DETERMINING THE EFFECT OF FINE MESH SOLDER POWDER ON FLUX RESIDUE REMOVAL

Timothy O'Neill
AIM
Cranston, RI, USA

Terry Munson
Foresite
Kokomo, IN, USA

Kalyan Nukala, M.S.Ch.E.
ZESTRON Americas
Manassas, VA, USA

Ravi Parthasarathy, M.S.Ch.E.
ZESTRON Americas
Manassas, VA, USA

ABSTRACT:

Solder paste users and developers face an unrelenting drive to miniaturize solder paste deposits. A key element to success is the incorporation of smaller solder particles in the solder paste. New flux formulas have been developed in parallel to enhance printing and soldering performance with finer powder. The focus of this development has been primarily on 'No-Clean' chemistries as this flux technology has emerged as the industry standard. While No-Clean flux residue is designed to be left in place after soldering, there are a variety of end use applications that require its removal including coating applications, RF and high voltage circuitry. When flux residue removal is mandated, wash chemistry is required in order to solubilize flux residue so that it can be washed and rinsed away.

At APEX 2018, a study titled 'Jet Printed Solder Paste and Cleaning Challenges' was presented whereby data was presented indicating that as solder powder becomes finer, the resulting flux residues become more difficult to remove. As a continuation of the APEX 2018 study, this study will test a common No-Clean flux chemistry with progressively finer SAC305 solder powders with a variety of cleaning chemistries and methods to attempt to quantify the implications of finer mesh powder on flux removal. This study was divided into two phases. For Phase 1, a fully populated ZESTRON test vehicle was assembled and cleaned. Post washed cleanliness levels on the surface as well as under-component were measured using visual inspection. Based on this analysis, Phase 2 trials were conducted utilizing the IPC-B-52 test vehicle cleaning agents yielding best and worst cleaning results from Phase 1. In this phase, cleanliness assessment was conducted using SIR and Ion Chromatography analyses. The results were analyzed to assess the influence of finer solder powder paste deposits on the cleaning process and materials. All cleanliness assessments were conducted in accordance with current IPC guidelines.

Keywords: Jetting Paste, Cleaning No-Clean, PCB Cleaning, SIR, Flux Residue Removal, Fine Pitch Solder Paste

BACKGROUND:

This study, conducted in cooperation with AIM, Foresite and ZESTRON, expands on earlier testing wherein several vendors Type 5 solder pastes were evaluated for effective cleaning using seven different cleaning chemistries. PCB cleanliness assessment was performed using visual inspection of the substrate surface and under-component.

Jetted solder paste offers several advantages over printed solder paste. Key among them are flexibility and non-contact application of paste. This makes jetting very attractive to low volume/high mix manufacturers as well as applications where a non-planar surface requires solder application. Paste jetting is also promising for high volume manufacturing as it can be coupled with solder paste inspection equipment to provide corrective and augmentative application of solder paste after an SMT print operation. It seems inevitable that jetting solder paste will be incorporated within applications where SMT printing is simply not feasible or cost effective.

Solder pastes used in jetting are similar to pastes used in SMT stencil printing, but with two major differences. Jetted solder powders are finer with smaller spheres and the flux content is greater relative to the solder powder. There are more subtle differences including solvent and rheological additive changes that are optimized for jetting applications. The forces applied to solder paste in jetting applications are very different than the forces imparted on paste during printing. During printing, relatively high shear force is applied to the paste that thins the paste at the squeegee interface thereby facilitating flow and aperture fill. With jet printing, the paste must flow to fill the ejector valve and the deposit must retain its shape after jetting. Generally speaking, jetted solder paste deposits are between 250 and 350 micron in diameter. In order to produce these results, the solder alloy powder size must be reduced considerably as compared to the printed paste. Solder powder classification is defined by IPC J-STD 005 [3]. Reference Table 1.

Table 1. Sample % by Weight: Nominal Size (in µm)

Type	Less than 0.5% larger than	10% max between	80% minimum between	10% maximum less than
1	160	150-160	75-150	75
2	80	75-80	45-75	45
3	60	45-60	25-45	25
4	50	38-50	20-38	20
5	40	25-40	15-25	15
6	25	15-25	5-15	5
7	15	11-15	2-11	2

Reference Figure 2 for a visual representation of the relative size of a Type 4 solder ball as compared to Type 5 and Type 6.

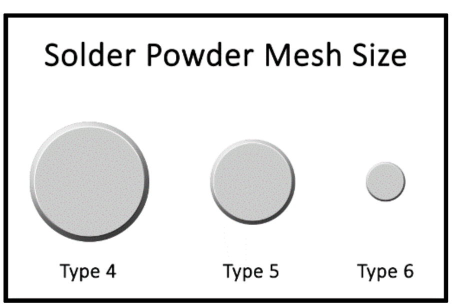

Figure 2. Solder Powder Size Comparison

The reduction in diameter of the powder sphere is significant on multiple levels with several that may impact flux residue characteristics and ultimately their removal. Type 6 solder paste spheres have nearly 4 times the available surface area as compared to Type 4 solder paste spheres for a given volume. Solder powder oxides are primarily present on the surface of the solder powder as illustrated in Figure 3. This increase of surface area introduces both soldering and cleaning challenges.

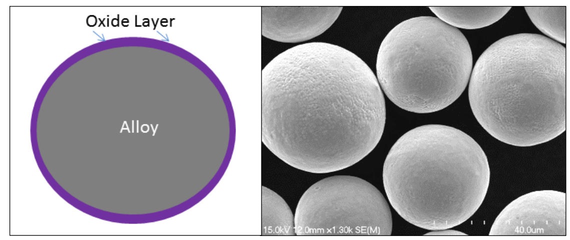

Figure 3. Solder Powder Oxide Layer

An increase in surface area increases the amount of oxide the flux vehicle needs to clean from the powder surface so that the alloy powder can coalesce into a singular mass. 'Graping' and other wetting related defects are the result of exhausted activators in the flux system. In addition to these immediate defects, flux residue becomes more difficult to remove due to the formation of metal salts and oxidation compounds due to interactions between the flux chemistry and additional oxides present. Additional cleaning challenges arise because jetted solder paste has a greater flux percentage than printed solder paste. Print grade solder paste is typically 88% to 91% metal by weight and 30% to 70% by volume, demonstrating that the relationship between metal percentage by weight and metal percentage by volume are not proportional. In other words, a seemingly small reduction in metal content by weight can significantly change the metal/flux ratio resulting in significantly more flux and therefore flux residue present after soldering.

This study was designed to examine the potential influence of mesh size on No-Clean flux removal by comparing No-Clean solder pastes formulated with Type 4 and Type 6 powder. One No-Clean solder paste flux medium was used for all trials.

All test vehicles used for Phase 1 and Phase 2 trials were assembled with SAC305 T4 and SAC305 T6 solder pastes.

METHODOLOGY:

Through the initial technical study presented at Apex 2018, the authors verified that cleaning jet printed solder paste is in fact more challenging as compared with screen printed solder pastes [1]. In this study, the authors' goal was to evaluate the effect of a common No-Clean flux chemistry with progressively finer solder powders using a variety of cleaning agents and methods in order to quantify the implication of finer mesh powder on flux removal.

As the primary focus of this study was a comparative analysis of cleaning efficacy with a focus on solder type or solder powder size, the DOE (Design of Experiment) was limited to a single solder paste formulation. Two versions of the same solder paste were used, one formulated with Type 4 and another with Type 6 solder powder. For purposes of this study and for a direct comparison of the effect of different solder powder size on flux residue removal, the Type 6 solder paste used was specially formulated for screen printing application as Type 4 powders are unsuitable for paste jetting.

The metal content was 88.5% and 88.2% for the Type 4 and Type 6 respectively. Each paste formulation was Lead Free No-Clean SAC 305 and screen printed for all trials.

As the authors' goal was to assess the influence, if any, of solder powder size on cleaning results, they opted to employ the same inline cleaning process and cleaning agents as used in the 2018 study [1]. With the exception of wash bath concentration and wash time or conveyor belt speed, cleaning process operating parameters were maintained constant throughout all trials.

The selected cleaning agents used for Phase 1 trials are identified in Table 2

Table 2. Cleaning Agent Descriptions

Cleaning Agent	Type
A	Microphase Alkaline Inhibited
B	Microphase Alkaline Uninhibited
C	Microphase pH Neutral Inhibited
D	Microphase pH Neutral Inhibited
E	Dynamic Surfactant Uninhibited
F	Dynamic Surfactant Inhibited

For each solder paste type and cleaning agent combination, two (2) process conditions and two (2) variables for each condition were analyzed. Reference Table 3.

Table 3. Cleaning Process: Conditions/Variables

Process Conditions/Variables		
Process Conditions	**No. Variables**	**Variable Type**
Cleaning Agent Concentration	2	10% / 15%
Conveyor belt speed: (Wash time)	2	0.7 fpm / 1.5 fpm (7.42 min / 3.46 min)

For Phase 1, the objective was to assess the cleaning effectiveness of the six aqueous-based cleaning agents with the Type 4 and Type 6 solder pastes. For each solder paste and process condition, the cleaning agent(s) yielding the best and worst results were identified as these would be used for the Phase 2 trials and analysis. For the Phase 1 trials, ZESTRON test vehicles were used and populated with numerous low standoff surface mount components. Cleanliness assessment was performed by shearing all components and conducting under-component visual analysis in accordance with current IPC standards.

For Phase 2 trials, IPC-B-52 test vehicles populated with SMT components were used and cleanliness analysis was performed using SIR and Ion Chromatography. However, based on the results of the cleaning trials from Phase 1, the cleaning agents selected for the Phase 2 trials were those that yielded the best and worst cleaning results from the visual inspection analysis from the Phase 1 trials.

For all test vehicles a 5 mil stencil was used and soldering was performed in air atmosphere condition.

METHODOLOGY – PHASE 1:

The ZESTRON test vehicle was selected for the Phase 1 trials and was fully populated with a total of 96 low standoff SMT components. Reference Figure 4 and Table 4 respectively.

The test vehicles were assembled at the AIM Application Center utilizing their recommended reflow profile and returned to the ZESTRON Technical Center for the cleaning trials.

Figure 4. Fully Populated ZESTRON Test Vehicle

Table 4. ZESTRON Test Vehicle: Component Type and Quantity

Component Type	No. of Components
QFP-256	1
6032	10
BGA-208	1
1825	10
MLF-68	1
0402	17
0603	15
0805	10
SOT-23	14
1206	10
1210	7
Total:	**96**

For Phase 1 trials, the DOE was designed as a full factorial analysis and required 48 test vehicles. Reference Table 5.

Table 5. Phase 1 Trial Matrix

Trial #	Cleaning Agent	Wash Conc. (%)	Conveyor Belt Speed (F/Min)	Solder Paste Type
1	A	10	0.7	4
2	A	15	0.7	4
3	A	10	0.7	6
4	A	15	0.7	6
5	A	10	1.5	4
6	A	15	1.5	4
7	A	10	1.5	6
8	A	15	1.5	6
9	B	10	0.7	4
10	B	15	0.7	4
11	B	10	0.7	6
12	B	15	0.7	6
13	B	10	1.5	4
14	B	15	1.5	4
15	B	10	1.5	6
16	B	15	1.5	6
17	C	10	0.7	4
18	C	15	0.7	4
19	C	10	0.7	6
20	C	15	0.7	6
21	C	10	1.5	4
22	C	15	1.5	4
23	C	10	1.5	6
24	C	15	1.5	6
25	D	10	0.7	4
26	D	15	0.7	4
27	D	10	0.7	6
28	D	15	0.7	6
29	D	10	1.5	4
30	D	15	1.5	4
31	D	10	1.5	6
32	D	15	1.5	6
33	E	10	0.7	4
34	E	15	0.7	4
35	E	10	0.7	6
36	E	15	0.7	6
37	E	10	1.5	4
38	E	15	1.5	4
39	E	10	1.5	6
40	E	15	1.5	6
41	F	10	0.7	4
42	F	15	0.7	4
43	F	10	0.7	6
44	F	15	0.7	6
45	F	10	1.5	4
46	F	15	1.5	4
47	F	10	1.5	6
48	F	15	1.5	6

It is interesting to note that the component standoff height for the Type 4 solder paste was greater than that achieved with the Type 6 solder paste. Reference Figures 5 – 10 for representative pictures. It is unclear why this occurred and further study is warranted. As component standoff is a significant cleaning variable, this finding may have considerable influence on cleaning outcomes.

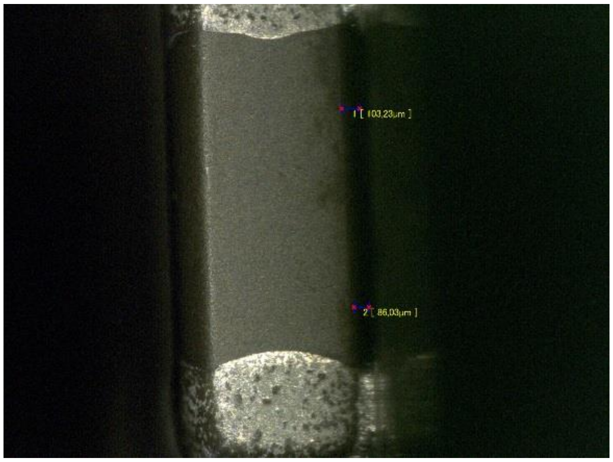

Figure 5. Type 4 - Component 1206 (3-4 mil)

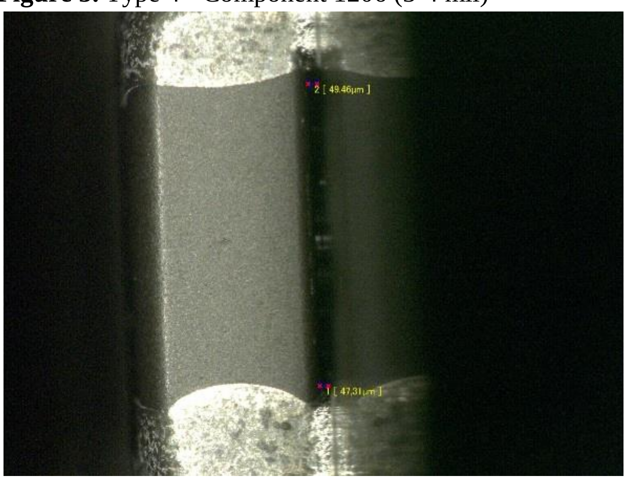

Figure 6. Type 6 – Component 1206 (≈ 2 mil)

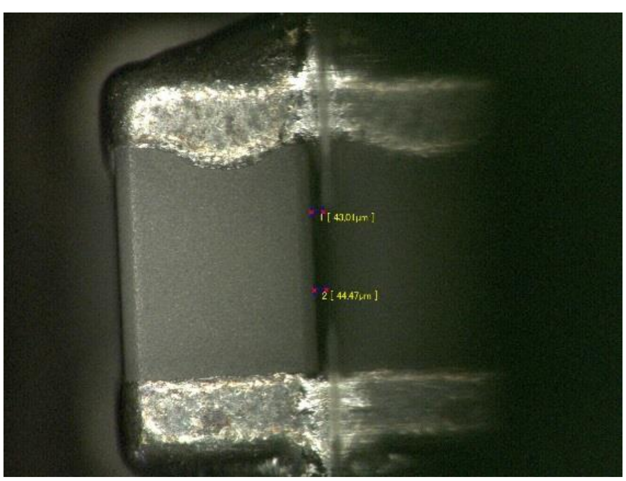

Figure 7. Type 4 – Component 0603 (≈ 2 mil)

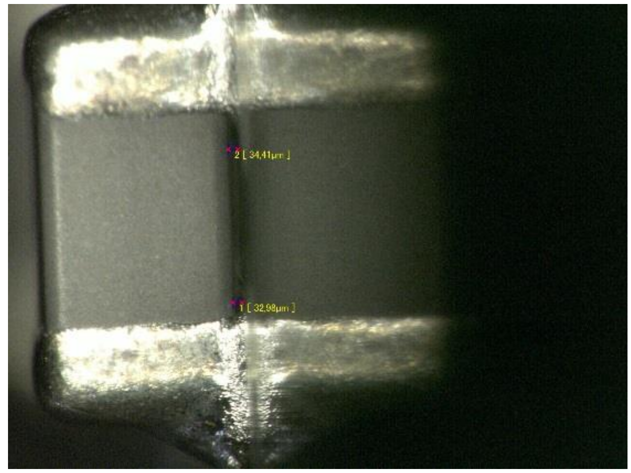

Figure 8. Type 6 – component 0603 (1-2 mil)

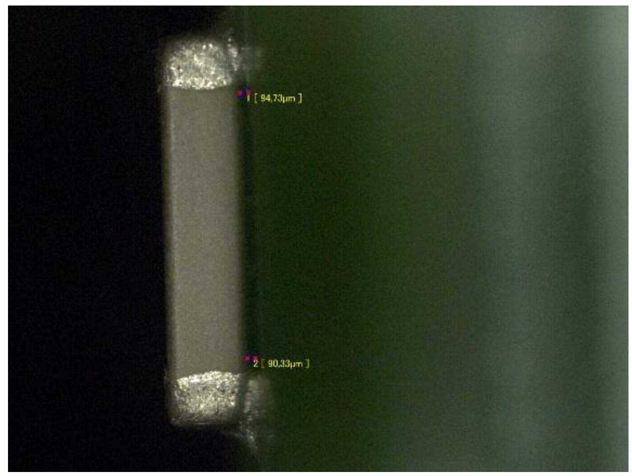

Figure 9. Type 4 – Component 1825 (≈ 4 mil)

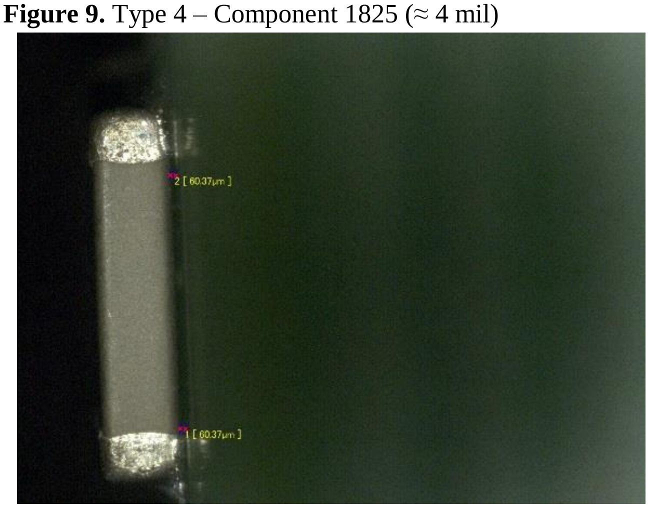

Figure 10. Type 6 – component 1825 (2-3 mil)

All cleaning trials were conducted using an inline spray-in-air cleaning system. With the exception of cleaning agent concentration and conveyor belt speed (wash time), the process parameters selected were maintained constant for all trials. Reference Table 6:

Table 6. Inline Cleaner Operating Parameters

Wash Stage	
Cleaning Process	**Spray-in-air Inline Cleaner**
Concentration	10% and 15% (by volume)
Conveyor Belt Speed	0.7 ft/min. and 1.5 ft/min.
Wash Dwell time	7.42 min and 3.46 min
Pre-Wash Pressure (Top/Bottom)	40 PSI / 40 PSI
Wash Spray Configuration	8-spray bar standard intermix
Wash Pressure (Top/Bottom)	75 PSI / 60 PSI
Wash Hurricane Pressure (Top/Bottom)	40 PSI / 40 PSI
Cleaning Temperature	150°F
Chem-Iso Pressure (Top/Bottom)	30 PSI / 30 PSI
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	75 PSI / 60 PSI
Rinse Hurricane Pressure (Top / Bottom)	40 PSI / 40 PSI
Rinsing Temperature	140°F
Final Rinse Pressure (Top/Bottom)	30 PSI / 30 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Dryer 1	160°F
Dryer 2	220°F
Dryer 3	220°F

After cleaning, all components were sheared from test vehicles in order to enable under-component visual inspection. Each test vehicle was independently inspected by three Application Engineers. Other than the QFP-256, BGA-208 and MLF components, the under-component surface was rated as either clean or not clean. The QFP-256, BGA-208, and MLF components were rated on a percent of under-component surface cleaned. The assigned ratings of the three engineers were averaged for all components for each test vehicle.

RESULTS – PHASE 1

Reference Figures 11 – 14 for overall cleanliness ratings

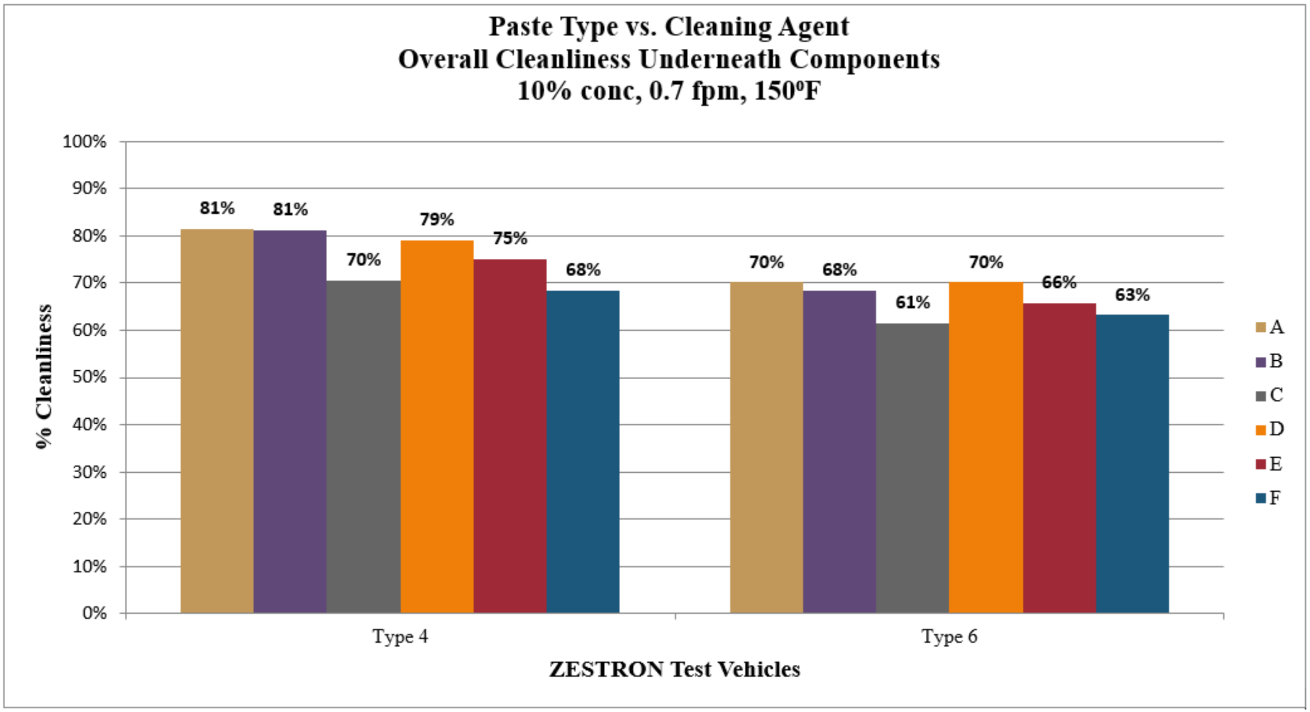

Figure 11.

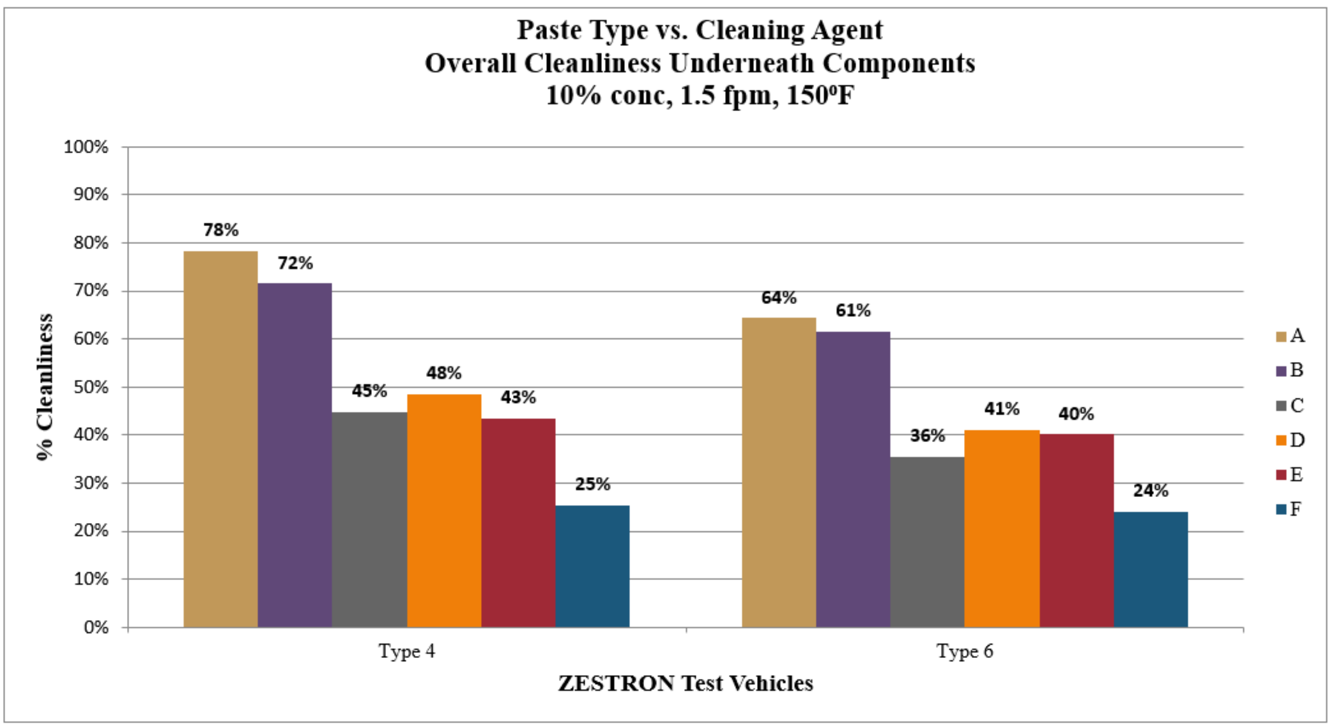

Figure 12.

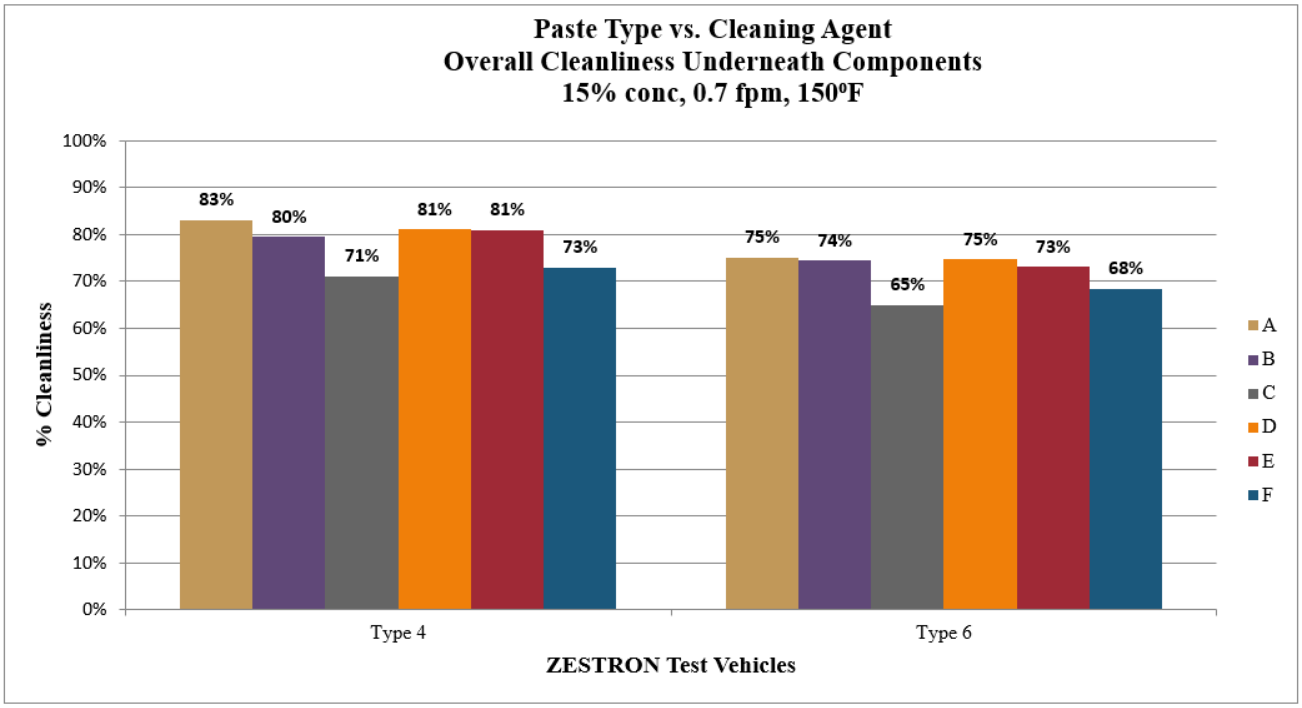

Figure 13.

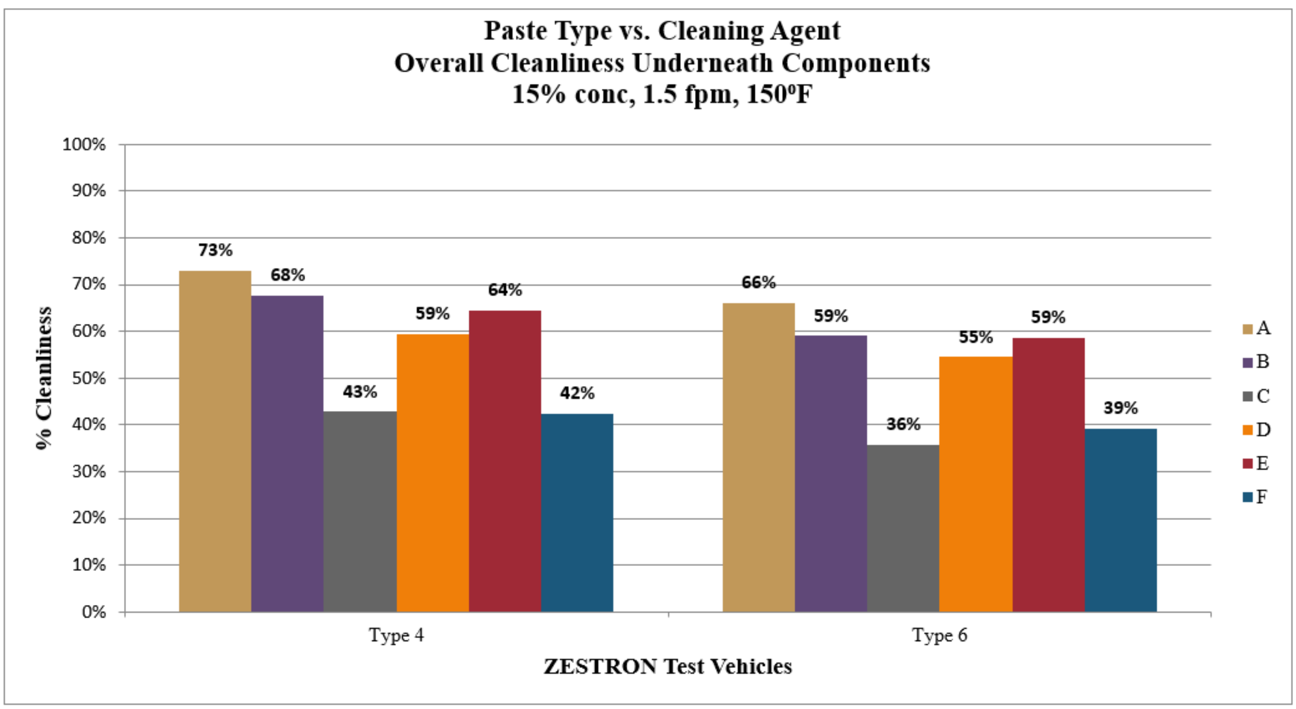

Figure 14.

Representative pictures of surface and under-component cleanliness utilizing Cleaning Agent A are detailed in Figures 15 and 16.

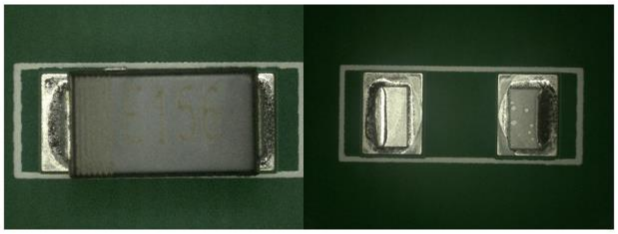

Figure 15. Type 4, Surface / Under-Component - 6032

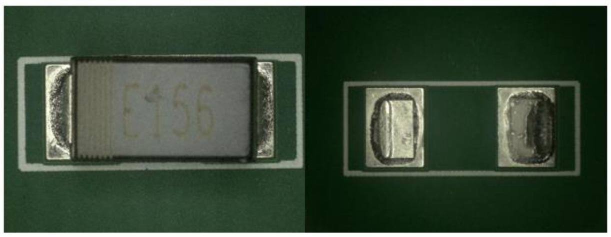

Figure 16. Type 6, Surface / Under-Component - 6032

Based on the results of under-component visual inspection, the cleaning agents that yielded the best and worst cleaning results are detailed in Tables 7 – 10.

Table 7. Cleaning Agent Comparison

10% Concentration, 0.7 fpm, 150°F			
Type 4	Trial 1	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 41	Worst	Cleaning Agent F (Dynamic Surfactant Inhibited)
Type 6	Trial 3	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 43	Worst	Cleaning Agent F (Dynamic Surfactant Inhibited)

Table 8: Cleaning Agent Comparison

10% Concentration, 1.5 fpm, 150°F			
Type 4	Trial 5	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 45	Worst	Cleaning Agent F (Dynamic Surfactant Inhibited)
Type 6	Trial 7	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 47	Worst	Cleaning Agent F (Dynamic Surfactant Inhibited)

Table 9. Cleaning Agent Comparison

15% Concentration, 0.7 fpm, 150°F			
Type 4	Trial 2	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 18	Worst	Cleaning Agent C (Microphase pH Neutral Inhibited)
Type 6	Trial 4	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 20	Worst	Cleaning Agent C (Microphase pH Neutral Inhibited)

Table 10. Cleaning Agent Comparison

15% Concentration, 1.5 fpm, 150°F			
Type 4	Trial 6	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 22	Worst	Cleaning Agent C (Microphase pH Neutral Inhibited)
Type 6	Trial 8	Best	Cleaning Agent A (Microphase Alkaline Inhibited)
	Trial 24	Worst	Cleaning Agent C (Microphase pH Neutral Inhibited)

Conclusions - Phase 1:

Irrespective of the conveyor belt speed, Cleaning Agent A outperformed all others at both 10% and 15% concentration for both the Type 4 and Type 6 solder pastes.

METHODOLOGY – PHASE 2:

For this phase of the study, the IPC-B-52 test coupons was selected to further assess the influence of a soldering process utilizing Type 4 versus Type 6 solder paste on the cleaning process. Use of these test coupons enabled cleanliness assessment through SIR and Ion Chromatography analyses.

Based on the results of the Phase 1 Trials, the authors selected the cleaning agents that produced the best and worst results for the Phase 2 Trials. The test matrix for these trials required sixteen (16) test vehicles. Reference Table 11.

Table 11. Phase 2 Trial Matrix

Trial #	Paste Type	Board ID	Best/ Worst Case	Process Settings: Conc % / °F / fpm	Cleaning Agent
1	T4	T4-1	Best	10/150/0.7	A (8 Trials)
2	T6	T6-1	Best	10/150/0.7	
3	T4	T4-2	Best	15/150/0.7	
4	T6	T6-2	Best	15/150/0.7	
5	T4	T4-3	Best	15/150/1.5	
6	T6	T6-3	Best	15/150/1.5	
7	T4	T4-8	Best	10/150/1.5	
8	T6	T6-8	Best	10/150/1.5	
9	T4	T4-4	Worst	10/150/0.7	F (4 Trials)
10	T4	T4-5	Worst	10/150/1.5	
11	T6	T6-4	Worst	10/150/1.5	
12	T6	T6-5	Worst	10/150/0.7	
13	T4	T4-6	Worst	15/150/1.5	C (4 Trials)
14	T4	T4-7	Worst	15/150/0.7	
15	T6	T6-6	Worst	15/150/0.7	
16	T6	T6-7	Worst	15/150/1.5	

In total, twenty (20) IPC-B-52 test coupons were assembled as two test coupons were required for base line analysis for each solder paste type. The test coupons for baseline analysis were not cleaned. The locations populated on the IPC-B-52 test coupons are detailed in Figure 17. The component types used are detailed in Table 12.

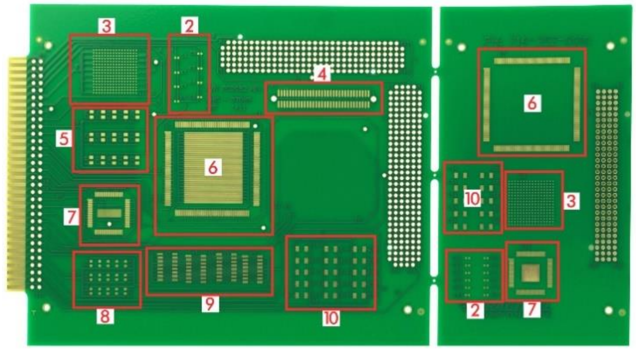

Figure 17. IPC-B-52 Test Coupon (SIR mini-coupons not used)

Table 12. IPC-B-52 Test Coupon – Component Type and Quantity

Location	Part Description	Quantity / Board
2	0402SMC-0.01pF	20
3	A-CABGA256-1.0mm-17mm-ISO	2
4	Conn-SMT-2x16-Molex	1
5	0805SMC-0.1pF	25
6	A-QFP160-28mm-.65mm-ISO	2
7	A-TQFP80-12mm-.5mm-ISO	2
8	0603SMC-0.01pF	15
9	A-SO16GT-3.8mm-ISO	4
10	1206SMC-10pF	25

As in Phase 1, these test coupons were assembled at the AIM Application Center and sent to the ZESTRON Technical Center for the cleaning trials.

After printing, all assemblies were inspected using SPI system to confirm paste area, volume and height. Reference Figure 18.

Figure 18. SPI System Analysis

All assemblies were reflowed in a Ramp-Soak-Spike profile. Soak Temperature (°C) 150-175, Soak time (sec) 75, TAL (sec) 60, Peak temperature (°C) 245 and Profile length (min) 4.5. Reference Figure 19.

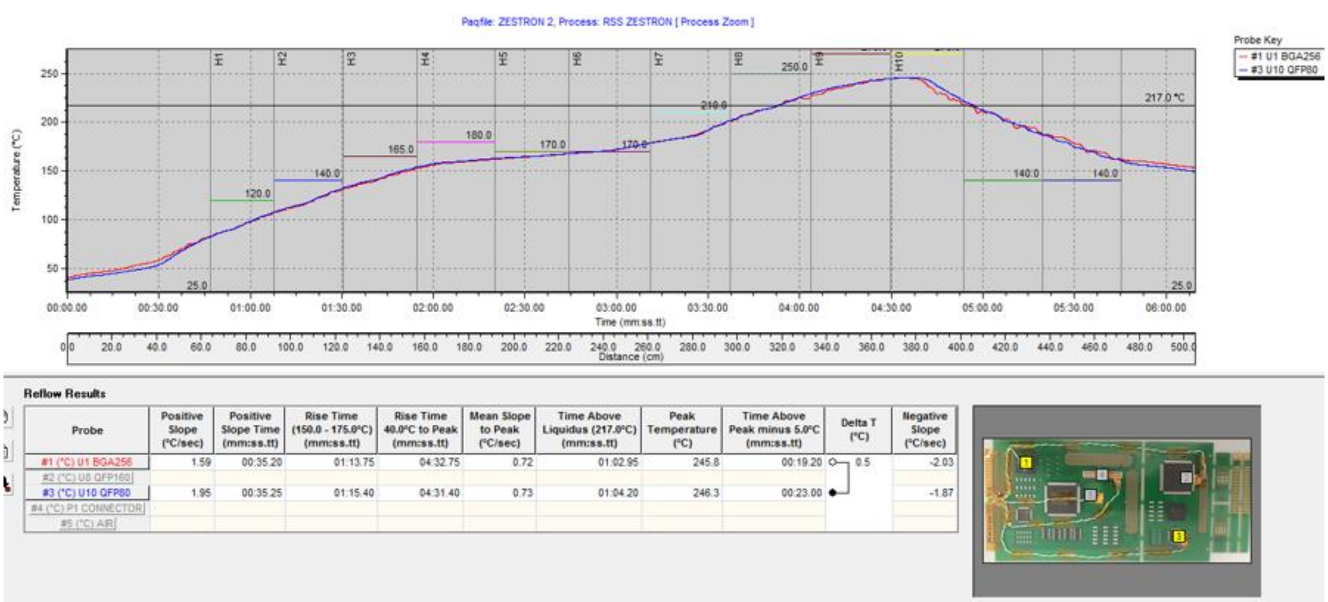

Figure 19. Reflow Profile

After reflow, all assemblies were examined using X-ray to verify placement and solder joint quality. Reference Figure 20.

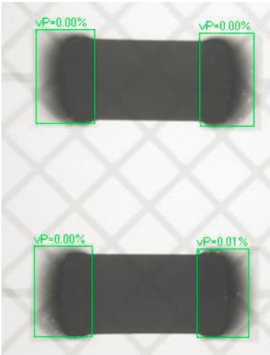

Figure 20. Soler Joint X-ray

Following inspection, the assemblies were packaged and shipped overnight to the ZESTRON Technical Center for cleaning.

For all trials, the same inline spray-in-air cleaning system was used as in the Phase 1 trials and all process parameters were maintained constant throughout. Reference Table 6.

Following the cleaning process, the test coupons were segmented. The Main SIR test coupon from each trial was sent to Foresite for SIR analysis and the Ion Chromatography test coupon was analyzed at the ZESTRON Technical Center.

RESULTS – PHASE 2:

IC and SIR analyses were conducted in accordance with IPC-TM-650, method 2.3.28 and method 2.6.3.7 respectively. For IC analysis, generally accepted industry standards were used for the contamination limits and are specified within the results data table. For SIR analysis, parameters used were; 40C, 90% RH with 5v bias for 168 hours. Per the IPC standard, an SIR value of 1.0e8 ohms of resistance or better is required for a passing result.

For all trials, both IC and SIR tests yielded passing results. The IC results are located in the appendix, Tables 15 (Type 4 Solder Paste) and 16 (Type 6 Solder Paste).

As all SIR tests passed. Only the results for the baseline coupons, sample 1, are represented for both the Type 4 and Type 6 solder pastes. Reference Figures 21 and 22.

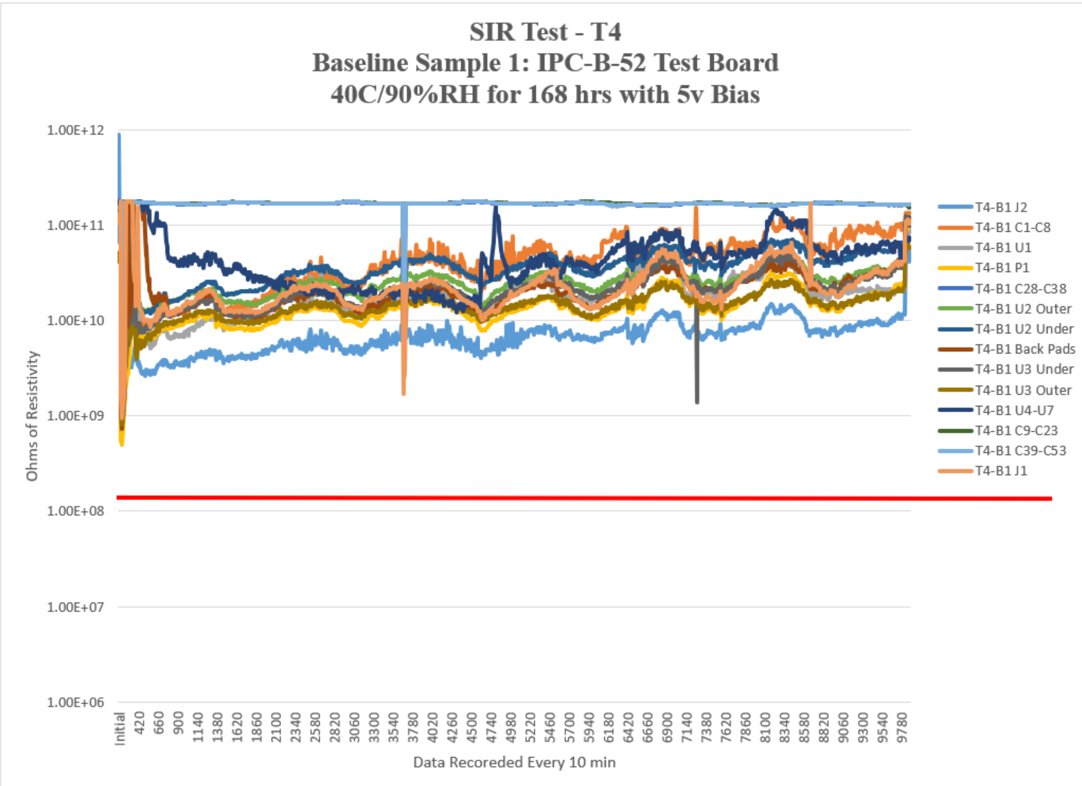

Figure 21. Overall SIR Results Type 4 Baseline Sample 1

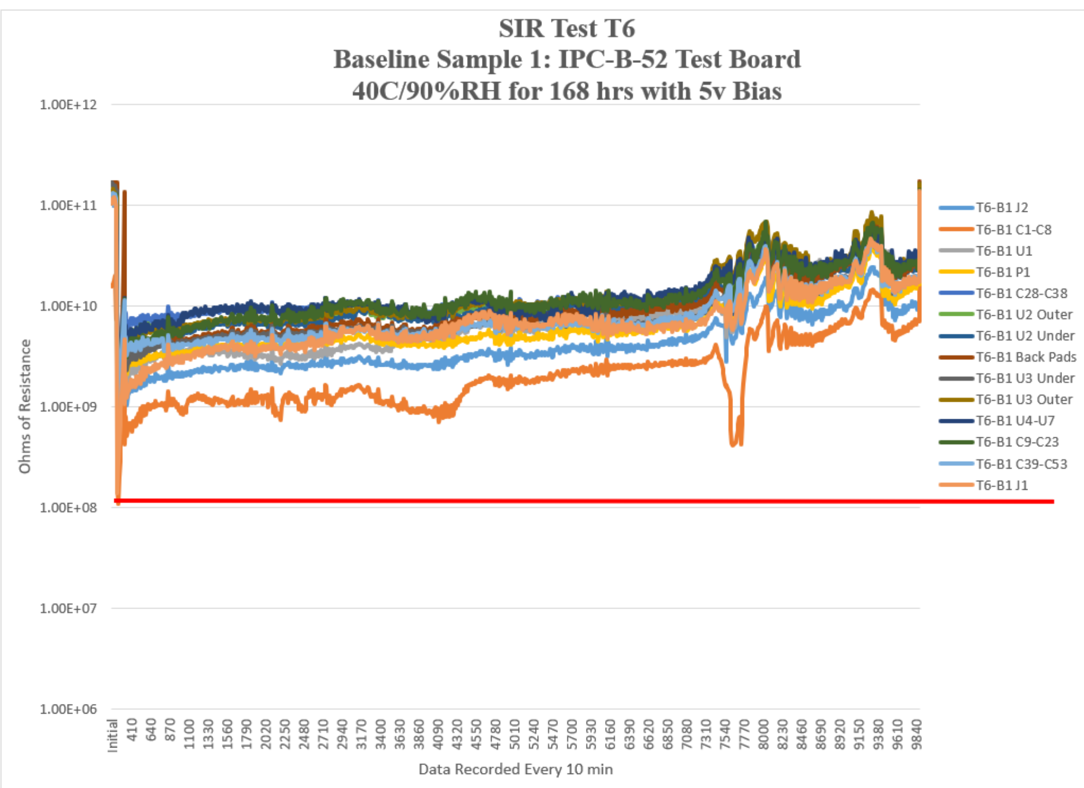

Figure 22. Overall SIR Results Type 6 Baseline Sample 1

As noted by the SIR data, all combinations of cleaning agents and solder paste types yielded passing results. In order to try to differentiate cleaning efficacy between Type 4 and Type 6 solder pastes, the authors chose to analyze the SIR values for individual coupon component groups. For this analysis, the authors selected component groups that were common to both IC and SIR analyses and included C1-C8, C39-C53 and U3. Reference Figure 23.

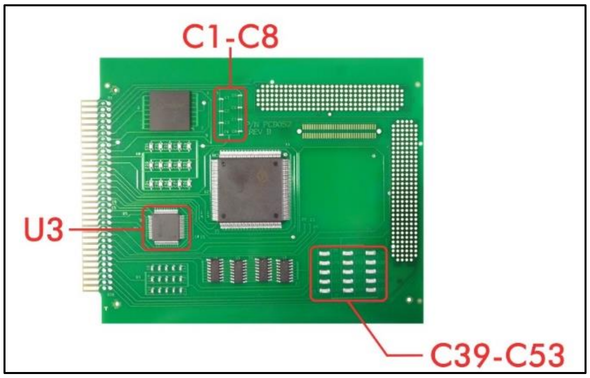

Figure 23. Component Group Identification

Other than SIR Baseline results, each plot graphs Trials 1 – 8 from Table 11 as these represent the best case results that were produced with Cleaning Agent A for each concentration and belt speed scenario. The component group SIR values are detailed in Figures 24-29.

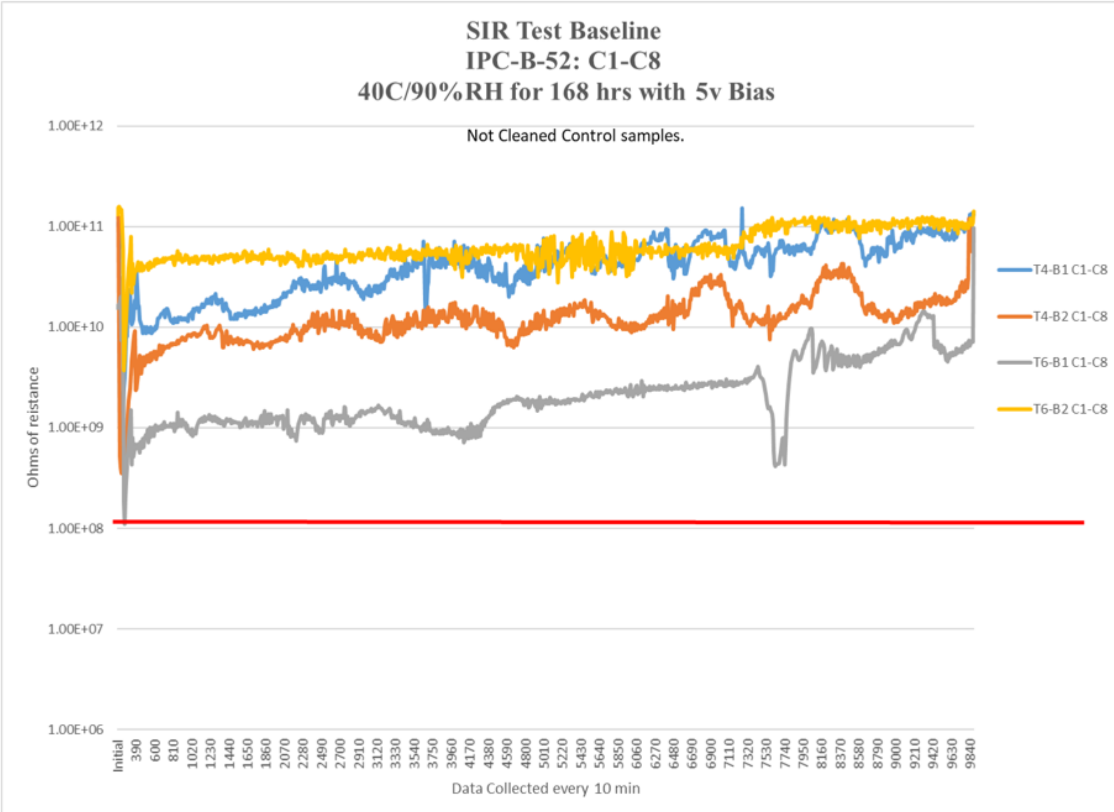

Figure 24. SIR Test Baseline C1-C8

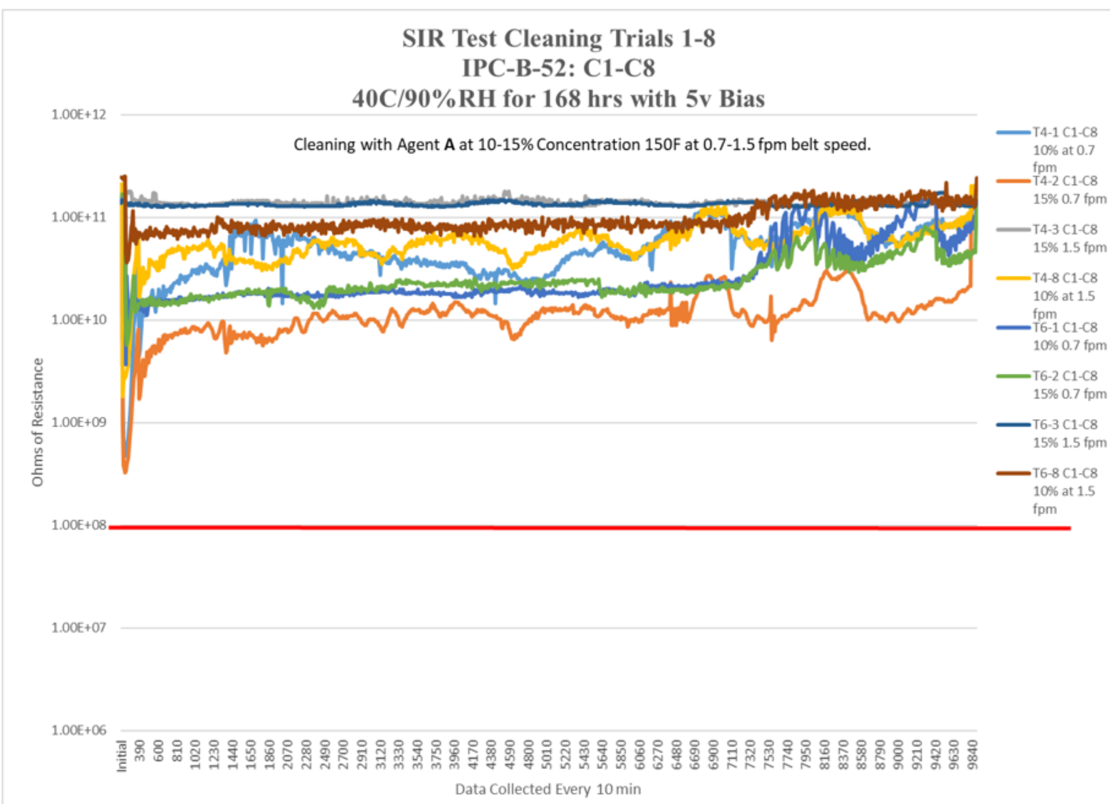

Figure 25. SIR Test Cleaning Trials 1-8: C1-C8

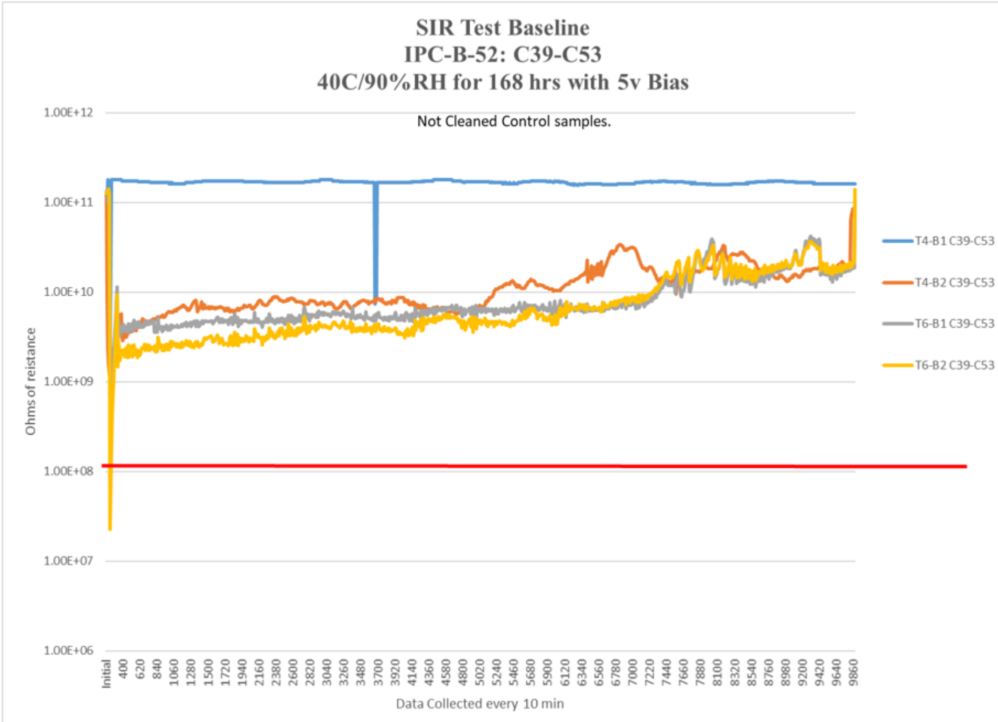

Figure 26. SIR Test Baseline C39-C53

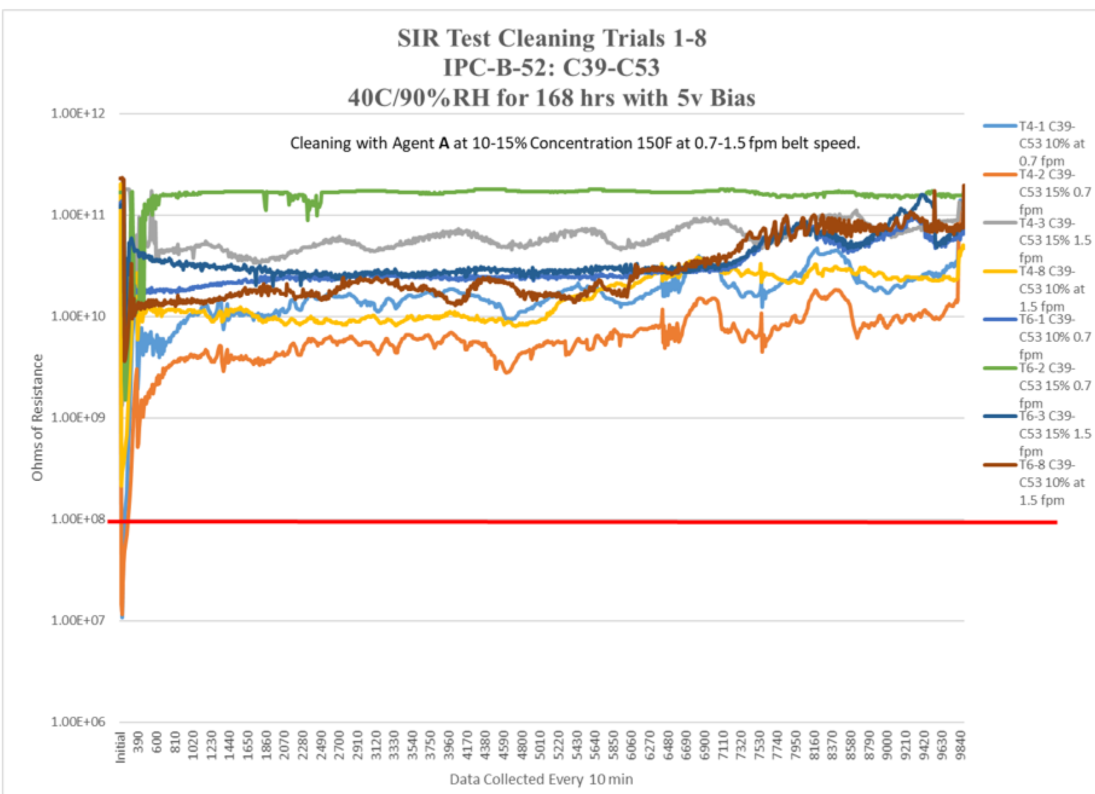

Figure 27. SIR Test Cleaning Trials 1-8: C39-C53

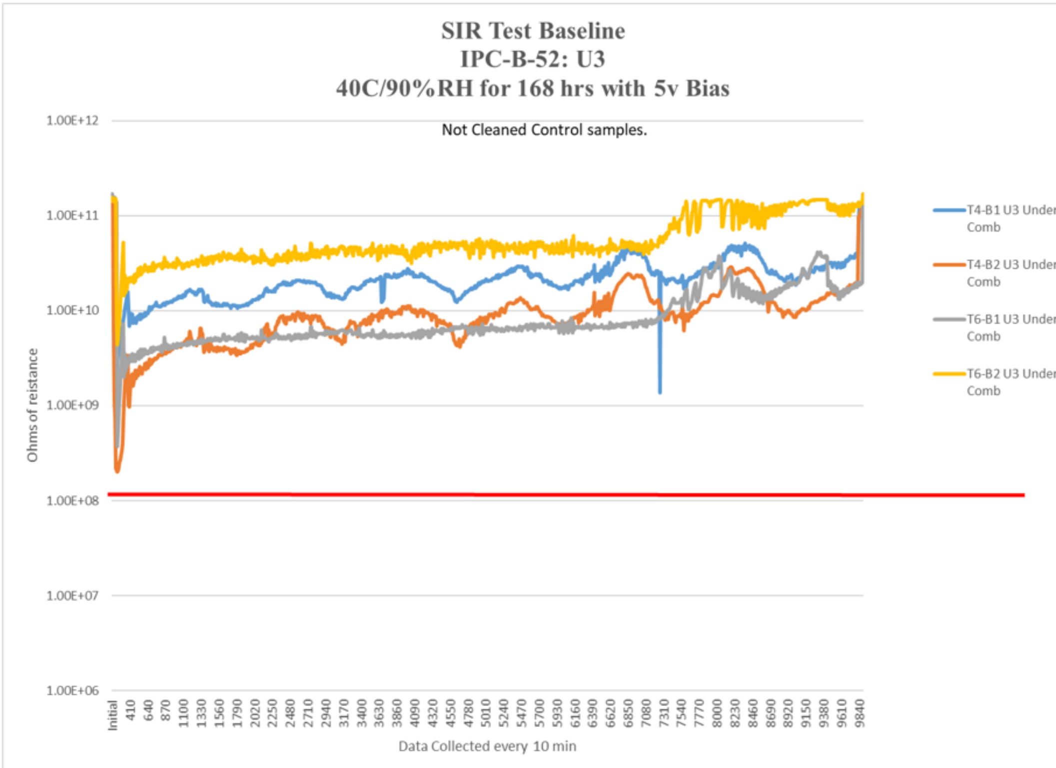

Figure 28. SIR Test Cleaning Trials 1-8 IPC-B-52: U3

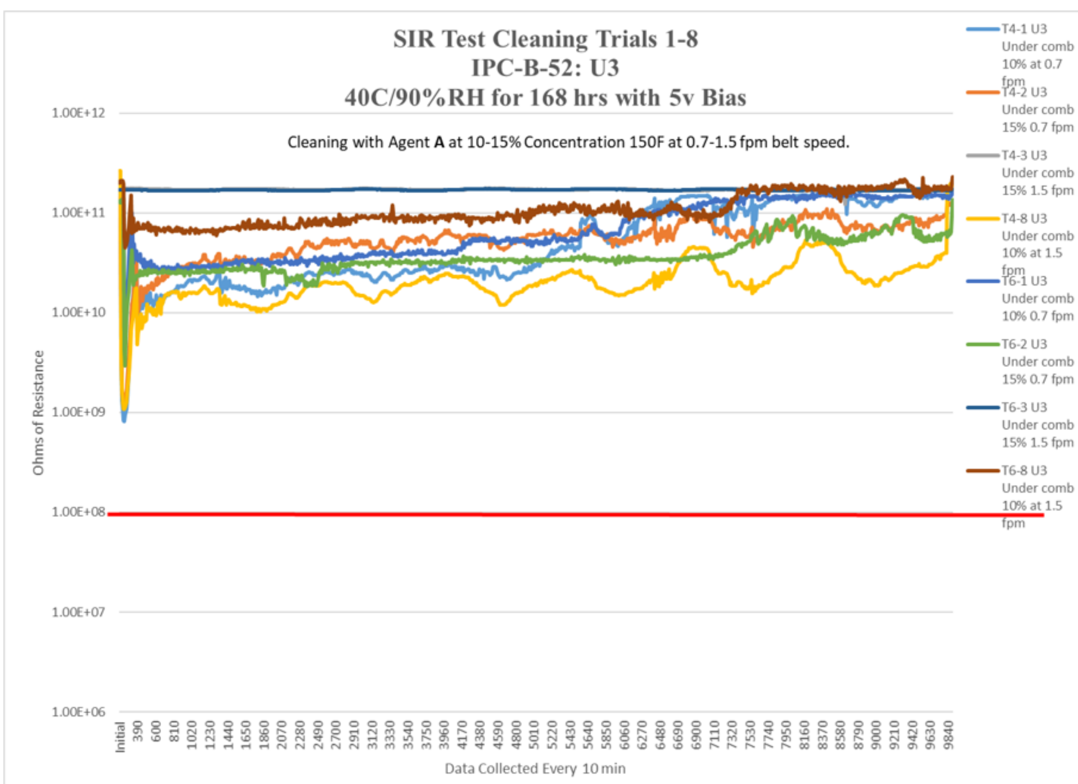

Figure 29: SIR Test Cleaning Trials 1-8: U3

Additionally, the authors chose to analyze the SIR results for the various component groups for both the Type 4 and Type 6 solder pastes from Trials 5 and 6. Reference Table 13.

Table 13.

Trial #	Paste Type	Board ID	Process Settings	Cleaning Agent
5	T4	T4-3	15% conc, 150F, 1.5fpm	A
6	T6	T6-3	15% conc, 150F, 1.5fpm	

For these trials, the faster belt speed was used creating a shorter wash time in order to see if one paste type yielded higher SIR values as compared to the other. This comparison was inconclusive. Reference Figures 30-32.

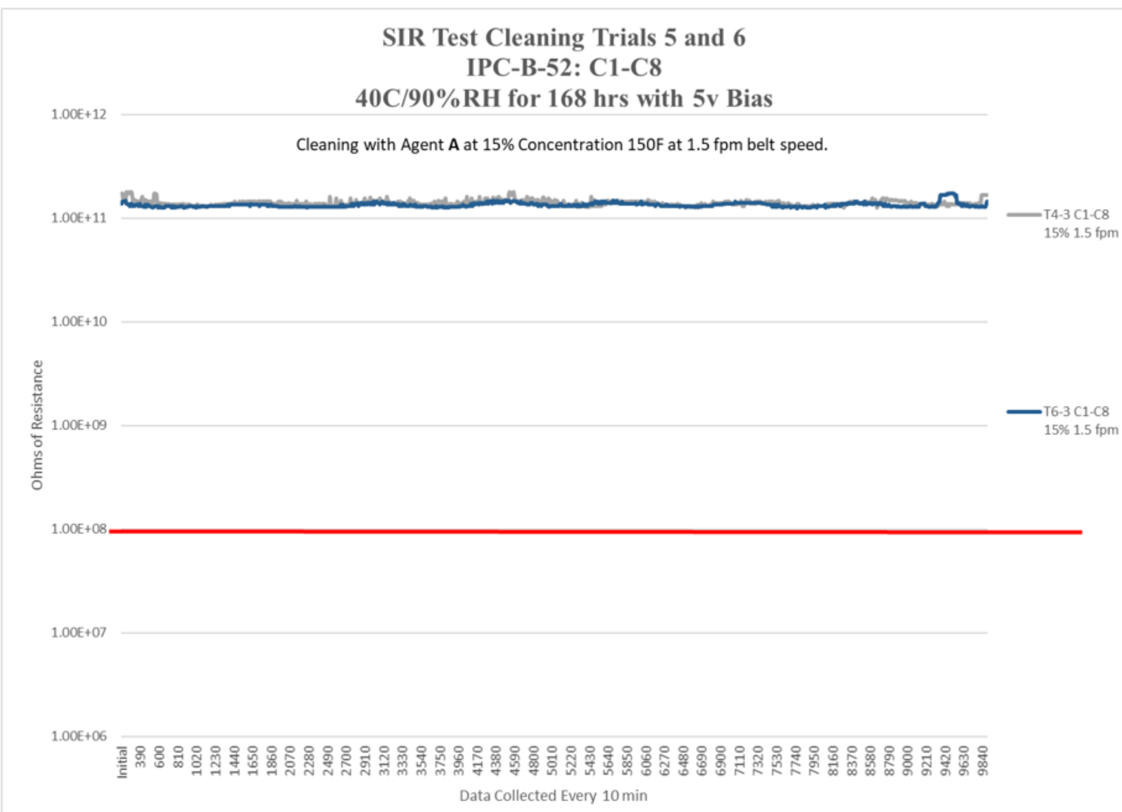

Figure 30. SIR Test Cleaning Trials 5 and 6: C1-C8

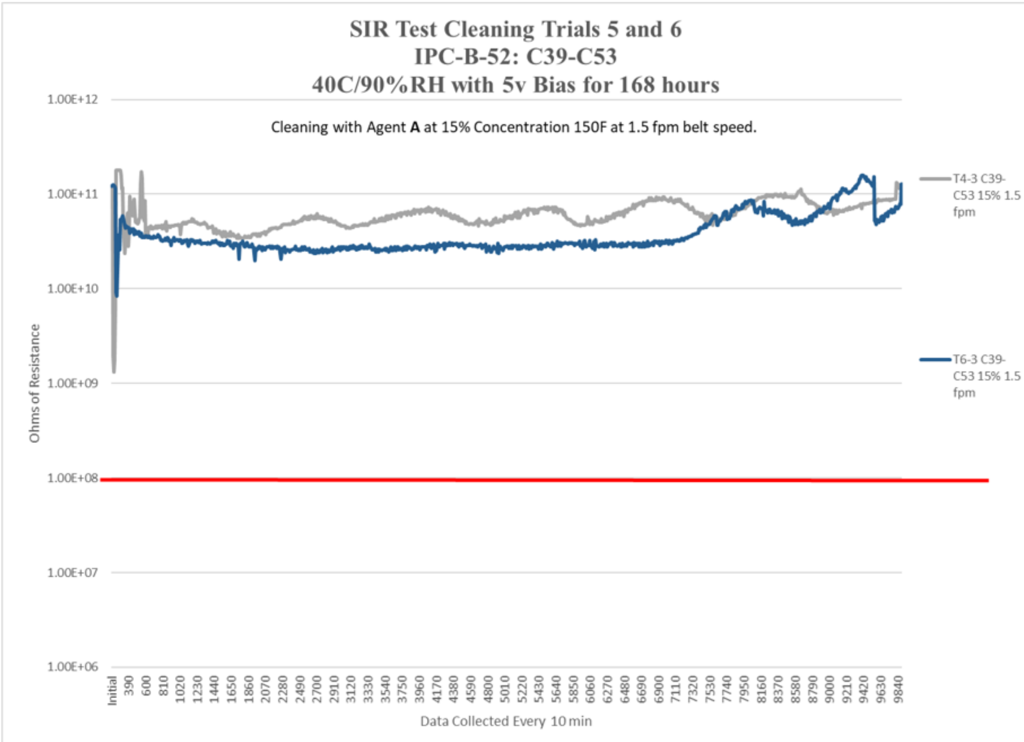

Figure 31. SIR Test Cleaning Trials 5 and 6: C39-C53

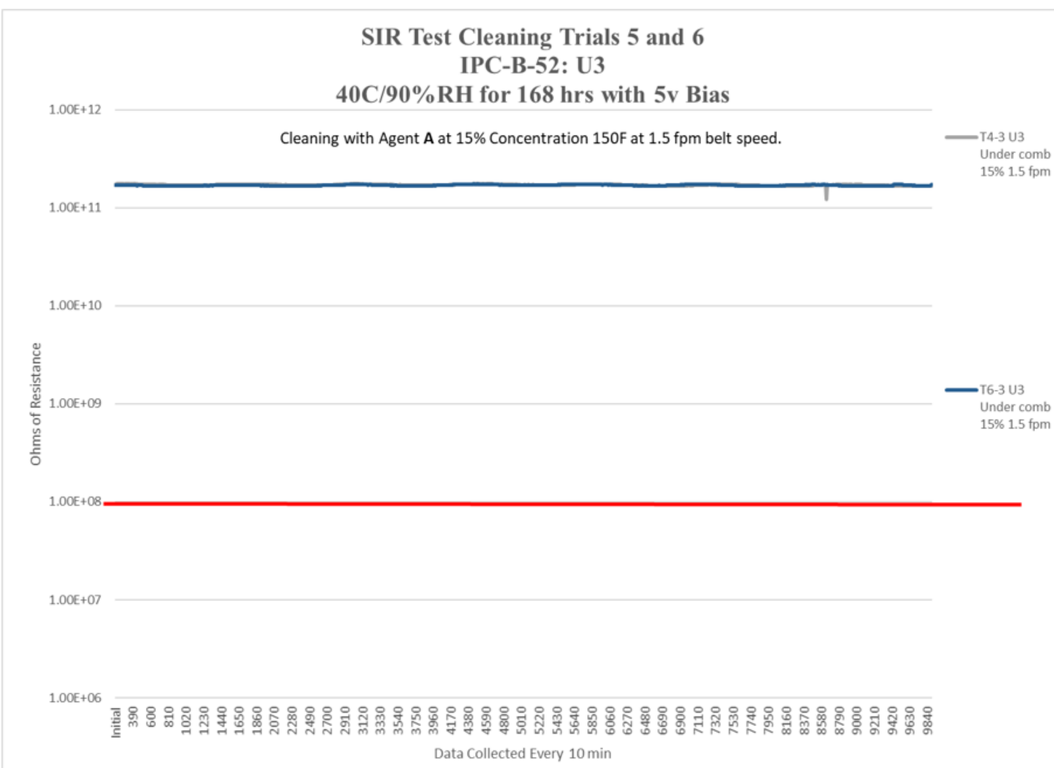

Figure 32. SIR Test Cleaning Trials 5 and 6: U3

Finally, referencing Trials 5 and 6 (Table 13), the authors decided to conduct under-component inspection of the chip cap capacitors of both baseline and cleaned coupons for a more thorough analysis. To enable this analysis, the components were sheared from the coupon surface. For the baseline trials whereby the test coupons were not cleaned, under-component flux residues were clearly visible whereas for the cleaned coupons, no flux residues were evident. Reference Figures 33 - 36.

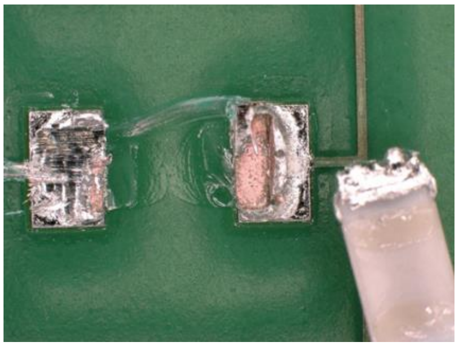

Figure 33. Baseline: T4-B1 (C39-C53)

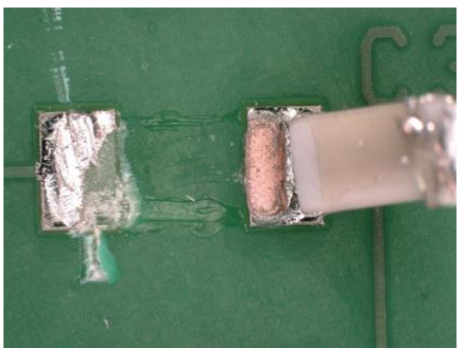

Figure 34. Baseline: T6-B1 (C39-C53)

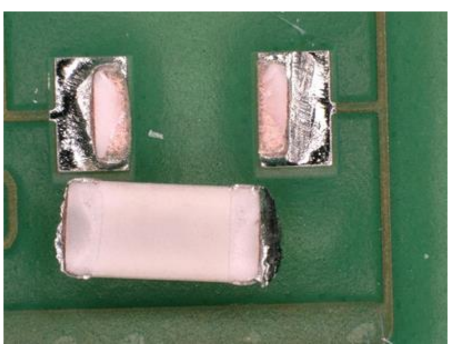

Figure 35. Trial 5: T4-3 (C39-C53)

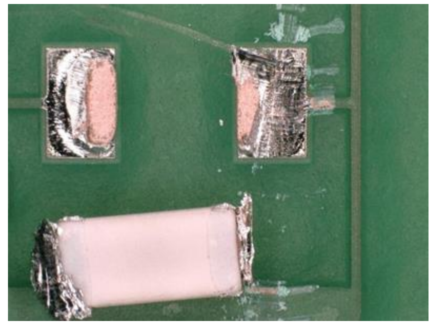

Figure 36. Trial 6: T6-3 (C39-C53)

With regard to the IC data (Appendix: Tables 15 and 16), all coupons yielded passing results with low ionic species. However, the authors wanted to compare under-component cleanliness from Trials 5 and 6 (Best Case; Reference Table 13) to the Trials 13 and 16 (Worst Case; Reference Table 14).

Table 14.

<table>
<tr><th>Trial #</th><th>Paste Type</th><th>Board ID</th><th>Process Settings</th><th>Cleaning Agent</th></tr>
<tr><td>13</td><td>T4</td><td>T4-6</td><td>15% conc, 150F, 1.5fpm</td><td rowspan="2">C</td></tr>
<tr><td>16</td><td>T6</td><td>T6-7</td><td>15% conc, 150F, 1.5fpm</td></tr>
</table>

For both trial sets, the same cleaning process conditions were used although Cleaning Agent A was used for Trials 5 and 6 and Cleaning Agent C was used for Trials 13 and 16.

For the visual inspection, the authors chose components that are common to both IC and SIR. Under-component inspection of the IC coupon, component C60, from Trials 13 and 16 yielded minor residues for both Type 4 and Type 6 solder whereas more were observed for Trials 5 and 6. Reference Figures 37 - 40.

Figure 37. Trial 5: T4-3 (C60)

Figure 38. Trial 6: T6-3 (C60)

Figure 39. Trial 13: T4-4 (C60)

Figure 40. Trial 16: T6-7 (C60)

CONCLUSIONS:

Effective removal or cleaning post solder flux residues is certainly critical for reliable performance of Class III electronic assemblies. It is well known that residues left behind can have a negative impact on reliability caused by either electrochemical migration or by corrosion failure mechanisms [2]. Thus, ensuring that post solder flux residues are completely removed from the substrate is critically important to the long-term reliability of the electronic assemblies.

The main goal of this study was to assess the effect of fine mesh powder on flux residue removal. In this case, two versions of a single No-Clean solder formulation were used, one formulated with Type 4 and another with Type 6 solder powders. However, each was formulated for screen printing. The cleaning process selected was a spray-in-air system that compared six different cleaning agents.

Through the Phase 1 trials and using populated test vehicles, under-component visual inspection was used to identify the best and worst combinations of cleaning agent type and cleaning process operating parameters. It is important to note that the authors did not optimize the cleaning process in order to achieve best results. Rather, industry standard operating parameters were selected and maintained constant throughout all trials as the intent of the trials was a comparative analysis between the two types of fine mesh solder powders. Based on visual analysis, Cleaning Agent A produced the best results for all Phase 1 cleaning trials. Reference Table 11.

Within Phase 2 of the study, IPC-B-52 coupons populated with SMT components were used and cleaned with the down selected cleaning agents from Phase 1. Both SIR and IC analyses were performed on all test coupons. For this analysis, baseline coupons (uncleaned) for both the Type 4 and Type 6 solder powder were also produced and analyzed.

It was interesting to note that all the Phase 2 test coupons had passing values for SIR and IC. As evidenced by the passing results of the SIR data for the Baseline coupons (Figures 21 and 22), the reflow process produced effective soldering results for both the Type 4 and Type 6 solder pastes.

With regard to SIR, the values remained steady or increased over time in all cases other than baseline (uncleaned) regardless of the cleaning agent used. Coupled with the passing IC results, the authors deduced that all cleaning agents were effectively rinsed thereby leaving no or minimal trace of ionics on the substrate surface. However, under-component visual inspection of the baseline components compared to the coupons that were cleaned revealed flux residues (Figures 33 - 36). Even though SIR and IC analysis yielded passing results, post reflow flux residues remained under-components in all but the best case scenarios utilizing Cleaning Agent A (Trials 5 and 6).

Focusing on Cleaning Agent A, the authors selected three component groups from the SIR coupon for further analysis (Figure 23). The SIR data for the best case scenario (Trials 5 and 6) for each solder paste type within the three component groups is detailed in Figures 30 - 32. In the case of the C1 - C8 and U3 component groups, the SIR values are the same for each paste type. With regard to the C39 – C53 component group, higher SIR values were realized for the Type 4 solder powder. Thus, each solder paste type was effectively cleaned.

In addition to this, under-component visual inspection was conducted on several of the C54 – C63 components examining the worst case cleaning scenarios, Trials 13 and 16 where Cleaning Agent C was used. Interestingly enough, even though IC analysis yielded passing results, flux residues were visible under components for both solder paste types.

This study confirmed that post reflow flux residues can be effectively removed as demonstrated through the use of the IPC-B-52 test coupon and resulting SIR and IC analysis.

However, cleaning agent selection and an effective cleaning process are critical to achieving the desired results. Although six different cleaning agents were used in this study, all yielded passing results for both SIR and IC analysis. However, under-component visual inspection analysis varied. Cleaning Agent A produced the best overall results.

Future studies will involve halide based water soluble pastes with different powder sizes.

REFERENCES:

[1] R. Parthasarathy, K. Nukala, U. Tosun, ZESTRON "Jet Printed Solder Paste and Cleaning Challenges", Proceedings of IPC APEX, February 2018.

[2] M.Ferrill, IBM, S. Bagheri, Celestica "The IPC-B-52 SIR Test Vehicle: A Discussion of the Current Test Vehicle Design and Possible Modifications for the Future", Proceedings of SMTA International, 2012.

[3] IPC J-STD 005

ACKNOWLEDGMENTS

Foresite – conducting the SIR analyses

AIM – providing the solder pastes and preparing all substrates used within this study

APPENDIX:

Table 15: IC Results – Type 4 Solder Paste

		Acceptance Criteria	T4-Baseline 1	T4-Baseline 2	T4-1	T4-2	T4-3	T4-4	T4-5	T4-6	T4-7	T4-8
Anions	Fluoride (F-)	3	0.3624	ND	0.0825	0.0775	0.1380	0.1286	0.2067	0.3589	0.1661	0.2737
	Acetate ($C2H3O-_2$)	3	ND	0.0000	ND	ND	ND	ND	ND	ND	ND	ND
	Formate (CHO_2)	3	0.0116	0.0038	ND	0.0173	0.0680	0.0064	0.0445	0.0100	0.0045	0.0090
	Chloride (Cl)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Nitrite (NO_2)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Bromide (Br)	6	1.4472	1.4220	ND	ND	ND	ND	ND	ND	ND	0.0212
	Nitrate (NO3)	3	ND	ND	0.0064	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0218
	Phosphate (PO_4^{2-})	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Sulfate (SO_4^{2-})	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	WOA	WOA (25)	0.9994	0.8574	0.0915	ND	ND	ND	0.0842	ND	ND	0.0956
Cations	Lithium (Li^+)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Sodium (Na^+)	3	0.4597	0.3833	0.3099	0.1803	0.2454	0.2868	0.3450	0.2445	0.3402	0.4752
	Ammonium (NH_4^+)	3	0.0000	0.0000	0.0478	0.1419	0.1277	0.0000	0.0000	0.0000	0.0000	0.0000
	Potassium (K^+)	3	0.5454	0.4292	0.2425	0.1457	0.2759	0.3419	0.5136	0.4193	0.4881	0.7912
	Magnesium (Mg^{2+})	1	0.0315	0.0285	0.0032	0.0022	0.0032	0.0000	0.0010	0.0000	0.0048	0.0019
	Calcium (Ca^{2+})	1	0.0205	0.0212	0.0010	0.0003	0.0006	0.0000	0.0000	0.0000	0.0000	0.0032

Table 16: IC Results Type 6 Solder Paste

		Acceptance Criteria	T6-Baseline 1	T6-Baseline 2	T6-1	T6-2	T6-3	T6-4	T6-5	T6-6	T6-7	T6-8
Anions	Fluoride (F-)	3	0.1873	0.2131	0.2973	0.2391	ND	0.2539	0.1468	0.2327	0.2830	0.2159
	Acetate (C2H3O-$_2$)	3	ND	ND	ND	ND	0.0000	ND	ND	ND	ND	ND
	Formate (CHO_2)	3	0.0071	0.0042	0.0070	0.0029	ND	0.0189	0.0038	0.0392	0.0360	0.0509
	Chloride (Cl)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Nitrite (NO_2)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Bromide (Br)	6	1.5548	1.5740	ND	ND	ND	ND	ND	ND	ND	ND
	Nitrate (NO3)	3	ND	ND	0.0000	0.0000	0.0016	0.0000	0.0074	0.0106	0.0000	0.0000
	Phosphate (PO_4^{2-})	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Sulfate (SO_4^{2-})	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	WOA	WOA (25)	1.2870	1.4557	ND	ND	0.1160	ND	ND	ND	ND	ND
Cations	Lithium (Li^+)	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Sodium (Na^+)	3	0.8226	0.7807	0.2199	0.3504	0.3778	0.2996	0.2965	0.3052	0.2981	0.2755
	Ammonium (NH_4^+)	3	0.0000	0.0000	0.0329	0.1045	0.0436	0.0000	0.0000	0.0000	0.0000	0.0000
	Potassium (K^+)	3	1.2520	1.4046	0.3887	0.6317	0.7486	0.6626	0.5568	0.6423	0.5296	0.5772
	Magnesium (Mg^{2+})	1	0.0273	0.0209	0.0157	0.0038	0.0045	0.0006	0.0013	0.0000	0.0023	0.0000
	Calcium (Ca^{2+})	1	0.0318	0.0186	0.0045	0.0045	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000