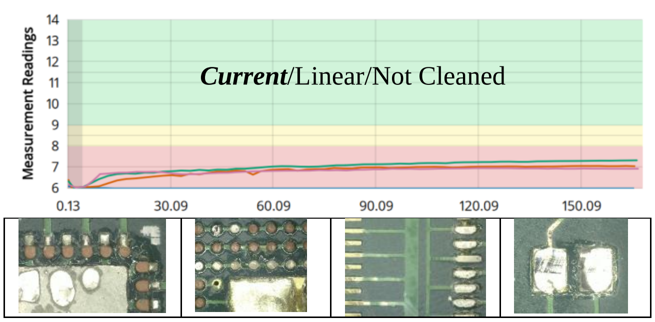


Figure 15: *Current* Solder Paste/Linear/Not Cleaned

Figure 16 illustrates the SIR test performance of the *new* water-soluble solder paste, linear profile, and not cleaned. Heavy flux residues were present under all component terminations. All SIR channels failed SIR testing.

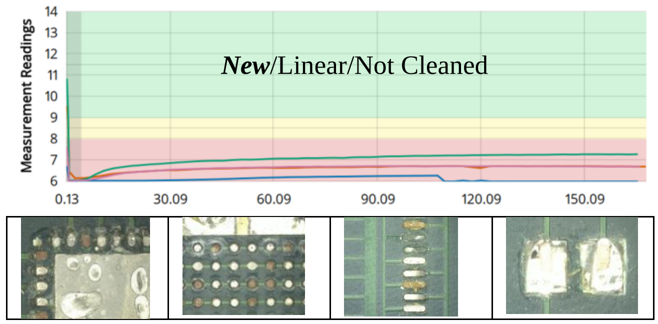


Figure 16: *New* Solder Paste/Linear/Not Cleaned

Figure 17 illustrates the SIR test performance of the current water-soluble solder paste, linear profile, and DI-Water cleaned. The FBGA and Caps were visually clean. There were minor traces of flux residue under the QFN and QFP-160 bottom terminated components. The FBGA and Caps were in the desired performance SIR zone. The QFN and QFP-160 were in the cautionary zone with instances of danger zone over the test period.

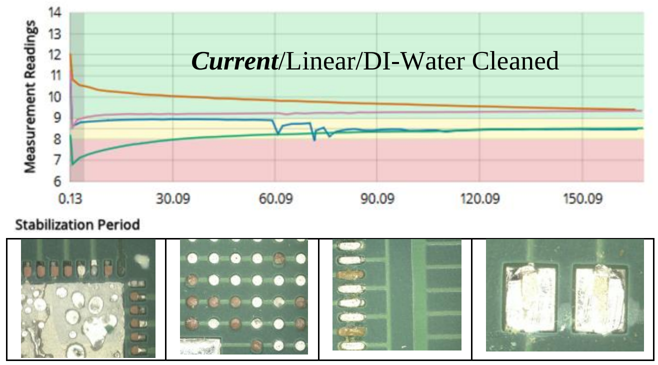


Figure 17: *Current* Solder Paste/Linear/DI-Water Cleaned

Figure 18 illustrates the SIR test performance of the *current* water-soluble solder paste, soak profile, and DI-Water cleaned. The FBGA, QFP-160, and Caps were visually clean. The QFN tracked in the cautionary zone with a slight decline to the danger zone. The QFN was visibly clean. The soak profile was more reliable than the linear profile.

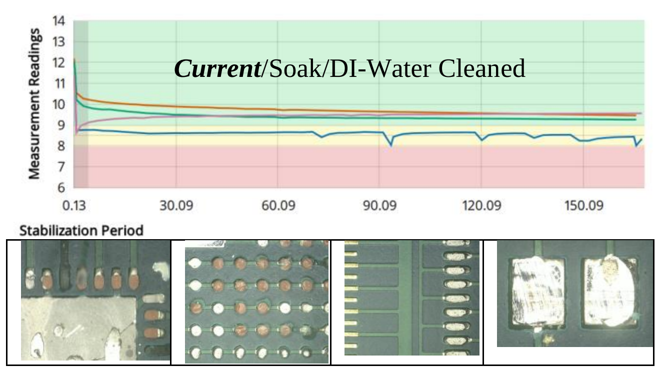


Figure 18: Current Solder Paste/Soak/DI-Water Cleaned

Figure 19 illustrates the SIR test performance of the *new* water-soluble solder paste, linear profile, and DI-Water cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The channels were stable and in the desired performance zone.

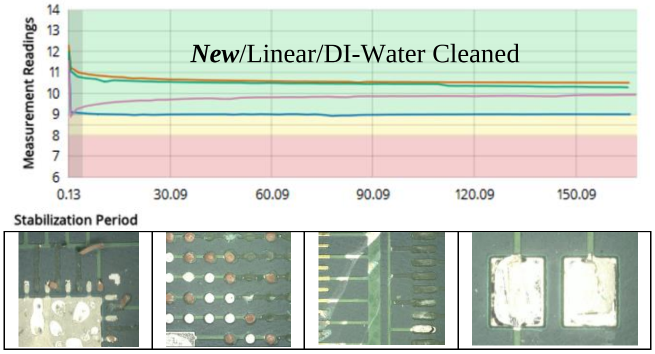


Figure 19: *New* Solder Paste/Linear/DI-Water Cleaned

Figure 20 illustrates the SIR test performance of the *new* water-soluble solder paste, soak profile, and DI-Water cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The channels were stable and in the desired performance zone.

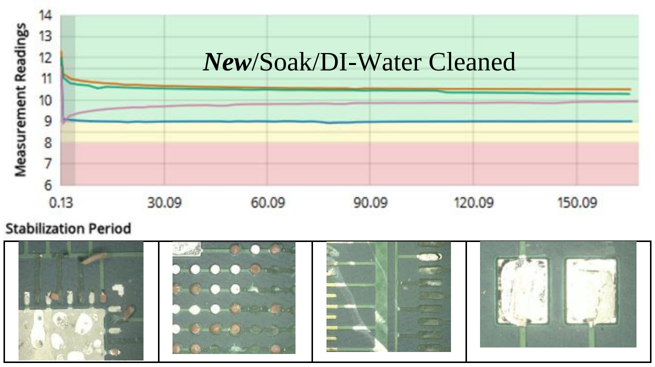
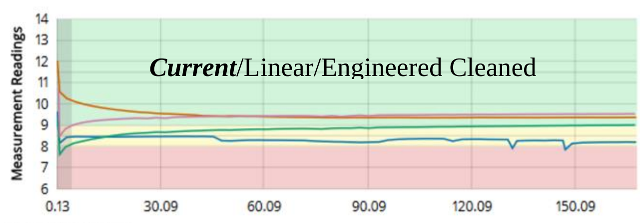


Figure 20: *New* Solder Paste/Soak/DI-Water Cleaned

Figure 21 illustrates the SIR test performance of the *current* water-soluble solder paste, linear profile, and DI-Water + Aqueous Engineered cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The FBGA and Caps were in the desired performance zone. The FBGA was in the cautionary zone. The QFN was in the cautionary zone with a few minor dips into the danger zone. There were minor differences between the DI-Water Clean and DI-Water + Engineered Aqueous Clean.



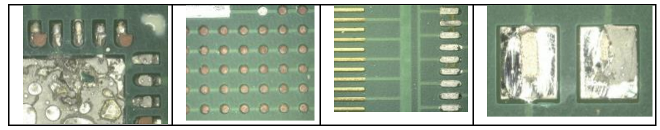


Figure 21: *Current* Solder Paste/Linear/Engineered Cleaned

Figure 22 illustrates the SIR test performance of the *current* water-soluble solder paste, soak profile, and DI-Water + Aqueous Engineered cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The FBGA and Caps were in the desired performance zone. The FBGA was in the cautionary zone. The QFN was in the cautionary zone with a minor dip into the danger zone. There were minor differences between the DI-Water Clean and DI-Water + Engineered Aqueous Clean.

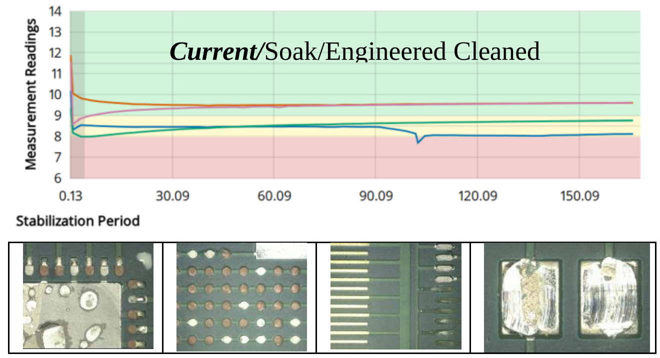


Figure 22: *Current* Solder Paste/Soak/Engineered Cleaned

Figure 23 illustrates the SIR test performance of the *new* water-soluble solder paste, linear profile, and DI-Water + Aqueous Engineered cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The QFN, FBGA, and Caps were in the desired performance zone. The QFP-160 was in the cautionary zone. There were minor differences between the DI-Water Clean and DI-Water + Engineered Aqueous Clean.

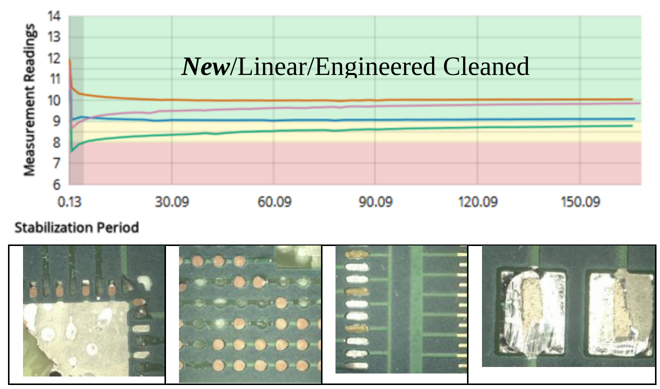


Figure 23: *New* Solder Paste/Linear/Engineered Cleaned

Figure 24 illustrates the SIR test performance of the *new* water-soluble solder paste, soak profile, and DI-Water + Aqueous Engineered cleaned. The QFN, FBGA, QFP-160, and Caps were visually clean. The QFN, FBGA and Caps were in the desired performance zone. The QFP-160 was in the cautionary zone. There were minor differences between the DI-Water Clean and DI-Water + Engineered Aqueous cleaned.

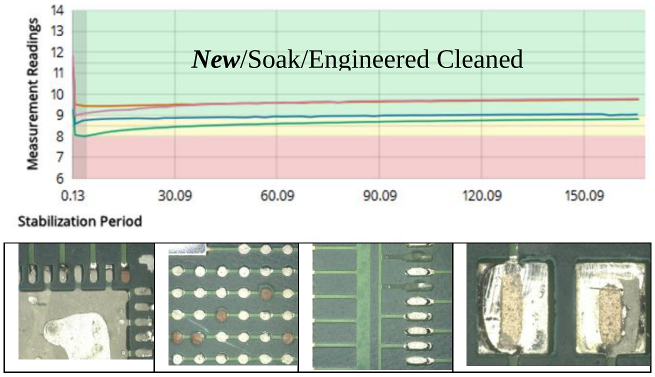


Figure 24: *New* Solder Paste/Soak/Engineered Cleaned

Reliability of the Flux Residues using SIR

Organic Acid (water soluble) solder pastes leave an ionic residue that dissolves in water. OA flux residues are active and must be cleaned to achieve field reliability. The following inferences can be made from the data findings.

- Organic Acid flux residues fail SIR
- The OA flux residues using the soak profile were more reliable
- The New solder paste was more reliable than the Current solder paste
- DI Water effectively cleaned both the New and Current solder paste residues
- The New solder paste was effectively cleaned with DI-Water
- The New solder paste cleaned better and was more reliable than the current solder paste
- When running the Linear profile, minor levels of flux residue caused failures
- The Linear profile did not clean as well as the Soak profile
- The engineered cleaning agent additive with DI-Water cleaned both the New and Current solder pastes
- The engineered cleaning agent was comparable to the DI water cleaning

Table 5 shows the minimum SIR value over the 168-hour test for the different conditions tested. As shown, the water-soluble fluxes not cleaned failed SIR testing. The new solder paste using the soak profile and cleaned with DI-water was the most reliable.

Table 5: Reliability of Flux Residues - Minimum SIR Values

Test #	Test Board	Solder Paste #1	Solder Paste #2	Solder Profile Ramp to Spike	Solder Profile Soak Profile	Inline - DI Water	Inline - Eng. Aq.	SIR [40°C/90% RH/ 5V / 168-Hours]	QFN-48 05 mm pitch	FCBA with a Center Lug 1.0 mm pitch	QFP-160 0.65 mm pitch	Net of Caps
		WS #1		x		No-Clean	No-Clean	x	6.00 $\mathrm{Log}_{10}\Omega$	7.06 $\mathrm{Log}_{10}\Omega$	7.34 $\mathrm{Log}_{10}\Omega$	6.93 $\mathrm{Log}_{10}\Omega$
1	MGX B52 Legacy 2	WS #1		x		x		x	8.49 $\mathrm{Log}_{10}\Omega$	9.42 $\mathrm{Log}_{10}\Omega$	8.54 $\mathrm{Log}_{10}\Omega$	9.37 $\mathrm{Log}_{10}\Omega$
2	MGX B52 Legacy 2	WS #1		x		x		x	8.95 $\mathrm{Log}_{10}\Omega$	9.06 $\mathrm{Log}_{10}\Omega$	8.54 $\mathrm{Log}_{10}\Omega$	9.55 $\mathrm{Log}_{10}\Omega$
3	MGX B52 Legacy 2	WS #1		x			x	x	8.21 $\mathrm{Log}_{10}\Omega$	9.38 $\mathrm{Log}_{10}\Omega$	9.02 $\mathrm{Log}_{10}\Omega$	9.55 $\mathrm{Log}_{10}\Omega$
4	MGX B52 Legacy 2	WS #1		x			x	x	7.76 $\mathrm{Log}_{10}\Omega$	9.46 $\mathrm{Log}_{10}\Omega$	9.32 $\mathrm{Log}_{10}\Omega$	9.59 $\mathrm{Log}_{10}\Omega$
		WS #1			x	No-Clean	No-Clean	x	6.00 $\mathrm{Log}_{10}\Omega$	6.87 $\mathrm{Log}_{10}\Omega$	7.38 $\mathrm{Log}_{10}\Omega$	6.96 $\mathrm{Log}_{10}\Omega$
5	MGX B52 Legacy 2	WS #1			x	x		x	8.37 $\mathrm{Log}_{10}\Omega$	9.48 $\mathrm{Log}_{10}\Omega$	9.29 $\mathrm{Log}_{10}\Omega$	9.58 $\mathrm{Log}_{10}\Omega$
6	MGX B52 Legacy 2	WS #1			x	x		x	8.40 $\mathrm{Log}_{10}\Omega$	9.44 $\mathrm{Log}_{10}\Omega$	9.68 $\mathrm{Log}_{10}\Omega$	9.69 $\mathrm{Log}_{10}\Omega$
7	MGX B52 Legacy 2	WS #1			x		x	x	8.14 $\mathrm{Log}_{10}\Omega$	9.62 $\mathrm{Log}_{10}\Omega$	8.78 $\mathrm{Log}_{10}\Omega$	9.62 $\mathrm{Log}_{10}\Omega$
8	MGX B52 Legacy 2	WS #1			x		x	x	8.07 $\mathrm{Log}_{10}\Omega$	9.55 $\mathrm{Log}_{10}\Omega$	8.76 $\mathrm{Log}_{10}\Omega$	9.59 $\mathrm{Log}_{10}\Omega$
			WS#2	x		No-Clean	No-Clean	x	6.00 $\mathrm{Log}_{10}\Omega$	6.70 $\mathrm{Log}_{10}\Omega$	7.28 $\mathrm{Log}_{10}\Omega$	6.70 $\mathrm{Log}_{10}\Omega$
1	MGX B52 Legacy 2		WS#2	x		x		x	9.02 $\mathrm{Log}_{10}\Omega$	10.53 $\mathrm{Log}_{10}\Omega$	10.30 $\mathrm{Log}_{10}\Omega$	9.95 $\mathrm{Log}_{10}\Omega$
2	MGX B52 Legacy 2		WS#2	x		x		x	9.04 $\mathrm{Log}_{10}\Omega$	10.79 $\mathrm{Log}_{10}\Omega$	10.00 $\mathrm{Log}_{10}\Omega$	9.87 $\mathrm{Log}_{10}\Omega$
3	MGX B52 Legacy 2		WS#2	x			x	x	9.13 $\mathrm{Log}_{10}\Omega$	10.06 $\mathrm{Log}_{10}\Omega$	8.80 $\mathrm{Log}_{10}\Omega$	9.87 $\mathrm{Log}_{10}\Omega$
4	MGX B52 Legacy 2		WS#2	x			x	x	9.10 $\mathrm{Log}_{10}\Omega$	10.07 $\mathrm{Log}_{10}\Omega$	9.31 $\mathrm{Log}_{10}\Omega$	9.87 $\mathrm{Log}_{10}\Omega$
			WS#2		x	No-Clean	No-Clean	x	6.27 $\mathrm{Log}_{10}\Omega$	6.57 $\mathrm{Log}_{10}\Omega$	7.17 $\mathrm{Log}_{10}\Omega$	6.65 $\mathrm{Log}_{10}\Omega$
5	MGX B52 Legacy 2		WS#2		x	x		x	9.04 $\mathrm{Log}_{10}\Omega$	10.82 $\mathrm{Log}_{10}\Omega$	10.26 $\mathrm{Log}_{10}\Omega$	9.95 $\mathrm{Log}_{10}\Omega$
6	MGX B52 Legacy 2		WS#2		x	x		x	9.02 $\mathrm{Log}_{10}\Omega$	10.63 $\mathrm{Log}_{10}\Omega$	10.27 $\mathrm{Log}_{10}\Omega$	9.91 $\mathrm{Log}_{10}\Omega$
7	MGX B52 Legacy 2		WS#2		x		x	x	9.04 $\mathrm{Log}_{10}\Omega$	9.84 $\mathrm{Log}_{10}\Omega$	8.83 $\mathrm{Log}_{10}\Omega$	9.75 $\mathrm{Log}_{10}\Omega$
8	MGX B52 Legacy 2		WS#2		x		x	x	9.06 $\mathrm{Log}_{10}\Omega$	9.76 $\mathrm{Log}_{10}\Omega$	8.84 $\mathrm{Log}_{10}\Omega$	9.81 $\mathrm{Log}_{10}\Omega$

CONCLUSIONS

Advances in Electronic Assembly are accomplished from material advances and assembly equipment. Many advances require smaller components and high density.

This research paper introduced a new Water-Soluble Solder Paste. Beneficial properties include tack time, open storage, and ultra-low voiding. A key limitation of water-soluble solder pastes is the activity level and the need to clean (remove) the flux residue post soldering. Partially cleaned water soluble flux residue under low profile leadless and bottom terminated components exhibit the risk of electrochemical failures. When using water-soluble materials, cleaning is a critical factor. The flux residue using the new water-soluble solder paste was less voluminous but drier than the current water-soluble paste. The flux residues were effectively cleaned when using DI-Water.

Engineered cleaning agents have been used to drop surface tension, provide a lower wetting angle, and assist in removing burnt flux residues. The required concentration is typically

5% in DI Water. The results from this study using the engineered cleaning were comparable to DI-Water.

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