PCB Cleanliness Assessment Methodologies – A Comparative Study

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ABSTRACT
PCB manufacturers use a wide variety of solder pastes and fluxes including No-Clean, RMA and OA, both leaded and lead-free within their processes. As part of the manufacturing process, components are soldered using reflow ovens and/or wave solder systems. Burnt-in flux residues may result on the PCB surface as well as in and around components. It has been well documented that flux residues can lead to failure mechanisms such as leakage current, electrochemical migration and dendritic growth and these can negatively impact the reliability of the PCB.

If OA paste and flux is used, cleaning is required using either a DI-water or chemically assisted aqueous cleaning process. Depending on the degree of reliability required, RMA and No-Clean residues may need to be cleaned as well. Once a manufacturer decides to implement a cleaning process, how does one assess its effectiveness?

Based on IPC TM-650 guidelines, there are numerous tests that can be implemented to assess PCB cleanliness. These include ionic contamination, ion chromatography and SIR to name a few. The procedures are well documented and the results can be interpreted through industry developed standards.

Ionic Conductivity analysis measures conductivity related to amounts of ionic materials (extracted from the PCB) present in solution and is usually expressed as equivalents of sodium chloride in micrograms per unit surface area (μg NaCl Eq./cm^2) of the sample. Ion Chromatography analysis measures individual ionic species (type and level of residue). However, each test is based on total board extraction.

As there may be a high contamination area within the PCB that may not be detected with standard ion chromatography analysis, a manufacturer may elect to analyze a specific component or part of a PCB by using a localized extraction method coupled with Ion Chromatography.

This study was conducted to assess PCB Cleanliness Assessment Methodologies including visual inspection, Ion Chromatography (IC) and SIR analyses resulting from a spray-in-air cleaning process with benchmark parameters. Seven lead-free No-Clean, RMA and OA paste types were considered. The test vehicle used was the IPC-B-52. Additionally, the authors chose several PCB areas for IC analysis via localized extraction and compared all results for overall cleanliness assessment.

KEY WORDS
PCB failure mechanisms, electronic assembly reliability, Accelerated Reliability Test, Functional Test, aqueous circuit board cleaning process

INTRODUCTION
Conducting reliability assessments of electronic assemblies is a critical procedure for any OEM or CM. However, one factor to consider in order to determine which reliability assessment method to employ is the assembly classification. These are [1]:

Class 1: General Electronic Products - Includes products suitable for applications where the major requirement is function of the completed assembly.
Class 2: Dedicated Service Electronic Products - Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.
Class 3: High Performance Electronic Products - Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

Regardless of the classification, the assemblies must meet the functional standards as defined by the process design. However, when considering Class 2 and/or Class 3 products, these assemblies must meet the functional design and reliability requirements within the harsh environments in which the assembly may be subjected to operate. In these cases, substrate cleaning and defluxing have been shown to be critical to the reliable functionality of the assembly whether using No-Clean, RMA or OA solder pastes [2].

If achieving the desired cleanliness levels is a key factor in meeting the functional and reliability standards required, measuring the cleanliness level achieved is a critical process step. There are numerous cleanliness assessment techniques that can be used that are in accordance with IPC and industry standards. So, how does one select the cleanliness assessment technique? Typically, assessment method selection is made based on the level of reliability one is seeking.

For high reliability applications, these tests should be used in conjunction with functional and ART (Accelerated Reliability Testing) evaluation techniques. A functional test will confirm if the circuit is assembled properly. An ART evaluation will provide confidence that the design and the manufacturing/assembly processes are capable of meeting the intended goals of product performance [3]. One must note that when considering accelerated testing, the operating environment of the assembly must be considered as this will influence the type of accelerated test used. For example, tests can be conducted to assess temperature cycling, vibration damage and thermal shock.

Through their work, the authors have consulted with numerous customers that were facing intermittent product field failures even when boards were passing standard analytical tests, particularly in cases where No-Clean paste was used and the boards were not cleaned. Following a review of the process and implementation of cleaning process optimization recommendations, customers have used an ART evaluation to confirm reliability. The following is an example from a solar panel manufacturer:

> The customer manufactured PCBs for solar panels. By design, the boards will be exposed to a wide range of temperature and humidity changes in the field depending on the location of the solar panel. Initially the customer was using a No-Clean solder paste and not cleaning the boards. During the initial qualification assessment the boards passed SIR tests; however, intermittent field failures resulted.
>
> The customer chose to use Accelerated Reliability Testing (ART) to simulate the environment where the boards are used to aid in resolving the quality issue. The test was conducted with two environmental scenarios:
>
> - Test 1: No humidity, high temperature test (85°C)
> - Test 2: Humidity (85% RH) and high temperature test (85°C)
>
> The pass requirement for each test was 1,000 hours.
>
> Additionally, the customer included a cleaning process to determine if this could impact the results. Thus, cleaned and uncleaned boards were subjected to SIR and ART evaluations with the following results:
>
> - Test 1: Uncleaned boards failed after 700 hours, while cleaned boards passed 2,500 hours (test was stopped at 2500 hours since requirement was only 1,000 hours)
> - Test 2: Uncleaned boards failed between 712 – 860 hours, while cleaned boards passed 1,000 hours
>
> In each scenario, both the uncleaned and cleaned boards passed the SIR test. Only during the ART evaluation was the customer able to see the impact of flux residue on the boards. As a result of this evaluation, the customer was able to modify the manufacturing process to include cleaning and resolve the intermittent field failures.

The purpose of this study was to compare PCB cleanliness assessment methodologies on boards that were cleaned and not cleaned following reflow. Three (3) lead-free paste types were used; that is No-Clean, RMA and OA. For the RMA and OA paste trials, boards were analyzed that were either cleaned or not cleaned. For the No-Clean paste trials, a "partial clean" scenario was also included as the authors wanted to consider this possibility as well. It is important to note that the same lead-free thermal profile was used for all solder pastes.

For the cleaning process, a spray-in-air system with an engineered aqueous based cleaning agent was used. The cleaning process parameters established were held constant for all trials. As this was a comparative study, cleaning process optimization was not considered.

Four (4) cleanliness assessment methodologies were considered for this study and each are included within IPC standards and test methods with the exception of the localized extraction electrical test. These are:

1) Visual Inspection: IPC-A-610F
2) Ion Chromatography: IPC-TM-650; 2.3.28.2

3) Localized Extraction:
- Ion Chromatography: IPC-TM-650; 2.3.28.2
- Electrical Testing: Class 2 – 3

4) Surface Insulation Resistance: IPC-650-TM; 2.6.3.7

METHODOLOGY

Seven (7) solder pastes were considered including No-Clean, RMA and OA pastes, all lead-free and identified as detailed in Table 1.

Table 1. Solder Pastes

Solder Pastes	
No-Clean Solder Pastes	A
	B
	C
RMA Solder Pastes	D
	E
OA Solder Pastes	F
	G

The test vehicle selected was the IPC-B-52 CRET (Cleanliness and Residue Evaluation Test Kit). Reference Figure 1.

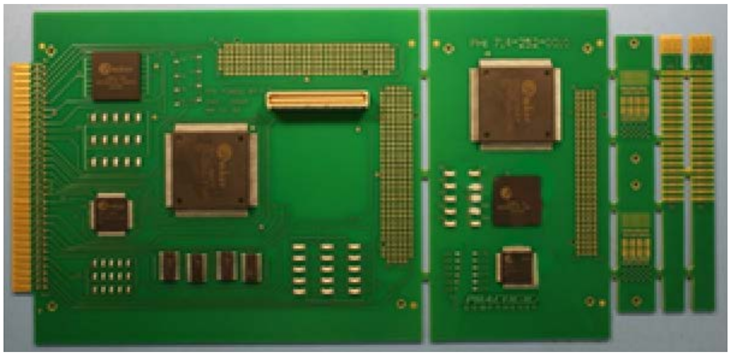


Figure 1.

Each IPC B-52 test vehicle was populated with 96 components as detailed in Table 2.

Table 2. IPC-B-52 CRET Components

IPC-B-52 CRET Components	
Type	**Quantity**
A-CABGA256-1.0mm-17mm-ISO-SAC305	2
A-QFP160-28mm-.65mm-2.6mm-ISO-Sn	2
A-TQFP80-12mm-.5mm-2.0mm-ISO-Sn	2
A-SO16GT-3.8mm-ISO-Sn	4
0402SMC-0.01pF-Sn	20
0603SMC-0.01pF-Sn	15
0805SMC-0.1pF-Sn	25
1206SMC-10pF-Sn	25
Conn-SMT-2x16	1
Total:	**96**

All IPC-B-52 test vehicles were reflowed employing the manufacturers' recommended lead-free thermal profile.

As the authors wanted to assess the impact of cleaning using the cleanliness test measurement methodologies outlined, three (3) cleaning conditions were considered for the No-Clean solder paste and two (2) cleaning conditions were considered for the RMA and OA solder paste. Reference Table 3.

Table 3. Solder Paste Clean Condition

Solder Paste Clean Condition	
No-Clean	
Condition 1	Not Clean (NC)
Condition 2	Partially Clean (PC)
Condition 3	Fully Clean (FC)
RMA	
Condition 1	Not Clean (NC)
Condition 3	Fully Clean (FC)
OA	
Condition 1	Not Clean (NC)
Condition 3	Fully Clean (FC)

Boards for high voltage applications, conformal coating, wire bonding, clean room applications, automotive, RF and medical applications and are usually the candidates for cleaning [4]. Thus, we wanted to assess the effect of various clean conditions on assembly reliability using lead free No-Clean, RMA and OA solder paste types.

For the partially and fully cleaned scenarios, the populated boards were cleaned using spray-in-air inline equipment and an engineered aqueous based cleaning solution. Different cleaning process parameters were selected for the partially cleaned and fully cleaned scenario. These were held constant for all trials. We decided not to optimize the cleaning process thereby enabling the comparative assessment of the cleanliness methodologies examined.

MAIN RESEARCH

The IPC B-52 test vehicle includes two Sections, A and B, enabling each vehicle to be used for both SIR and IC testing. Reference Figure 2.

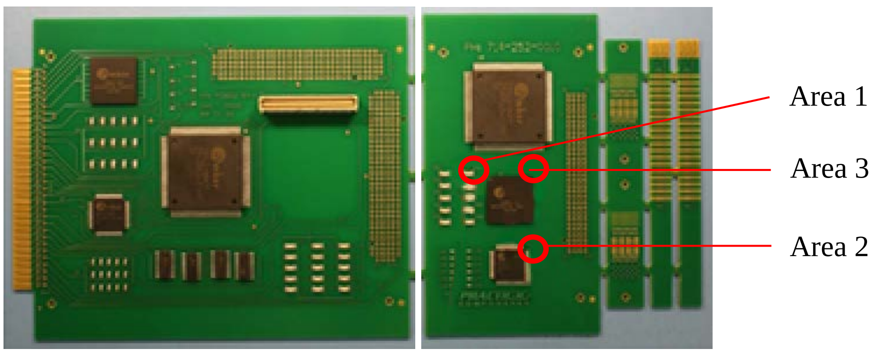


Figure 2

Section A Section B

For this study, four (4) cleanliness assessments were conducted for each paste and condition scenario. For the SIR and IC tests, each was conducted on a unique board. Furthermore, SIR and full board IC tests were conducted on Section A of unique boards and localized IC was conducted on Section B of unique boards. For localized IC, three (3) locations were examined and referenced as Area 1, Area 2 and Area 3. The component types for each area are detailed in Table 4.

Table 4.

Extraction Location #	Location on Board	Part Description
Area 1	C59	1206SMC
Area 2	U10	TQFP80
Area 3	U9	CABGA256

For all solder pastes and conditions considered, 34 test vehicles were required and populated. Reference Table 5.

Table 5. No. Populated IPC-B-52 Test Vehicles

Solder Paste Types		Condition	J-STD-004 B Classification	SIR	Full Board IC and Localized IC	Totals
		No. Populated IPC-B-52 Test Vehicles				
No-Clean Solder Pastes	A	NC, PC, FC	ROL0	3	3	6
	B	NC, PC, FC	ROL0	3	3	6
	C	NC, PC, FC	ROL1	3	3	6
Subtotal No-Clean				9	9	18
RMA Solder Pastes	D	NC, FC	ROL0	2	2	4
	E	NC, FC	ROH0	2	2	4
Sub-total RMA Pastes				4	4	8
OA Solder Pastes	F	NC, FC	ORH0	2	2	4
	G	NC, FC	ORL0	2	2	4
Sub-total OA Solder Pastes				4	4	8
Total No / IPC B-52						**34**

For PC(Partially Cleaned) and FC(Fully Cleaned) conditions, the post soldered boards were cleaned utilizing an inline spray in air cleaner and an engineered aqueous based cleaning agent. The cleaning process parameters are detailed in Table 6.

Table 6. Cleaning Process

Cleaning Process		
Equipment	**Inline Spray-in-Air**	
Cleaning Agent	Engineered Aqueous Based	
	Partially Cleaned	**Fully Cleaned**
Concentration	6%	15%
Conveyor Belt Speed	2 ft/min	1 ft/min
Cleaning Temperature	140°F	150°F
Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI	
Wash Pressure (Top/Bottom)	70 PSI / 40 PSI	
Wash Hurricane Pressure (Top/Bottom)	40 PSI / 20 PSI	
Rinse		
Rinsing Agent	DI-water	
Rinse Pressure (Top/Bottom)	80 PSI / 60 PSI	
Rinse Hurricane Pressure (Top/Bottom)	40 PSI / 20 PSI	
Rinsing Temperature	140°F	
Final Rinse Pressure (Top/Bottom)	25 PSI / 25 PSI	
Final Rinse Temperature	Room Temperature	
Drying		
Drying Method	Hot Circulated Air & Torrid Zone	
Drying Temperature	180°F - 190°F	

Cleanliness Assessment Methodologies

Four (4) cleanliness assessment methods were employed for all conditions considered. These are (1) visual inspections on the board surface and under-component, Ion Chromatography both (2) full board and (3) localized sections, and (4) SIR.

RESULTS

Results - Visual Inspection - Surface

Visual inspection was conducted on all board surfaces. Additionally, under-component inspection was conducted; however, only under the three (3) components that were selected for localized extraction thereby enabling direct comparison of these results. For under-component inspection, the components were removed from the board. All visual analyses were vertically viewed and analyzed with 4 to 60x magnification.

For all paste types, the boards that were fully cleaned resulted in no residues found on the board surface. Reference Table 7.

Table 7. Results – Visual Inspection - Surface

Surface Inspection Results IPC-B-52			
Paste Type	**Not Cleaned**	**Partially Cleaned**	**Fully Cleaned**
No-Clean			
A	Transparent untouched residue present near the solder joints on all boards	Very minor residue identified on solder mask for all pastes	No residue found on the board surface for all pastes
B & C		No residue found on the board surface	
RMA			
D & E	Transparent untouched residue present near the solder joints on all boards	N/A	No residue found on the board surface for all pastes
OA			
F & G	Transparent untouched residue present near the solder joints on all boards	N/A	No residue found on the board surface for all pastes

Reference Figures 3 - 9 for representative pictures of surface cleanliness for Condition 3 (FC) for all paste types:

Figure 3: Paste A

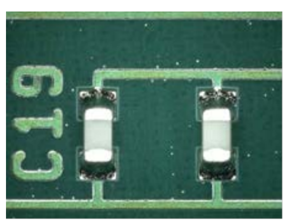


Figure 4: Paste B

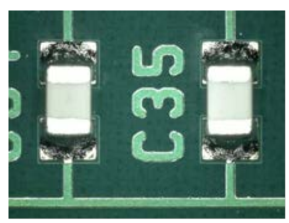


Figure 5: Paste C

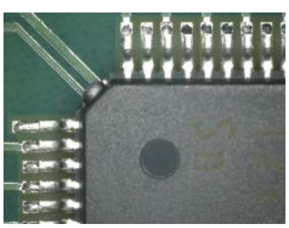


Figure 6: Paste D

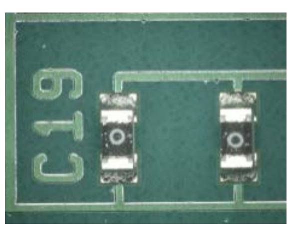


Figure 7: Paste E


Figure 8: Paste F

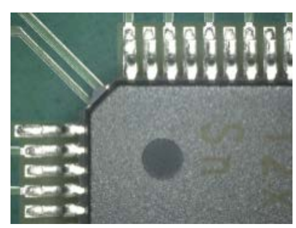


Figure 9: Paste G

Results - Visual Inspection – Under-component

For all paste types, the boards that were fully cleaned resulted in no residues remaining under the component. Reference Table 8.

Table 8. Results – Visual Inspection Under-component

Solder Paste		Condition	Under-component Inspection		
			Area 1	Area 2	Area 3
No-Clean	A	Not Cleaned	Residue	Residue	Residue
	A	Partially Cleaned	Residue	Residue	Residue
	A	Fully Cleaned	Clean	Clean	Clean
	B	Not Cleaned	Residue	Residue	Residue
	B	Partially Cleaned	Residue	Residue	Residue
	B	Fully Cleaned	Clean	Clean	Clean
	C	Not Cleaned	Residue	Residue	Residue
	C	Partially Cleaned	Residue	Residue	Residue
	C	Fully Cleaned	Clean	Clean	Clean
RMA	D	Not Cleaned	Residue	Residue	Residue
	D	Fully Cleaned	Clean	Clean	Clean
	E	Not Cleaned	Residue	Residue	Residue
	E	Fully Cleaned	Clean	Clean	Clean
OA	F	Not Cleaned	Residue	Residue	Residue
	F	Fully Cleaned	Clean	Clean	Clean
	G	Not Cleaned	Residue	Residue	Residue
	G	Fully Cleaned	Clean	Clean	Clean

Reference Figures 10 - 12 for representative pictures of fully cleaned under-component results for all solder paste types:


Figure 10: Paste A, Area 1

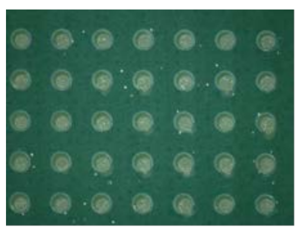


Figure 11: Paste B, Area 2

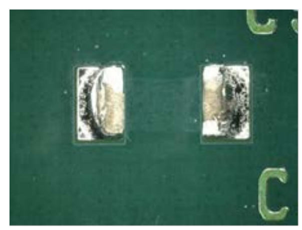


Figure 12: Paste C, Area 3

Results - Ion Chromatography
Both full board and localized IC were conducted on the IPC-B-52 Test Vehicle for each solder paste and condition in accordance with IPC-TM-650, method 2.3.28. The full board IC was conducted on Section A and localized IC on Section B at three locations. The localized IC was conducted using the localized extraction method [5]. All IC analysis, including the eluent generated from the localized extraction method tests, were conducted at the company technical center. The company standards for passing IC results are based on an average used by certified industry labs. The standards used and the IC data is detailed in the appendix.

As part of the localized extraction analysis, an electrical test was conducted whereby a leakage current event can be identified based on Class 2 – 3 setting established by the manufacturer of this specific equipment. In brief, using a sacrificial Y-pattern electrode immersed in the collected extraction solution, a 10 volt bias (+/-0.1V) is applied to the electrode and an internal timer is started to measure the time it takes to achieve a leakage event. The system is measuring the leakage current across the electrode generated by the extraction solution plus the residues extracted from the board surface. A threshold of 250 µA has been set to identify when a current leakage event has occurred. If 250µA is achieved in less than 120 seconds, this correlates to a corrosive surface and is identified as “dirty”. In theory, the more corrosive / conductive the residue, the faster it will take to achieve this event.

The less corrosive or conductive the residue, the longer it will take to achieve. Thus, timing events that take longer than 120 seconds have correlated to cleaner less corrosive residues and are identified as “clean” [5].

For boards that were fully cleaned, or Condition 3, full board extraction yielded passing IC results and local extraction yielded passing results for both IC and electrical tests. It is interesting to note that full board IC yielded passing results for the boards were not cleaned and partially cleaned.

Reference Table 9 - 11 for all IC and electrical test results for all solder pastes and conditions.

Table 9. No-Clean Ion Chromatography Results

No-Clean Ion Chromatography Results - Localized & Full Board Extraction						
No-Clean Solder Paste	**Condition**	**Area**	**Localized Extraction**		**Localized Extraction Electrical Test**	**Full Board Extraction**
			Anion/WOA	**Cation**		
A	Not Cleaned	1	Pass	Fail	Pass	Pass
A	Not Cleaned	2	Pass	Pass	Pass	
A	Not Cleaned	3	Pass	Fail	Pass	
A	Partially Cleaned	1	Pass	Fail	Pass	Pass
A	Partially Cleaned	2	Pass	Pass	Pass	
A	Partially Cleaned	3	Pass	Pass	Fail	
A	Fully Cleaned	1	Pass	Pass	Pass	Pass
A	Fully Cleaned	2	Pass	Pass	Pass	
A	Fully Cleaned	3	Pass	Pass	Pass	
B	Not Cleaned	1	Pass	Fail	Pass	Pass
B	Not Cleaned	2	Pass	Pass	Pass	
B	Not Cleaned	3	Pass	Fail	Fail	
B	Partially Cleaned	1	Pass	Fail	Pass	Pass
B	Partially Cleaned	2	Pass	Pass	Pass	
B	Partially Cleaned	3	Pass	Fail	Pass	
B	Fully Cleaned	1	Pass	Pass	Pass	Pass
B	Fully Cleaned	2	Pass	Pass	Pass	
B	Fully Cleaned	3	Pass	Pass	Pass	
C	Not Cleaned	1	Fail	Fail	Pass	Pass
C	Not Cleaned	2	Pass	Fail	Pass	
C	Not Cleaned	3	Pass	Fail	Pass	
C	Partially Cleaned	1	Fail	Fail	Fail	Pass
C	Partially Cleaned	2	Pass	Fail	Pass	
C	Partially Cleaned	3	Pass	Fail	Pass	
C	Fully Cleaned	1	Pass	Pass	Pass	Pass
C	Fully Cleaned	2	Pass	Pass	Pass	
C	Fully Cleaned	3	Pass	Pass	Pass	

Table 10. RMA Ion Chromatography Results

RMA Ion Chromatography Results - Localized and Full Board Extraction						
RMA Solder Paste	Condition	Area	Localized Extraction		Localized Extraction Electrical Test	Full Board Extraction
			Anion/WOA	Cation		
D	Not Cleaned	1	Pass	Fail	Pass	Pass
D	Not Cleaned	2	Pass	Pass	Pass	
D	Not Cleaned	3	Pass	Pass	Pass	
D	Fully Cleaned	1	Pass	Pass	Pass	Pass
D	Fully Cleaned	2	Pass	Pass	Pass	
D	Fully Cleaned	3	Pass	Pass	Pass	
E	Not Cleaned	1	Pass	Pass	Pass	Pass
E	Not Cleaned	2	Pass	Fail	Pass	
E	Not Cleaned	3	Pass	Fail	Pass	
E	Fully Cleaned	1	Pass	Pass	Pass	Pass
E	Fully Cleaned	2	Pass	Pass	Pass	
E	Fully Cleaned	3	Pass	Pass	Pass	

Table 11. OA Ion Chromatography Results

OA Ion Chromatography Results - Localized and Full Board Extraction						
OA Solder Paste	Condition	Area	Localized Extraction		Localized Extraction Electrical Test	Full Board Extraction
			Anion/WOA	Cation		
F	Not Cleaned	1	Pass	Pass	Pass	Pass
F	Not Cleaned	2	Pass	Fail	Pass	
F	Not Cleaned	3	Fail	Fail	Fail	
F	Fully Cleaned	1	Pass	Pass	Pass	Pass
F	Fully Cleaned	2	Pass	Pass	Pass	
F	Fully Cleaned	3	Pass	Pass	Pass	
G	Not Cleaned	1	Pass	Fail	Pass	Pass
G	Not Cleaned	2	Fail	Fail	Fail	
G	Not Cleaned	3	Fail	Pass	Fail	
G	Fully Cleaned	1	Pass	Pass	Pass	Pass
G	Fully Cleaned	2	Pass	Pass	Pass	
G	Fully Cleaned	3	Pass	Pass	Pass	

Results - SIR Test

SIR tests were conducted on Section A of the IPC B-52 board for all pastes and all conditions and were conducted by an independent lab. The SIR test parameters used are detailed in Table 12.

Table 12.

Test Conditions	40°C / 90% RH
Test Duration	168 hours
Bias Voltage	5V (unbiased during ramp up and ramp down)
Measurement Voltage	5V (same polarity as bias voltage)
Measurement Frequency	Every 20 minutes

The SIR tests were conducted in accordance with IPC-TM-650 and method 2.6.3.7. In total, fourteen (14) test patterns were measured. Reference Figure 13.

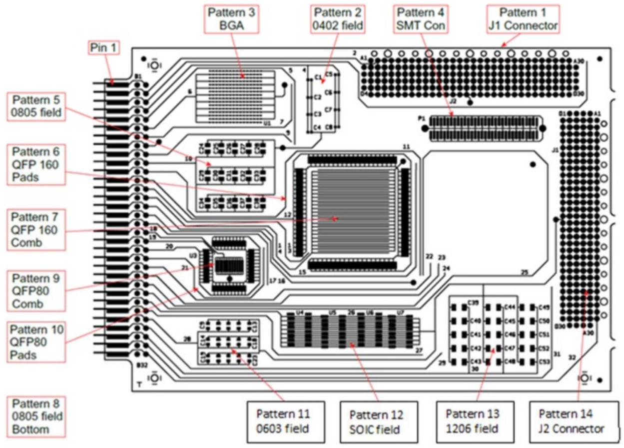


Figure 13.

Post SIR visual inspection was made as well. In all cases, there was no presence of dendrites, corrosion, discoloration between conductors, water spots, or subsurface metal migration.

In all cases, the fully cleaned boards resulted in passing SIR tests. No-Clean Paste C, Condition 1 (Not Clean), RMA Pastes D and E, Condition 1 (Not Cleaned) and OA Pastes F and G, Condition 1 (Not Cleaned) resulted in failed SIR tests.

SIR test results for all pastes and conditions are detailed in Tables 13 - 15:

Table 13. No-Clean Solder Paste SIR Results

No-Clean Solder Paste SIR Results		
Solder Paste	**Condition**	**SIR Result**
A	Not Cleaned	Passed
A	Partially Cleaned	Passed
A	Fully Cleaned	Passed
B	Not Cleaned	Passed
B	Partially Cleaned	Passed
B	Fully Cleaned	Passed
C	Not Cleaned	Failed (7)
C	Partially Cleaned	Passed
C	Fully Cleaned	Passed

Table 14 . RMA SIR Test Results

RMA SIR Test Results		
Solder Paste	**Condition**	**Result**
D	Not Cleaned	Failed (10)
D	Fully Cleaned	Pass
E	Not Cleaned	Failed (2, 10, 12)
E	Fully Cleaned	Pass

Table 15. OA SIR Test Results

OA SIR Test Results		
Solder Paste	**Condition**	**Result**
F	Not Cleaned	Failed (2, 3, 11, 12)
F	Fully Cleaned	Pass
G	Not Cleaned	Failed (2, 12)
G	Fully Cleaned	Pass

CONCLUSIONS

If one is manufacturing Class 2 or Class 3 electronic assemblies, achieving high reliability is critical if not mandatory. The key to achieving high reliability is an understanding of what constitutes high reliability given the assembly design, and how to adapt processes and assessment standards to assure attainment.

In this study, there was focus on post solder flux residues and how to assess their impact on assembly reliability as measured by IPC cleanliness assessment methodologies. In order to gain an understanding of the impact of a cleaning process on assembly reliability, cleanliness assessment was conducted on post reflow boards that were not cleaned, partially cleaned and fully cleaned in the case of lead-free No-Clean solder pastes, and not cleaned and fully cleaned in the case of lead-free RMA and OA solder pastes. The cleanliness assessment methodologies employed included Visual Inspection, Ion Chromatography and SIR.

Visual Inspection

Both surface and under-component inspection is useful to establish a baseline for the assembly process employed. Under-component inspection is also useful as for depending upon the PCB component geometry and density, remaining ionic residues can lead to leakage current, electrochemical migration and dendritic growth and thus suspect long term reliability.

In this study, under-component inspection of all pastes under Condition 3 (Fully Cleaned) resulted in fully cleaned surfaces. This correlated with the results of the other test methods, as IC (Full Board and Localized Extraction), electrical tests and SIR yielded passing results under Condition 3 (Fully Cleaned).

Ion Chromatography

Based on the paste types and cleaning conditions investigated, localized extraction was found to be the preferred method as compared to the full board surface extraction.

When measuring full board IC, the eluent is generated by immersing the PCB in an IPA and DI-Water mixture at 80°C for one hour. A sample of the eluent is analyzed for anions, cations and weak organic acids. This test identifies ions present in micrograms of ion per square centimeter; however, the result is based on the sample surface area. Thus, even a small amount of flux residues present in a given area or areas that may be above the specific ion(s) limit may yield a passing test result.

Localized board extraction can pinpoint the distribution of the residues on a component level and in critical areas that may cause the board to fail in the field. For a process qualification, IC testing may be required and should be conducted. However, localized IC on critically sensitive areas is recommended to insure that the desired reliability standards are achieved.

SIR and Localized extraction Electrical Test

For Condition 3 (Fully Cleaned), the electrical and SIR results correlated for all pastes yielding pass results. For the OA pastes, the electrical test and SIR also correlated for Condition 1 (Not Cleaned) yielding failed results. However, the electrical test and SIR did not correlate for the No-Clean and RMA pastes for Condition 1 (Not Cleaned) and Condition 2 (Partially Cleaned).

In the authors opinion, this discrepancy may result from the use of steam (water vapor) technique in the localized extraction method electrical test. Steam may be able to solubilize water soluble residues created by OA type pastes, but not the hard residues created by RMA and No-Clean paste types.

SIR and Localized Board Extraction for Ion Chromatography Test

All pastes evaluated in this study passed the SIR tests under Condition 3 (Fully Cleaned). Additionally, No-Clean Paste A and Paste B had passing SIR results under Condition 1(Not Cleaned) and Condition 2 (Partially Cleaned). RMA Paste D and Paste E and OA Paste F and Paste G failed SIR testing under Condition 1 (Not Cleaned).

Based on these observations, the cleanliness assessment could first be done by SIR test. If the SIR test fails, the assessment could further be complimented by localized board extraction for Ion Chromatography test to determine if the failure is due to ionic residues. It is important to note that the SIR test is an industry standard that is normally conducted on designated test vehicles that may not be representative of more complex production boards but could be used as a starting point for the cleanliness assessment.

Accelerated Reliability Testing and Localized Board Extraction

As in the example presented regarding the solar panel manufacturer, many clients prefer to pursue ART (Accelerated Reliability Testing) evaluation on their actual production boards in order to gather more reliable data on how the boards will function during their life-span in the environment they will be used. If ART evaluation fails, then localized board extraction for Ion Chromatography test could be conducted to determine if the failure may be linked to ionic contaminants.

Each of the cleanliness assessment methodologies presented and reviewed within this study can provide effective insight as to the long-term reliability of an electronic assembly. Understanding the benefits and drawbacks of each as well as how one test may compliment another, is critical in determining which quality assessment methodologies are best for a given electronic assembly and process.

References

[1] Acceptability of Electronic Assemblies, IPC-A-610 F

[2] Umut Tosun, Jigar Patel, Michael McCutchen, "Comparative Cleaning Study to Showcase the Effective Removal of OA Flux Residues," SMTAI 2012

[3] Guidelines for Accelerated Reliability Testing of Surface Mount Solder Attachments, IPC-SM-785

[4] Verification of Cleaning Under Leadless Components; Flavius Dehel, Ishrat Hasan

[5] Steve Shoda, Terry Munson, Cleanliness Assessment Correlation to Electronics Hardware Reliability, IPC APEX 2007

APPENDIX

Contamination origination for the species with contamination level above the suggested maximum is detailed in the table below.

Anions	
Species	**Origination**
Fluoride (F^-)	Flux Chemistry
Phosphate (PO_4^{2-})	Flux Chemistry
Bromide (Br^-)	Flux Chemistry Halides
Cations	
Species	**Origination**
Sodium (Na)	Flux and Solder Mask Chemistries
Organic Acids	
Species	**Origination**
Formate	Flux System Activators

IC Data - No-Clean Solder Paste - Not Cleaned

Anion Species always tested for (µg/in^2)										
Ionic Species	**Maximum Contamination Levels**	**Paste A Area 1**	**Paste B Area 1**	**Paste C Area 1**	**Paste A Area 2**	**Paste B Area 2**	**Paste C Area 2**	**Paste A Area 3**	**Paste B Area 3**	**Paste C Area 3**
Fluoride (F^-)	**3**	ND	0.4136	1.0745	0.4191	ND	0.2355	ND	0.2091	0.4418
Acetate ($C_2H_2O_2$)	**3**	0.9373	ND	ND	ND	0.7991	ND	2.5345	ND	ND
Formate (CH_2O_2)	**3**	1.7664	0.1818	3.0964	0.1964	0.1809	2.3773	0.1618	2.9555	2.6764
Chloride (Cl^-)	**4**	1.5382	2.7509	19.4864	2.1345	1.2518	0.4045	2.67	0.3191	0.9782
Nitrite (NO_2^-)	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromide (Br^-)	**10**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (NO_3^-)	**3**	ND	ND	ND	0.1655	ND	ND	ND	ND	ND
Phosphate (PO_4^{2-})	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulfate (SO_4^{2-})	**3**	ND	ND	ND	0.2255	ND	ND	0.4164	0.3255	0.2918
WOA (Weak Organic Acid)	**25**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cation Species always tested for (µg/in^2)										
Lithium (Li)	**3**	ND	ND	ND	ND	0.4682	ND	ND	ND	ND
Sodium (Na)	**3**	4.4236	3.4018	7.1364	2.8182	2.9236	3.2382	4.2409	5.1791	5.1236
Ammonium (NH_4)	**3**	ND	ND	ND	ND	ND	0	ND	ND	ND
Potassium (K)	**3**	0.3945	0.1827	2.7382	0.1773	0.6118	ND	0.4255	0.0518	0.5655
Magnesium (Mg)	**1**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (Ca)	**1**	0.0445	0	0.1173	0.0027	0.0118	0.0545	0	0.0009	0

ND: Not Detected

Red: Above Maximum Contamination Level

No-Clean Solder Paste - Partially Cleaned

Anion Species always tested for (µg/in^2)										
Ionic Species	**Maximum Contamination Levels**	**Paste A Area 1**	**Paste B Area 1**	**Paste C Area 1**	**Paste A Area 2**	**Paste B Area 2**	**Paste C Area 2**	**Paste A Area 3**	**Paste B Area 3**	**Paste C Area 3**
Fluoride (F^-)	**3**	ND	0.78	1.0518	1.23	ND	0.9273	0.24	0.2291	0.3727
Acetate ($C_2H_2O_2$)	**3**	1.1536	ND	ND	ND	2.2755	ND	ND	ND	ND
Formate (CH_2O_2)	**3**	1.8036	2.5673	3.0527	0.2345	0.1509	2.6191	1.9936	0.7891	2.4391
Chloride (Cl^-)	**4**	0.9936	1.88	2.0973	3.3782	2.82	1.71	0.6745	2.7809	1.69
Nitrite (NO_2^-)	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromide (Br^-)	**10**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (NO_3^-)	**3**	ND	0.3973	ND	ND	ND	ND	ND	ND	0.6982
Phosphate (PO_4^{2-})	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulfate (SO_4^{2-})	**3**	0.1436	ND	ND	0.2345	ND	ND	ND	0.3418	0.6527
WOA (Weak Organic Acid)	**25**	ND	ND	ND	ND	ND	ND	ND	1.4309 (Succinate)	ND
Cation Species always tested for (µg/in^2)										
Lithium (Li)	**3**	ND	0.4673	ND	ND	ND	ND	ND	ND	ND
Sodium (Na)	**3**	4.8945	5.3791	4.6582	2.75	2.3482	3.1164	2.6273	4.8936	3.3145
Ammonium (NH_4)	**3**	0	ND	ND	0	0	0	0	ND	0
Potassium (K)	**3**	0.3218	0.9655	1.0382	1.1027	0.3382	0.75	0.2545	ND	0.4345
Magnesium (Mg)	**1**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (Ca)	**1**	0.04	0.0327	0.1309	0.0273	0.15	0.1209	0.1127	ND	0.5582

ND: Not Detected

Red: Above Maximum Contamination Level

No-Clean Solder Paste - Fully Cleaned –

Anion Species always tested for (µg/in^2)										
Ionic Species	**Maximum Contamination Levels**	**Paste A Area 1**	**Paste B Area 1**	**Paste C Area 1**	**Paste A Area 2**	**Paste B Area 2**	**Paste C Area 2**	**Paste A Area 3**	**Paste B Area 3**	**Paste C Area 3**
Fluoride (F^-)	**3**	0.2091	0.2409	0.1809	ND	0.1891	0.1682	0.2009	0.2127	0.1591
Acetate ($C_2H_2O_2$)	**3**	ND	ND	ND	2.1764	ND	ND	ND	ND	ND
Formate (CH_2O_2)	**3**	ND	1.3773	0.4364	ND	2.22	1.3945	1.0018	0.6509	1.2009
Chloride (Cl^-)	**4**	1.9436	0.7373	0.81	1.9936	0.8173	0.5155	0.8827	1.0445	0.2891
Nitrite (NO_2^-)	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromide (Br^-)	**10**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrate (NO_3^-)	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phosphate (PO_4^{2-})	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulfate (SO_4^{2-})	**3**	ND	ND	ND	0.1482	0.2045	ND	ND	0.2682	0.2936
WOA (Weak Organic Acid)	**25**	6.4291 (MSA)	ND	ND	ND	ND	ND	ND	ND	ND
Cation Species always tested for (µg/in^2)										
Lithium (Li)	**3**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sodium (Na)	**3**	2.3773	1.8555	2.7373	2.78	2.21	2.6264	1.8691	2.5582	2.3045
Ammonium (NH_4)	**3**	0	0.0027	ND	0	ND	0	ND	0	0
Potassium (K)	**3**	0.0191	0.2782	0.0927	0.0591	0.0655	0.1536	0.1982	0.0582	0.0355
Magnesium (Mg)	**1**	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (Ca)	**1**	0.0409	ND	0	ND	0.0073	0.0082	0.0618	ND	0.0518

ND: Not Detected

RMA/OA Solder Paste - Not Cleaned –

Anion Species always tested for (µg/in²)									
Ionic Species	**Maximum Contamination Levels**	**Paste D Area 1**	**Paste E Area 1**	**Paste F Area 1**	**Paste G Area 1**	**Paste D Area 2**	**Paste E Area 2**	**Paste F Area 2**	**Paste G Area 2**
Fluoride (F^-)	3	0.007	0.002	0.278	0.153	0.002	0.243	2.124	1.669
Acetate ($C_2H_3O^-_2$)	3	0.05	0.102	ND	ND	0.108	ND	ND	ND
Formate (CHO^-_2)	3	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (Cl^-)	3	0.178	0.136	0.102	0.124	0.147	0.239	0.29	1.133
Nitrite (NO_2^-)	3	0.013	ND	ND	0.014	0.01	0.003	ND	0.003
Bromide (Br^-)	12	0.025	2.071	ND	1.719	0.052	4.737	0.296	20.627
Nitrate (NO_3^-)	3	0.032	0.05	0.071	0.136	0.039	0.069	0.679	0.106
Phosphate (PO_4^{2-})	3	ND	ND	ND	1.478	ND	0.11	ND	19.046
Sulfate (SO_4^{2-})	3	0.251	0.32	0.238	0.373	0.318	0.499	0.342	0.477
WOA (Weak Organic Acid)	25*	0.384	0.852	1.725	0.417	1.173	1.902	10.222	5.862
Cation Species always tested for (µg/in²)									
Lithium (Li^+)	3	0.002	0.002	ND	0.002	0.002	0.002	0.001	0.002
Sodium (Na^+)	3	4.207	2.42	2.22	3.751	2.067	3.366	3.971	4.576
Ammonium (NH_4^+)	3	0.189	0.251	0.109	0.167	0.241	0.392	0.128	0.201
Potassium (K^+)	3	0.249	0.222	0.577	0.223	0.194	0.9	1.009	1.419
Magnesium (Mg^{2+})	1	0.022	0.082	0.068	0.067	0.019	0.112	0.015	0.035
Calcium (Ca^{2+})	1	0.124	0.402	0.47	0.5	0.302	0.735	0.837	0.783

ND: Not Detected

Red: Above Maximum Contamination Level

Anion Species always tested for (µg/in^2)					
Ionic Species	**Maximum Contamination Levels**	**Paste D Area 3**	**Paste E Area 3**	**Paste F Area 3**	**Paste G Area 3**
Fluoride (F^-)	3	0.021	0.148	3.796	0.599
Acetate ($C_2H_3O^-_2$)	3	0.05	ND	ND	ND
Formate (CHO^-_2)	3	ND	ND	ND	ND
Chloride (Cl^-)	3	0.39	0.175	0.303	0.273
Nitrite (NO_2^-)	3	0.018	0.012	ND	0.014
Bromide (Br^-)	12	0.028	4.199	0.37	6.427
Nitrate (NO_3^-)	3	0.039	0.053	0.373	0.533
Phosphate (PO_4^{2-})	3	ND	ND	0.001	6.112
Sulfate (SO_4^{2-})	3	0.4	0.475	0.357	0.54
WOA (Weak Organic Acid)	25*	0.25	2.986	16.288	4.184
Cation Species always tested for (µg/in^2)					
Lithium (Li^+)	3	0.002	0.002	0.003	0.002
Sodium (Na^+)	3	1.747	4.062	5.891	2.796
Ammonium (NH_4^+)	3	0.239	0.425	0.128	0.204
Potassium (K^+)	3	0.259	0.614	1.438	0.684
Magnesium (Mg^{2+})	1	0.134	0.073	0.06	0.111
Calcium (Ca^{2+})	1	0.483	0.661	0.73	0.913

ND: Not Detected

Red: Above Maximum Contamination Level

RMA/OA Solder Paste - Fully Cleaned

Ionic Species	Maximum Contamination Levels	Paste D Area 1	Paste E Area 1	Paste F Area 1	Paste G Area 1	Paste D Area 2	Paste E Area 2	Paste F Area 2	Paste G Area 2
Anion Species always tested for (µg/in^2)									
Fluoride (F^-)	3	0	0	0.049	0.01	0	0.071	0.052	0.03
Acetate ($C_2H_3O^-_2$)	3	0.089	ND	ND	0.046	0.163	ND	ND	0.061
Formate (CHO^-_2)	3	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (Cl^-)	3	0.114	0.074	0.186	0.148	0.13	0.203	0.185	0.27
Nitrite (NO_2^-)	3	0.015	ND	ND	0.02	0.015	0.018	0.027	0.018
Bromide (Br^-)	12	ND	ND	ND	ND	ND	ND	ND	0.019
Nitrate (NO_3^-)	3	0.052	0.051	0.213	0.085	0.063	0.057	0.49	0.491
Phosphate (PO_4^{2-})	3	0.133	ND	0.127	ND	ND	0.298	ND	ND
Sulfate (SO_4^{2-})	3	0.252	0.233	0.293	0.315	0.324	0.342	0.277	0.311
WOA (Weak Organic Acid)	25*	0.261	0.743	0.2	0.252	1.725	1.213	1.09	0.863
Cation Species always tested for (µg/in^2)									
Lithium (Li^+)	3	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.001
Sodium (Na^+)	3	2.017	2.188	2.264	2.8	2.547	1.694	1.762	2.609
Ammonium (NH_4^+)	3	0.186	0.16	0.16	0.164	0.264	0.275	0.297	0.289
Potassium (K^+)	3	0.124	0.09	0.181	0.138	0.151	0.214	0.306	0.359
Magnesium (Mg^{2+})	1	0.081	0.034	0.051	0.063	0.185	0.05	0.041	0.082
Calcium (Ca^{2+})	1	0.362	0.34	0.591	0.649	0.564	0.561	0.623	0.956

ND: Not Detected

Anion Species always tested for (µg/in^2)					
Ionic Species	**Maximum Contamination Levels**	**Paste D Area 3**	**Paste E Area 3**	**Paste F Area 3**	**Paste G Area 3**
Fluoride (F^-)	3	0.085	0.008	0.005	0.035
Acetate ($C_2H_3O^-_2$)	3	ND	ND	0.114	0.073
Formate (CHO^-_2)	3	ND	ND	ND	ND
Chloride (Cl^-)	3	0.217	0.128	0.156	0.386
Nitrite (NO_2^-)	3	0.041	0.012	0.022	0.019
Bromide (Br^-)	12	ND	ND	ND	0.03
Nitrate (NO_3^-)	3	0.069	0.043	0.204	1.949
Phosphate (PO_4^{2-})	3	0.225	0.301	ND	ND
Sulfate (SO_4^{2-})	3	0.416	0.447	0.353	0.368
WOA (Weak Organic Acid)	25*	0.644	3.267	0.41	2.117
Cation Species always tested for (µg/in^2)					
Lithium (Li^+)	3	0.002	0.003	0.002	0.002
Sodium (Na^+)	3	1.756	2.715	1.478	2.014
Ammonium (NH_4^+)	3	0.339	0.283	0.299	0.313
Potassium (K^+)	3	0.327	0.185	0.229	0.659
Magnesium (Mg^{2+})	1	0.047	0.059	0.053	0.068
Calcium (Ca^{2+})	1	0.551	0.429	0.542	0.257

ND: Not Detected

PCB Cleanliness Assessment Methods – A Comparative Study

Umut Tosun

ZESTRON Americas

PCB Cleanliness Assessment Methods - A Comparative Study

- **Introduction**
- Methodology
- Main Research
- Results
- Conclusion

Introduction

- PCB manufacturers use a wide variety of leaded and lead-free solder pastes
  - No-Clean
  - RMA
  - OA
- Burnt-in flux residues may result on the PCB can lead to failure mechanisms
  - Leakage current
  - Electrochemical migration
  - Dendritic growth

Introduction

- If OA paste and flux is used, cleaning is required using either a DI-water or chemically assisted aqueous cleaning process
- RMA and No-Clean residues may need to be cleaned as well
- How does one assess cleanliness?
  - Visual Inspection
  - Ionic Contamination (Resistivity of Solvent Extract)
  - Ion Chromatography
  - SIR

Introduction

- Electronic assemblies can be classified as:
  - Class I: General Electronic Products
  - Class II: Dedicated Service Electronic Products
  - Class III: High Performance Electronic Products

Introduction

- Assemblies must meet the functional standards as defined by the process design
  - Class II and Class III products, must meet the functional design and reliability requirements within harsh environments

Cleaning/Defluxing is critical to reliable functionality!

Introduction

- Measuring the cleanliness level achieved is a critical process step
- How does one select the right cleanliness assessment technique?

Introduction

- Numerous customers face intermittent product field failures even when boards pass industry standard tests
- This is particularly more pronounced for cases where No-Clean pastes are used and boards are not cleaned
- Customers have used Accelerated Reliability Testing (ART) evaluation techniques to confirm field reliability

Introduction

- Case Study
  - Solar Panel manufacturer
  - Boards exposed to wide range of temperature and humidity changes
    - Initially used No-Clean paste and did not clean boards
    - Passed SIR tests, but still resulted in field failures
    - ART to simulate field conditions and determine field failures
    - Included cleaning process to determine if it will impact the results

Introduction

- ART Tests were done in two scenarios
  - Test 1: No humidity, high temperature test (85^{o}C)
  - Test 2: Humidity (85% RH) and high temperature test (85^{o}C)
- Pass requirement: 1000 hours
  - Test 1: Uncleaned boards failed after 700 hours, cleaned boards passed 1,000 hours
  - Test 2: Uncleaned boards failed between 712 – 860 hours, cleaned boards passed 1,000 hours

Introduction

- Both uncleaned and cleaned boards passed SIR testing
- Only during ART evaluation was the customer able to see the impact of flux residues

Introduction

- Purpose of this study was to compare cleanliness assessment methodologies on boards that were cleaned and not cleaned following reflow

PCB Cleanliness Assessment Methods - A Comparative Study

- Introduction
- **Methodology**
- Main Research
- Results
- Conclusion

Methodology

- Seven (7) solder pastes were considered

Solder Pastes	
No-Clean Solder Pastes	A
	B
	C
RMA Solder Pastes	D
	E
OA Solder Pastes	F
	G

Methodology

- Four (4) cleanliness assessment methodologies were considered
  1) Visual Inspection: IPC-A-610F
  2) Full Board Extraction
     Ion Chromatography: IPC-TM-650; 2.3.28.2
  3) Localized Extraction:
     - Ion Chromatography: IPC-TM-650; 2.3.28.2
     - Electrical Testing: Class 2 – 3
  4) Surface Insulation Resistance: IPC-650-TM; 2.6.3.7

Methodology

- IPC-B-52 Test vehicle
  - Populated with ninety-six (96) components, reflowed employing recommended lead-free thermal profile
- For all solder pastes and conditions considered, thirty-four (34) test vehicles were required

PCB Cleanliness Assessment Methods - A Comparative Study

- Introduction
- Methodology
- **Main Research**
- Results
- Conclusion

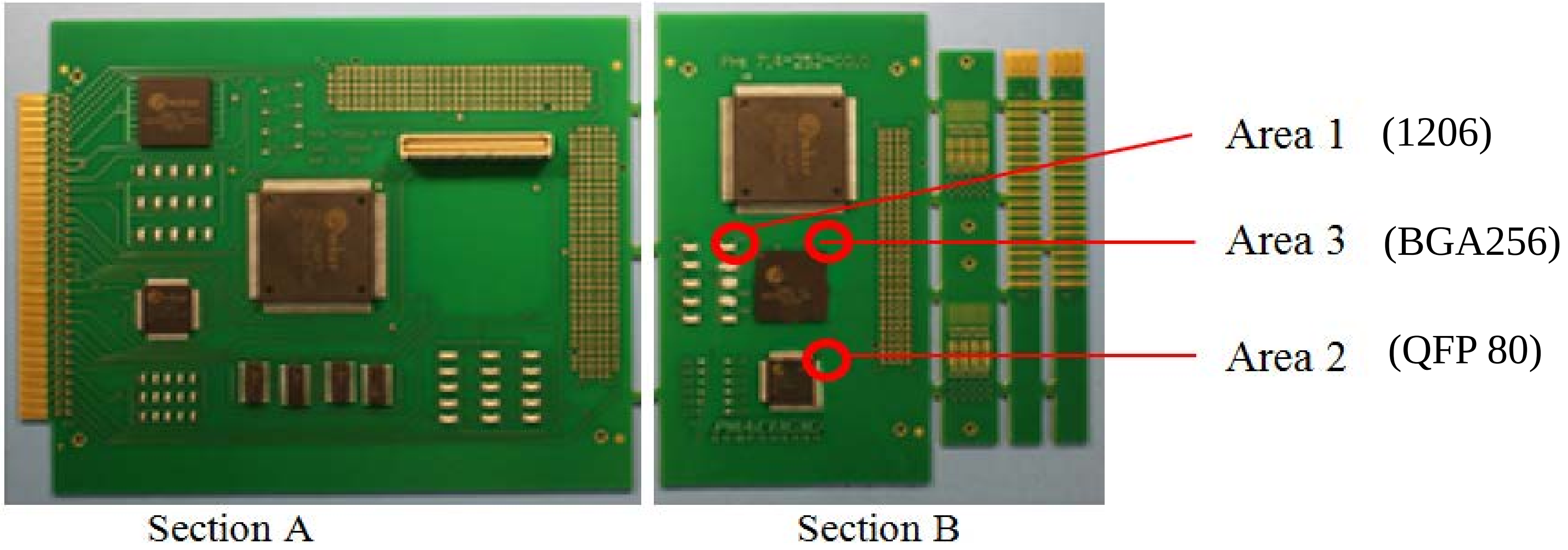
Main Research

No. Populated IPC-B-52 Test Vehicles						
Solder Paste Types		Condition	J-STD-004 B Classification	SIR	Full Board IC and Localized IC	Totals
No-Clean Solder Pastes	A	NC, PC, FC	ROL0	3	3	6
	B	NC, PC, FC	ROL0	3	3	6
	C	NC, PC, FC	ROL1	3	3	6
RMA Solder Pastes	D	NC, FC	ROL0	2	2	4
	E	NC, FC	ROH0	2	2	4
OA Solder Pastes	F	NC, FC	ORH0	2	2	4
	G	NC, FC	ORL0	2	2	4
Total IPC B-52 #						**34**

NC: Not Cleaned PC: Partially Cleaned FC: Fully Cleaned

Main Research

- IPC-B-52 test vehicle has two (2) sections
  - Section A – SIR, full board Ion Chromatography
  - Section B – Localized Ion Chromatography



Main Research

Cleaning Process	Equipment	Inline Spray-in-Air	
	Cleaning Agent	Engineered Aqueous Based	
		Partially Clean	Fully Clean
	Concentration	6%	15%
	Conveyor Belt Speed	2 ft/min	1 ft/min
	Cleaning Temperature	140˚F	150˚F
	Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI	
	Wash Pressure (Top/Bottom)	70 PSI / 40 PSI	
	Wash Hurricane Pressure (Top/Bottom)	40 PSI / 20 PSI	
Rinse	Rinsing Agent	DI-water	
	Rinse Pressure (Top/Bottom)	80 PSI / 60 PSI	
	Rinse Hurricane Pressure (Top/Bottom)	40 PSI / 20 PSI	
	Rinsing Temperature	140˚F	
	Final Rinse Pressure (Top/Bottom)	25 PSI / 25 PSI	
	Final Rinse Temperature	Room Temperature	
Drying	Drying Method	Hot Circulated Air & Torrid Zone	
	Drying Temperature	180˚F - 190˚F	

Optimization not considered

Main Research

- Four (4) assessment methods were employed
  - Visual inspection on board surface and under-component (using 4 to 60x magnification)
  - Full Board Ion Chromatography
  - Localized Ion Chromatography
  - SIR

PCB Cleanliness Assessment Methods - A Comparative Study

- Introduction
- Methodology
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- **Results**
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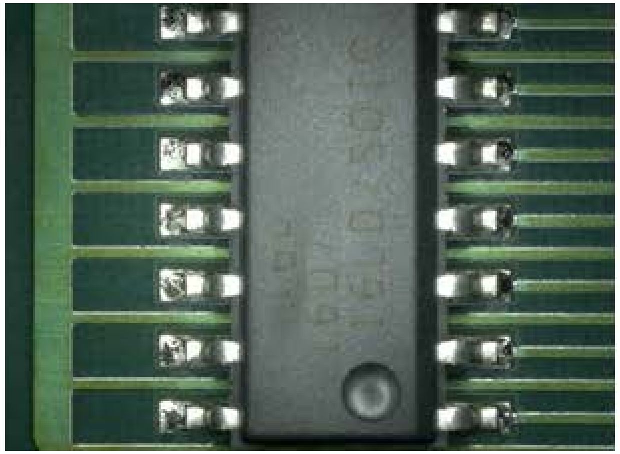
Results – Visual Inspection (Surface)

- Paste A: No-Clean
  - Not cleaned: Transparent untouched residue present
  - Partially cleaned: Very minor residue identified
  - Fully cleaned: No residue found

Not Cleaned

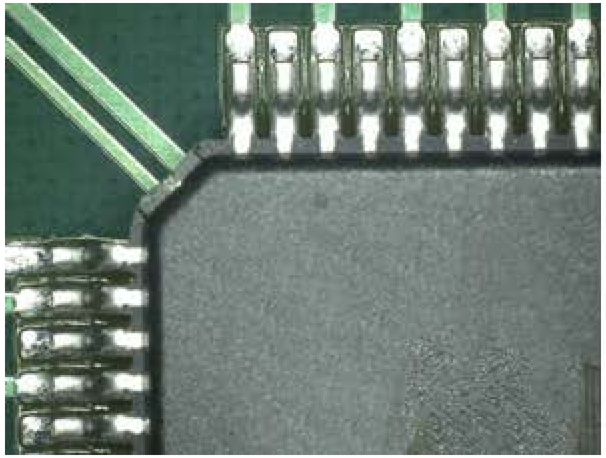


Partially Cleaned

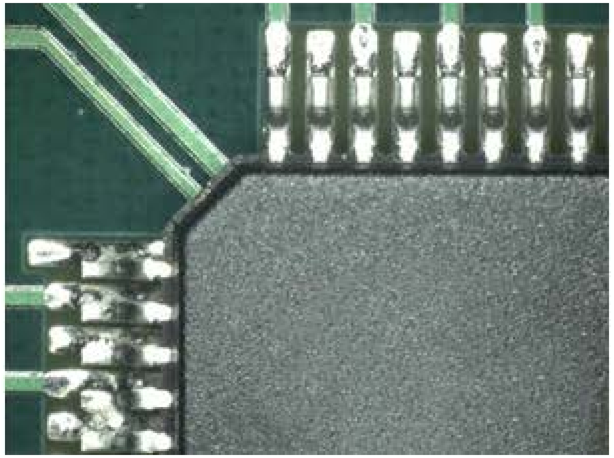
Fully Cleaned

Results – Visual Inspection (Surface)

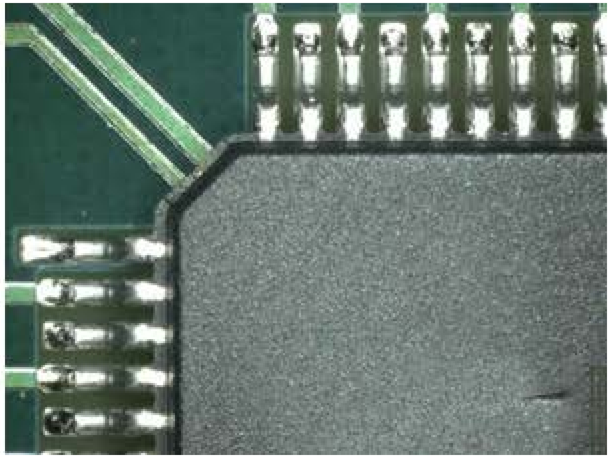
- Paste B and C: No-Clean
  - Not cleaned: Transparent untouched residue present
  - Partially cleaned: No residue found on surface
  - Fully cleaned: No residue found for both pastes



Not Cleaned



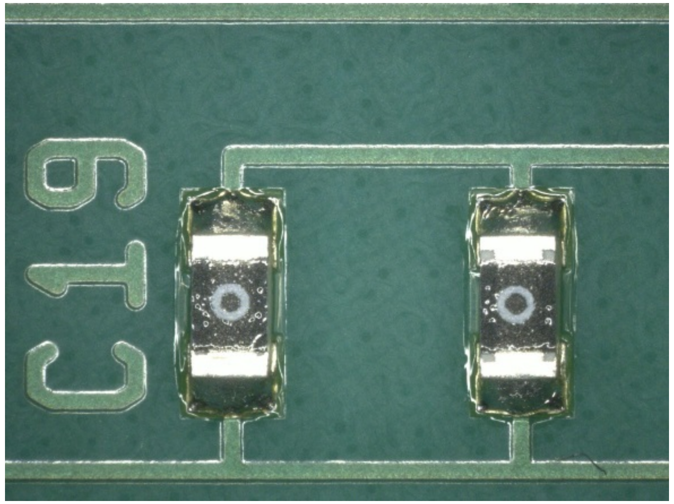
Partially Cleaned



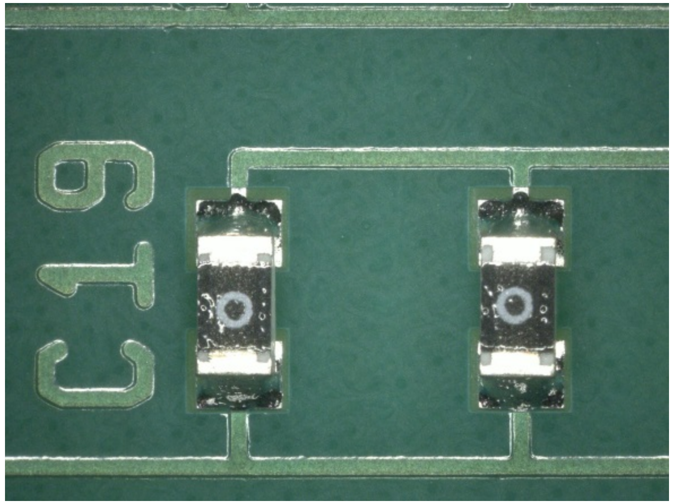
Fully Cleaned

Results – Visual Inspection (Surface)

- Paste D and E: RMA
  - Not cleaned: Transparent untouched residue present
  - Fully cleaned: No residue found for both pastes



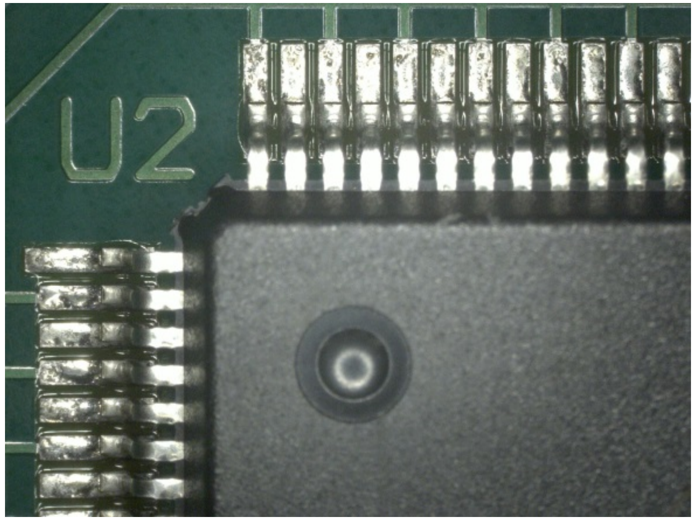
Not Cleaned



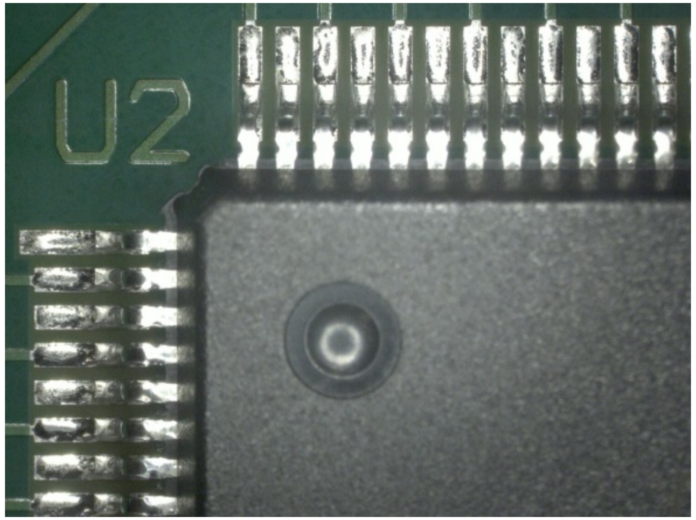
Fully Cleaned

Results – Visual Inspection (Surface)

- Paste F and G – OA
  - Not cleaned: Transparent untouched residue present
  - Fully cleaned: No residue found for both pastes



Not Cleaned



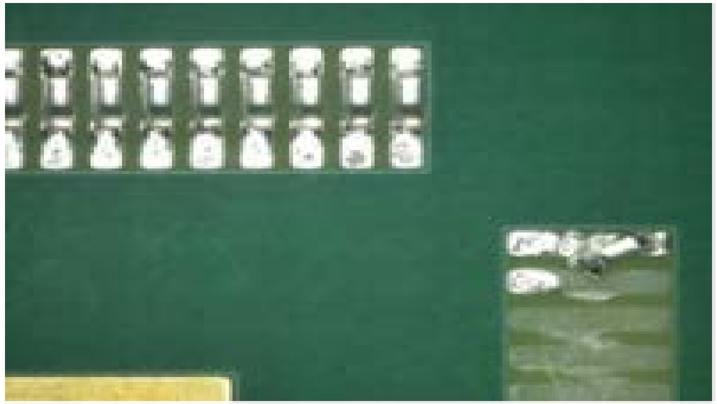
Fully Cleaned

Results – Visual Inspection (Under-component)

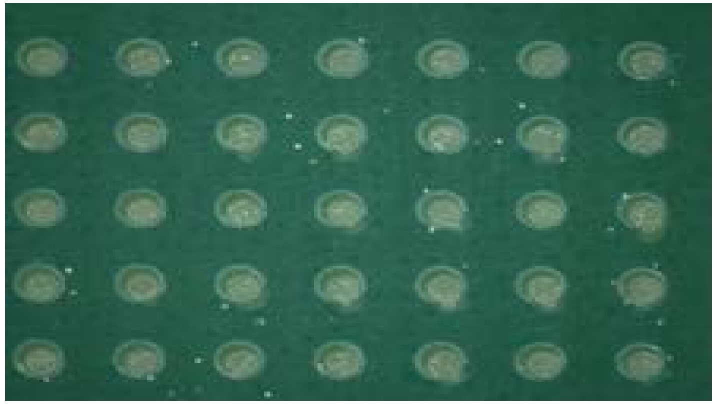
Solder Paste		Condition	Under-component Inspection		
			Area 1	Area 2	Area 3
No-Clean	A	Not Cleaned	Residue	Residue	Residue
	A	Partially Cleaned	Residue	Residue	Residue
	A	Fully Cleaned	Clean	Clean	Clean
	B	Not Cleaned	Residue	Residue	Residue
	B	Partially Cleaned	Residue	Residue	Residue
	B	Fully Cleaned	Clean	Clean	Clean
	C	Not Cleaned	Residue	Residue	Residue
	C	Partially Cleaned	Residue	Residue	Residue
	C	Fully Cleaned	Clean	Clean	Clean
RMA	D	Not Cleaned	Residue	Residue	Residue
	D	Fully Cleaned	Clean	Clean	Clean
	E	Not Cleaned	Residue	Residue	Residue
	E	Fully Cleaned	Clean	Clean	Clean
OA	F	Not Cleaned	Residue	Residue	Residue
	F	Fully Cleaned	Clean	Clean	Clean
	G	Not Cleaned	Residue	Residue	Residue
	G	Fully Cleaned	Clean	Clean	Clean

Results – Visual Inspection (Under-component)

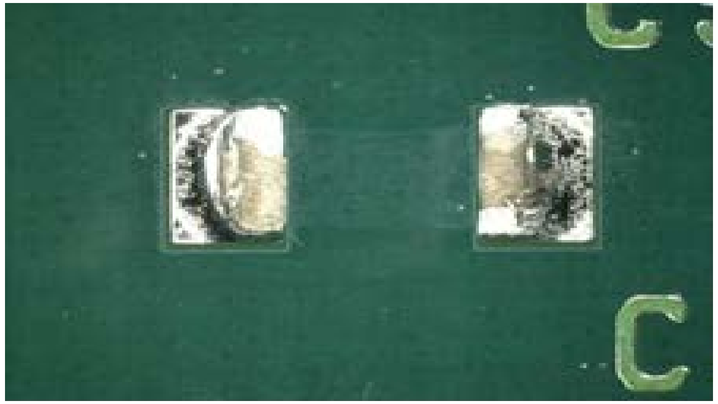
- For all paste types, fully cleaned boards resulted in no residues remaining under-component



Paste A – Area 2



Paste B – Area 3



Paste C – Area 1

Results – Ion Chromatography

- Full board and localized extraction IC tests were conducted in accordance with IPC TM 650 Method 2.3.28
- Localized extraction electrical test feature utilized for potential leakage current detection

Results – Ion Chromatography

No-Clean Ion Chromatography Results - Localized & Full Board Extraction						
No-Clean Solder Paste	Condition	Area	Localized IC		Localized Electrical Test	Full Board IC
			Anion/WOA	Cation		
A	Not Cleaned	1	Pass	Fail	Pass	Pass
A	Not Cleaned	2	Pass	Pass	Pass	
A	Not Cleaned	3	Pass	Fail	Pass	
A	Partially Cleaned	1	Pass	Fail	Pass	Pass
A	Partially Cleaned	2	Pass	Pass	Pass	
A	Partially Cleaned	3	Pass	Pass	Fail	
A	Fully Cleaned	1	Pass	Pass	Pass	Pass
A	Fully Cleaned	2	Pass	Pass	Pass	
A	Fully Cleaned	3	Pass	Pass	Pass	

Results – Ion Chromatography

No-Clean Ion Chromatography Results - Localized & Full Board Extraction						
No-Clean Solder Paste	Condition	Area	Localized IC		Localized Electrical Test	Full Board IC
			Anion/WOA	Cation		
B	Not Cleaned	1	Pass	Fail	Pass	Pass
B	Not Cleaned	2	Pass	Pass	Pass	
B	Not Cleaned	3	Pass	Fail	Fail	
B	Partially Cleaned	1	Pass	Fail	Pass	Pass
B	Partially Cleaned	2	Pass	Pass	Pass	
B	Partially Cleaned	3	Pass	Fail	Pass	
B	Fully Cleaned	1	Pass	Pass	Pass	Pass
B	Fully Cleaned	2	Pass	Pass	Pass	
B	Fully Cleaned	3	Pass	Pass	Pass	

Results – Ion Chromatography

No-Clean Ion Chromatography Results - Localized & Full Board Extraction						
No-Clean Solder Paste	Condition	Area	Localized IC		Localized Electrical Test	Full Board IC
			Anion/WOA	Cation		
C	Not Cleaned	1	Fail	Fail	Pass	Pass
C	Not Cleaned	2	Pass	Fail	Pass	
C	Not Cleaned	3	Pass	Fail	Pass	
C	Partially Cleaned	1	Fail	Fail	Fail	Pass
C	Partially Cleaned	2	Pass	Fail	Pass	
C	Partially Cleaned	3	Pass	Fail	Pass	
C	Fully Cleaned	1	Pass	Pass	Pass	Pass
C	Fully Cleaned	2	Pass	Pass	Pass	
C	Fully Cleaned	3	Pass	Pass	Pass	

Results – Ion Chromatography

RMA Ion Chromatography Results - Localized & Full Board Extraction						
RMA Solder Paste	Condition	Area	Localized IC		Localized Electrical Test	Full Board IC
			Anion/WOA	Cation		
D	Not Cleaned	1	Pass	Fail	Pass	Pass
D	Not Cleaned	2	Pass	Pass	Pass	
D	Not Cleaned	3	Pass	Pass	Pass	
D	Fully Cleaned	1	Pass	Pass	Pass	Pass
D	Fully Cleaned	2	Pass	Pass	Pass	
D	Fully Cleaned	3	Pass	Pass	Pass	
E	Not Cleaned	1	Pass	Pass	Pass	Pass
E	Not Cleaned	2	Pass	Fail	Pass	
E	Not Cleaned	3	Pass	Fail	Pass	
E	Fully Cleaned	1	Pass	Pass	Pass	Pass
E	Fully Cleaned	2	Pass	Pass	Pass	
E	Fully Cleaned	3	Pass	Pass	Pass	

Results – Ion Chromatography

OA Ion Chromatography Results - Localized & Full Board Extraction						
OA Solder Paste	Condition	Area	Localized IC		Localized Electrical Test	Full Board IC
			Anion/WOA	Cation		
F	Not Cleaned	1	Pass	Pass	Pass	Pass
F	Not Cleaned	2	Pass	Fail	Pass	
F	Not Cleaned	3	Fail	Fail	Fail	
F	Fully Cleaned	1	Pass	Pass	Pass	Pass
F	Fully Cleaned	2	Pass	Pass	Pass	
F	Fully Cleaned	3	Pass	Pass	Pass	
G	Not Cleaned	1	Pass	Fail	Pass	Pass
G	Not Cleaned	2	Fail	Fail	Fail	
G	Not Cleaned	3	Fail	Pass	Fail	
G	Fully Cleaned	1	Pass	Pass	Pass	Pass
G	Fully Cleaned	2	Pass	Pass	Pass	
G	Fully Cleaned	3	Pass	Pass	Pass	

Results – Ion Chromatography

- For all pastes, fully cleaned boards passed
  - Localized Extraction IC and Electrical tests
  - Full board Extraction IC test
- For all pastes, partially cleaned and uncleaned boards passed the full board IC test
- Surprisingly for some pastes, partially cleaned and uncleaned boards also passed the localized extraction electrical and IC tests

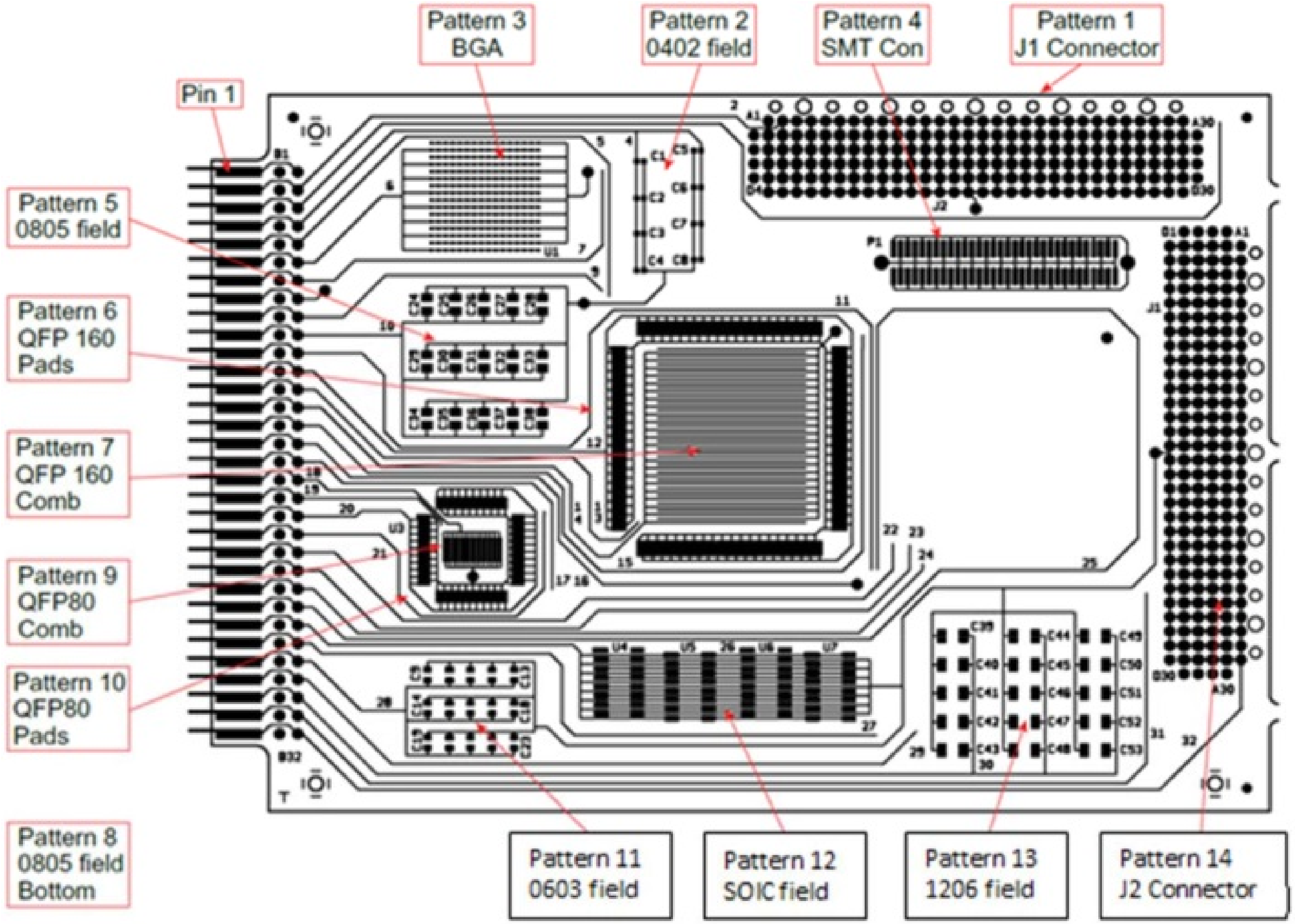
Results - SIR

- SIR tests were conducted on Section A in accordance to IPC TM 650 Method 2.6.3.7

SIR Test Parameters	
Test Conditions	40°C / 90% RH
Test Duration	168 hours
Bias Voltage	5V (unbiased during ramp up and ramp down)
Measurement Voltage	5V (same polarity as bias voltage)
Measurement Frequency	Every 20 minutes

Results - SIR

- Fourteen (14) test patterns were measured



Results - SIR

- Post SIR visual inspection
  - No presence of dendrites, corrosion, discoloration between conductors, water spots, or subsurface metal migration
- Only fully cleaned boards passed SIR tests for all pastes
- Surprisingly for some pastes, partially clean and unclean boards also passed the SIR test

Results - SIR

No-Clean Solder Paste SIR Results		
Solder Paste	**Condition**	**SIR Result**
A	Not Cleaned	Passed
A	Partially Cleaned	Passed
A	Fully Cleaned	Passed
B	Not Cleaned	Passed
B	Partially Cleaned	Passed
B	Fully Cleaned	Passed
C	Not Cleaned	Failed
C	Partially Cleaned	Passed
C	Fully Cleaned	Passed

Results - SIR

RMA Solder Paste SIR Test Results		
Solder Paste	**Condition**	**Result**
D	Not Cleaned	Failed
D	Fully Cleaned	Pass
E	Not Cleaned	Failed
E	Fully Cleaned	Pass

Results - SIR

OA Solder Paste SIR Test Results		
Solder Paste	**Condition**	**Result**
F	Not Cleaned	Failed
F	Fully Cleaned	Pass
G	Not Cleaned	Failed
G	Fully Cleaned	Pass

PCB Cleanliness Assessment Methods - A Comparative Study

- Introduction
- Methodology
- Main Research
- Results
- **Conclusions**

Conclusions

- Visual Inspection
  - Both surface and under-component inspection is useful to establish a baseline
    - Passing visual inspection correlates with results of localized and full board IC and SIR tests

Conclusions (cont.)

- Localized versus Full Board IC Test
  - Full Board IC
    - Small amount of flux residues present may yield a passing test result however
  - Localized IC: local distribution of residues
    - Small amount of residue may result in test failure

Conclusions (cont.)

- SIR versus Localized Extraction Electrical Test
  - For OA paste there was correlation
  - For No-Clean and RMA, there may not be a correlation
    - This could be due to use of steam technique in Localized electrical test
    - Steam is able to solubilize water soluble residues created by OA type pastes, but may not be able to fully solubilize the hard residues created by RMA and No-Clean paste

Conclusions (cont.)

- SIR and Localized IC Test
  - SIR Testing is an industry standard conducted on test vehicles that may not be representative of more complex production boards
  - If the SIR test fails, the assessment could be complimented by localized IC tests

Conclusions (cont.)

- ART and Localized IC Test
  - ART is preferred in order to gather more reliable data on how the production boards will function in the environment they will be used
  - If evaluation fails, then localized IC test could be conducted to determine if the failure may be linked to ionic contaminants

Thank you!
Questions?

Umut Tosun

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