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Ensuring the Reliability of Critical Assemblies When Implementing a new Cleaning Chemistry

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ABSTRACT
In recent years, there have been significant improvements in soldering and cleaning chemistries, and, in addition, the complexity of the PCB assemblies has also drastically increased. Because of the increase in PCB assembly complexity, the cleanliness of high-reliability assemblies has become more critical for the product's performance in the field. Therefore, the process and procedure can be very complex and complicated when qualifying a new cleaning chemistry and wash system for these high-reliability assemblies.

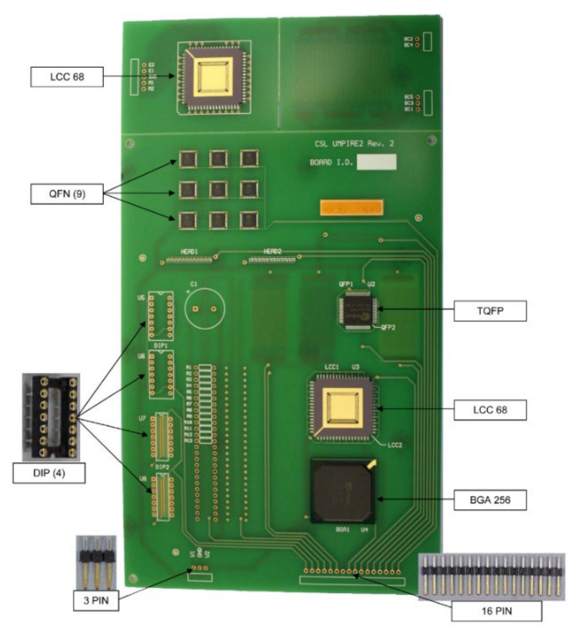
Spartronics developed a reliability testing matrix that included multiple soldering materials (e.g., paste, wire, fluxes) and their interactions. The reliability validation testing included the following processes: Label Application, SMT Paste Application, SMT component placement, Solder paste reflow, Wave soldering, Selective wave soldering, Manual soldering, Rework, BGA rework, and In-line cleaning. The following reliability tests were completed: Surface Insulation Resistance (SIR) testing, Ion Chromatography, and ROSE testing.

The reliability testing results concluded that the new cleaning process was in control and provided excellent cleanliness for all the various soldering process interactions. Finally, a comparison of the cleaning chemistries was completed on the effectiveness of component integrity, part markings, silkscreen, and printed labels on real PCB assemblies. These assemblies were washed 12 times through the in-line washer and inspected for any degradation.

This paper will provide the detailed process set up and parameters completed for the experiments and the test results.

Key words: Surface Insulation Resistance, Ion Chromatography, Cleaning Chemistry, Flux removal.

INTRODUCTION / EXPERIMENTATION
Spartronics is a contract manufacturer of electronic assemblies for the Defense & Aerospace, Medical Device, were and Industrial markets. And typically, these electronic assemblies are IPC Class 3 rated. Therefore, these assemblies require consistently high quality and reliability, and if any changes are made to the manufacturing processes of the assemblies, then significant qualification requirements must be completed. To implement new cleaning chemistries for high-reliability products, an array of testing must be completed to ensure product quality. The testing completed to qualify the new cleaning chemistry included SIR Testing, Ion Chromatography, and ROSE testing. For the Surface Insulation Resistance (SIR) testing of the full matrix of soldering materials was completed per the IPC-TM-650 2.6.3.7 for SnPb and PbF, as well as No Clean and Water Wash materials. The test vehicle chosen for the SIR testing was the Foresite Umpire 2 Test board. The Umpire 2 Test board utilizes several key components, such as LCCs, TQFPs, QFNs, BGAs, DIP devices, and through-hole connectors. The Umpire 2 test boards correlate to the B-24, B-25 & B-36 test boards and are valid for Bellcore testing. The Umpire 2 test board also allows the ability to evaluate various solder and flux combinations for compatibility and the evaluation of a new cleaning chemistry for the primary soldering processes. See below the Foresite Umpire 2 test board and components.



Spartronics has customers requiring SnPb and Pb-free soldering applications and utilizing No Clean and Water-Soluble fluxes. Therefore, all those flux materials for the following processes were evaluated:

- SMT
- Wave Solder
- Selective Solder
- Manual Rework
- BGA Rework
- Manual Soldering

The soldering material matrix included 20 different Umpire 2 test boards (10 No Clean and 10 Water-soluble). See below a copy of the No Clean matrix – Table 1.

Table 1

No Clean Test Matrix		
		Material
SMT	Solder Paste	SnPb 1
		SnPb 2
		PbF 1
		PbF 2
Through Hole	Wave Flux	SnPb 1
		PbF 1
	Selective Flux	SnPb 1
		PbF 1
Rework	Manual Rework flux	SnPb 1
		PbF 1
	Manual solder wire	SnPb 1
		PbF 1
	BGA Rework flux	SnPb 1
		PbF 1
	BGA Rework Paste flux	SnPb 1
		PbF 1
	BGA wire solder	SnPb 1
		PbF 1
Manual	Manual soldering wire	SnPb 1
		PbF 1
	Manual liquid flux	SnPb 1
		PbF 1

The SIR tests were completed following the IPC-TM-650 2.6.3.7 test requirements for 168 hours at 40C and 90% RH with measurements taken every 10 minutes. See the SIR Testing Environment – Figure 1.

SIR Analysis
Test Environment (IPC-TM-650 2.6.3.7)

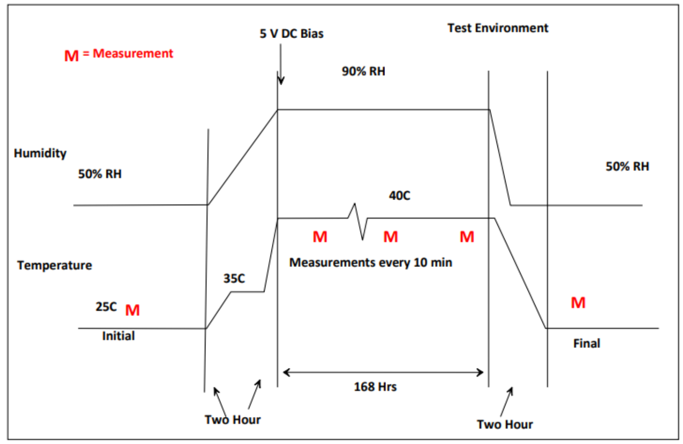


Figure 1

After 168 hours of Surface Insulation Resistance testing, site-level Ion Chromatography was completed on specific locations using the C3 – Critical Cleanliness Control test method by Foresite. After the Ion Chromatography testing, components were removed and inspected for residues. Additionally, customer product assemblies were built and cleaned using the new cleaning process and then sent to Foresite to complete local site Ion Chromatography using the C3 testing method, and then components were removed and inspected for residues.

After the SIR and Ion Chromatography testing, a study on the new cleaning chemistry was completed for the degradation of labels and component markings on various assemblies. For the component markings, the study will focus on metal components and flex assemblies. The assemblies will be cleaned with the new chemistry 12 times and visually inspected for degradation.

RESULTS

Spartronics is in the process of qualifying a new flux cleaning chemistry for the high-reliability assembly products. Spartronics completed the assembly of 20 Foresite Umpire 2 Test boards with all the dummy components, encompassing all the flux variations used in Production. The 20 Umpire 2 Test boards with components and one bare Umpire 2 Test board were then sent to Foresite to complete the SIR and site-specific Ion Chromatography.

All the 21 Foresite Umpire 2 Test boards met the minimum IPC SIR limits of 1e8 ohms resistance throughout the 168-hour test at 40C / 90% RH. Examples of the SIR test results for the various flux combinations are shown in Figures 2, 3, and 4. Figure 2 shows an example of one of the SnPb / No Clean Solder flux combinations. Figure 3 shows one of the Pb-free / No Clean solder flux combinations. And Figure 4 shows an example of one of the SnPb Water Wash Solder flux combinations.

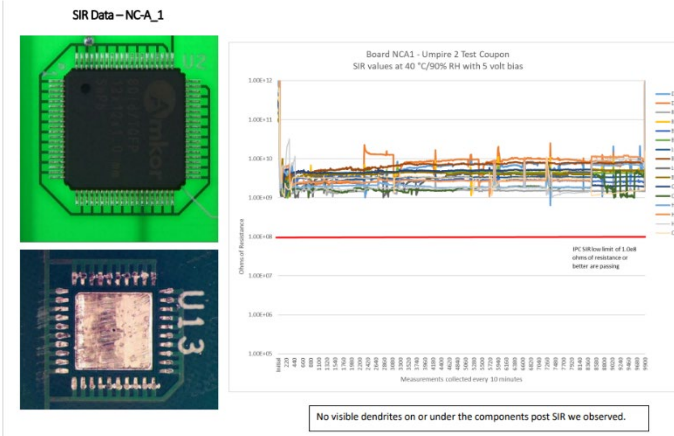


Figure 2

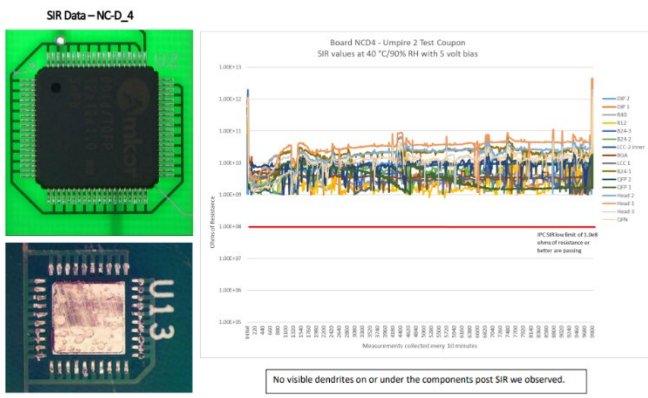


Figure 3

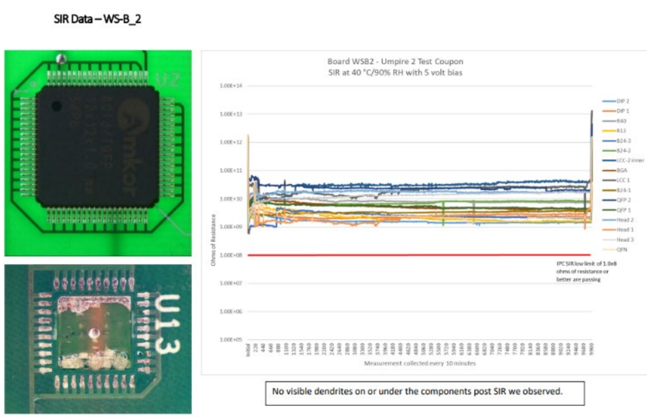


Figure 4

After successful SIR Test results for all of the Solder / Flux combinations, some components were removed and inspected for dendrites and/or residues. No dendrites or residues were found on any of the Umpire 2 Test boards. The next qualification test completed on the Umpire 2 Test boards was site-specific Ion Chromatography testing. The site-specific IC was completed utilizing the C3 Extraction test developed by Foresite. The component locations chosen for the site-specific Ion Chromatography were the large BGAs and Bottom Terminated ICs. Additionally, three Spartronics customer product assembles were also evaluated using the C3 Extraction testing. The site-specific IC test locations for the customer assemblies were under large BGAs, and flush-mounted soldered connectors. See below for the various components tested.

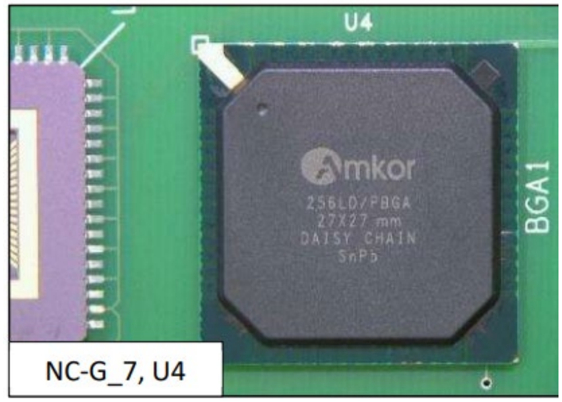


Figure 5

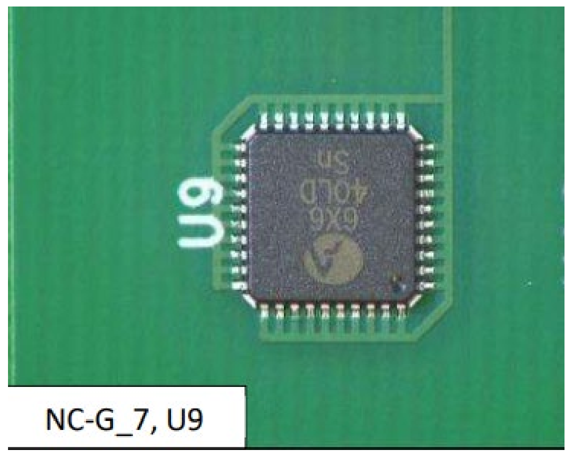


Figure 6

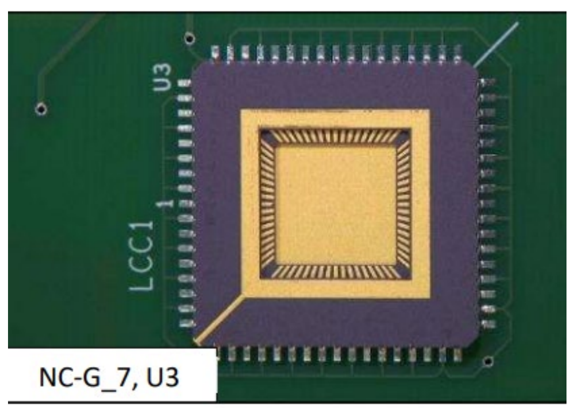


Figure 7

Per the IPC document, the boards should be tested for the following Ionic species:

- Bromide
- Chloride
- Fluoride
- Sulfate
- Phosphates
- Nitrates
- Weak Organic Acids

Per the IPC TM-650, 2.3.28, the maximum contamination levels are shown in Table 2.

Table 2

Contamination Levels Per IPC-TM-650, 2.3.28		
Minimum Ionic Species		**Mircograms/square inch**
Bromide		< 10
Chloride		< 6
Fluoride		< 3
Sulfate		< 3
Phosphates		< 7
Nitrates		< 3
Weak Organic Acids		< 25

Foresite also tested for the following materials:

- Acetates
- Formates
- Nitrite
- MSA
- Lithium
- Sodium
- Ammonium
- Potassium
- Magnesium
- Calcium

Appendix 1 Chart – shows some of the Ion Chromatography data for the various flux variations.

All the Umpire 2 Test boards and Spartronics customer assemblies provided results lower than the maximum allowable IPC ionic contaminate levels.

The final qualification testing was completed to evaluate whether the cleaning chemistry affects the components or labels after multiple washing cycles. Because some of the Spartronics customer assemblies can be cleaned up to six times before completion. Two different customer assemblies were used to evaluate the effect of the cleaning chemistry. The new cleaning chemistry was compared to the present cleaning chemistry, and the following areas were inspected for degradation after each wash cycle:

- Label marking
- Component marking
- Solder Mask degradation
- Silkscreen marking
- Staking / Bonding material degradation, discoloration, or softening
- Flex circuit etching or softening

From the observations after cleaning of the two different cleaning chemistries, both chemistries had some effect on the component markings, silkscreen, and label marking legibility or adhesion degradation. For the Flex Cable assembly, it was observed that the older chemistry degraded the silkscreen markings after the third wash cycle. The newer chemistry was observed to have some silkscreen degradation after the fourth wash cycle. For the observed component markings, the newer chemistry began causing degradation after the fifth wash cycle, whereas the older cleaning chemistry did not have any observed degradation until the eighth wash cycle. As a note, the degradation of the component markings was only observed on metal-capped components. Additionally, it was noted that the newer chemistry influenced the label discoloring and becoming unreadable after the fifth wash cycle. See Figures 8 and 9 comparing the different chemistries for the label degradation.

Figure 8: Older Chemistry

Figure 9: Newer Chemistry

See Appendix 2 for the results. For the Appendix 2 Chart – the observations were taken after the second wash.

For the Rigid PCB Card Assembly, similar observations were made. The label marking degradation was observed after six wash cycles. Silkscreen degradation was observed using the older chemistry after the seventh additional wash, and both chemistries were observed to contribute to silkscreen degradation after the eighth wash cycle. For component marking degradation, only the newer was observed to cause an issue after the eighth wash cycle. For the Appendix 3 Chart – the observations were noted after the sixth wash cycle. The newer cleaning chemistry does have some effect on the type of label and/or component marking. But no significant differences were observed in degradation between the two cleaning chemistries.

CONCLUSION

Spartronics completed reliability testing that included multiple soldering materials (e.g., paste, wire, fluxes) and their interactions. The matrix included SnPb No Clean, SnPb Water wash, and Pb-free No Clean fluxes, along with every process step: Solder paste printing, reflow, wave soldering, selective soldering, manual soldering, rework soldering, and in-line cleaning. Surface Insulation Resistance (SIR) testing was completed using the Umpire 2 Test boards, and all the flux combinations and variations passed the minimum test requirements. Site-specific Ion Chromatography was completed on the Umpire 2 test boards, and three customer assemblies, and all the ionic residue measurements were lower than the maximum allowable contaminate levels specified by IPC TM-650, 2.3.28. The new cleaning chemistry and cleaning process passed all the IPC and testing requirements for implementation. Additionally, the new cleaning chemistry was tested for excessive cleaning and effect on labels, component markings, and any other degradation and showed no significant difference from the older chemistry. The new chemistry and process have been implemented and have significantly improved in removing flux residues and eliminating the occurrence of white residues from the circuit assemblies.

Ion Chromatography Data

	all values in ug/in²	Ion Chromatography (Dionex ICS 3000 at Foresite) n/a = not applicable																	C3 Tester	
	Sample Description	Fluoride	Acetate	Formate	Chloride	Nitrite	Bromide	Nitrate	Phosphate	Sulfate	WOA	MSA	Lithium	Sodium	Ammonium	Potassium	Magnesium	Calcium	Results	Time(sec)
	Foresite recommended limits for Bare Boards	3	2.5	2.5	2.0	2.5	2.5	2.5	2.5	3.0	n/a	0.5	2	2	2.5	2	n/a	n/a	Clean	>120
	Foresite recommended limits for PCBA (clean)	1	3	3	6.0	3	6.0	3	3	3.0	25	1	3	3	3	3	n/a	n/a	Clean	>120
	Foresite recommended limits for PCBA (no clean)	1	3	3	3.0	3	6.0	3	3	3.0	150	1	3	3	3	3	n/a	n/a	Clean	>120
ID																				
37	A4625-WS-A_1 U13	0	0.57	0.41	0.63	0	4.99	0.07	0	0.13	2.03	0	0	0	1.40	0	0	0.42	Clean	180
38	A4625-WS-B_2 U13	0	0.83	0.62	0.24	0	0.94	0.08	0	0.09	0.63	0	0	0	0.01	0	0	0.28	Clean	180
39	A4625-WS-C_3 U13	0	0.26	0.56	0.69	0	3.61	0.11	0	0	1.24	0	0	0.05	1.43	0	0	0.36	Clean	180
40	A4625-WS-D_4 U13	0	1.52	0.49	1.95	0	2.48	0.05	0	0.23	1.01	0	0	0	0.10	0	0	0.22	Clean	180
41	A4625-WS-E_5 U13	0	2.55	1.71	1.66	0	3.69	0.18	0	0.56	1.86	0	0	0	1.43	0	0	0.22	Clean	180
42	A4625-WS-F_6 U13	0	0.93	0.72	0.13	0	2.78	0.05	0	0	0.49	0	0	0	0.75	0	0	0.58	Clean	180
43	A4625-WS-G_7 U13	0	0	0.21	0.25	0	2.78	0.06	0	0	0.04	0	0	0	0.65	0	0	0.17	Clean	180
44	A4625-WS-H_8 U13	0	0.24	0.76	2.12	0	2.49	0.11	0	0.10	0.89	0	0	1.50	1.02	0	0	0.45	Clean	180
45	A4625-WS-I_9 U13	0	1.10	0.62	0.89	0	1.06	0.07	0	0.14	1.97	0	0	0.02	0.34	0	0	0.39	Clean	180
46	A4625-WS-J_10 U13	0	0.01	0	0.28	0	0	0.04	0	0.28	0	0	0	0	0	0	0	0.21	Clean	180
47	A4625-NC-A_1 U13	0	0.55	0.48	0.71	0	0.93	0.08	0	0.10	0.40	0	0	0.03	0.12	0	0	0.48	Clean	180
48	A4625-NC-B_2 J4	0	0.24	1.09	1.94	0	0.13	0.41	0	1.21	2.15	0	0	1.24	1.35	0	0	0.63	Clean	180
49	A4625-NC-B_2 U4	0	1.24	1.60	0.98	0	0.02	0.82	0	1.10	1.54	0	0	1.06	1.01	0	0	0.68	Clean	135
50	A4625-NC-B_2 U3	0	0.36	2.69	1.24	0	0.01	0.21	0	0.46	1.36	0	0	0.50	0.30	0	0	0.89	Clean	180
51	A4625-NC-B_2 U9	0	0.46	0	0.57	0	0	0.06	0	0.13	0.57	0	0	0	0.02	0	0	0.51	Clean	180
52	A4625-NC-B_2 U13	0	0.14	0	0.44	0	0.01	0.04	0	0	0	0	0	0	0	0	0	0.50	Clean	180
53	A4625-NC-C_3 U13	0	0.54	0.50	0.59	0	0	0.06	0	0.33	1.11	0	0	0	0.04	0	0	0.61	Clean	180
54	A4625-NC-D_4 U13	0	0	0	0.23	0	2.62	0.01	0	0.10	0	0	0	0	0	0	0	0.59	Clean	180
55	A4625-NC-E_5 J4	0	2.20	0.54	1.03	0	0.02	0.22	0	1.03	6.79	0	0	2.44	1.24	0	0	0.61	Clean	180
56	A4625-NC-E_5 U4	0	0.36	1.24	1.31	0	0.05	0.75	0	1.98	5.32	0	0	2.91	1.01	0	0	1.13	Clean	180
57	A4625-NC-E_5 U3	0	0.25	2.70	3.56	0	0.02	0.18	0	0.74	1.28	0	0	0.45	0.26	0	0	0.95	Clean	180
58	A4625-NC-E_5 U9	0	0.83	0.37	0.37	0	0	0.08	0	0.56	0.83	0	0	0	0	0	0	0.31	Clean	180
59	A4625-NC-E_5 U13	0	0.38	0.42	0.68	0	0.01	0.07	0	0.54	1.20	0	0	0.08	0.11	0	0	0.29	Clean	180
60	A4625-NC-F_6 J4	0	1.90	0.68	1.15	0	0.13	0.22	0	1.36	1.99	0	0	1.36	1.21	0	0	0.61	Clean	180
61	A4625-NC-F_6 U4	0	0.25	1.69	1.23	0	0.31	0.79	0	2.14	7.72	0	0	1.25	1.48	0	0	0.88	Clean	180
62	A4625-NC-F_6 U3	0	0.41	1.54	1.25	0	0.02	0.26	0	2.01	2.02	0	0	2.15	0.45	0	0	0.77	Clean	180
63	A4625-NC-F_6 U9	0	0	0.12	1.83	0	0	0.03	0	0.75	0	0	0	0.82	0	0	0	0.11	Clean	174
64	A4625-NC-F_6 U13	0	0.19	0.03	0.78	0	0.02	0.06	0	0	1.26	0	0	0.15	0	0	0	0.17	Clean	131
65	A4625-NC-G_7 J4	0	1.79	0.57	2.01	0	0.08	0.23	0	1.54	2.65	0	0	1.36	1.30	0	0	0.84	Clean	180
66	A4625-NC-G_7 U4	0	0.65	1.25	1.24	0	0.03	2.25	0	2.21	3.71	0	0	1.06	0.92	0	0	0.68	Clean	180
67	A4625-NC-G_7 U3	0	0.54	1.41	3.17	0	0.03	0.28	0	0.85	1.50	0	0	0.31	0.21	0	0	0.80	Clean	180
68	A4625-NC-G_7 U9	0	0.54	0	0.36	0	0.02	0.04	0	0.96	2.38	0	0	0	0.05	0	0	0.21	Clean	180
69	A4625-NC-G_7 U13	0	0.90	0.66	0.65	0	0	0.04	0	0.22	0.88	0	0	0.01	0.03	0	0	0.41	Clean	180
70	A4625-NC-H_8 J4	0	2.30	0.51	0.71	0	0.01	0.19	0	0.97	0.66	0	0	2.40	1.39	0	0	0.32	Clean	180
71	A4625-NC-H_8 U4	0	0.98	1.41	1.05	0	0.03	0.73	0	1.64	3.39	0	0	1.24	0.74	0	0	0.58	Clean	180
72	A4625-NC-H_8 U3	0	1.25	2.88	1.93	0	0.02	0.19	0	0.81	1.22	0	0	0.28	0.05	0	0	0.33	Clean	176

Appendix 1

		Flex Cable Assembly												
Inspected Characteristic	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry
Total Wash Cycles	2	2	3	3	4	4	5	5	6	6	7	7	8	8
Label marking legibility degrades or label adhesion degrades	No	No	No	No	No	No	No	No	No	Yes	No	Yes	No	Yes
Component markings legibility degrades	No	No	No	No	No	No	No	Yes	No	Yes	No	Yes	Yes	Yes
Solder Mask degrades	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Silkscreen marking legibility degrades	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Staking / Bonding material degradation, discoloration or softening	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Flex Circuit etching, softening or material loss	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Appendix 2

			Typical Rigid PCB Assembly											
Inspected Characteristic	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry	Old Chemistry	New Chemistry
Total Wash Cycles	6	6	7	7	8	8	9	9	10	10	11	11	12	12
Label marking legibility degrades or label adhesion degrades	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Component markings legibility degrades	No	No	No	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Solder Mask degrades	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Silkscreen marking legiblity degrades	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Staking / Bonding material degradation, discoloration or softening	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Flex Circuit etching, softening or material loss	No	No	No	No	No	No	No	No	No	No	No	No	No	No

Appendix 3