The Relationship Between Cleanliness and Reliability/Durability

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Outline/Agenda

- Introduction of Ionics and ROSE
- Evolution in technology
- Rev H in the IPC-J-STD-001
- Real World Case Study
- Conclusions
- Acknowledgements
- Q & A

Contamination

Ionic

Wide number of sources

Flux residue is commonly the primary source:

- Inorganic ions
- Wide variety of Weak Organic Acids

Creates an electric charge in humid conditions

Ionic Residues on PCB Assemblies

-Electrically conductive

-Lead to Several Failure Mechanisms

Non-Ionic

Not conductive

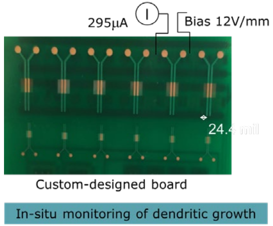
Insulating properties of residue surrounding conductors can lead to unwanted impedance.

No Clean fluxes are made with both organic and inorganic soils

If any component is soluble with liquid + either negatively or positively charge, they are ionic!

hydrogen, oxygen, nitrogen, sulfur

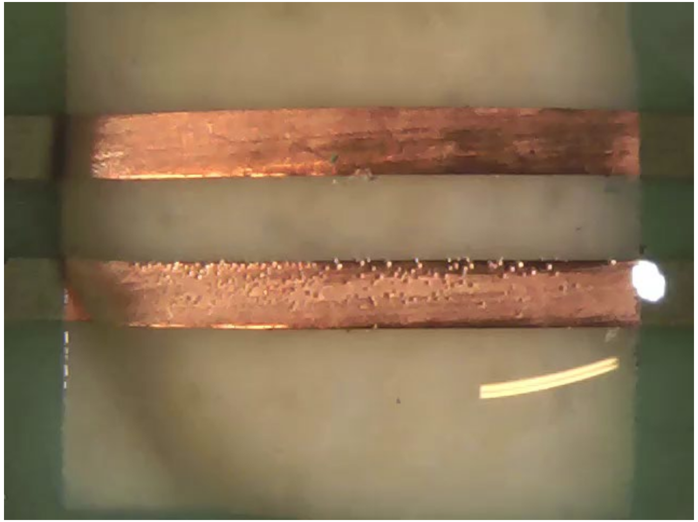
Every Flux Can (under certain conditions) Short or Fail!



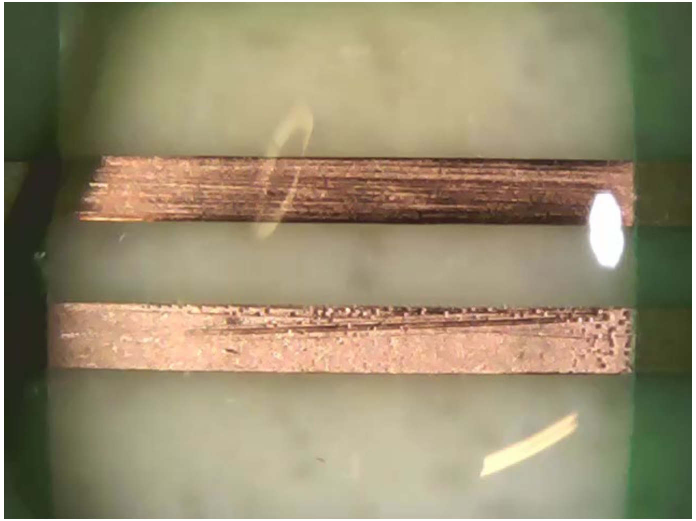
In Real Time

Reflowed per Manufacturer's reflow profile

Flux B



Flux A



Contamination

White residue propagates from anode to cathode

Resistivity Of Solvent Extract (R.O.S.E) *WAS...*

The Ionic Contamination Test Widely used prior to 2020

- Used as both a validation test and a process control tool for collecting ionic data
  - Equivalents of sodium chloride (NaCl) using Resistivity/conductivity
  - 75/25 or 50/50 IPA/DI solvent media mixture.
- Different variations with/without heat, different tank sizes, pumps, differ sensitivity levels, cool software, etc….

Omega Meter


Ionograph

Zero Ion

P.I.C.T.

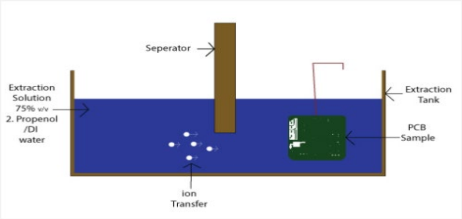
Resistivity of Solvent Extraction

- Developed in 1970's
- Never intended as a cleanliness test or for acceptability, only monitoring
- Method developed for (wave solder flux) high solids (35%) rosin fluxes, large components, and few components which established the 1.56µg/cm^2
- The US Government of Defense desired a Pass/Fail Criteria
- No Clean Flux did NOT exist

PCB in 1970s

R.O.S.E. Overview

Resistivity of Solvent Extract (ROSE ~ IPC-TM 650 – 2.3.25)



Determination of ionic bulk through ROSE test.

PRO's

- ☑ Quick "on the floor" test for large amounts of soluble Ionics
- ☑ Can identify if you have an excessive amount of Ionics on any part of the PCB.
- ☑ Quickly identifies handling or rinsing issues.
- ☑ Inexpensive tool and easy to operate

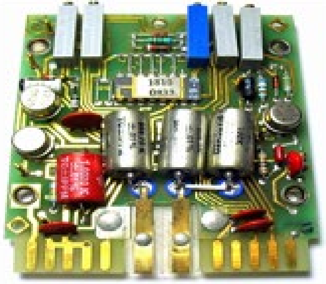
Worked well in the 1970's

CON's

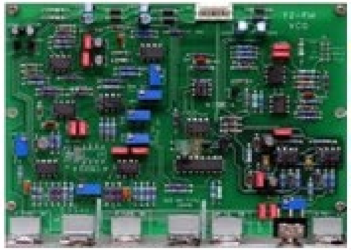
- ☑ Only identifies NaCl. Does not identify other types of Ionics present on the PCB
- ☑ Probably will not identify if you have flux bridging the conductive path on a miniature type component.
- ☑ No Clean Flux and some surface contaminate **are not** completely soluble in IPA/DI water solution
- ☑ Different flux types take longer extraction times.
- ☑ No longer considered objective evidence.

Evolution of Technology, Cleaning Methodology & Validation

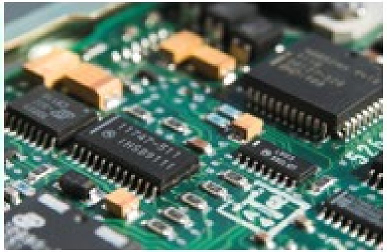
1970's & 80's | 1990's | 2000's | 2010's | Tomorrow



Vapor Degreasing



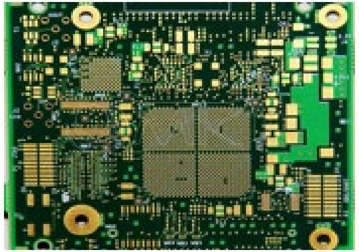
Saponifier



Solvent Sprayable

"pH Neutral"

Better Compatibility



Multi-Functional Aqueous

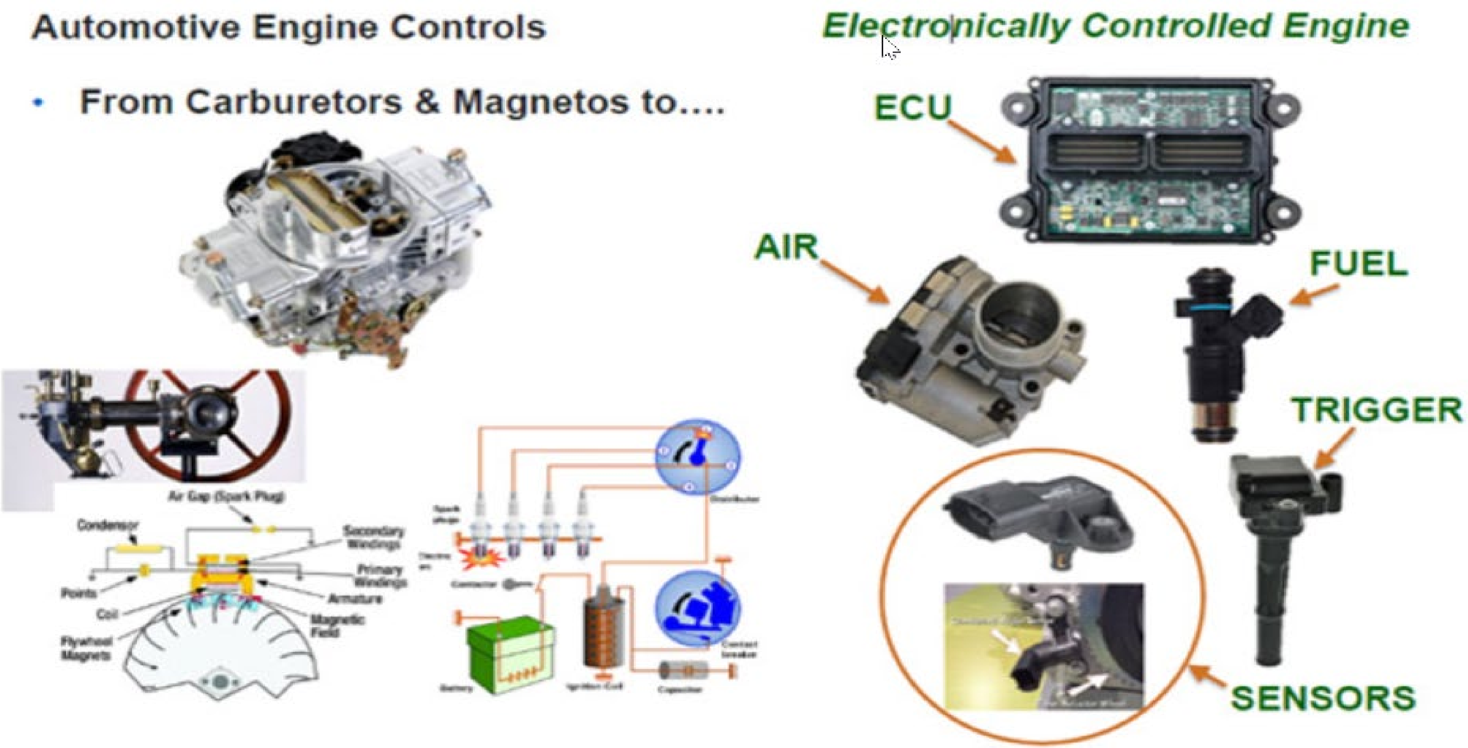
Improved Rinsing & Cleaning Compatibility & Long Bath Life

RMA & Sn/Pb → R.O.S.E.

"No Clean" & Early Lead-Free → R.O.S.E. /IC/SIR

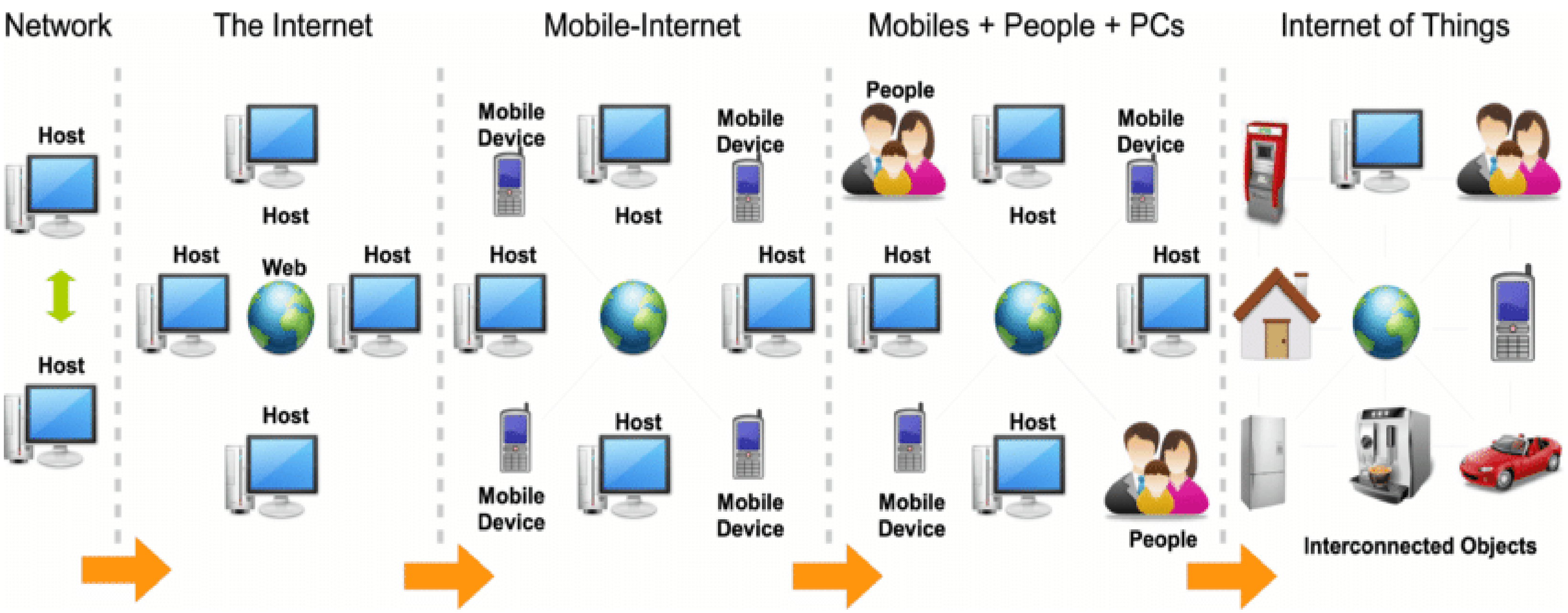
Halide Free & Lead-Free → IC / SIR Combination Testing

Mechanical to Electronic Control



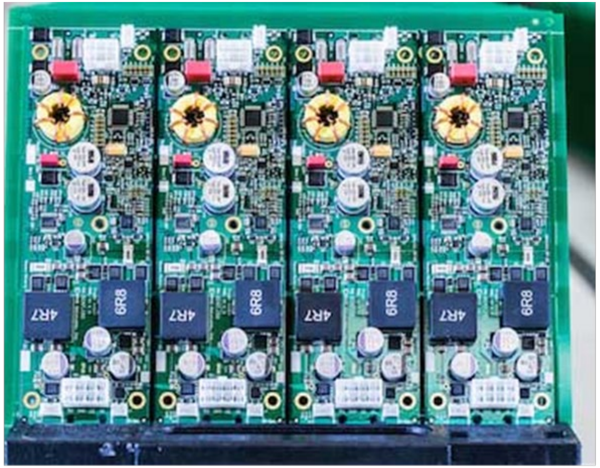
Source: Eaton

Computers to IoT

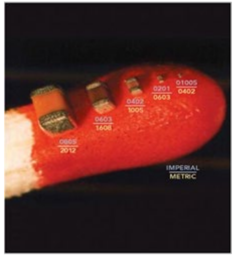


Source: VTS, 15cS81_IoT module

Component & Flux Technology



Source: Apx Mfg



Source: Indium

Source: Shea Eng.

IPC J-STD-001 Rev G, Section 8

- 2018 Rev G Published (WP-019 can be referenced)
  - Required objective evidence for qualifications/ acceptance.
  - Determined no good answer on how to use the ROSE test on No clean assemblies,
    - Recommended it should not be used for monitoring of no-clean fluxes
    - Classified it as non-value-added testing, **Obsolete practice.**
  - Requalification Major vs. Minor
  - Ruled the ROSE test as not “Objective Evidence”

There is no ONE ***method*** *to determine acceptably clean and unacceptably dirty*

IPC J-STD-001 Rev H, Section 8

- September, 2020 Rev H Published (WP-019B)
  - **Reemphasized** “ROSE testing for monitoring of **No-Clean** assembly process should not be used”
    - Values of No-Clean materials do not equal cleanliness
    - Can be a destructive test
    - Non-value added testing
  - Emphasized the technology advancements and limitations of ROSE to detect value added levels
  - Still Required objective evidence
  - **Removed 1.56µg/cm^2 value as a pass/fail**
    - No single value can be used as a pass/fail for every product,
    - UCL limit **may** be determined in qualification with objective evidence

IPC Standards

- If you are IPC certified or claim you are following IPC guidelines, you must be using the latest IPC-Standard.
- If you are not certified, you *should* still be using the latest IPC-Standard or better quality controls

This is a preview of "IPC J-STD-001H-2020". Click here to purchase the full version from the ANSI store.

IPC

IPC J-STD-001H

Requirements for Soldered Electrical and Electronic Assemblies

If a conflict occurs between the English and translated versions of this document, the English version will take precedence.

Developed by the J-STD-001 Task Group (5-22A), J-STD-001 Task Group – Europe (5-22A-EU), J-STD-001 Task Group – China (5-22ACN) of the Assembly and Joining Committees (5-20) of IPC

Supersedes:
J-STD-001G - October 2017
J-STD-001F WAM1 - February 2016
J-STD-001F - July 2014
J-STD-001E - April 2010
J-STD-001D - February 2005
J-STD-001C - March 2000
J-STD-001B - October 1996
J-STD-001A - April 1992

Users of this publication are encouraged to participate in the development of future revisions.

Contact:

IPC

No-Clean Process and ROSE

- Rose Test will identify
  - A rinsing issue
  - Improper handling of an assembly

- ROSE TEST Might identify
  - Dirty bare board

IT WILL NOT TELL YOU IF YOUR BOARD IS RELIABLE or Clean

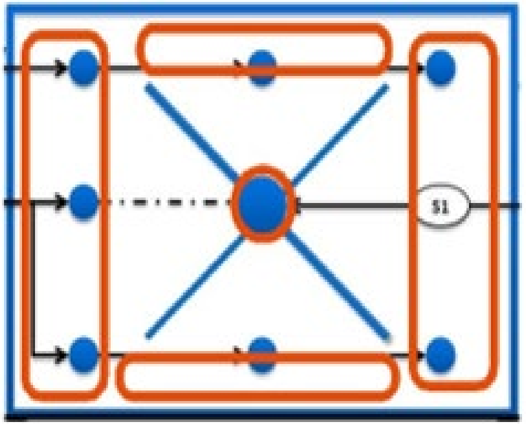
Real World Case Study

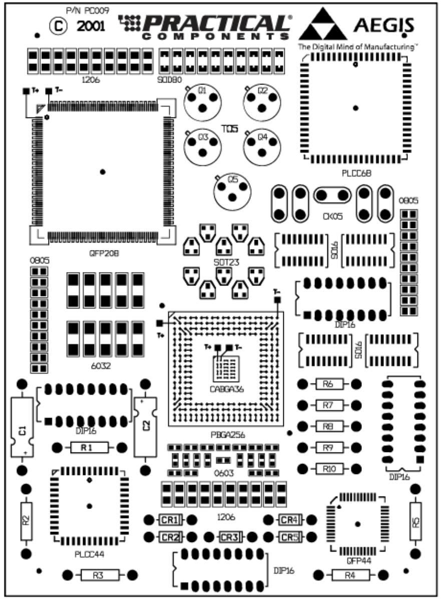
- Class 3 OEM-New chemistry qualification
  - Concentration was determined by lab testing
  - Objective to optimize cleaning parameters
    - Temperature and time
    - PCB location (as shown on next slide)
  - Validate the process
  - All other materials are stayed the same
  - ROSE Test used for monitoring

Optimization

IPC PCB-009 48 Test Coupons

- RMA-35% solids wave flux
- SAC 305 No-Clean Paste
- SAC 305 No-Clean Core Wire for hand soldering
- Spray in Air Batch machine with low pressure (15-20 PSI)

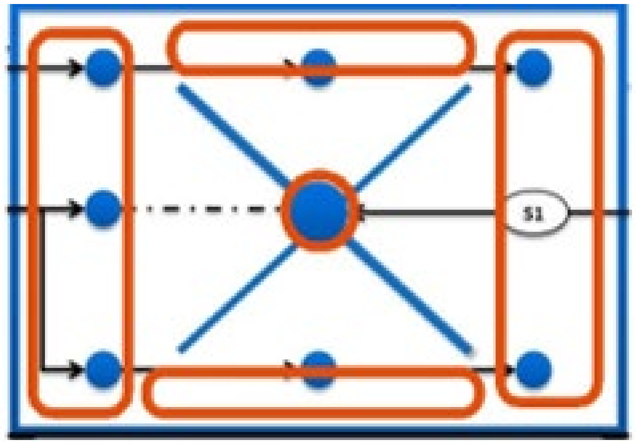




PCB Sample Size	Conc %	Wash Temp	Wash Times
12	20%	60°C/140°F	20 min
12	20%	60°C/140°F	30 min
12	20%	68°C /155°F	20 min
12	20%	68°C /155°F	30 min

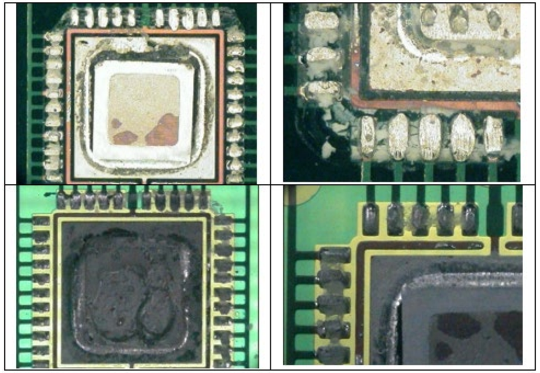
Optimization

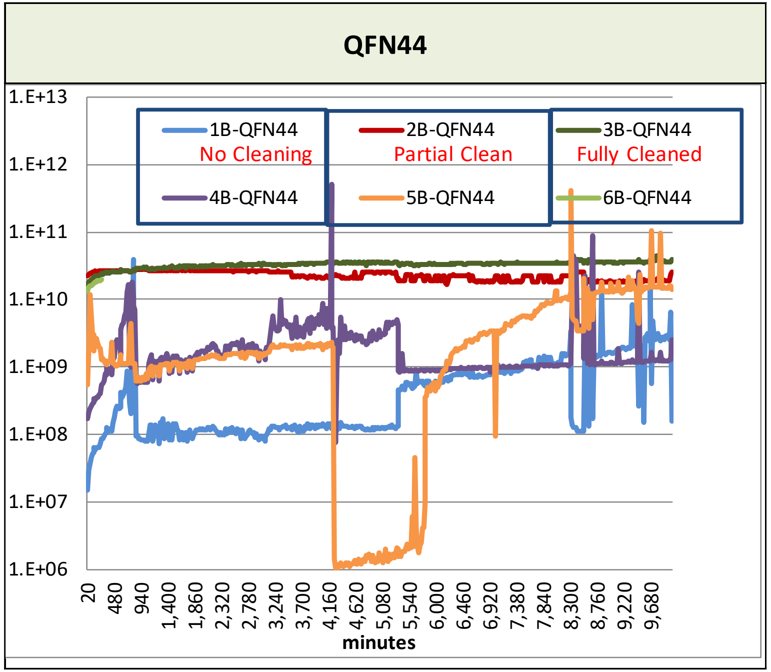
- Score Each Set (6) PCBs Comparing
  - Location inside chamber
  - Temperature
  - Time
- Inspection Methodology
  - Visual (10X) (2 of both)
  - Mechanical removal of components after visual inspection
  - ROSE Test (2 from each set)
  - Ion Chromatography (2 of best results)



Past Studies

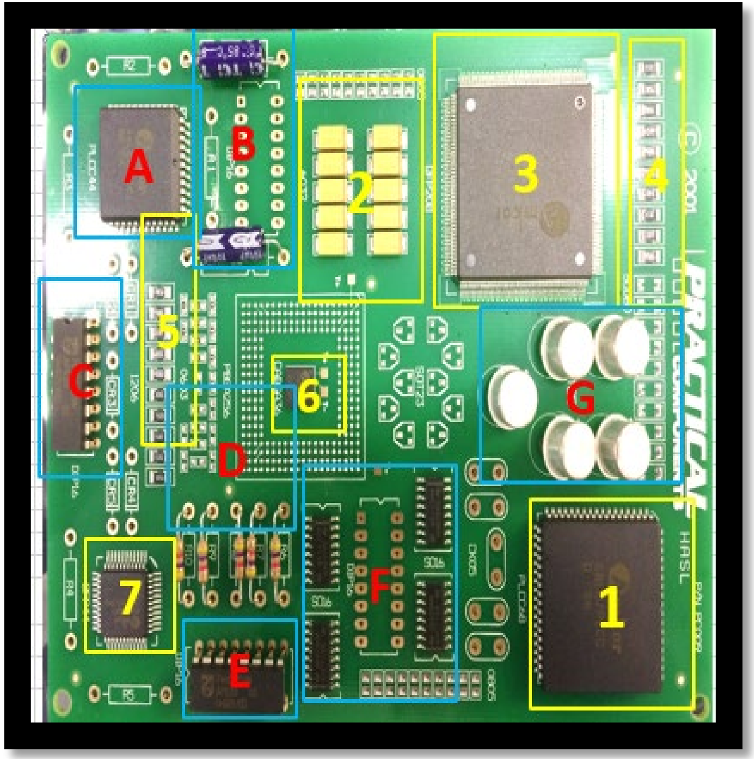
- **Various reflow and cleaning conditions**
- Non cleaned, partially cleaned, show significant variation in performance, Visually and SIR



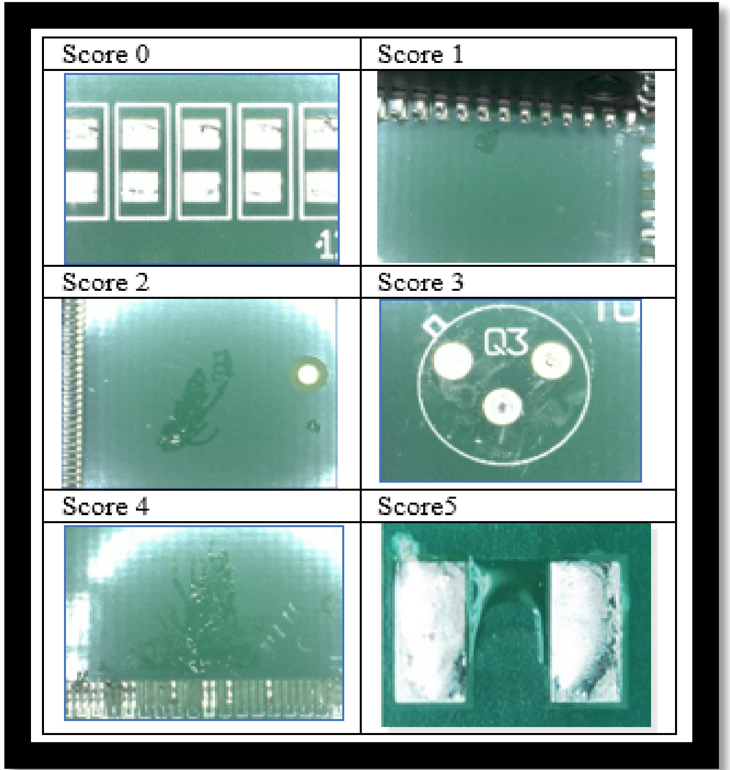


Site Locations and Scoring

PCB inspection Site Locations

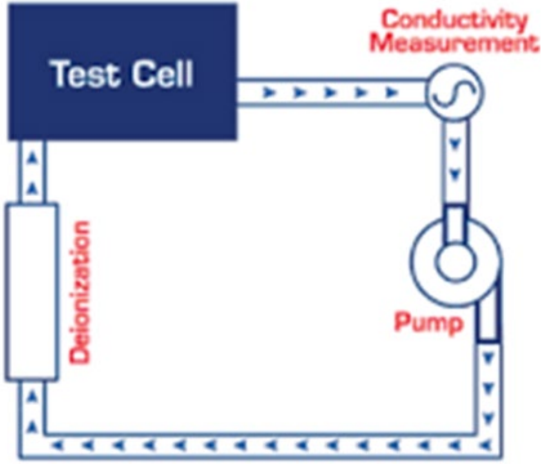


Visual Key Guide



PCB ROSE Readings

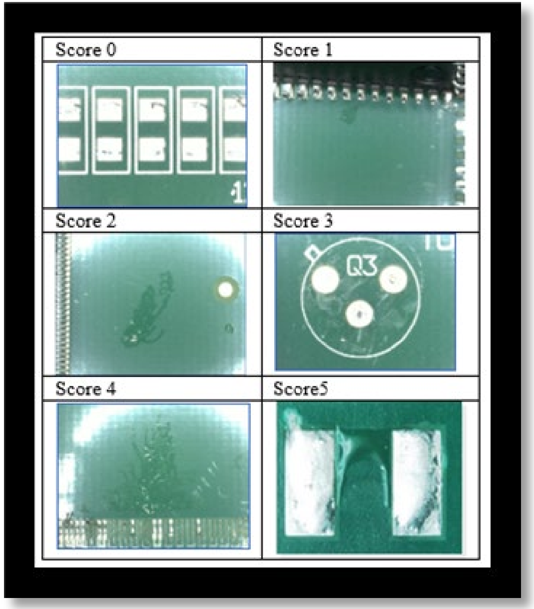
- PCB's handled with fresh clean gloves
- PCB was placed onto a clean aluminum foil for inspection under microscope
- All assemblies passed the 1.56µg/cm^2
  - Range from 0.1 to slightly over 0.45µg/cm^2
- ROSE tests were non-conclusive:
  - Amount of flux residue
  - Location in Wash Chamber
  - Temperature or Time



Under Component Scores

Run	Conditions	Middle Right		Middle Left		Middle Middle		TOP Corner		Bottom Corner		Top Middle	Bottom Middle
		C	D	B	F	A	E	C	B	D	F	A	E
8	140F	B-.32/ NC1.9 / A.82			5-1/ 1-2 /2-3 = 13 total	5-1/1-2/1-3 = 10 total	1-1 1 total						
4	140F	B-.31/ NC .51 / A.64			4-1/1-3 = 7 total	6-1 = 6 total							
1	140F							3-1	B-.23/ NC.48 / A.72			3-1	3-1
6	140F							B-.36/ NC 1.6 / A.69				3-1	3-1
2	155F								B-.26/ NC 2.24 / A.71				4-1
3	155F								B-.25/ NC 2.41 / A.67				5-1
5	155F	B-.20/ NC 2.75 / A.72				9-1 /2-2/1-4 = 17 total							
7	155F	B-.27/ NC 2.48 / A.66				3-1 /1-2 = 5 total							

Visual Inspection Summary



Visual Key Guide

ROSE Scores Ranged in the 0 .3- 2.75 μg/in^2 NaCl

Under Component Scores

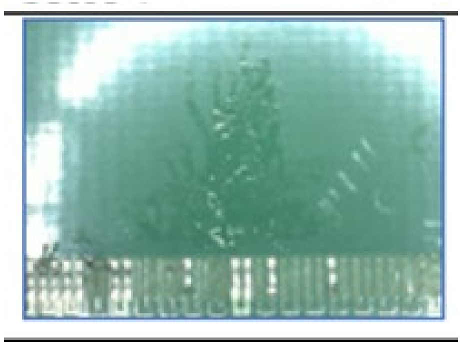
Run	Conditions	Middle Right		Middle Left		Middle Middle		TOP Corner		Bottom Corner		Top Middle	Bottom Middle
		C	D	B	F	A	E	C	B	D	F	A	E
8	140F	B-.32/ NC1.49 / A.82			2-3	1-3							
4	140F	B-.31/ NC.51 / A.64			1-3 =								
1	140F							3-1	B-.23/ NC .48 / A.72				
6	140F							B-.36/ NC 1.6 / A.69					
2	155F								B-.26/ NC 2.24 / A.71				
3	155F								B-.25/ NC 2.41 / A.67				
5	155F	B-.20/ NC 2.75 / A.72				1-4 =							
7	155F	B-.27/ NC 2.48 / A.66											

PCB's With Scores Of 1-2 Summarized

Visual Scoring Summary

Visual inspection at 10X	No measurable difference on amount of flux residue between both 60ºC and 68ºC,
Measurable difference in the middle and outer edges of the chamber under components	More residue in center of the inner chamber. Slightly more residue at 60ºC
IC Testing was completed on PCB's not placed in the center area of the chamber	

- *The middle of the chamber produced the most flux residue overall.*
  - Outer edges and Middle of the chamber do not receive as much mechanical action, and this was visually noticed.



Impingement energy drives cleaning

ROSE was Found as a Non-Value Add Test

Ion Chromatography

IPC-PCB-009

	Anion IC Data							
	2B	3B	5C	7C	1B	4C	6C	8C
	Middle Edge	Top Right Corner	Top Left Corner	Top Right Corner	Top left Corner	Middle edge	Middle edge	Middle Edge
	155F	155F	155F	155F	140F	140F	140F	140F
	µg/in2	µg/in2	µg/in2	µg/in2	µg/in2	µg/in2	µg/in2	µg/in2
Fluoride	0	0.12384	0	0.124485	0	0	0.06192	0
Chloride	0.65145	0.201885	0.19479	0.333465	0.47859	0.378615	0.716595	0.240585
Nitrite	0.045795	0	0.04773	0	0	0	0	0
Bromide	0.28767	0.25284	0.19608	0.266385	0.234135	0.30702	0.359265	0.315405
Nitrate	0.271545	0.314115	0.427635	0.37668	0.650805	0.33927	0.58308	0.36636
Phosphate	0	0	0	0	0	0	0	0
Sulfate	0	0	0	0	0	0	0	0
Total Weak Organic Acids	2.24073	2.41488	2.74512	2.48325	0.480525	0.51342	1.602825	1.38804
	Cation IC Data							
Lithium	0	0	0	0	0	0	0	0
Sodium	0.249615	0.416025	1.0449	0.400545	0.72627	0.557925	1.23582	0.844305
Ammonium	0.706275	0.66951	0.72369	0.661125	0.723045	0.636615	0.685635	0.818505
Potassium	0.456015	0	0.58953	0.401835	0	0	0.048375	0
Magnesium	1.51962	2.126565	1.52091	1.187445	1.669905	1.467375	1.30677	1.530585
Calcium	0.199305	0.178665	0.196725	0.21156	0.187695	0.17802	0.179955	0.17931

Typical Industry Limits

		Fluoride	Acetate	Formate	Methanesulfonic Acid	Chloride	Nitrate	Bromide	Nitrite	Phosphate	Sulfate	Weak Organic Acid	Weak Organic Acid	Lithium	Sodium	Potassium	Ammonium	Calcium	Magnesium	C3 - IPC Class 2 & 3	C3 - IPC Class 1
		F^-	$C_2H_3O_2^-$	HCO_2^-	MSA	Cl^-	NO_3^-	Br^-	NO_2^-	PO_4^{3-}	SO_4^{2-}	SMT hand & selective	Wave direct contact	Li^+	Na^+	K^+	NH_4^+	Ca^{2+}	Mg^{2+}	time/µA	time/µA
Bare Boards	PCB Pre-mask	2.5	2.5	2.5	0.5	2	2.5	2.5	2.5	2.5	3	n/a	n/a	2	2	2	2.5	n/a	n/a	>120s/250µA	>60s/500µA
	Via or PTH																				
	Soldermask Surface																				
	SMT Pad Area																				
	Innerlayer*										*10										
Component	BGA	1	3	1	1	1	2	6	2	2	1	25	n/a	1	2	2	2.5	n/a	n/a	>120s/250µA	>60s/500µA
	Reballed BGA																				
	Tinned																				
	IC Flip Chip																				
	Trayed Component																				
PCBA (no clean)	NC Via Top	1	3	3	1	3	3	6	3	3	3	25	150	3	3	3	3	n/a	n/a	>120s/250µA	>60s/500µA
	Solder Area																				
	NC SMT																				
	NC Wave																				
	Reworked																				
PCBA (clean)	NC/WSF Via Top	1	3	3	6	6	3	6	3	3	3	25	25	3	3	3	3	n/a	n/a	>120s/250µA	>60s/500µA
	Selective																				
	NC/WSF SMT																				
	NC/WSF Wave																				
	Rework/Misprint																				
Support Hardware	Heat Sink	1	3	3	1	2	3	6	3	3	3	n/a	n/a	1	1	3	2	n/a	n/a	>120s/250µA	>60s/500µA
	Housing/ESD Foam																				
	Thermal Material																				
	Thermal Pad																				
	Battery Housing																				

Source Foresite Labs

Optimization Conclusion

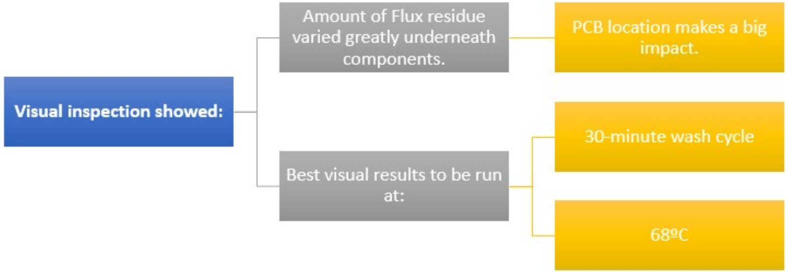
If only using Ion Chromatography and ROSE, All parameters would have been **classified as** reliable/clean

Visual residue scores of 3-4 could fail under bias due to ECM/Dendrites.

Middle and outer corner locations of chamber scored higher number of 3-4's at:

60ºC

20 Minute wash cycle



Qualification

19 PCB test boards for each test

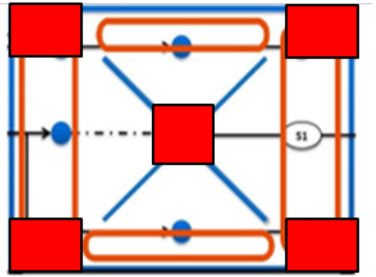
IPC-B52 PCB

- 30 Minute Wash
- 20% Cleaning Agent
- 68ºC Wash Temperature
- No PCB's place in center of chamber
- Avoided placing PCB on outer edges

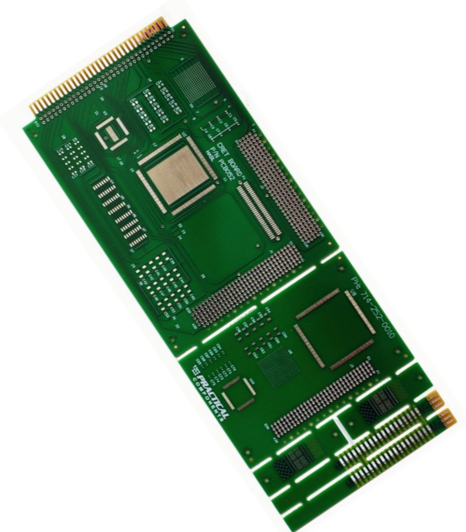
Ion Chromatography

Surface Insulation Resistance (SIR)

- IPC-TM-650, Method 2.6.3.7



Areas in orange should be avoided to prevent inconsistent and indirect cleaning due to lack of pressure.



SMTA
A Global Association Working at a Local Level

Ion Chromatography

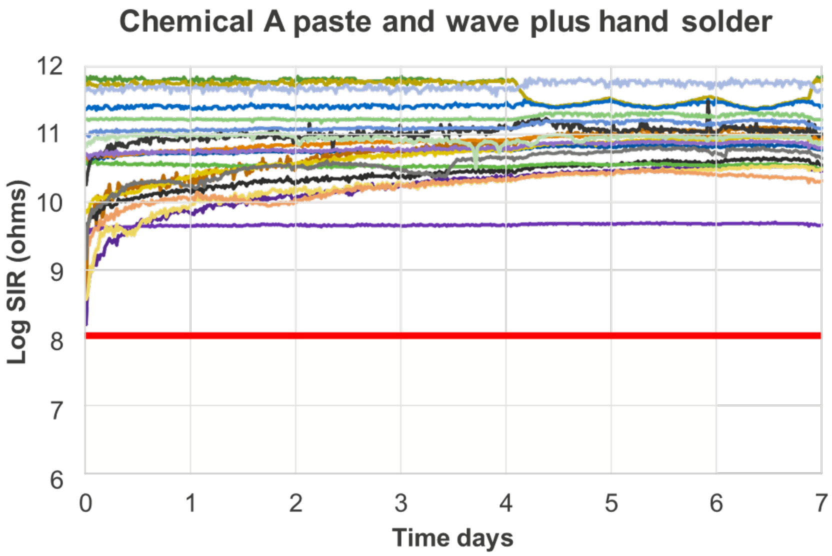
IPC- B-52 Cards

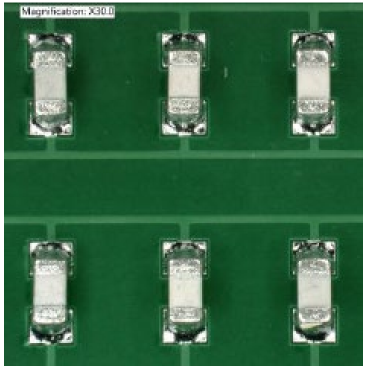
Anion IC Data																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Fluoride	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Chloride	0.0478	0.0427	N/D	0.0489	N/D	N/D	N/D	N/D	0.0495	0.0896	0.0744	N/D	0.0421	N/D	N/D	0.1846	0.0580	0.0611	0.0551
Nitrite	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Bromide	0.0959	0.0717	N/D	0.0974	0.0275	0.0156	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.3467	0.2398	N/D
Nitrate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.0048	N/D	0.0318	N/D	0.0082	0.0152	N/D	N/D	N/D	0.0530
Phosphate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sulfate	N/D	N/D	N/D	0.1291	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.1436	0.1151	N/D	N/D	N/D	N/D
Acetate	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Formate	0.0090	0.1507	0.3469	0.1915	0.1493	0.2200	0.1301	0.0955	0.0715	0.0907	0.0922	0.0814	0.0827	0.1108	0.2533	0.1839	0.0306	0.0614	0.0869
Methane Sulfonate	N/D	0.0263	0.0290	0.0533	0.0379	0.1004	0.0798	0.0858	0.1003	0.0495	0.0605	0.1295	0.0985	0.0826	0.1679	0.1027	0.1310	0.2199	0.1525
Total Weak Organic Acids	0.0090	0.1770	0.3759	0.2447	0.1872	0.3204	0.2098	0.1813	0.1718	0.1401	0.1527	0.2109	0.1812	0.1935	0.4212	0.2866	0.1616	0.2813	0.2394
Cation IC Data																			
Lithium	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D
Sodium	0.2417	0.2757	0.2786	0.2836	0.2482	0.2663	0.2539	0.2543	0.2541	0.2306	0.2253	0.2396	0.2350	0.2254	0.2384	0.2669	0.2495	0.2545	0.2713
Ammonium	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	N/D	0.0144	0.1540	0.0859	N/D	N/D	N/D
Potassium	0.1247	0.1360	0.1368	0.1505	0.1170	0.1478	0.1141	0.1053	0.1131	0.1083	0.1138	0.1069	0.1068	0.1118	0.1180	0.1089	0.1466	0.1370	0.1238
Magnesium	0.0354	0.0348	0.0872	0.1350	0.1308	0.2245	0.1132	0.0487	0.0376	0.0395	0.0376	0.0351	0.0348	0.1038	0.1415	0.1280	0.0409	0.0334	0.1331
Calcium	0.1080	0.1360	0.1979	0.3760	0.1932	0.4030	0.2611	0.1455	0.1530	0.2299	0.2230	0.2127	0.2337	0.2719	0.2984	0.3135	0.2319	0.1916	0.4066

Table 1: Results of Anion/Cation IC Testing N/D=Not detectable. Units are µg/in2

IPC-B-52 SIR Summary

- All 19 card assemblies SIR values were all well above 1 x 10^9 ohms
- All 19 cards showed no dendritic growth or corrosion at 10X to 40X magnification





Transition to Newer Technology

QFN and similar flush mounted devices being implemented into designs

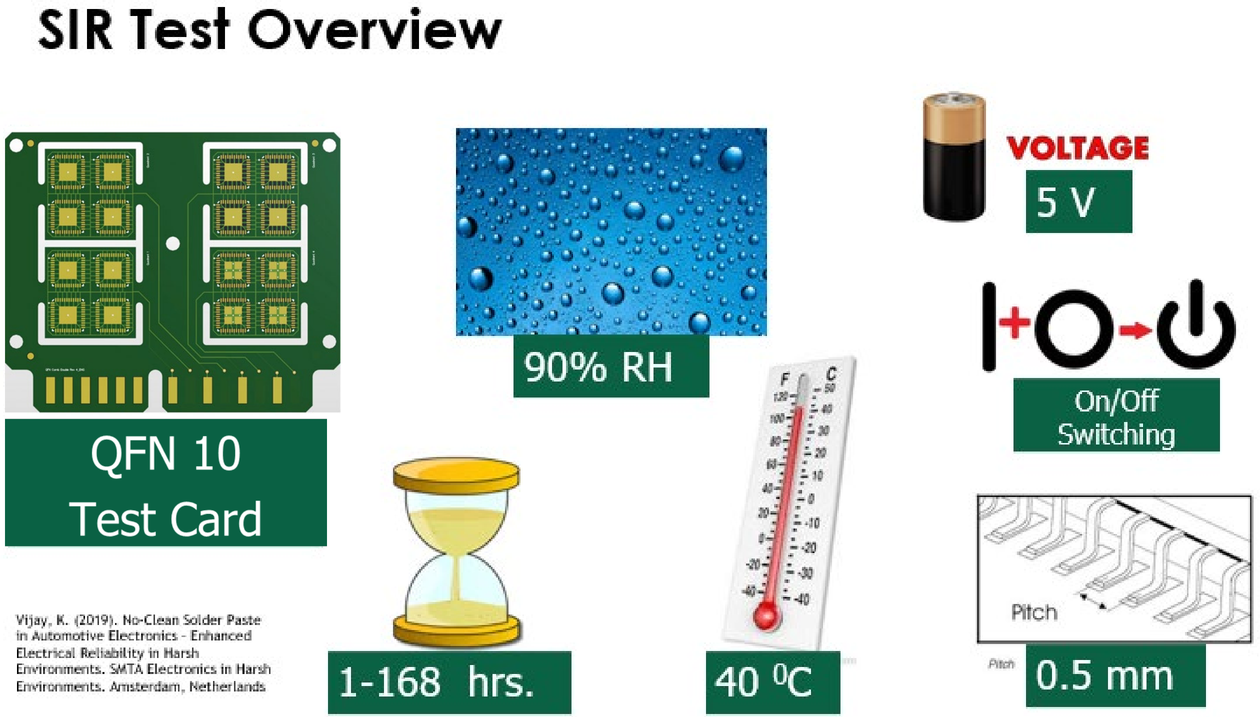
Supplier moved from batch process to inline cleaning at 0.5ft/min

Chemistry B @ 65ºc, 15% concentration

Due to earlier data findings, only SIR was completed on the QFN.

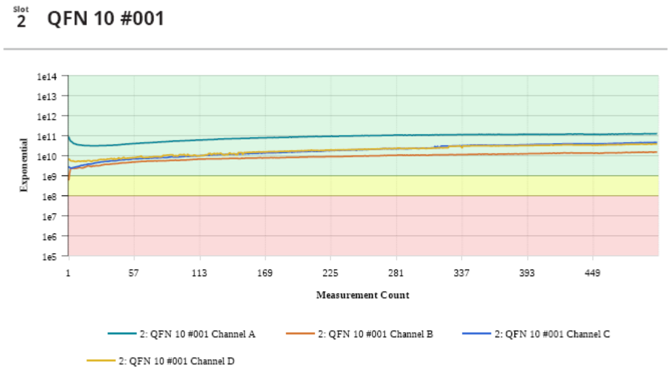
QFN 10 Card

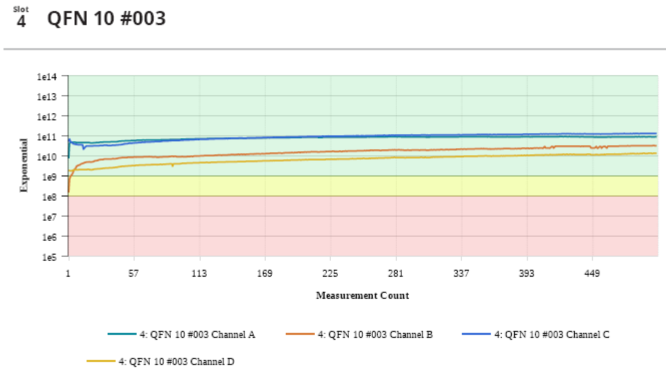
Quantity 5

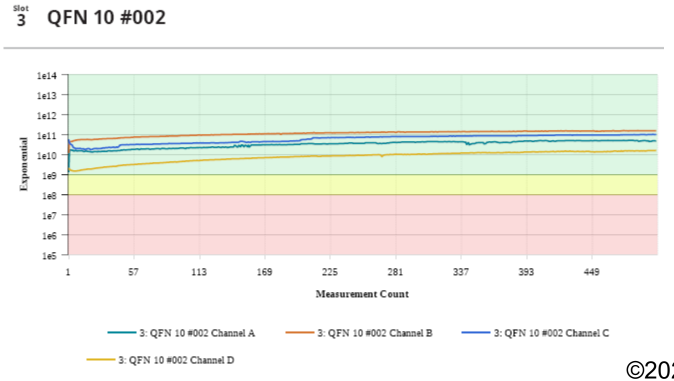


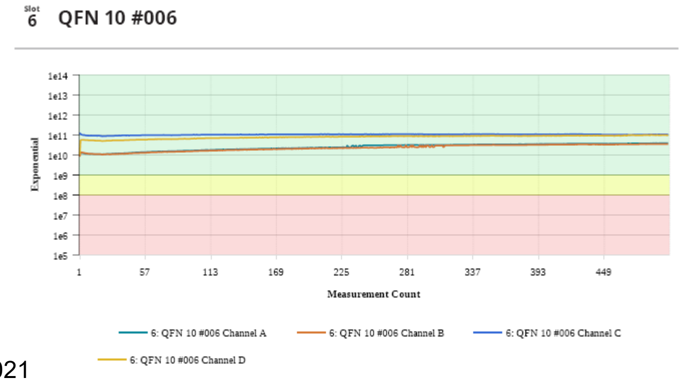
Source: Magnalytix with permission

QFN SIR Summary









Conclusion

The Class 3 OEM validated the use of ROSE for measuring cleanliness is obsolete for their processes:

- Not all areas of the batch wash chamber provided the same cleanliness.
- ROSE Limit of 1.56µg/cm^2 does not provide useful monitoring readings.
  - Flux residue quantity under components from the center would likely fail under bias, yet measured well below 1.56µg/cm2
  - Different flux types and processes react differently in the ROSE.
- Ion Chromatography is a better measuring tool, but did not provide as much data as SIR testing to make process decisions.

Final Impressions

Step 1	Understand not all devices or components require the same level of cleanliness. • ROSE limit 1.56µg/cm2 is obsolete.
Step 2	Identify who needs to be involved in establishing cleanliness levels and methods (OEM and/or Manufacturer)
Step 3	Document the end-use environment and required lifespan, and test methodology, cleanliness requirement based on the demand.
Step 4	As your design changes, your cleanliness limits may also need to change.

The Cost Of Not Cleaning Correctly

Recall vs. Cleaning Correctly

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Thank You!

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Q&A Session