

Duo-Solvent Cleaning Process Development for Removing Flux Residue from Class 3 Hardware

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Abstract

Packaging trends enable disruptive technologies. The miniaturization of components reduces the distance between conductive paths. Cleanliness of electronic hardware based on the service exposure of electrical equipment and controls can improve the reliability and cost effectiveness of the entire system. Problems resulting from leakage currents and electrochemical migration lead to unintended power disruption and intermittent performance problems due to corrosion issues.

Solvent cleaning has a long history of use for cleaning electronic hardware. Limitations with solvent based cleaning agents due to environmental effects and the ability to clean new flux designs commonly used to join miniaturized components has limited the use of solvent cleaning processes for cleaning electronic hardware. To address these limitations, new solvent cleaning agents and processes have been designed to clean highly dense electronic hardware.

The research study will evaluate the cleaning and electrical performance using the IPC B-52 Test Vehicle. Lead Free no-clean solder paste will be used to join the components to the test vehicle. Ion Chromatography and SIR values will be reported.

Introduction

The challenge for assemblers and OEMs is to design reliable hardware that performs consistently in the field. Smart electronic devices require increased functionality, small form factor and fast data transfer. Information technology needed to support these devices lead to electronic component complexity, switches that require signal flow rates and higher transmission frequencies. The concern is that electronic hardware failures will become more prevalent.

Electronic assemblies increase in value as a part of the overall product in which the technology is implemented. Cleaning is not so much due to the value of the PWB itself, but due to its place in the overall system. Most think of cleaning as a chemical. In reality, cleaning is a process designed to remove undesirable soils without changing the surface in an unacceptable manner.

Years ago, the initial PCB cleaning process was typically solvent cleaning. Chloro-fluorinated solvents dominated the market until ozone depletion reared its ugly head. The dominate technology that emerged to replace solvent cleaning was flux compositions that left behind low levels of non-ionic residues. In addition, the spacing between conductive paths was sufficient to safely build electronic assemblies without the need for cleaning.

Over the past twenty years since the Montreal Protocol was enacted, the number of transistors in a dense integrated circuits doubled approximately every two years. The observation is named after Gordon E. Moore, co-founder of the Intel Corporation.¹ Highly dense interconnected devices emerged. As components decreased in size, the distance between conductors decreased. With the emergence of Lead-Free soldering, planar board finishes and leadless components became commonplace. As a result, the Z-Axis reduced to a point where flux volatiles can become entrapped under bottom termination components. Non-activated flux residues in combination with decreased spacing between conductors increased the importance of cleaning production assemblies.

Key factors to consider when designing the cleaning process are (1.) Part being cleaned, (2.) Soils encountered (3.) Standoff gaps lower than 50 μ m, (4.) Exposed metals, (5.) Cleaning agent, (6.) Cleaning machine, (7.) Process parameters needed to clean, (8.) Process control and (9.) Environmental health & safety.

Transition of Solvents, Fluxes and PCBs

Customer needs and innovation creates an environment where continuous improvements ensue. Over the past 20 years, printed circuit boards have transitioned from through-hole, surface mount combined with through-hole, surface mount only and to today's highly dense surface mount assemblies. Flux compositions used for wave soldering, paste flux and solder paste compositions have transitioned from liquid rosin based fluxes to low residue no clean and water soluble fluxes. The flux components within solder paste have become highly complex with a high amount of variability among the no-clean, rosin and water soluble solder paste residues offered to industry. For assemblers who clean, the challenge is the design of cleaning agents that clean a wide range of soils and cleaning equipment designed to penetrate bottom terminations. Matching the cleaning and rinsing agents with the cleaning equipment is critical to achieving clean parts on a consistent basis.

Cleaning solvents for electronic applications have transitioned from CFCs (ozone depleting & global warming issues) to HCFCs (lower ozone depletion values but high global warming values ~ examples are R-141b and 225), and toward HFCs (non-ozone depleting solvents, but high global warming potentials ~ examples are HFCs and HFEs). A new class of Hydrofluoro-olefin solvents with favorable toxicity properties is a recent innovation that offers new promise to solvent cleaning processes. Hydrofluoro-olefin solvents are non-flammable, low global warmers; do not contribute to ground level smog, and not a volatile organic compound as determined by the U.S. EPA. A safe solvent cleaning process that offers numerous environmental benefits and has the ability to solvate no-clean flux residues fills a void for cleaning highly dense assemblies soldered with modern flux technologies.

The importance of cleaning electronic hardware is critical as assemblies reduce conductive paths. Components with tighter pitch and high interconnects require solder paste flux compositions with multifunctional properties to achieve acceptable soldering yields. The remaining residues contain a range of materials that require cleaning agents engineered with dispersive, polarity and hydrogen bonding properties. Solvent cleaning agents work well when the soil dissolves in the cleaning fluid. When some of the components within the flux residue are not miscible in the solvent cleaning agent, white residues are present post cleaning. To address this limitation, an innovative approach to cleaning electronic assemblies using a waterless solvent cleaning process has emerged.

Duo-Solvent Cleaning Technology

Duo-Solvent Cleaning Technology is designed to clean challenging soils using a solvent cleaning agent matched to the soil and then rinsed with a Hydrofluoro-olefin solvent. Electronic assemblies are introduced in an agitated solvating immersion tank. The solvating tank contains an engineered cleaning agent designed to remove lead-free no clean, rosin and water soluble flux residues. Once the residues are removed, the assemblies are transferred to a vapor degreasing boil sump to rinse the assembly free of the solvating agent and other process soils. Assemblies free of flux residue go through a Hydrofluoro-olefin immersion rinse followed by a vapor rinse. The parts exit the system clean and dry. A solvent separation system is designed within the process to extract contaminants out of the system and to maintain a highly purified solvent rinse. The process produces a clean and dry part in one machine with short cycle time, low energy usage and small footprint (Figure 1).²

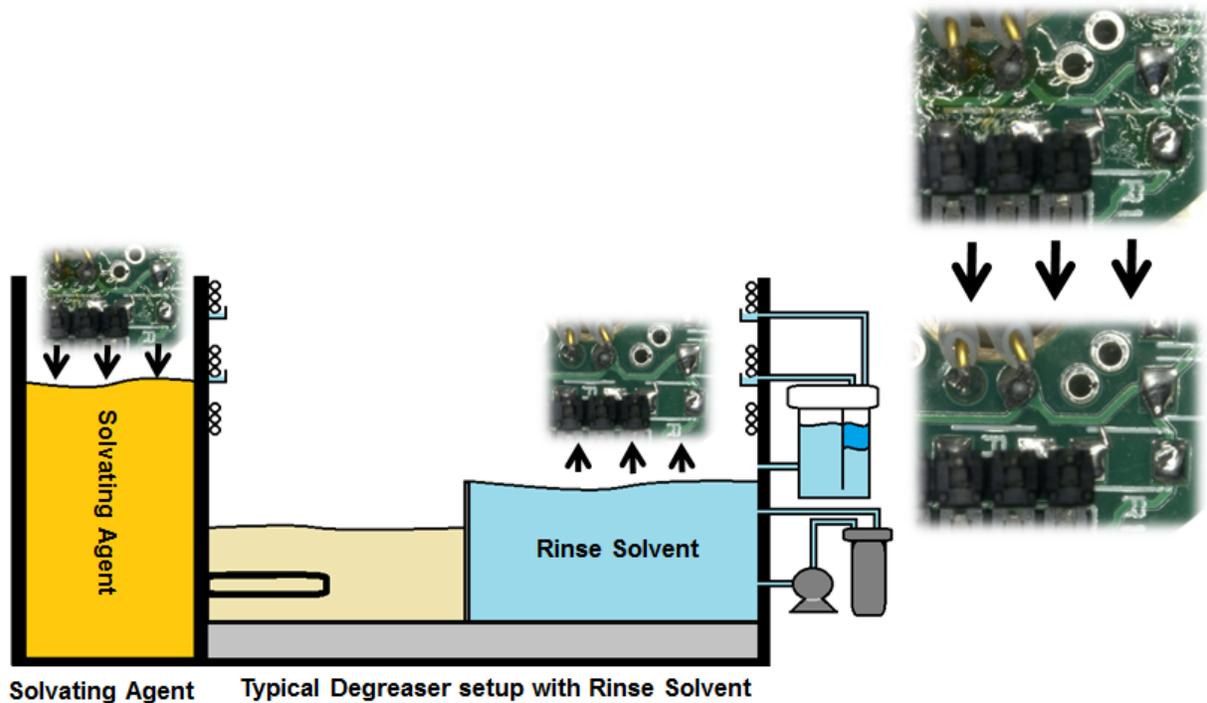


Figure 1: Duo-Solvent Cleaning Process



Figure 2: Duo-Solvent Approach

The solvating agent is an engineered cleaning fluid composition with balanced dispersive, polarity and hydrogen bonding solubility forces. The cleaning agent is engineered to the soil being cleaned, in this example, lead-free no-clean flux residues. The slow evaporating cleaning agent exhibits a strong hydrophilic/hydrophobic balance, non-flammability and rinses well with the Hydrofluoro-olefin rinse solvent. The rinse solvent exhibits desirable environmental, performance, stability, compatibility and safety properties.

Table 1

Property	Solvating Agent	Rinsing Agent
Chemical Name	Oxygenated Engineered Mixture	Hydrofluoro-Olefin
Boiling Point	203°C	19°C
Surface Tension @ 20°C	32.7 dyne/cm	12.7 dyne/cm
Flash Point	88°C	None
Water Soluble @ 25°C	Partial	460 ppm
VOC	Non-Exempt	Exempt

Solubility of the Soil in the Cleaning Agent

Electronic assembly processing residues that dissolve in the cleaning agent are based on the following forces:

- Dispersive ~ Soil dissolves in a cleaning agent
 - Soil has “like” chemical properties to the cleaning agent
 - Like dissolves Like
 - Temperature and Energy typically increase the dispersion rate
- Polarity³
 - Intermolecular force of attraction or repulsion which act between neighboring molecules or ions (Van der Waals force)
 - Force between two permanent dipoles (Keesom force)
 - Force between a permanent dipole and a corresponding induced dipole (Debye force)
 - Force between two instantaneously induced dipoles (London Dispersive Force)
- Hydrogen Bonding⁴
 - Electrostatic attraction between polar molecules
 - Hydrogen atom bound to a highly electronegative atom such as nitrogen, oxygen or fluorine
 - Attracted a nearby highly electronegative atom

A Teas Diagram is a way to plot the relative strengths of the dispersive, polarity and hydrogen bond forces.⁵ If the relative strengths of the forces are known, a compound can be plotted in an equilateral triangle. The three legs of the triangle each represent the percentage of one of the three forces for that compound. For instance, a compound that is characterized as 35% polar, 15% hydrogen bonding, and 50% non-polar would be plotted as follows:

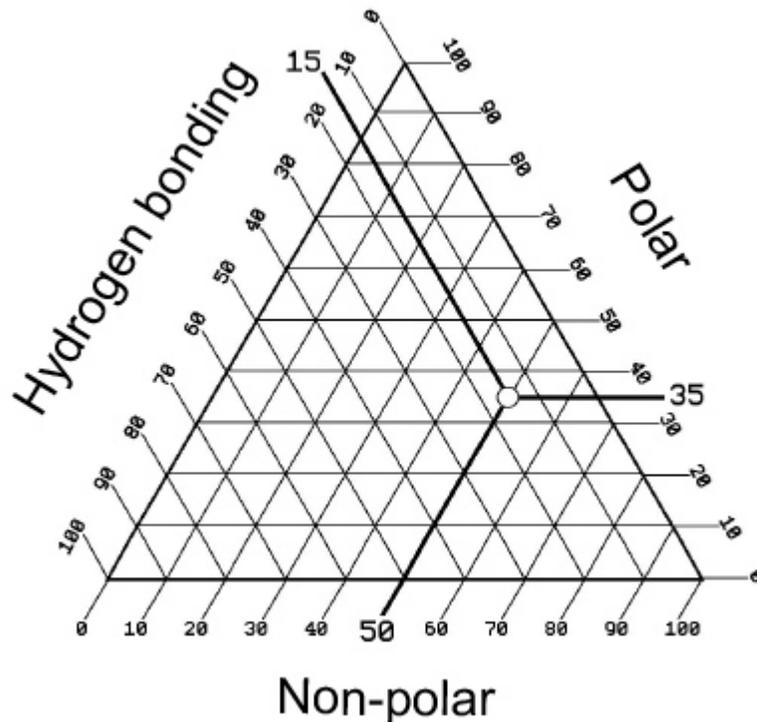


Figure 3: Teas Diagram (from J. Burke, “The Handbook for Critical Cleaning, CRC Press, 2001)

The Hildebrand solubility parameter provides a numerical estimate of the degree of interaction between materials, and can be a good indication of solubility, particularly for nonpolar materials.⁶ Building from the Hildebrand solubility work, Hansen developed Hansen Solubility Parameters to predict if one material will dissolve in particular solvent or cleaning material.⁷

Hildebrand and Hansen theorems postulate that solvents will clean soils will dispersive, polarity and hydrogen solubility forces near the solvent used to clean a particular soil. When cleaning electronic flux residues, the soil is typically a combination of ingredients that have different solubility parameters. The challenge is engineering a solvent cleaning agent that provides a balance of the three forces within the range of the soils being targeted (Figure 4).

- **H – Hydrogen Bonding**
- **P – Polarity**
- **D – Dispersion**

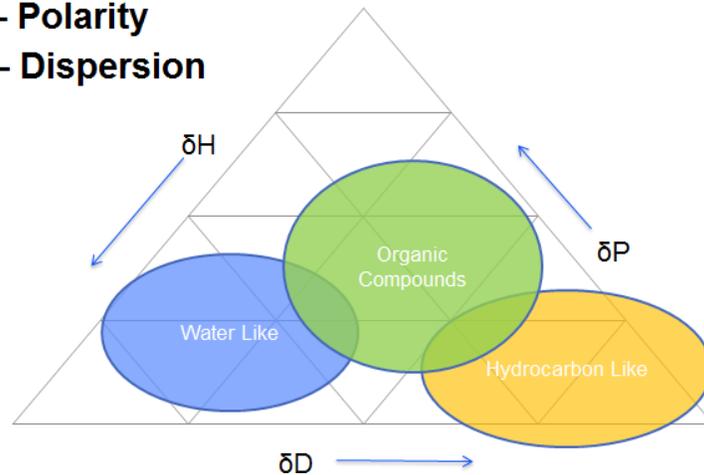


Figure 4: Solubility Forces Plotted within the Teas Chart

Experimental data of several common solvents with known solubility parameters can be used to determine the solubility parameters of flux residues by product name. The data findings can be used to calculate a solubility parameter for the each soil tested. Figure 5 illustrates the position on the Teas Chart for a number of soils from Solder Pastes tested.

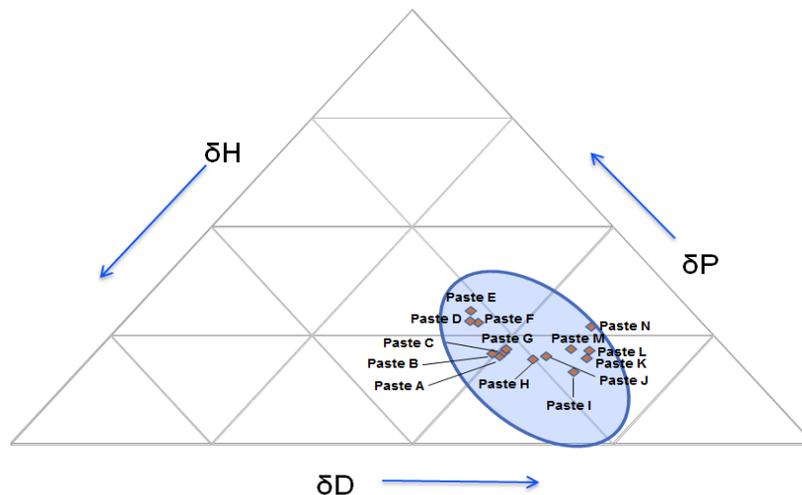


Figure 5: Solder Paste Flux Residues Position on the Teas Chart

Flux residues from a multitude of soldering materials are not a single point on the Teas chart. The flux residue for each material tested is distributed to a larger area away from its calculated area due to the different materials contained within the residue. Flux residues, being multi-component soils, require an engineered cleaning solvent to remove the soil.

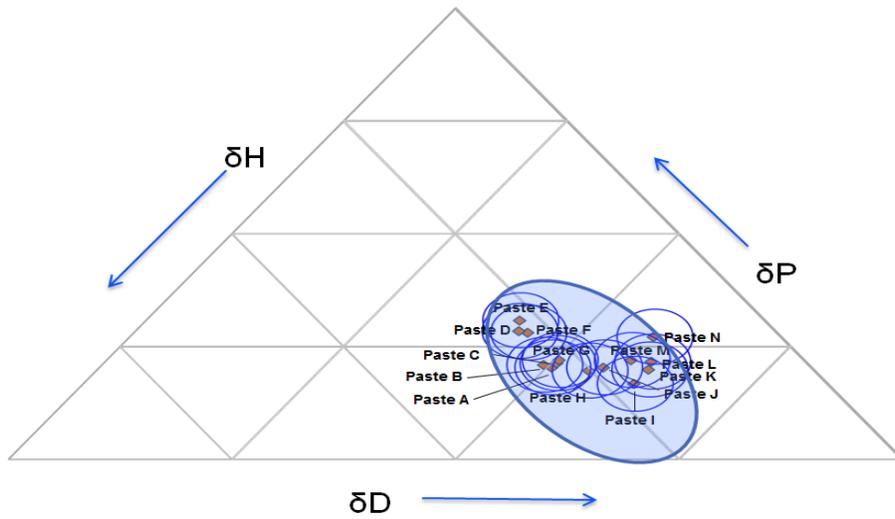


Figure 6: Flux Residue Distributed in a Larger Area Represented by the Circles

A partial list of solvents with “like” solubility parameters to the flux residue soils in question are listed in Figure 7.

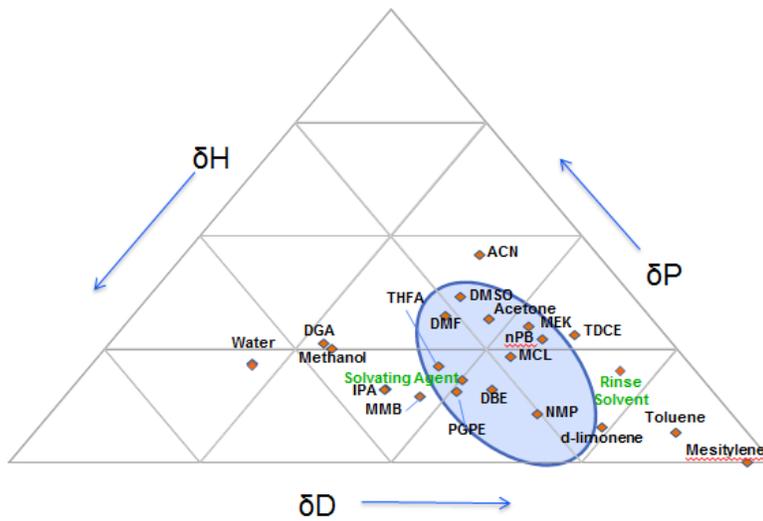


Figure 7: Solvents Solubility Position on the Teas Chart

Removal of solvents with high order of toxicity narrows possible candidates as shown in Figure 8.

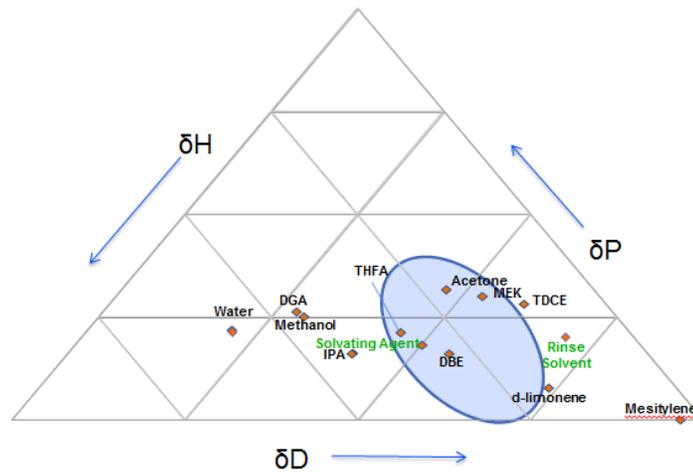


Figure 8: Solvent with Lower Levels of Toxicity

Removal of flammable solvents narrows the list of candidates as shown in Figure 9.

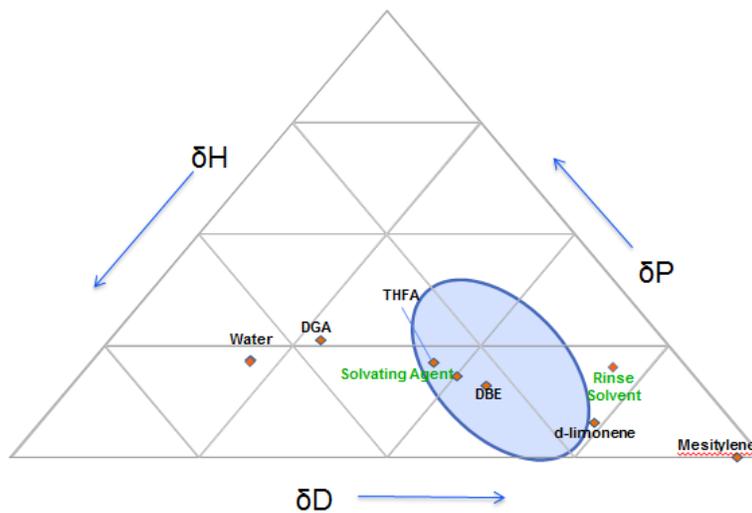


Figure 9: Solvent Candidates with Low Levels of Flammability

The key to cleaning any soil is the ability to engineer a cleaning material that has “like” properties to the soil. Engineering the three forces into the cleaning material formulation allows for the ability to dissolve the targeted soil. The dispersive property targets the soil nonpolar material set, in this case the resin flux structure. The polarity property creates the attractive and repulsive forces needed to dissolve the polar molecules within the flux composition. Hydrogen bonds create an electrostatic attraction between polar molecules. An engineered material that combines these attractive forces will be more successful in cleaning a multitude of flux residues with different properties.

Cleaning Machine

Duo-Solvent cleaning machines contain two stages. Stage 1 is an immersion cleaning chamber charged with the engineered cleaning solvent. Multi-stage agitation and thermal heat provide the thermodynamic forces needed to displace and dissolve the flux residues from the surface and under bottom termination components. Stage 2 is designed to rinse the assemblies free of the solvating agent and ionic residues.

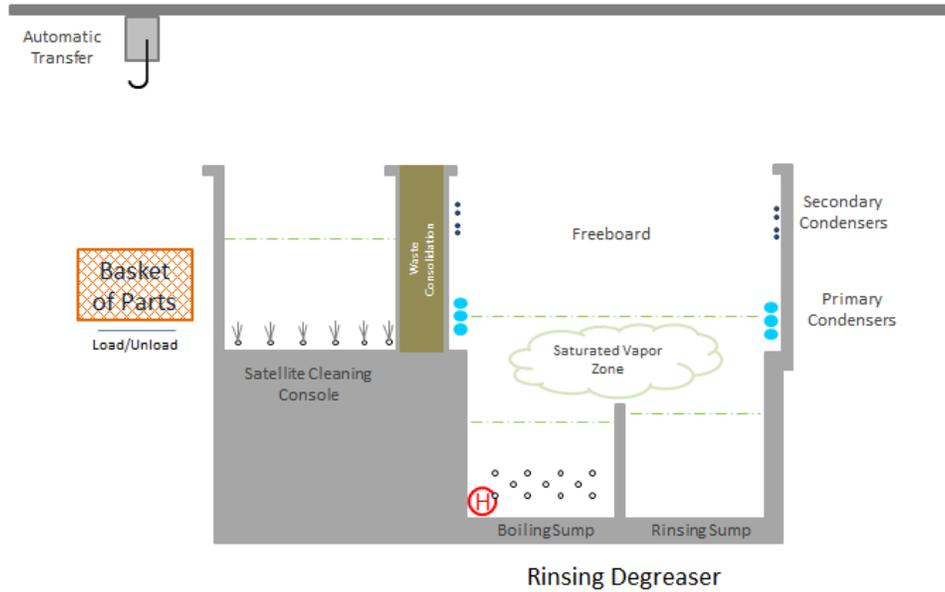


Figure 10: Cleaning Machine Designed for the Duo-Solvent Process

The cleaning machine has an engineered solvent separation system designed to continuously, in real time, remove the engineered solvent and flux soils carried from Stage 1 into Stage 2 (Figure 11). The vapor pressure of the rinse solvent is higher than engineered solvating agent. The solvent separation system extracts the cleaning solvent from the rinse solvent. Purification and recovery of the rinse solvent real time provides a high level of reproducibility with time.

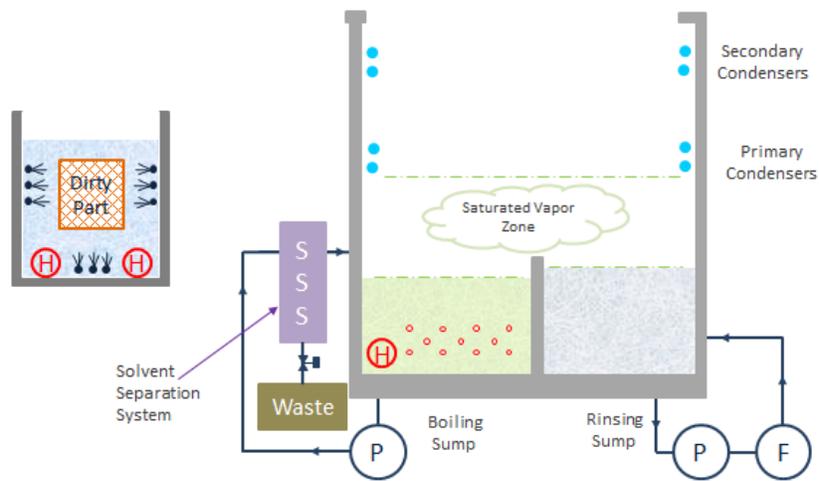


Figure 11: Solvent Separation Systems Continuously Purifies the Rinse Solvent

Experimental

The IPC PCB052-ENIG / CRET test vehicle was selected to run cleanliness on an industry accepted Lead-Free solder paste (Figure 12). The boards were assembled by a defense contractor. Following assembly, the boards were sent for cleaning using the Duo-Solvent cleaning process.

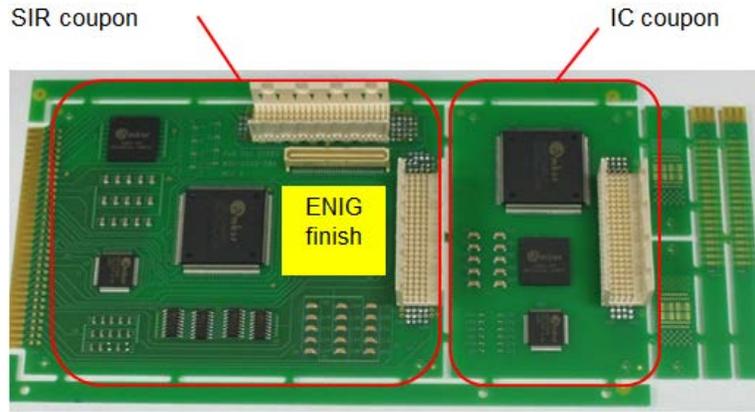


Figure 12: IPC B-52 Test Vehicle

Table 2 provides an overview of the DOE matrix.

RunOrder	Test Board	Solder Paste	Cleaning	Testing Main Board	IC Break Out Board
1	B-52	No Solder Paste	Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
2	B-52	No Solder Paste	Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
3	B-52	Lead Free No-Clean	Lead Free NC ~ Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
4	B-52	Lead Free No-Clean	Lead Free NC ~ Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
5	B-52	Lead Free No-Clean	Partially Cleaned with Rinse Solvent	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
6	B-52	Lead Free No-Clean	Partially Cleaned with Rinse Solvent	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
7	B-52	Lead Free No-Clean	Totally Cleaned Solvent Process	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
8	B-52	Lead Free No-Clean	Totally Cleaned Solvent Process	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28

Data Findings

Figure 13 provides an example of the Lead-Free no clean flux residues after soldering.

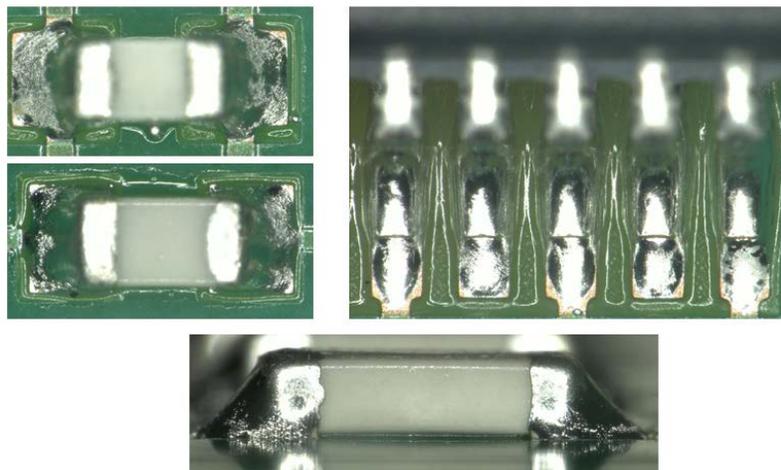


Figure 13: Flux Residue Examples after Solder

To achieve a partially cleaned condition, the assemblies to meet this condition within the DOE were cleaned with the Rinse Solvent only. Figure 14 provides an example of the Partially Cleaned test boards.

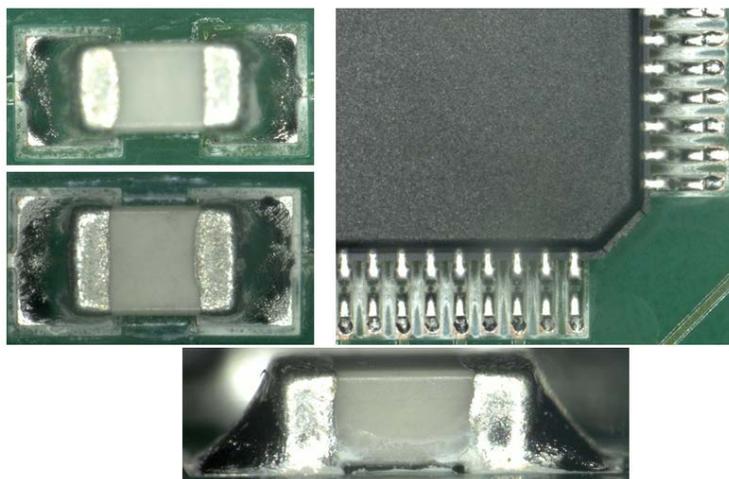


Figure 14: Partially Cleaned Test Board Images

Test boards cleaned with the Duo-Solvent process were free of visible white residues (Figure 15).

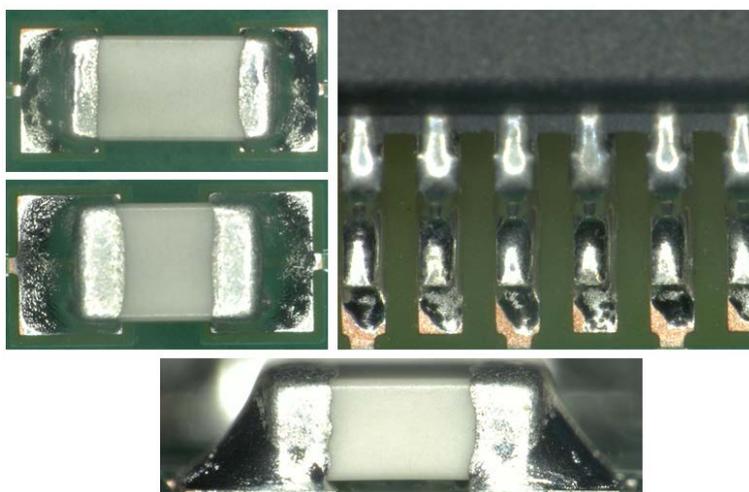


Figure 15: Clean Test Board Images

Ion Chromatography was performed per IPC TM-650 2.3.28. Boards were extracted with 20 ml of 75% IPA / 25% DI at 80°C for 1 hour. Samples were split for detection of anions and cations. The data from the IC was used to calculate micrograms per square inch.

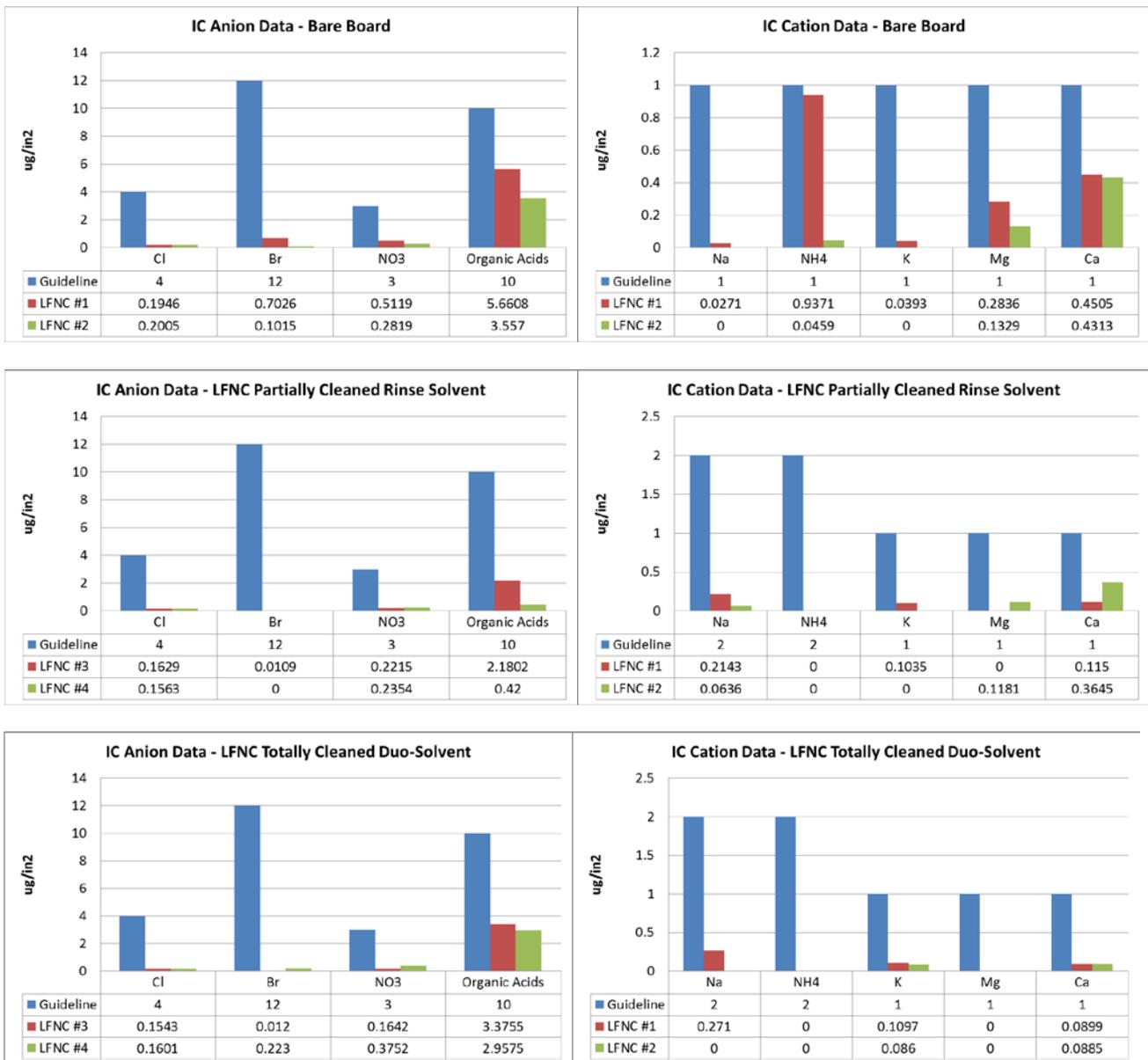
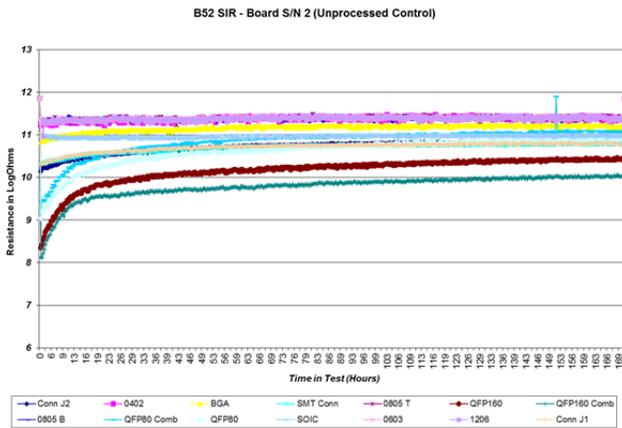


Figure 16: IC Data Findings

Surface Insulation Resistance is used to determine the propensity of a material and how the material is processed that may lead to an electrochemical event (Ex. Corrosion, dendrites or leakage). For this evaluation the test was performed using IPC-TM-650, method 2.6.3.7 with a slight modification. The boards were analyzed at 40°C/90% RH; 5 VDC bias; 7 Day test and 14 Day test with 20 minute measurement intervals. Two sets of test conditions are represented in the data findings. One set was run from the traditional 7 days and other for 14 days.

Surface Insulation Resistance is important test in determining electrical reliability impacted by flux residues / ionic contaminants, conductive / corrosive nature of residues, and the potential formation of dendrites and/or leakage issues. Measurements exceeding 100 MΩ (1.0E+08 Ohms or 8.0 LogOhms) for processed test boards and measurements exceeding 1000 MΩ (1.0E+09 Ohms or 9.0 LogOhms) for unprocessed control boards are required to pass.

Unprocessed Control ~ 7 Days



Unprocessed Control ~ 14 Days

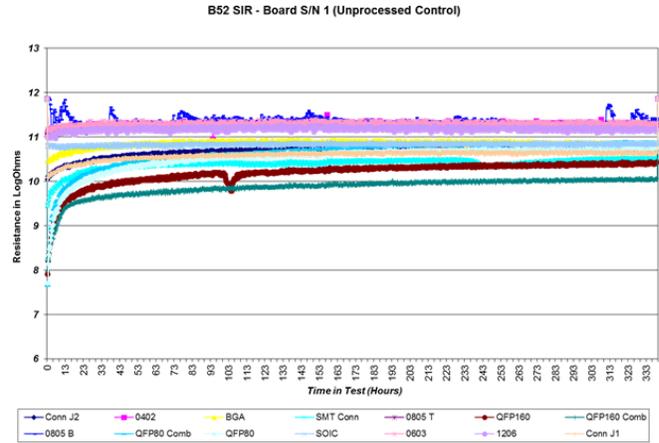
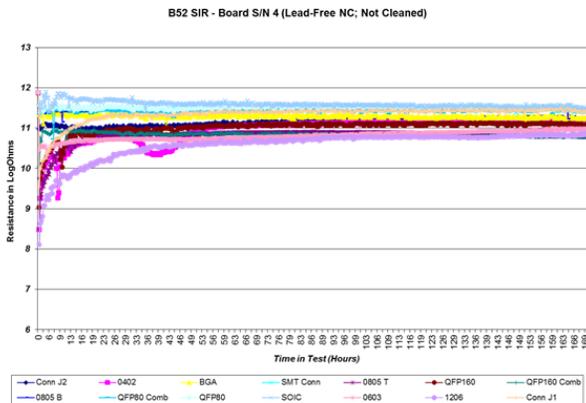


Figure 17: Unprocessed Controls

For the 7 day unprocessed control board, all test patterns maintained well above 1000 MΩ limit. For the 14 day unprocessed control board, the data grouping was tight and maintained well above the 1000 MΩ limit. The QFP160 data dropped approximately 101 hours into test, but recovered. A fiber was observed, but no other visual anomalies were noted. The 0805B (bottom side) showed erratic behavior throughout test. Again, a fiber was noted and was plated over. Additionally, solder mask over traces was discolored on one side of the pattern. No evidence of any water spotting, corrosion or dendritic activity.

Lead Free NC – Not Cleaned- 7 days



Lead Free NC – Not Cleaned- 14 days

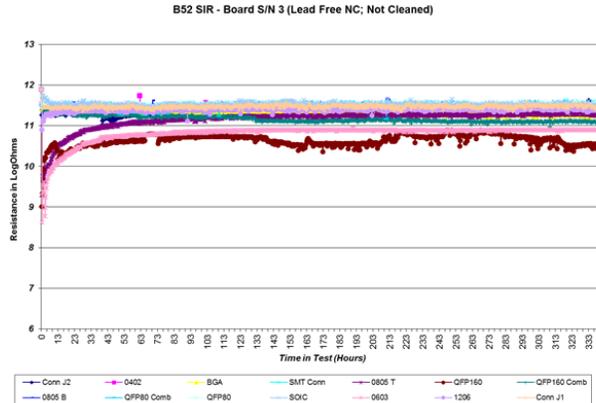
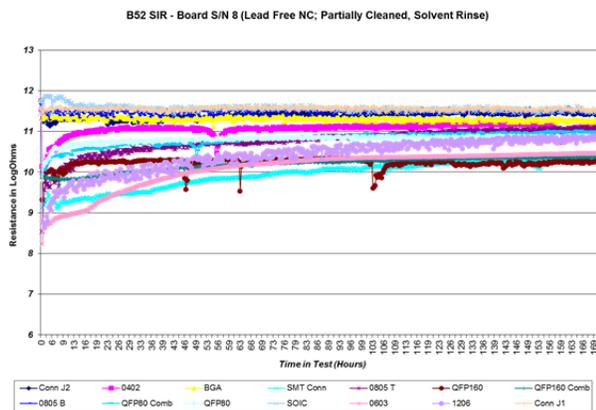


Figure 18: Lead Free Not Cleaned Boards

The 7 day data findings for the Lead-Free not cleaned boards found all patterns maintained well above the 100 MΩ limit beyond 24-hour grace period. Data variability was observed during first few hours of test due to acclimation of the test board and material. This is common. Data was tightly grouped beyond 49 hours and very stable. For the 14 day data findings, the uncleaned NC board showed good SIR levels overall well above the 100 MΩ limit. The data was somewhat erratic, which is likely due to the presence of flux residues. The QFP160 was the lowest trending pattern on the board and also showed the most pronounced erratic behavior. There was no evidence of any water spotting, corrosion or dendritic activity noted.

Rinse Solvent 7 Days – Partially Cleaned



Rinse Solvent 14 Days – Partially Cleaned

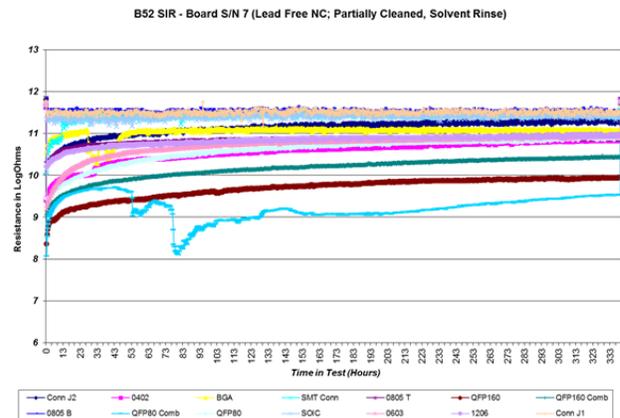


Figure 19: Rinse Solvent Cleaned Boards

The 7 day data findings for the Rinse Solvent, pattern data maintained above 100 MΩ limit. However, considerably more variability resulted. Patterns QFP160 comb, 1206 cap field and 0402 cap field showed more erratic performance. Since the parts were rinsed only in the solvent and not cleaned in solvating agent, more white residue remained. White residues contributed to erratic performance. The 14 day data findings for the Rinse Solvent, the board showed good SIR performance, except for the QFP80 comb.

Visually, there was evidence of white residue left under the part. Figure 20, photo A, shows an outline in the middle of the comb pattern. Visually, there appeared to be possible dendrites present. The direction of the growths further suggests dendritic activity (See photo's B and C).

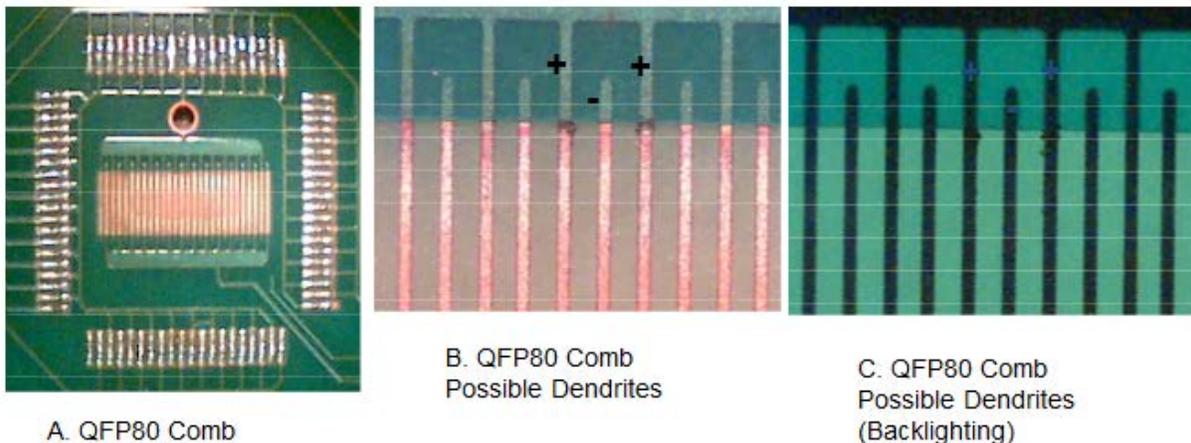


Figure 20: Rinse Solvent Cleaned SIR Images

Duo Solvent – Clean – 7 days

Duo Solvent – Clean – 14 days

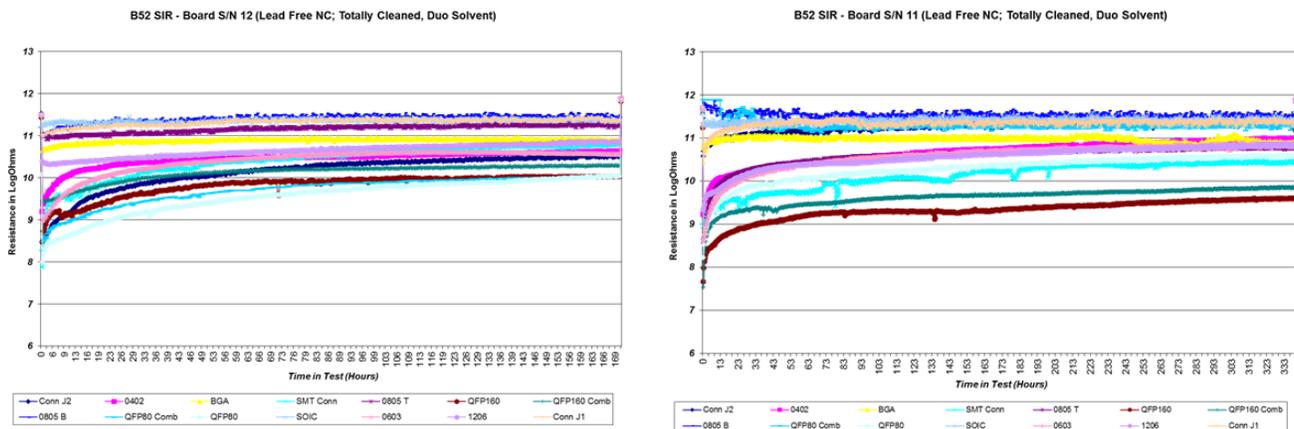


Figure 20: Duo-Solvent Cleaned Boards

Overall the data from the Duo-Solvent cleaned boards was good and maintained well above the 100 M Ω limit. Duo-Solvent S/N 12 showed better data stability. The variation observed in the two samples may be an indication of process / material variability. Starting board cleanliness may also be at work in the data. The SMT Connector on S/N 11 had some intervals where the data jumped around. Visually, the only item observed was some very mild process debris. There was no evidence of any water spotting, corrosion or dendritic growth.

Inferences from the Data Findings

Visual, IC and SIR results find that the Duo-Solvent cleaning process is effective for cleaning electronic assemblies soldered with no-clean solder pastes. A summary of the findings are as follows:

1. Unprocessed boards
 - Both were adequately clean
 - Met the minimum SIR requirements to pass the test.
2. Lead Free NC ~ not cleaned
 - Overall good electrical resistivity when left uncleaned. Some data variability observed, especially in the QFP160 location.
 - The second board (S/N 4) showed better overall SIR performance, less data variability. This suggests potential process variability.
 - Met the minimum SIR requirements to pass the test.
3. Duo-Solvent Rinse cleaned
 - The QFP80 comb of S/N7 saw some loss in resistivity but recovered
 - The cause appeared to be white residue next to component terminations. Possible dendritic activity led to lower resistance levels.
 - Most patterns met the minimum SIR requirements to pass the test.
4. Duo-Solvent Totally cleaned
 - Some data variability was observed across several components. The SMT Connector showed the most pronounced variability, but maintained above the defined limit.
 - QFP160 values passed but trended lower than other values
 - Met the minimum SIR requirements to pass the test.

Research Conclusions

The Duo-Solvent cleaning process is designed to remove flux from Printed Circuit boards using an engineered solvating cleaning composition. Following the cleaning process, the PCB is rinsed in a solvent to remove excess solvating agent and ionic residues. The process produces clean and dry PCBs in one machine with short cycle time, low energy usage and small footprint.

Flux compositions are multi compositional soils. Cleaning fluids designed for Duo-Solvent process require a combination of dispersive, polar and hydrogen bonding forces. Engineered cleaning fluids require the ability to clean multi-compositional flux residues and rinse with a high vapor pressure solvent composition. The high vapor pressure rinse solvent enables a waterless solvent-based process for cleaning printed circuit assemblies. The data found that the process is effective at *removing* no-clean Lead-free flux residues. The rinse fluid is effective at removing drag-out from wash process and ionic residues during the rinse process.

Properly designed cleaning equipment enables the process. The solvating agent is processed in a cleaning module external to the vapor degreaser. The rinse solvent requires a low surface tension and solubility with the cleaning solvent. The first rinse takes place in the boil sump with the rinse sump and vapor zones providing final rinses. A solvent separation system cleans and recovers the rinse solvent on a continuous basis. The process design provides a waterless cleaning design.

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⁷Hansen Solubility Parameter (November, 2014). Retrieved from http://en.wikipedia.org/wiki/Hansen_solubility_parameter

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Agenda

- Introduction
- Post Montreal Protocol
- Designing the Cleaning Process
- Solvent Cleaning Technology
- Duo-Solvent Cleaning
- Soil Solubility
- Cleaning Machine
- Experimental

INTRODUCTION

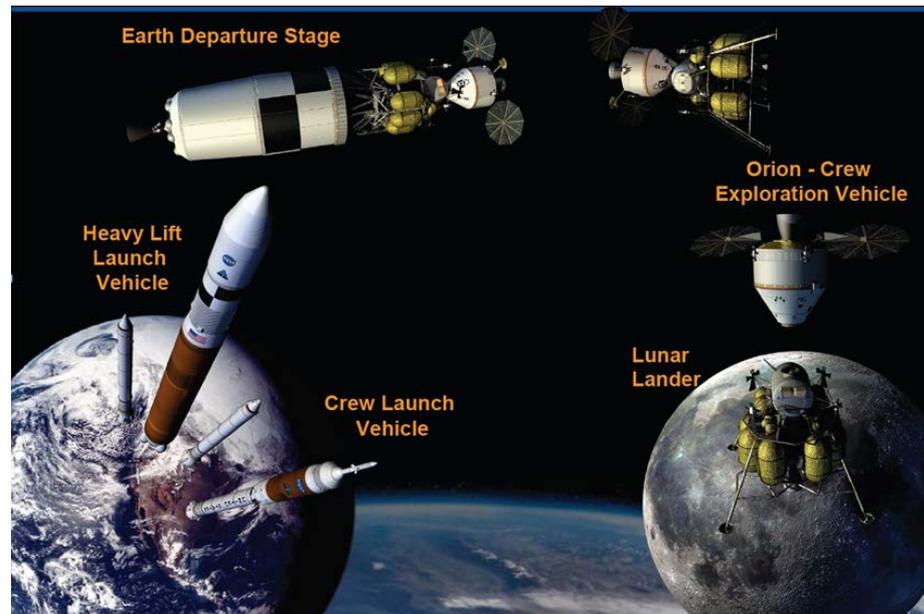
Circuit Device Reliability

- The challenge for assemblers and OEMs is to
 - Design reliable electronic hardware
 - Performs consistently in the field
- Highly Dense Interconnects
 - Increased functionality
 - Small form factor
 - Fast data transfer



Cleaning Value

- PWBs increase in value as a part of
 - Product in which the technology is implemented
- Cleaning is not due to the value of the PWB
 - But due to its place in the overall system



CFC Cleaning

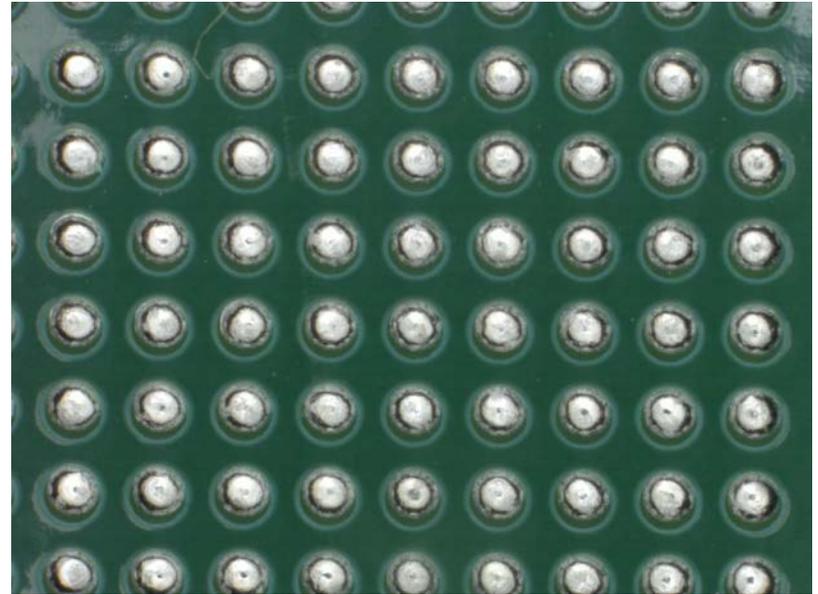
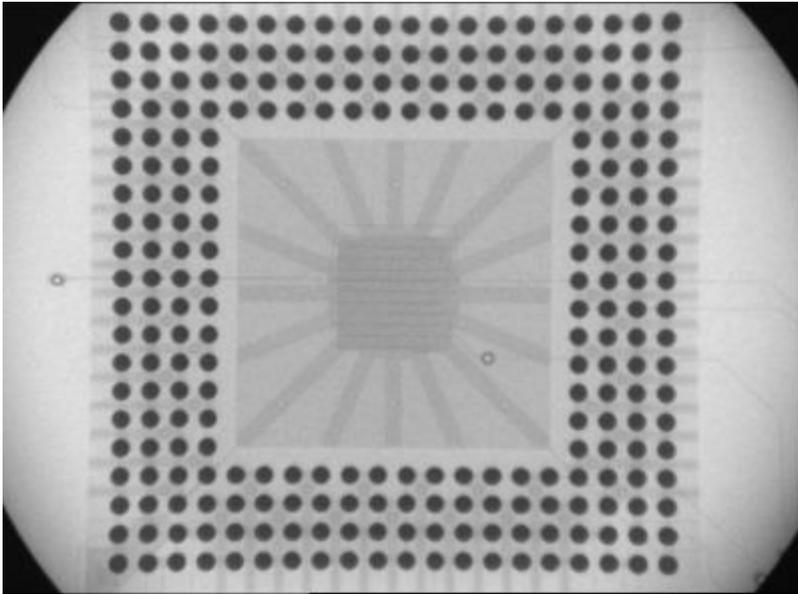
- PCB cleaning was typically solvent cleaned
- CFCs dominated market
- Montreal Protocol reduced solvent cleaning



POST MONTREAL PROTOCOL

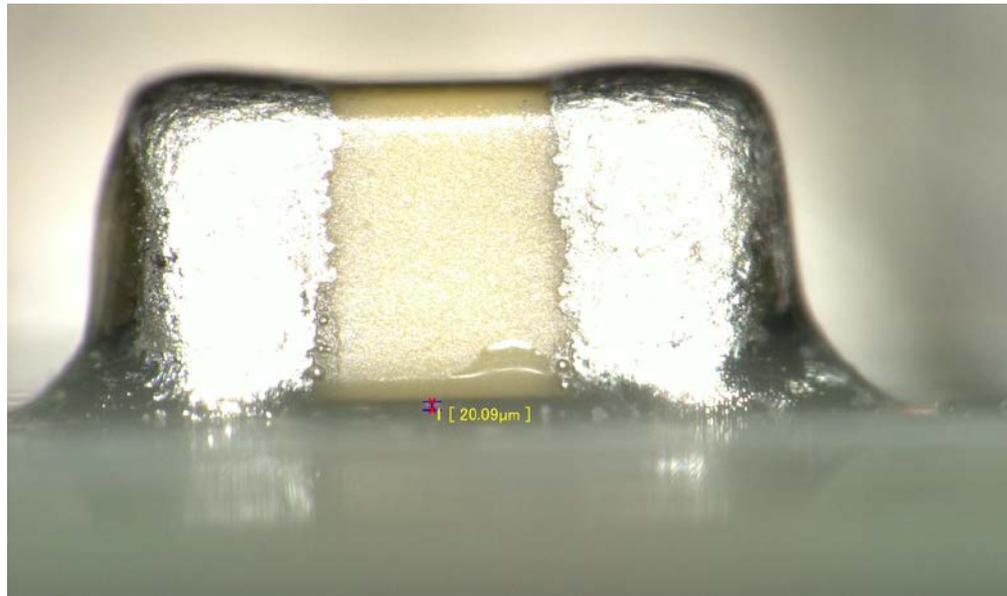
No-Clean Flux Residues

- Initially, spacing between conductors was larger
- Residues posed minimal reliability risks
- In many applications, cleaning was not required



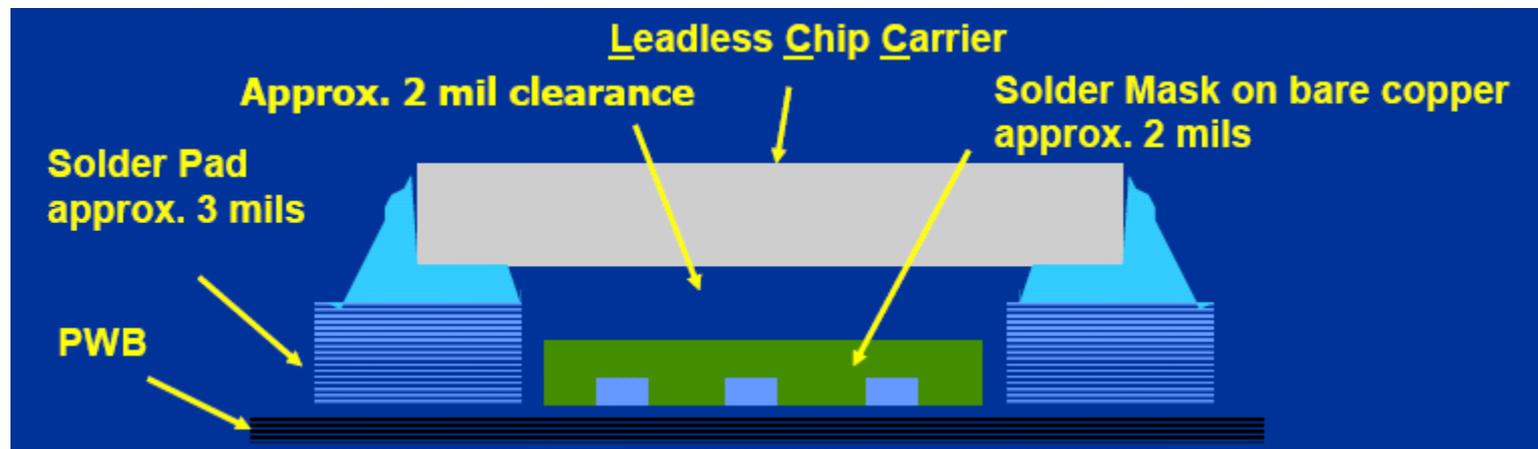
Highly Dense Interconnects

- Z-Axis of the component reduces
- Flux volatiles collect under component
- Non activated flux residues may still be active



Cleaning Challenge

- Today's Cleaning Agents
 - The key differentiator
 - Must rapidly dissolve a wide range of residues
 - Must not materially attack the assembly
 - Match to the cleaning machine
 - Be environmentally safe to use



Woody, 2008

DESIGNING THE CLEANING PROCESS

Key Factors to Consider

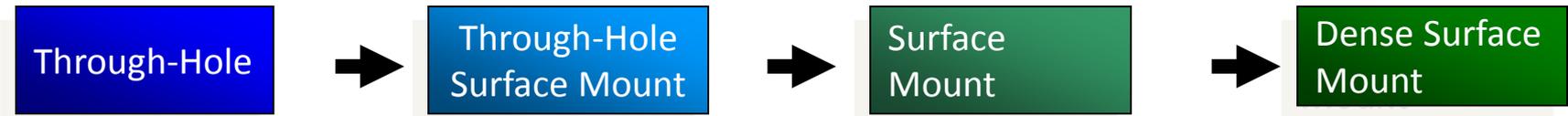


1. Part being cleaned
2. Soils encountered
3. Gap heights below 50 μ m
4. Exposed metals
5. Cleaning machine
6. Process Parameters needed to Clean
7. Process Control
8. Environmental Health and Safety

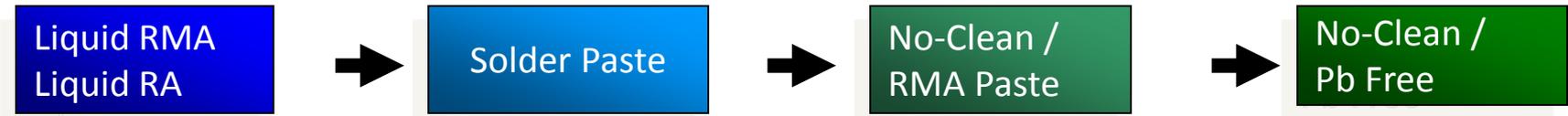
SOLVENT CLEANING TECHNOLOGY

Transition of Solvents, Fluxes and PCBs

PCB Transition



Flux Transition



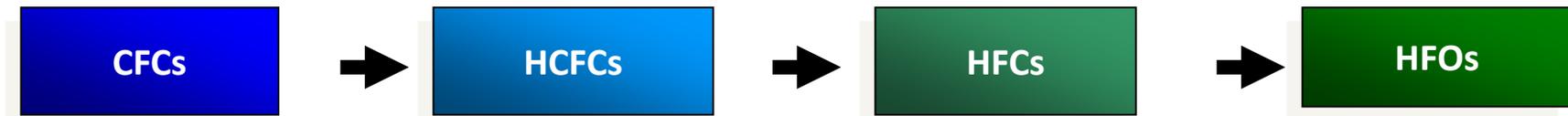
Solvent

Aqueous
Solvent

No-Clean
Solvent/Aqueous

Solvent/Aqueous
✓ **DuoSolvent**

Solvent Transition



✗ Ozone
✗ Global warming

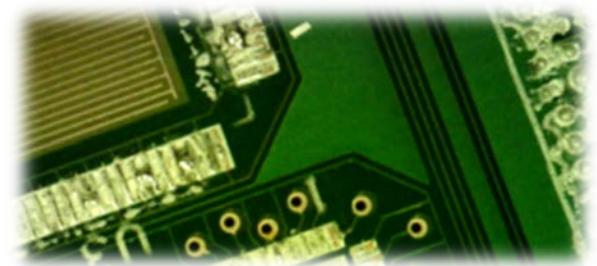
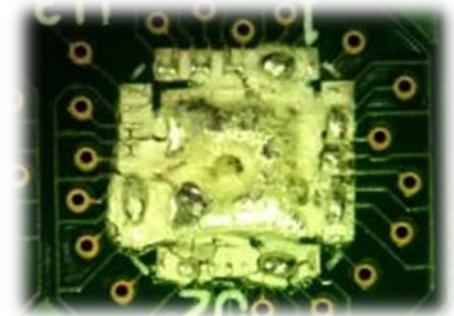
✗ Ozone
✗ Global warming
Examples: R-141b, 225

✓ Ozone
✗ Global warming
Examples: HFCs, HFEs

✓ Ozone
✓ Global warming
Examples: HFOs

Current issues

- Variety of Fluxes which are difficult to clean
 - Transition from Sn/Pb → Pb free
 - High Process temperatures: Pb free
 - Aged flux
- Limited number of general purpose solvents
 - Cleaning solutions are needed for each specific case
 - Users need the flexibility to clean varied fluxes
- Looming stability, environmental, safety and toxicity concerns
 - Need to constantly monitor solution to maintain cleaning
 - High energy cost for drying
 - Toxicity profile of cleaning solution
 - Flammability, stability....



DUO-SOLVENT CLEANING

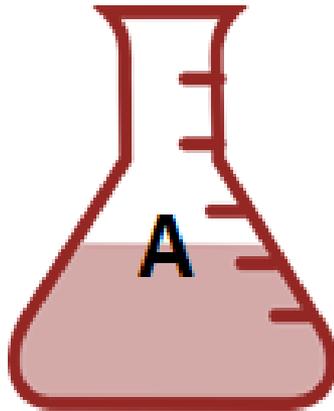
Solvent Cleaning



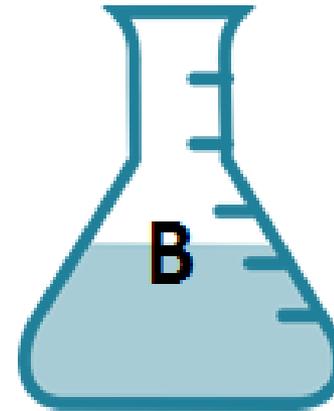
- Cleaning Criteria
 - Effective cleaning
 - Waterless Process
 - Small footprint
 - Non-flammable
 - Meets environmental standards
 - Low toxicity
 - Able to clean a variety of fluxes
- No one solvent brings all the solutions.
- Can these criteria be met with a DuoSolvent approach?

DuoSolvent is a single solution for today's fluxes.

Duo Solvent



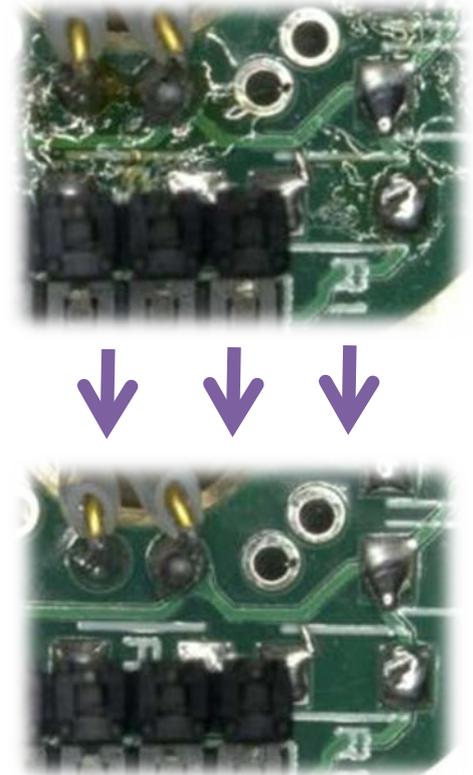
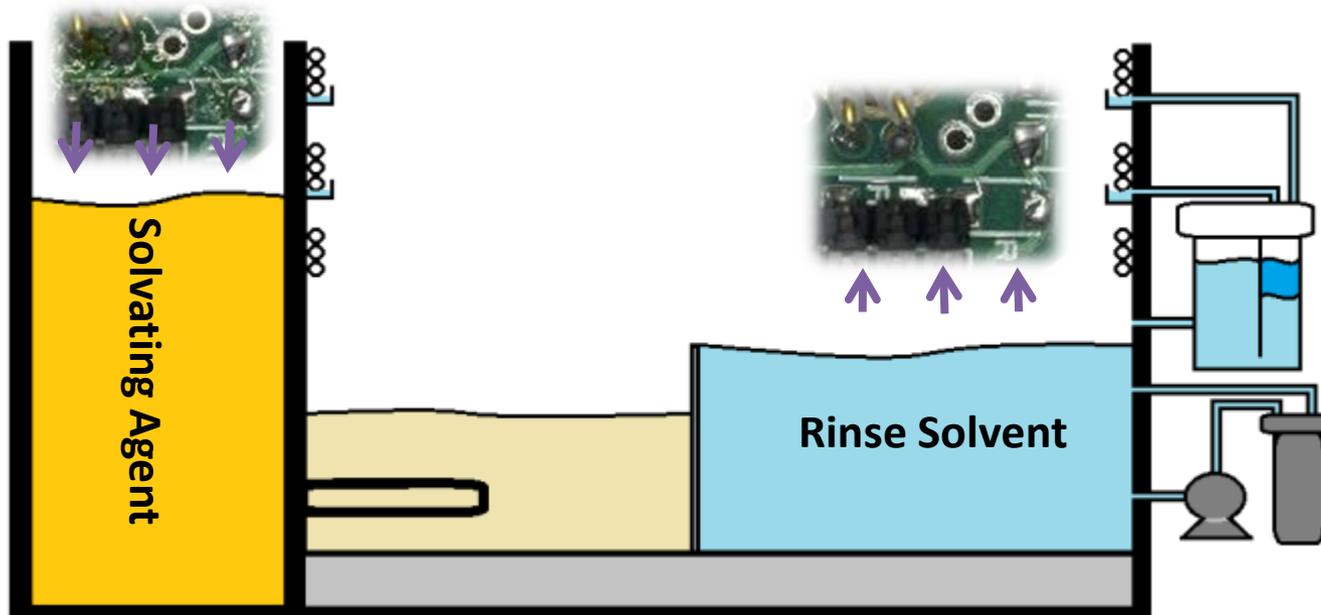
DuoSolvent



Property	Solvating Agent	Rinsing Agent
Chemical Name	Oxygenated Engineered Mixture	Hydrofluoro-Olefin
Boiling Point	203°C	19°C
Surface Tension @ 20°C	32.7 dyne/cm	12.7 dyne/cm
Flash Point	88°C	None
Water Soluble @ 25°C	Partial	460 ppm
VOC	Non-Exempt	Exempt

Duo-Solvent Process

- Cleaning Process –
 - Remove flux in solvating agent.
 - Final rinse in solvent to remove excess solvating agent and final clean of part.
 - Produce clean and dry part in one machine with short cycle time, low energy usage and small footprint



Solvating Agent Typical Degreaser setup with Hydrofluoro Olefin blend

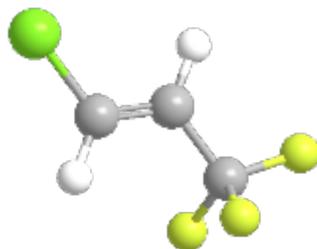
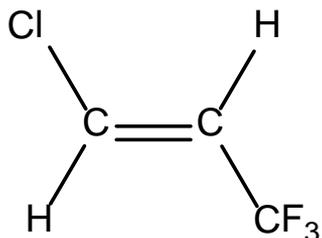
Solvating Agent

- Engineered cleaning fluid composition
- Solubility forces balanced
 - Dispersive > 14
 - Polarity > 6
 - Hydrogen Bonding > 8
- Slow Evaporating Cleaning Agent
 - Vapor Pressure ~ 0.036 mm Hg @ 20°C
 - Hydrophilic / Hydrophobic balance
 - Non Flammable
 - Rinses well with New Solvent Vapor Phase fluids
- Clean flux residues post soldering
 - No-Clean
 - Rosin
 - Water soluble



Rinse Solvent

Hydrofluoro-Olefin Technology



Environmental

VOC exempt by EPA and SCAQMD

GWP = 1 (100-year ITH)

Performance

High Degree of Solvency

KB Value 25

Low Surface Tension

Surface tension 12.7 dynes/cm

Stability/Compatibility

Excellent Metal and plastic compatibility

No stabilizers required – no monitoring

Safety

Nonflammable

Very Low Order of Toxicity

OEL 800 PPM

SOLUBILITY OF THE SOIL IN THE CLEANING AGENT

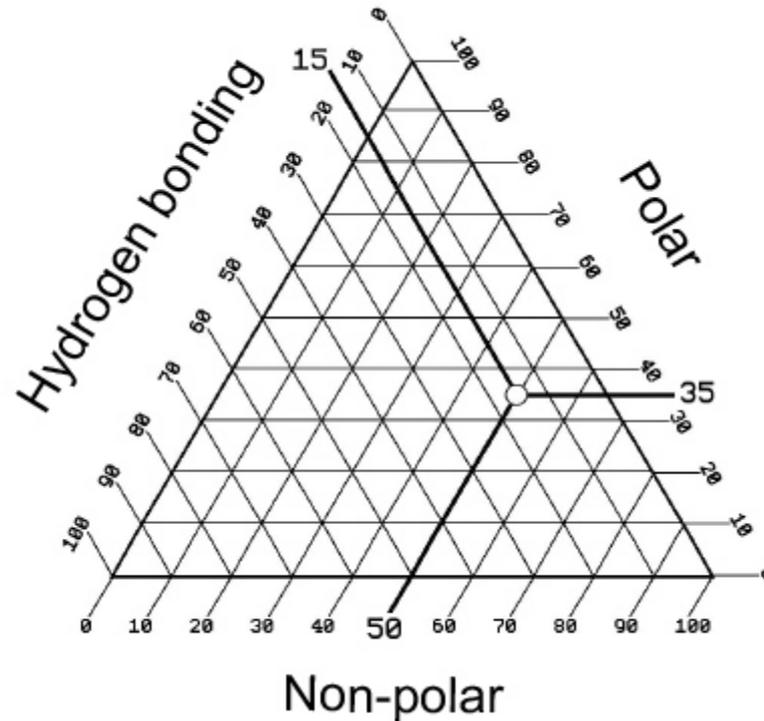
Cleaning Agent Forces



- Dispersive ~ Soil dissolves in a cleaning agent
 - Soil has “like” chemical properties to the cleaning agent
 - Like dissolves Like
 - Temperature and Energy typically increase the dispersion rate
- Polarity³
 - Intermolecular force of attraction or repulsion which act between neighboring molecules or ions (Van der Waals force)
 - Force between two permanent dipoles (Keesom force)
 - Force between a permanent dipole and a corresponding induced dipole (Debye force)
 - Force between two instantaneously induced dipoles (London Dispersive Force)
- Hydrogen Bonding⁴
 - Electrostatic attraction between polar molecules
 - Hydrogen atom bound to a highly electronegative atom such as nitrogen, oxygen or fluorine
 - Attracted a nearby highly electronegative atom

Teas Diagram

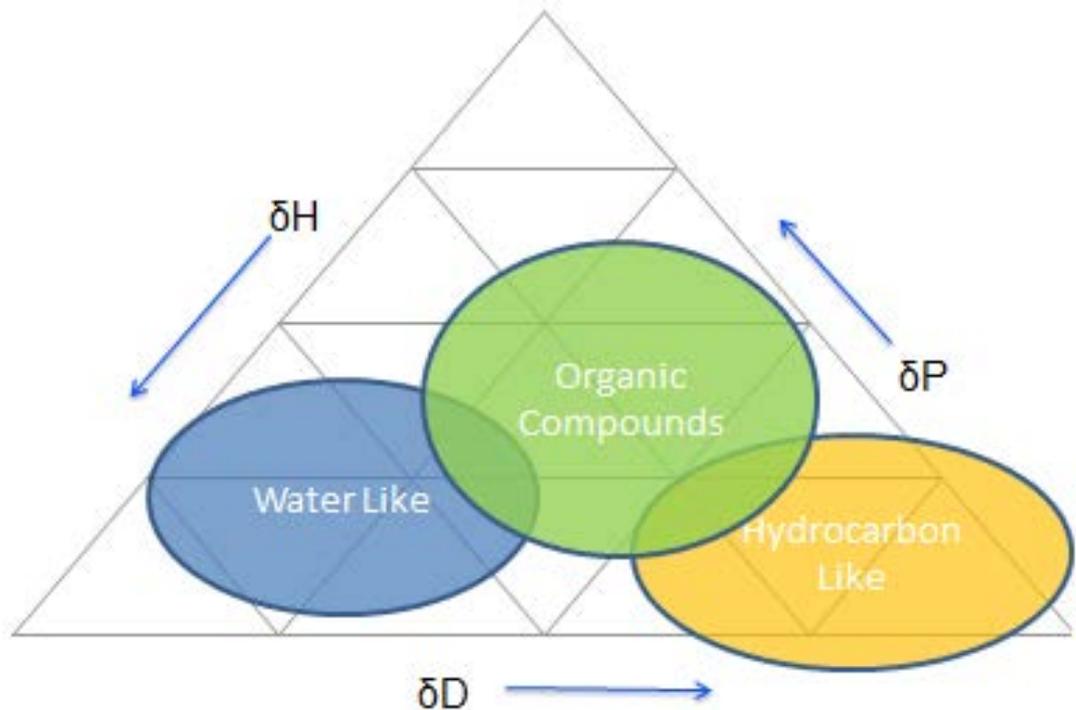
- Equilateral Triangle
- Plot Dispersive/Polarity/Hydrogen Bonding forces



Teas Diagram (from J. Burke, "The Handbook for Critical Cleaning, CRC Press, 2001)

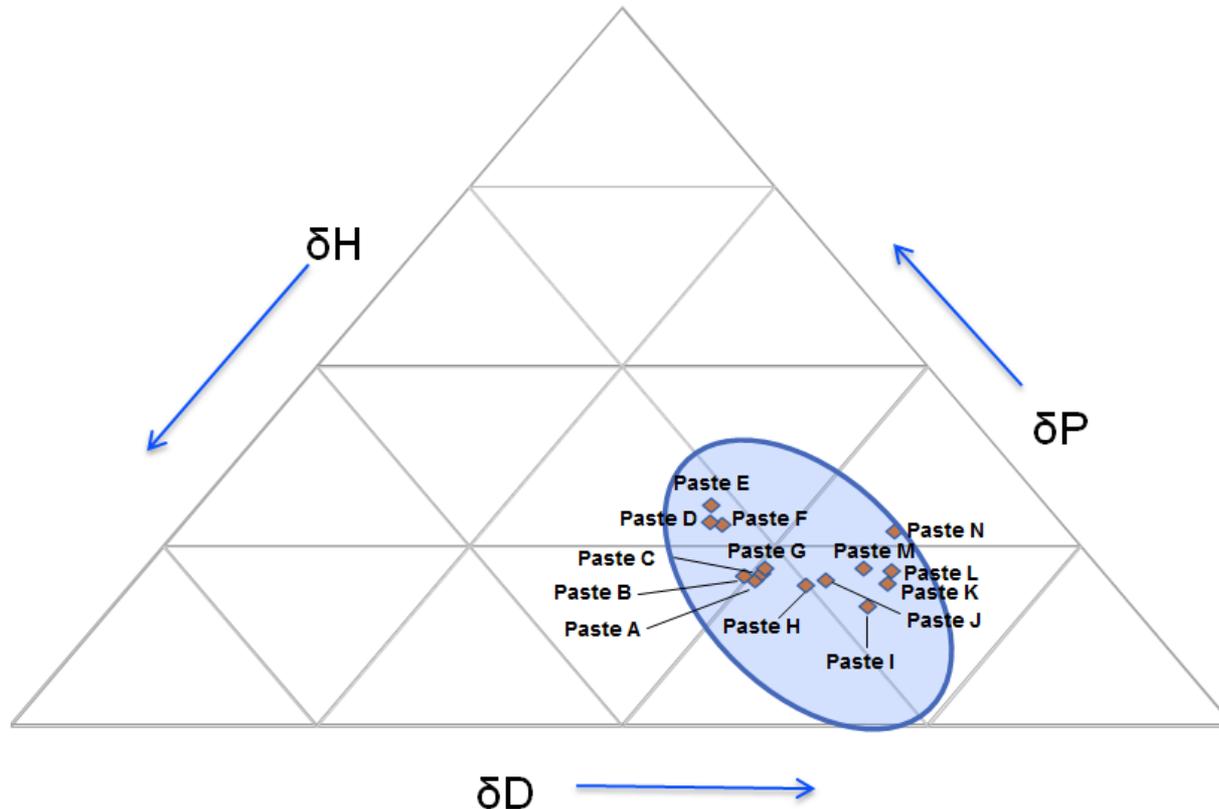
Solubility Forces

- H – Hydrogen Bonding
- P – Polarity
- D – Dispersion



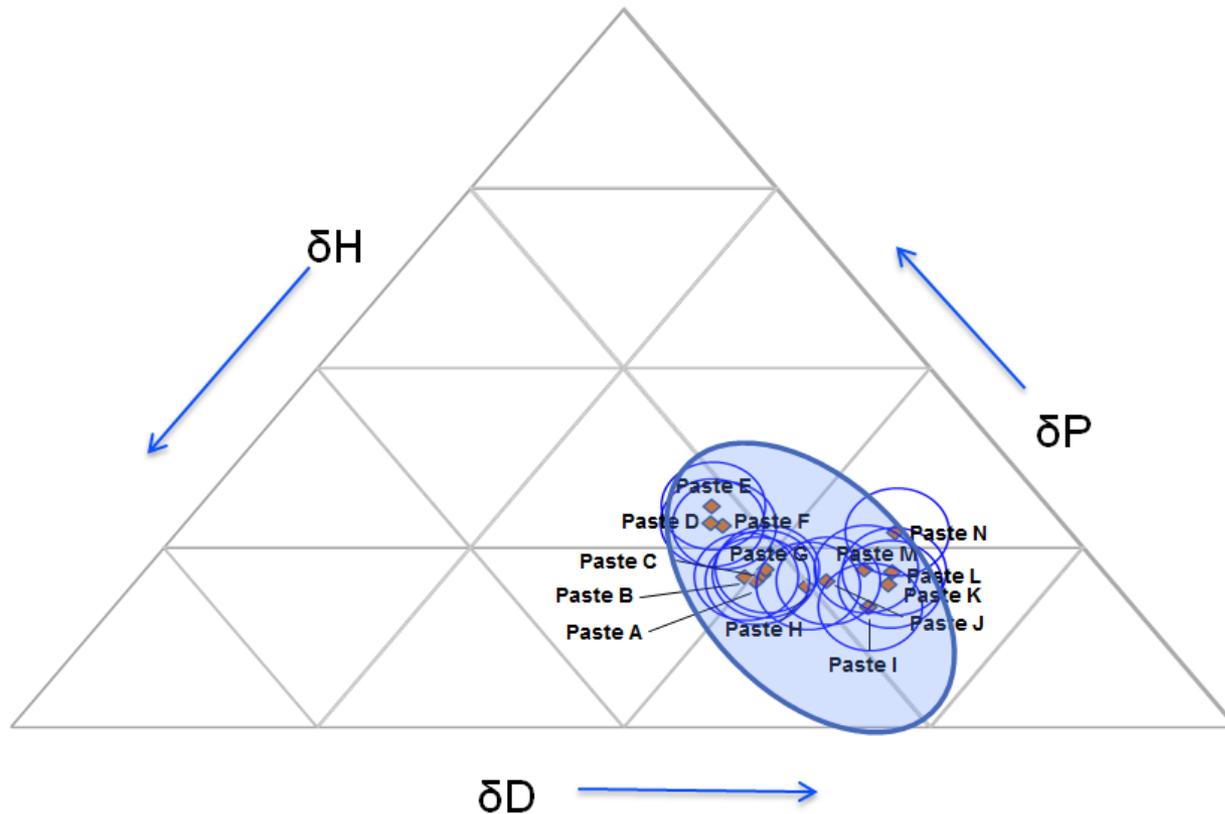
- Theory is that solvents will clean soils that lie near them on the chart more effectively.
- By no means an exact art but gives a first approximation.
- Must be experimentally validated.

Teas Diagram for some Fluxes



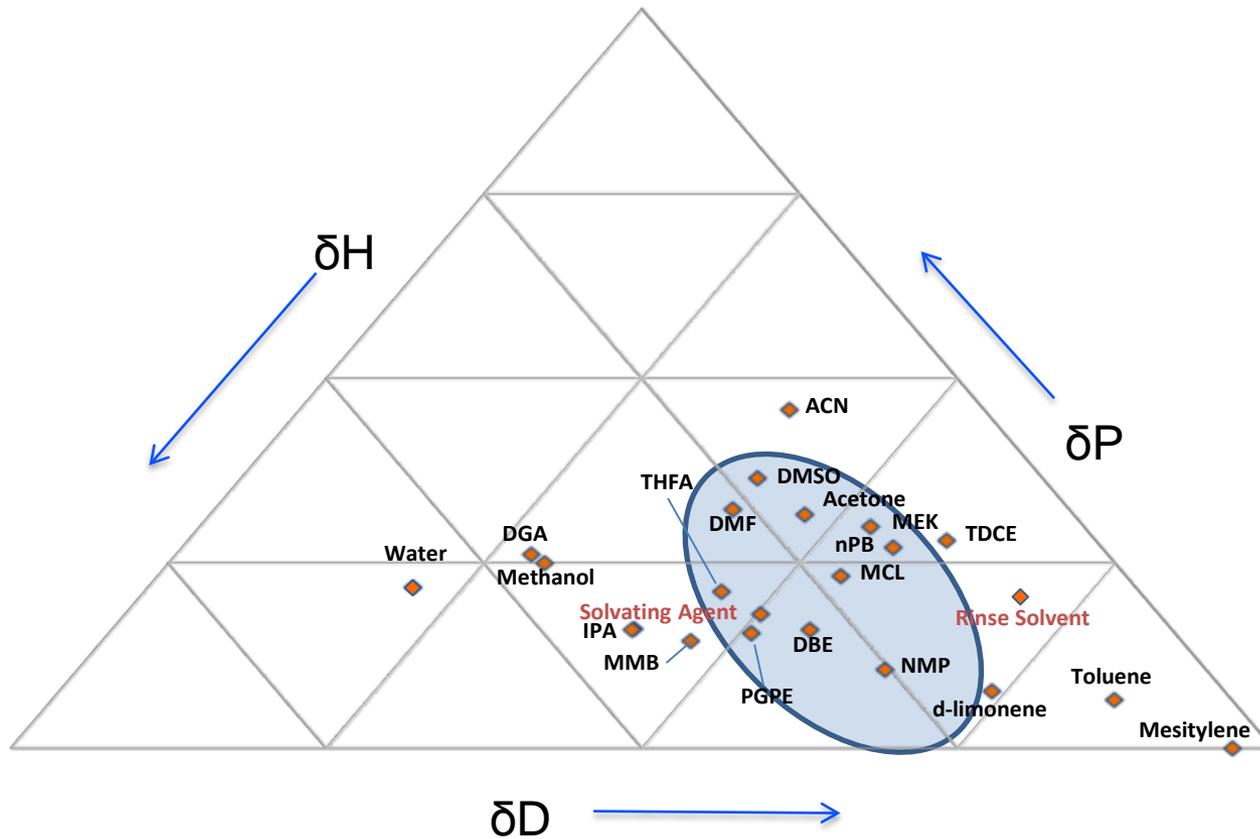
- Experimental data of several common fluxes are shown on the teas diagram.
- Common fluxes are highlighted.

Teas Diagram for some Fluxes

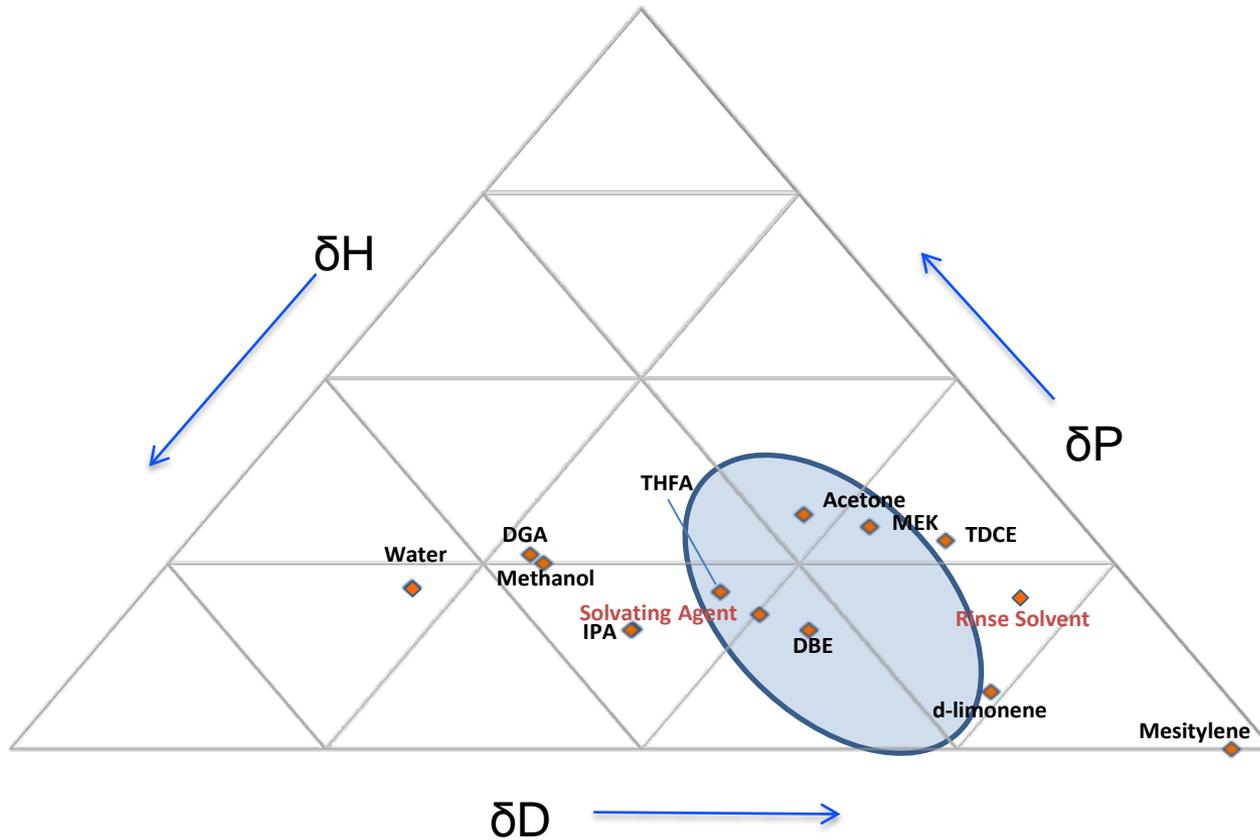


- Fluxes are not actually a single point on the graph.
- The flux is distributed in a larger area represented by the circles.

Teas Diagram for Solvents

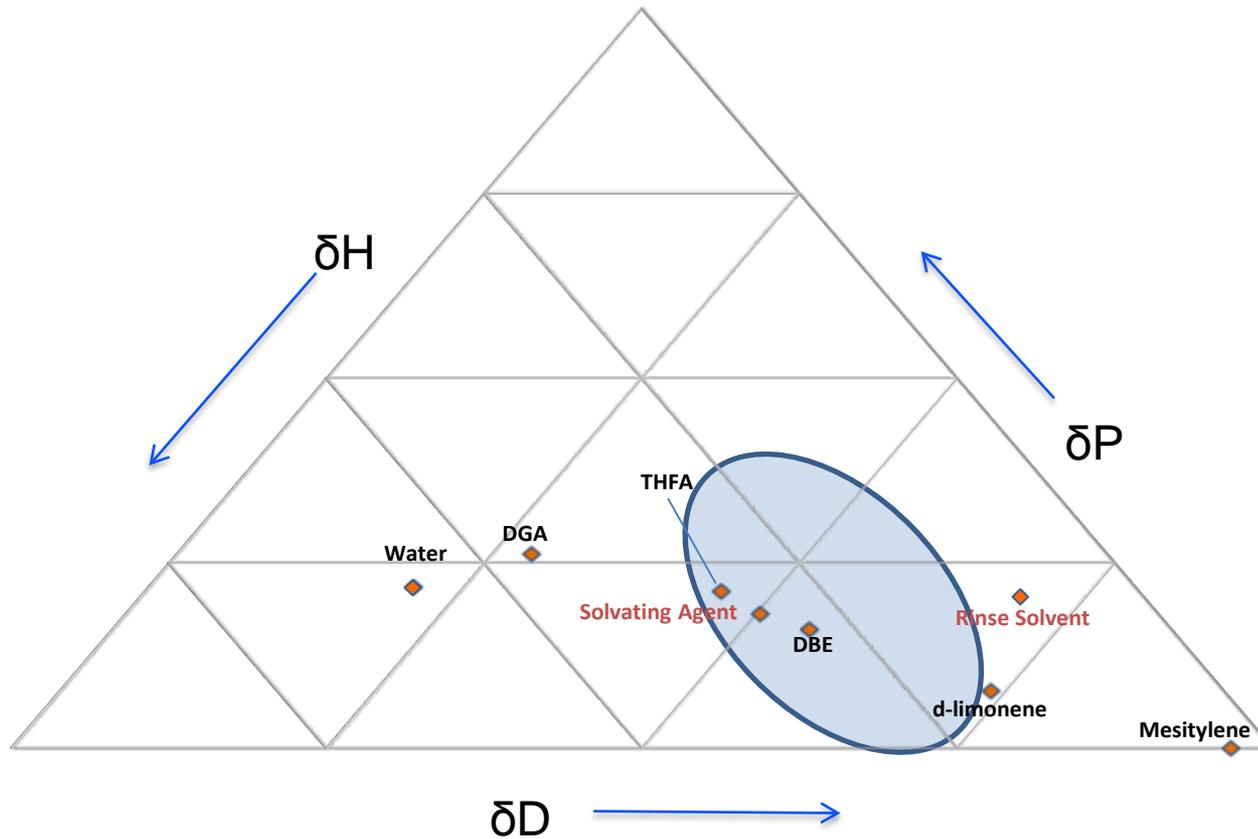


Teas Diagram for Solvents



Remove Solvent with High order of Toxicity

Teas Diagram for Solvents



Remove Flammable (FP < 90°C) Solvents

Flux Residues

- Soil composition requires
 - Dispersive Force
 - Non-polar portion of flux residue
 - Polar Force
 - Polar activators within the flux residue
 - Hydrogen Bonding
 - Carboxylic acids within flux residue
 - Electrostatic force to dissolve polar activators
- Requires an Engineered Cleaning Material

CLEANING MACHINE

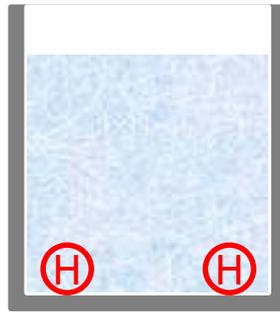
Stage 1

Soil specific solvent added to Satellite Cleaning Console



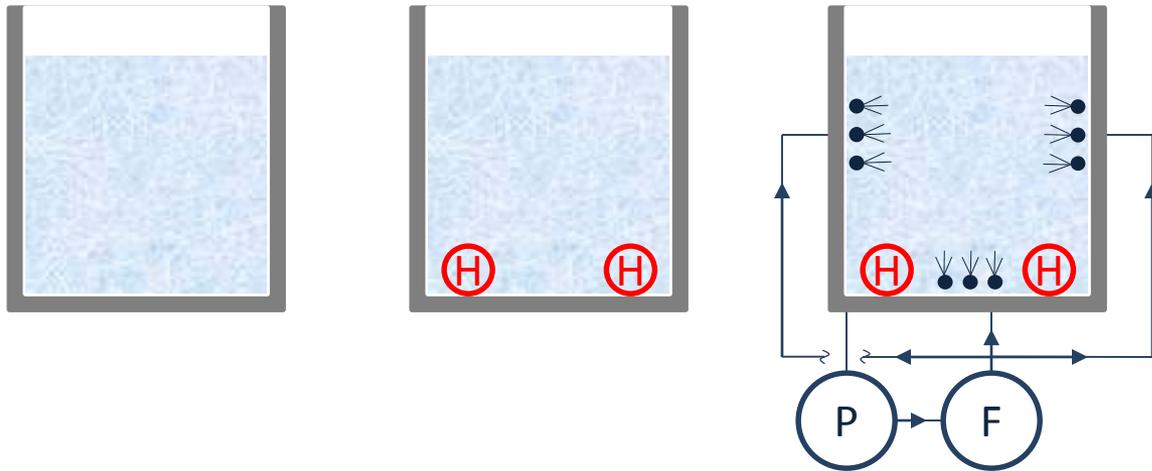
Stage 1

Add Heat
(Thermostatically Controlled)



Stage 1

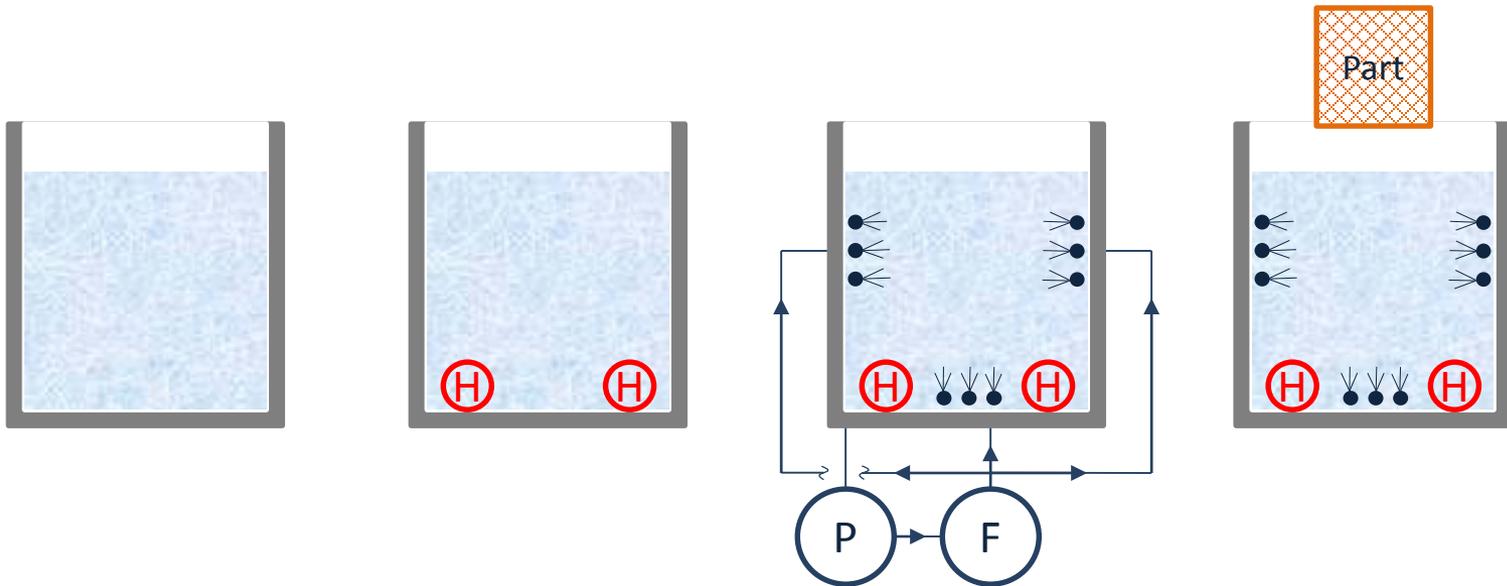
Add Mechanical Agitation (Spray Under Immersion / Pulse Action)



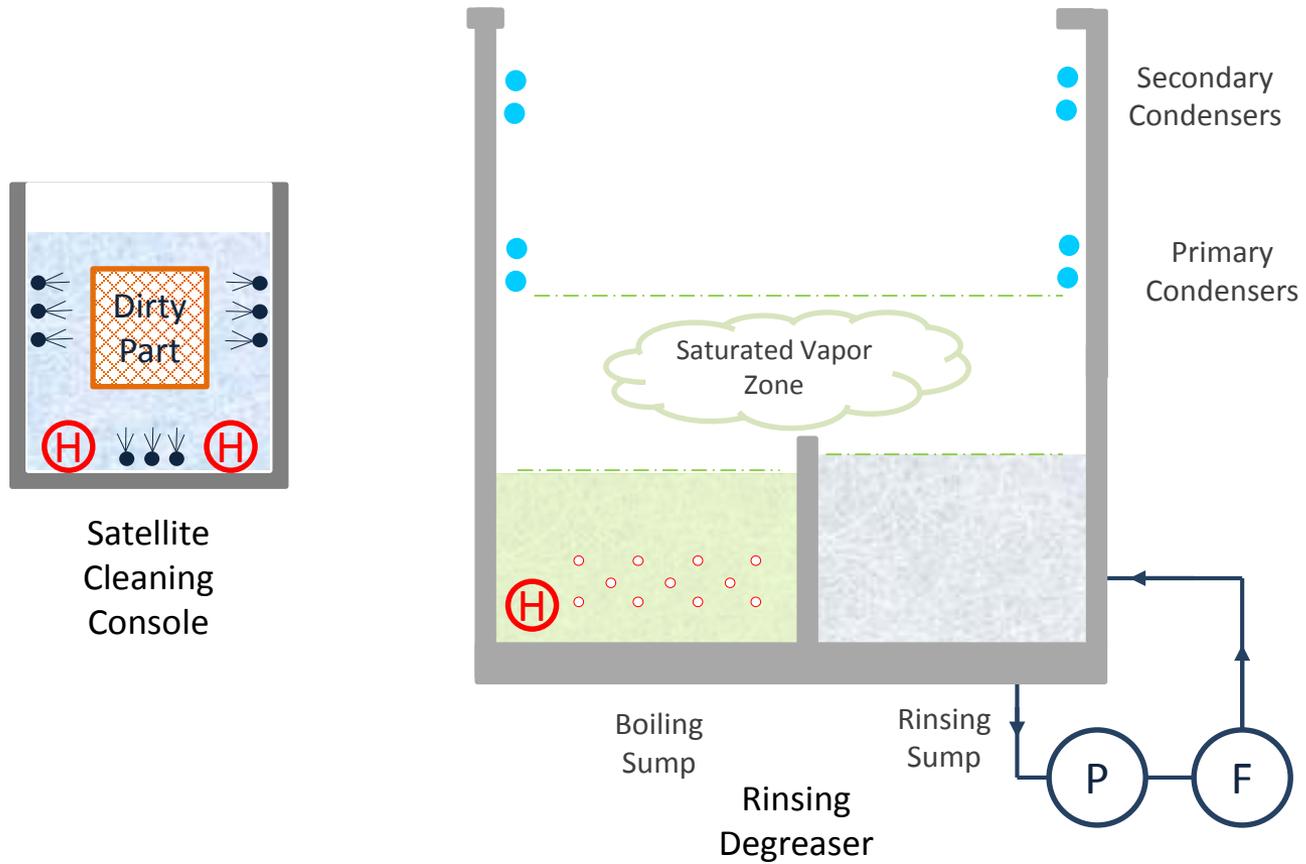
Stage 1

Submerge Part

(Parts must be racked for maximum exposure/best results. Dwell time must be established)

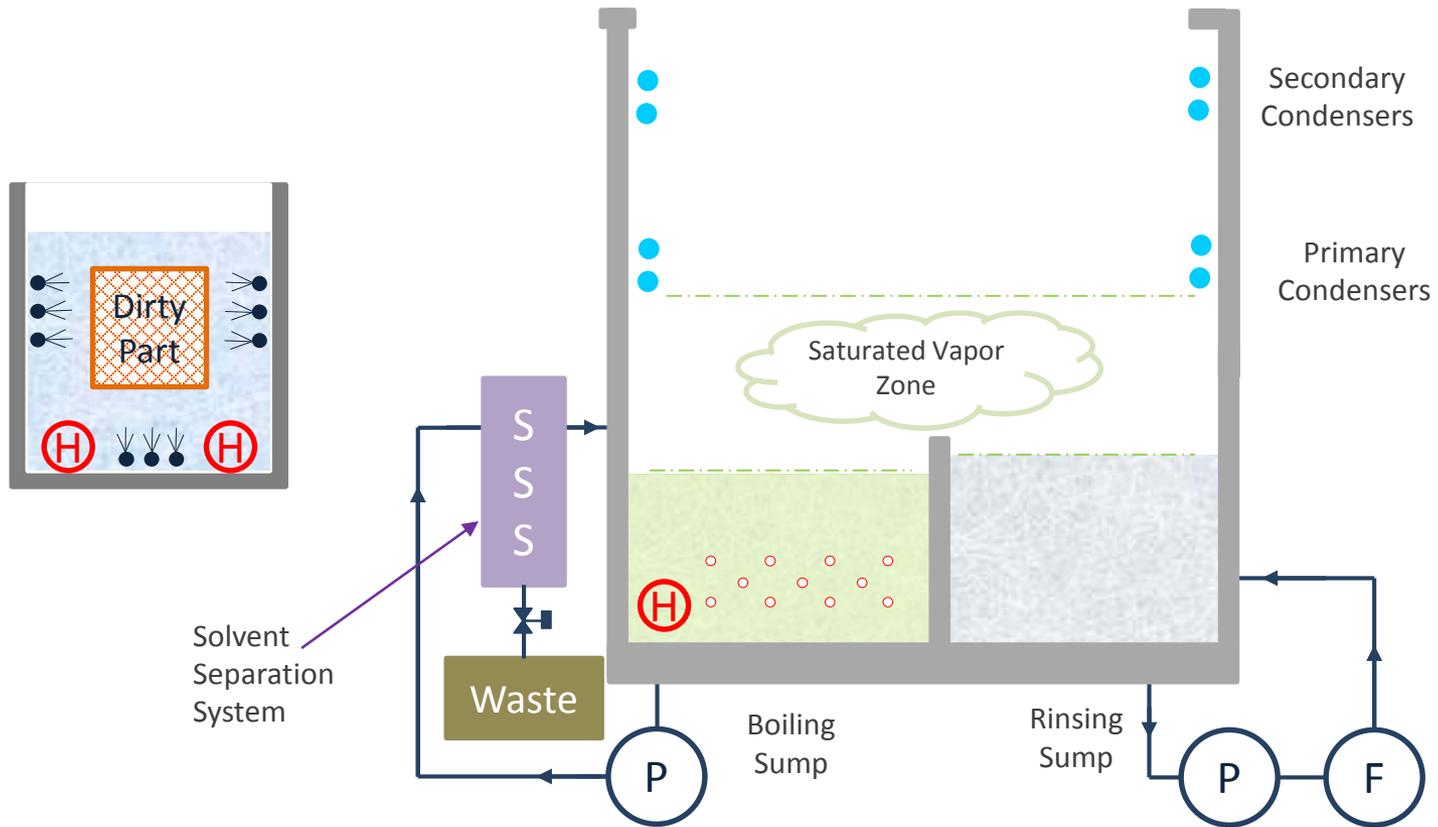


Stage 2



Chemical Isolation Rinse

Stage 3



Waste Separation/Consolidation

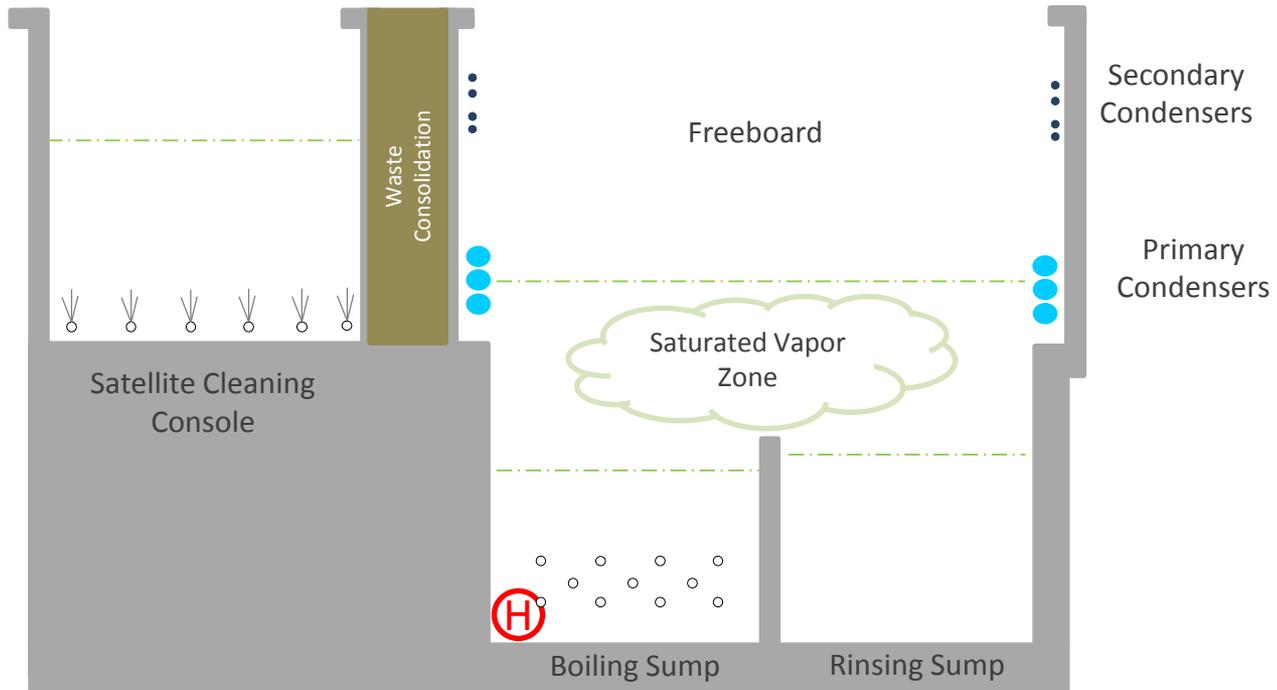
Fully Automatic DuoSolvent Process

Automatic Transfer



Basket of Parts

Load/Unload

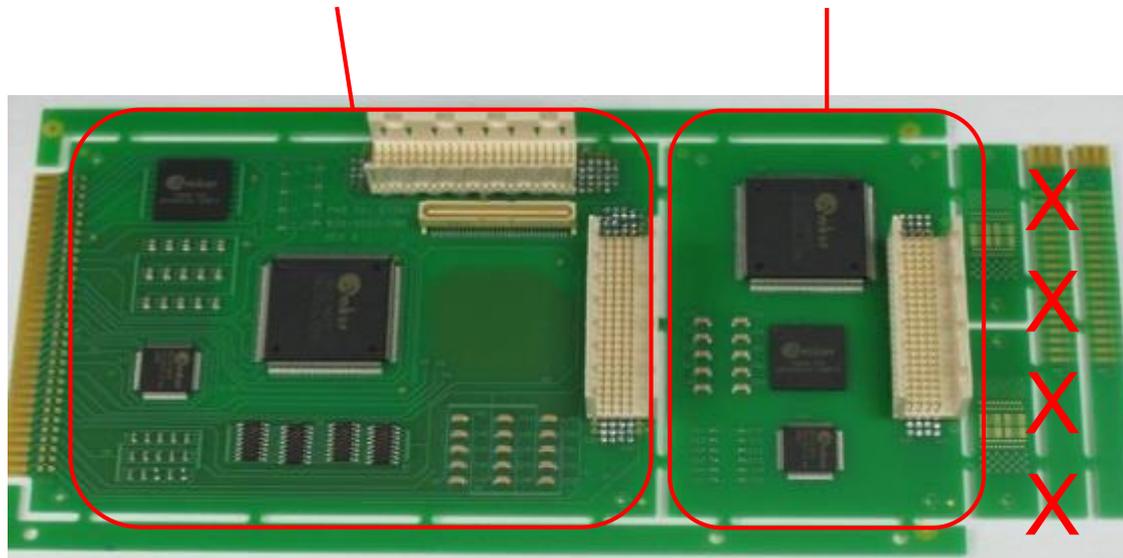


Rinsing Degreaser

EXPERIMENTAL

IPC Test Vehicle

- IPC-B-52 (ENIG) test vehicle
- Designed for the following cleanliness testing:
 - Surface Insulation Resistance (SIR)
 - Ion Chromatography (IC)



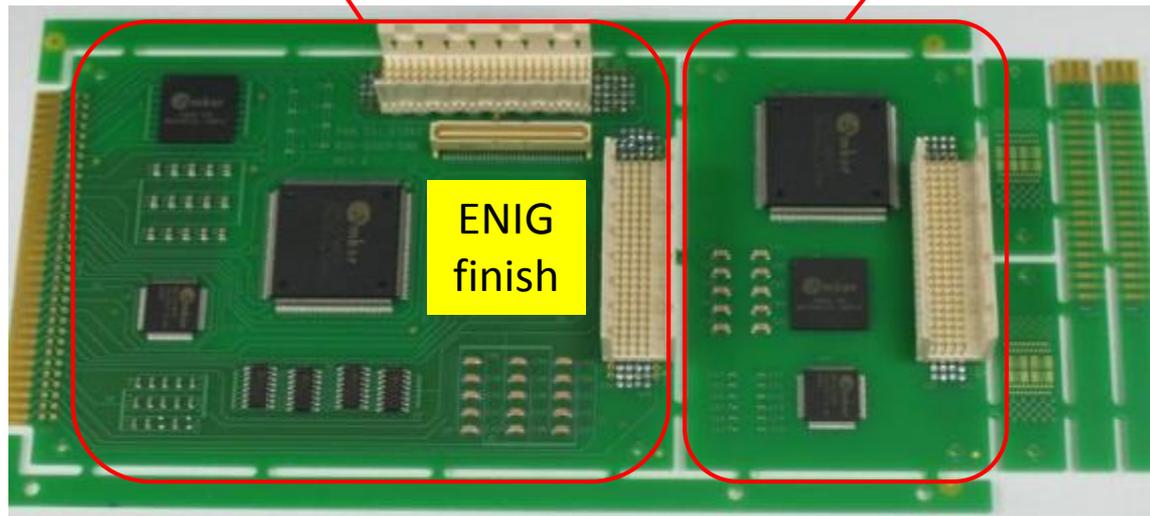
Assembled B52

Data Collection

RunOrder	Test Board	Solder Paste	Cleaning	Testing Main Board	IC Break Out Board
1	B-52	No Solder Paste	Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
2	B-52	No Solder Paste	Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
3	B-52	Lead Free No-Clean	Lead Free NC ~ Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
4	B-52	Lead Free No-Clean	Lead Free NC ~ Not Cleaned	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
5	B-52	Lead Free No-Clean	Partially Cleaned with Rinse Solvent	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
6	B-52	Lead Free No-Clean	Partially Cleaned with Rinse Solvent	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
7	B-52	Lead Free No-Clean	Totally Cleaned Solvent Process	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28
8	B-52	Lead Free No-Clean	Totally Cleaned Solvent Process	SIR 2.6.3.7 for 7 & 14 days	IC 2.3.28

SIR coupon

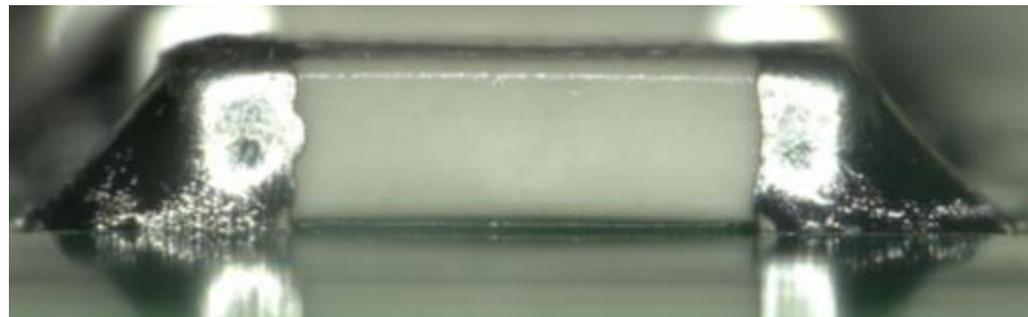
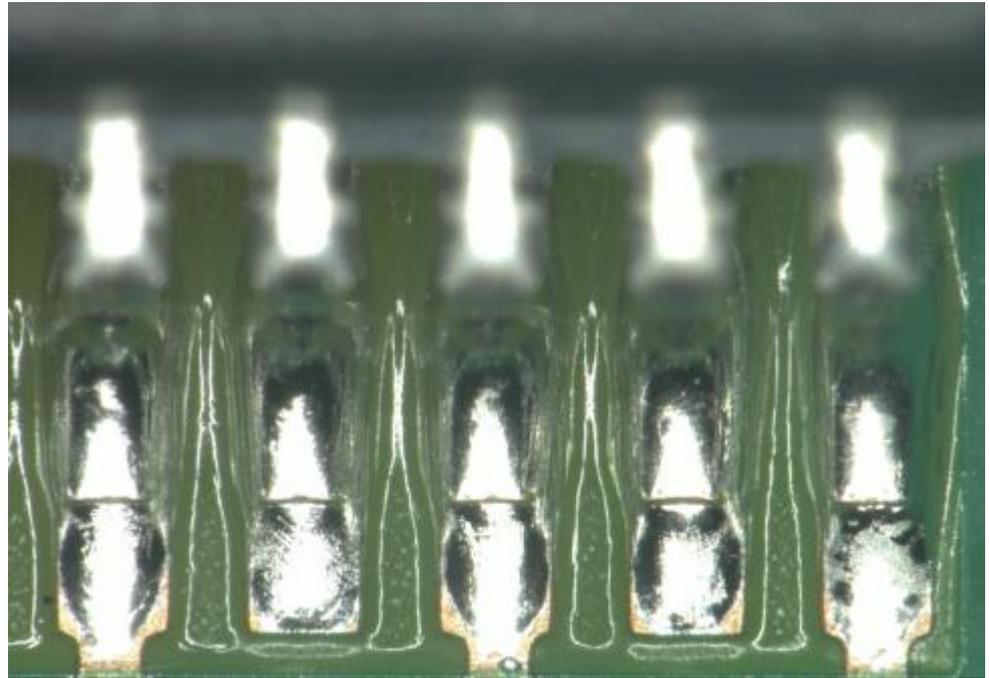
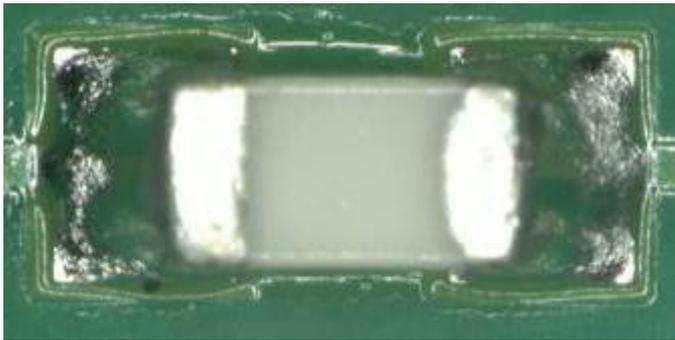
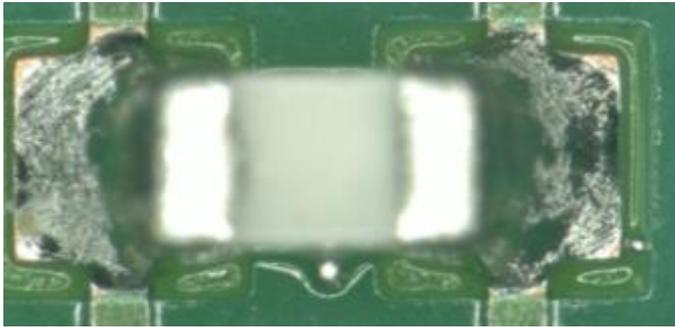
IC coupon



Assembled B52

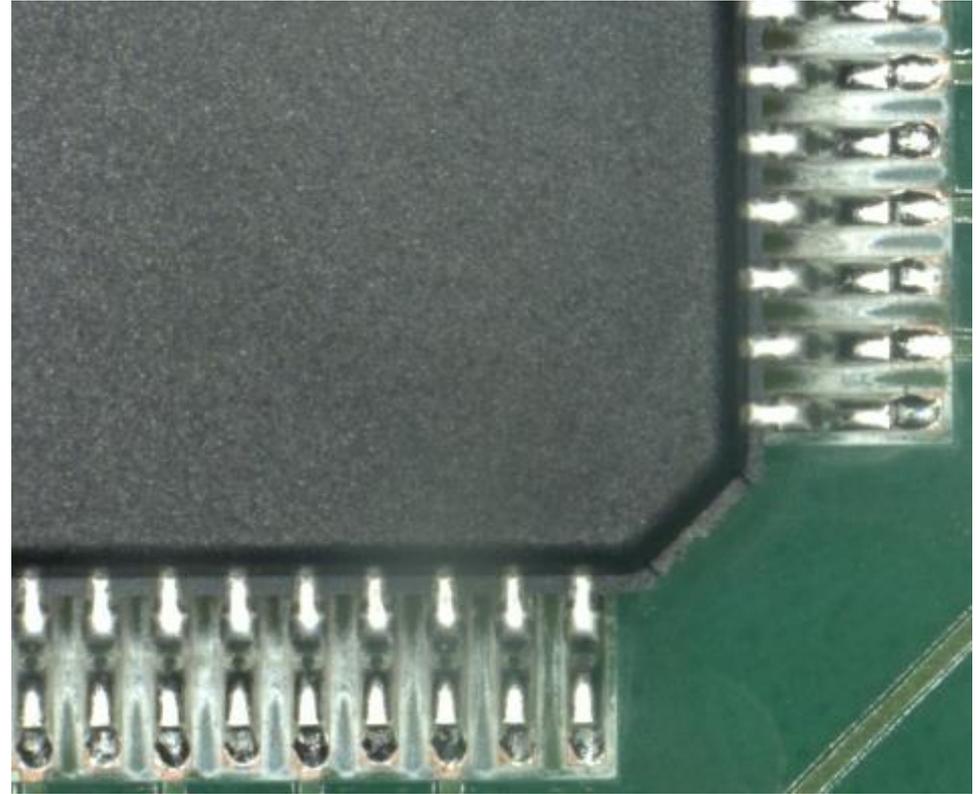
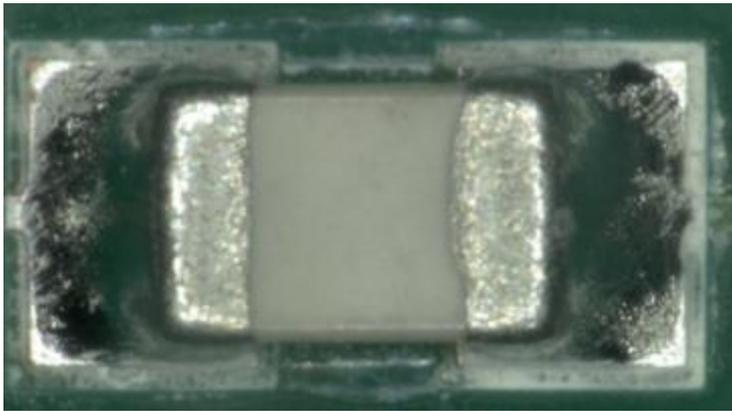
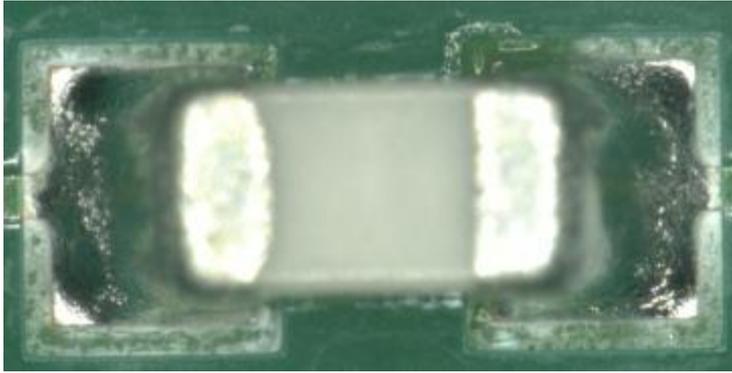
Visual Data Findings

- Lead Free NC Before Cleaning



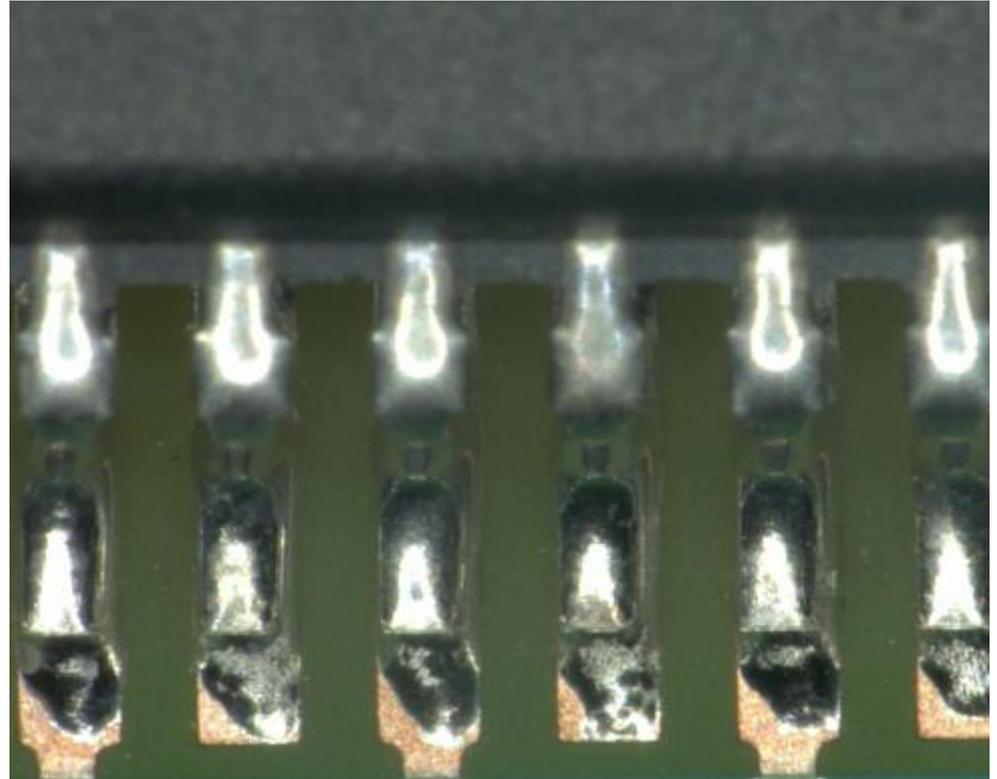
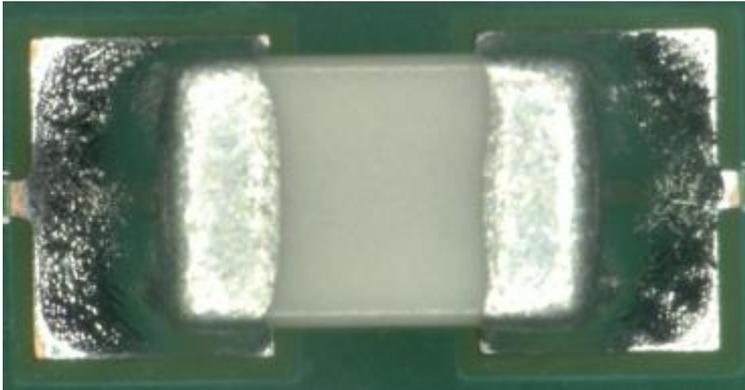
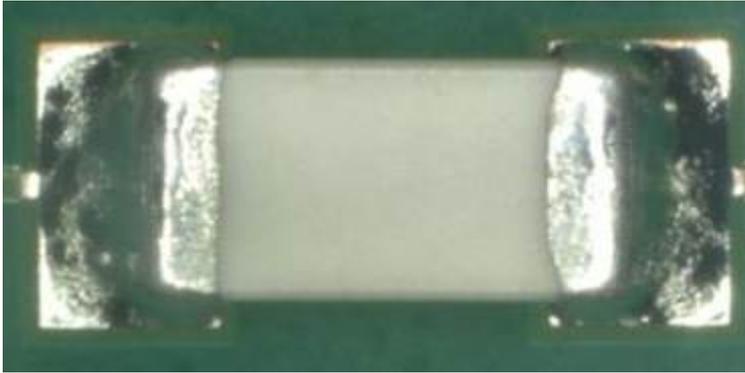
Visual Data Findings

- Rinse Solvent Cleaned

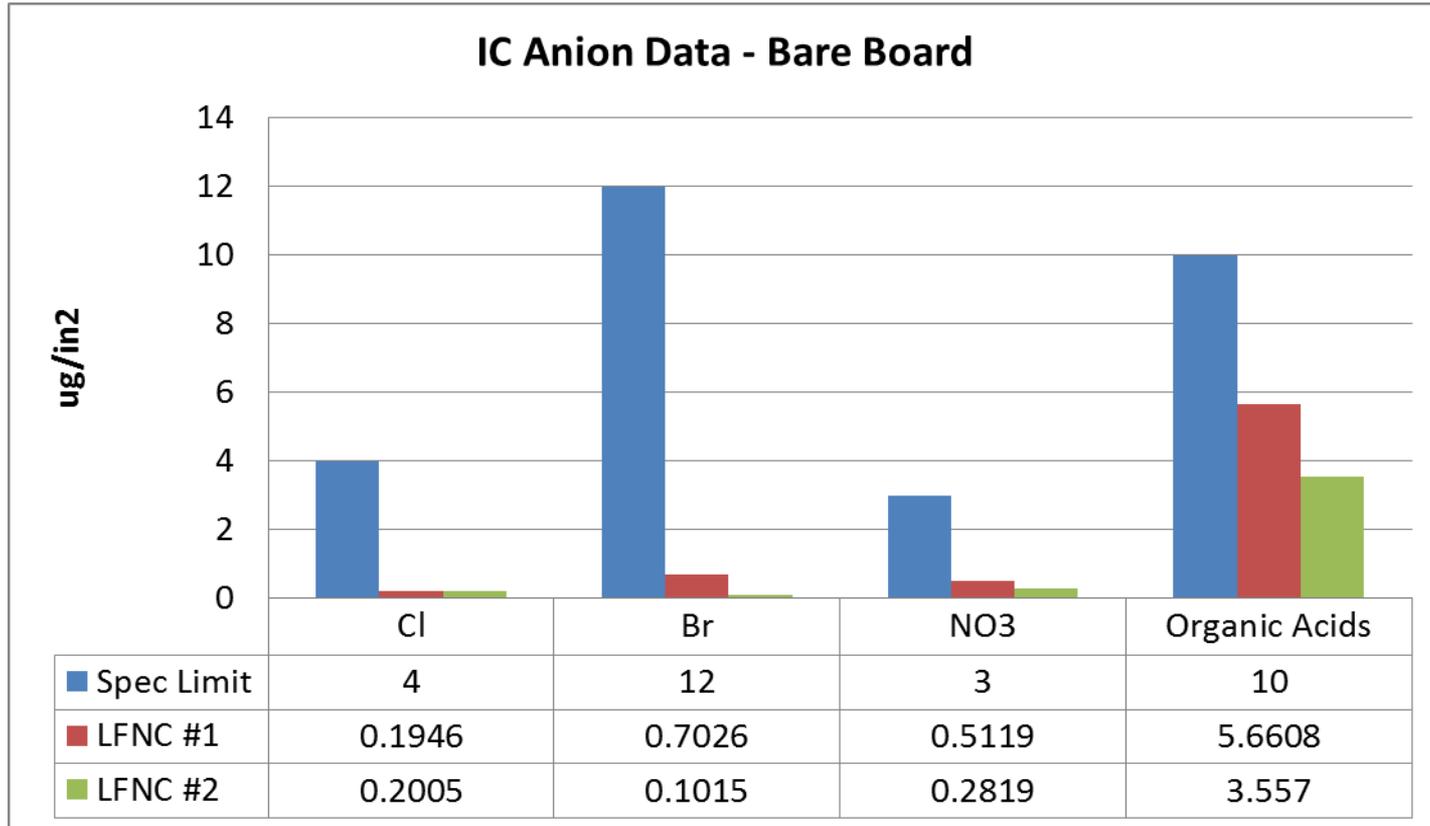


Visual Data Findings

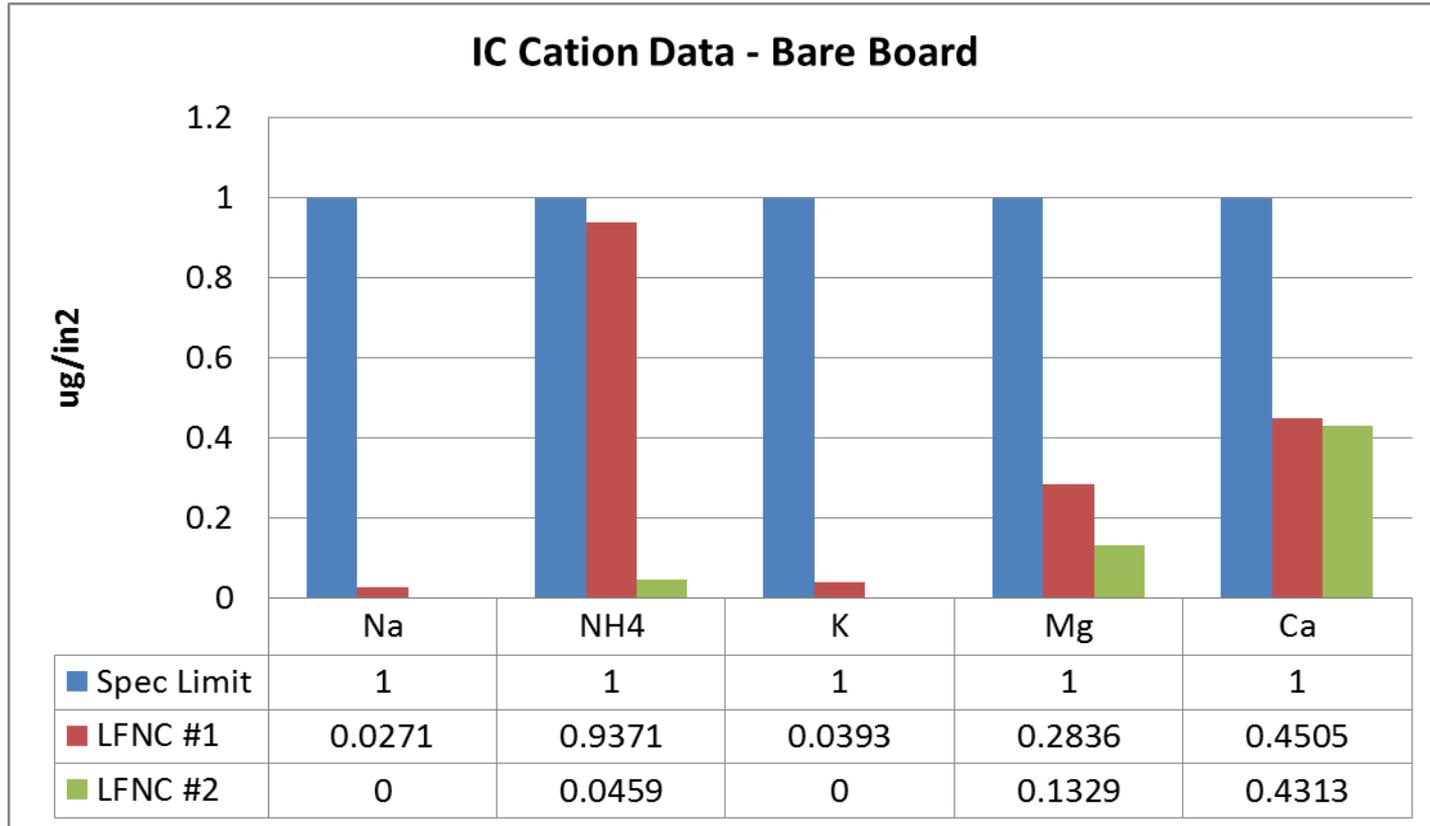
- Duo-Solvent Cleaned



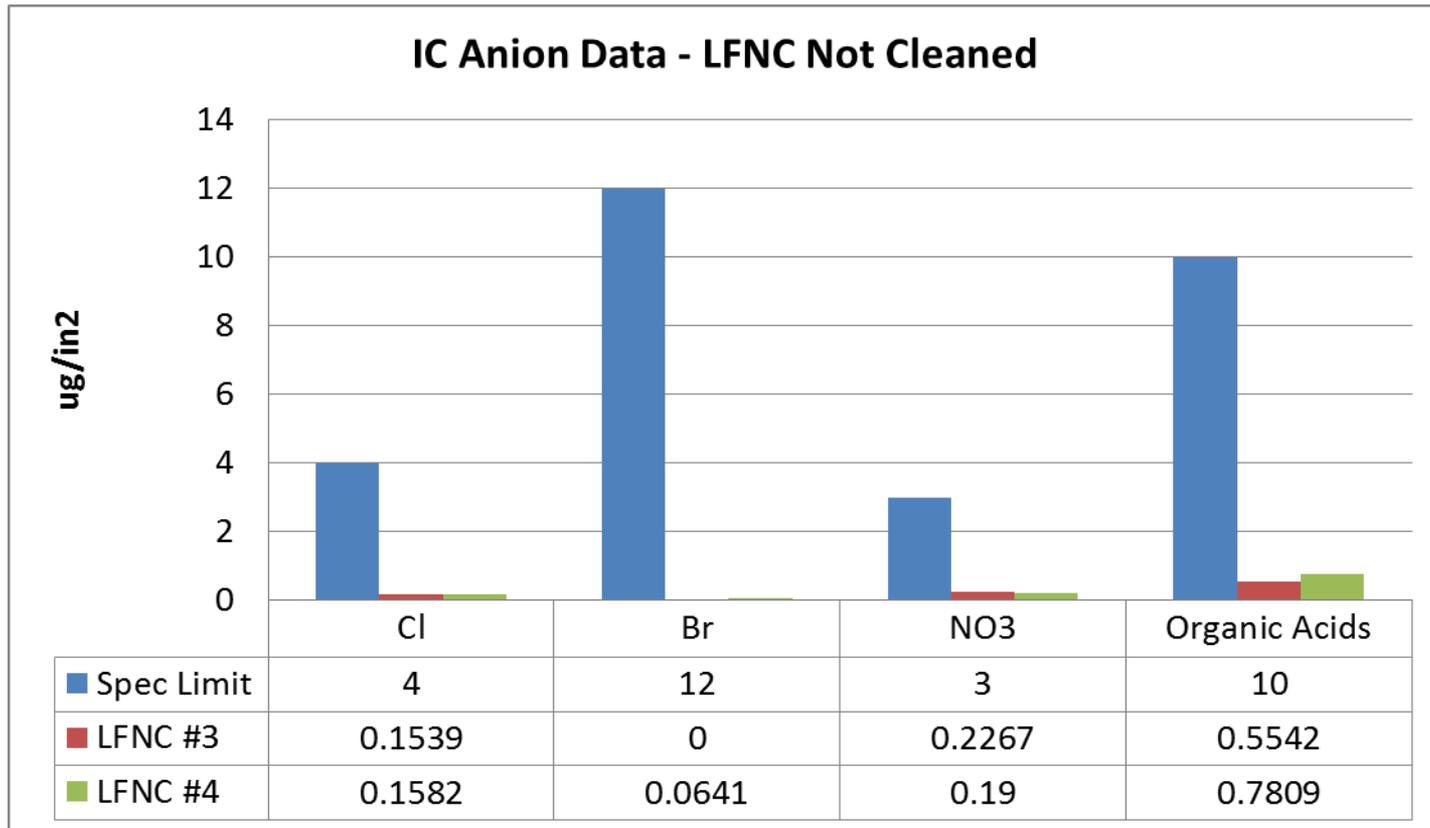
Lead Free NC ~ Bare Board



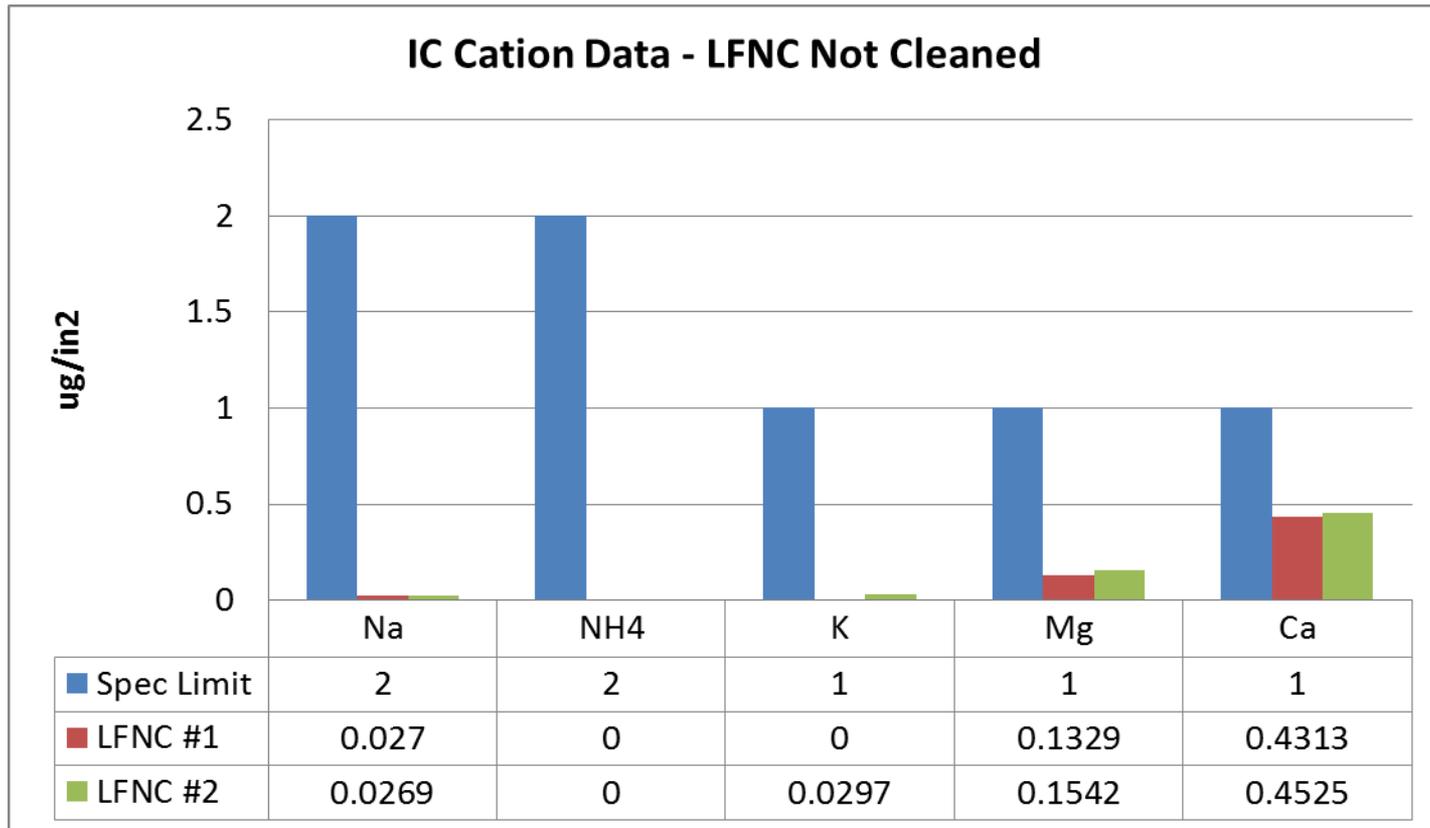
Lead Free NC ~ Bare Board



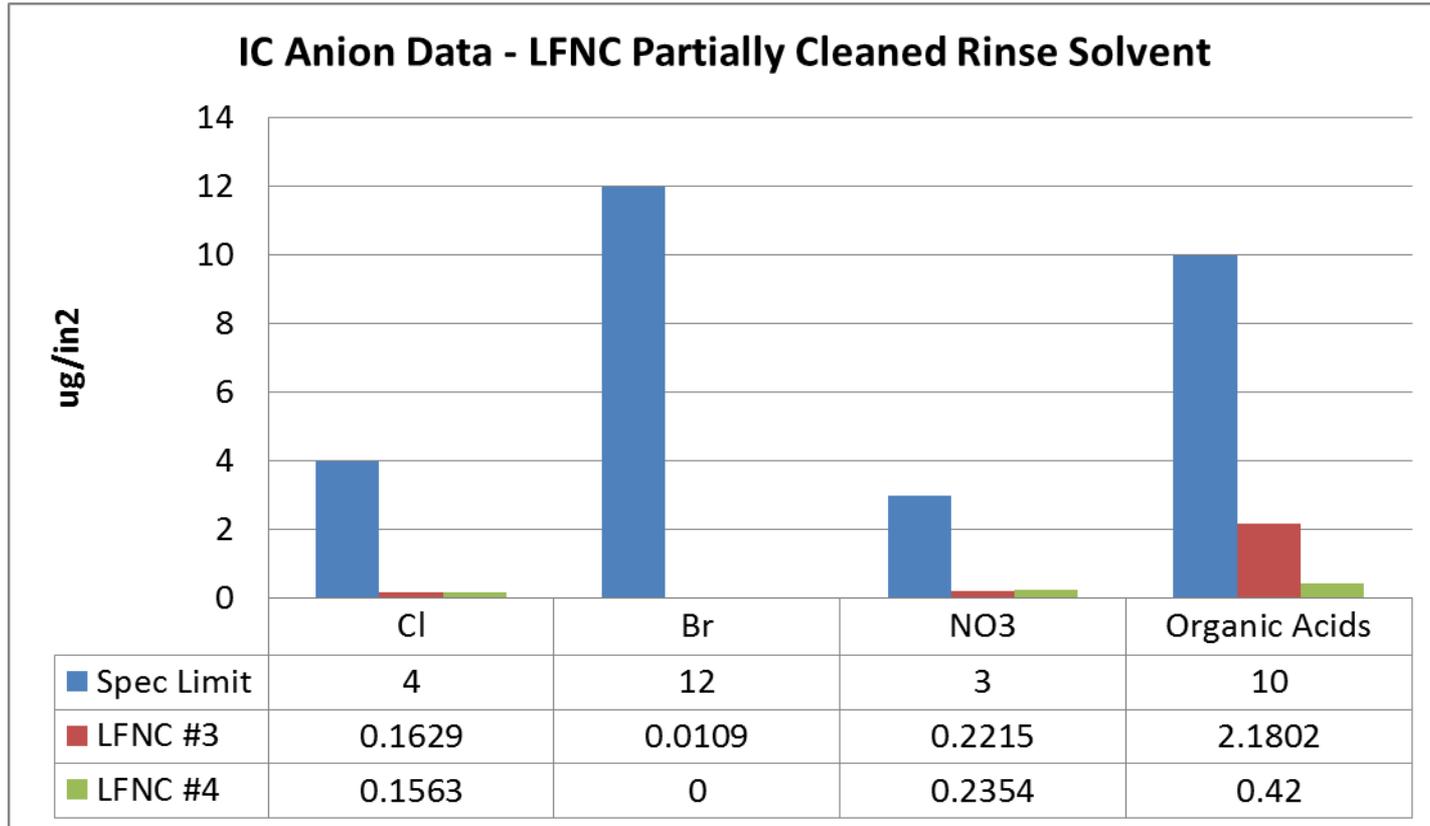
Lead Free NC ~ Not Cleaned



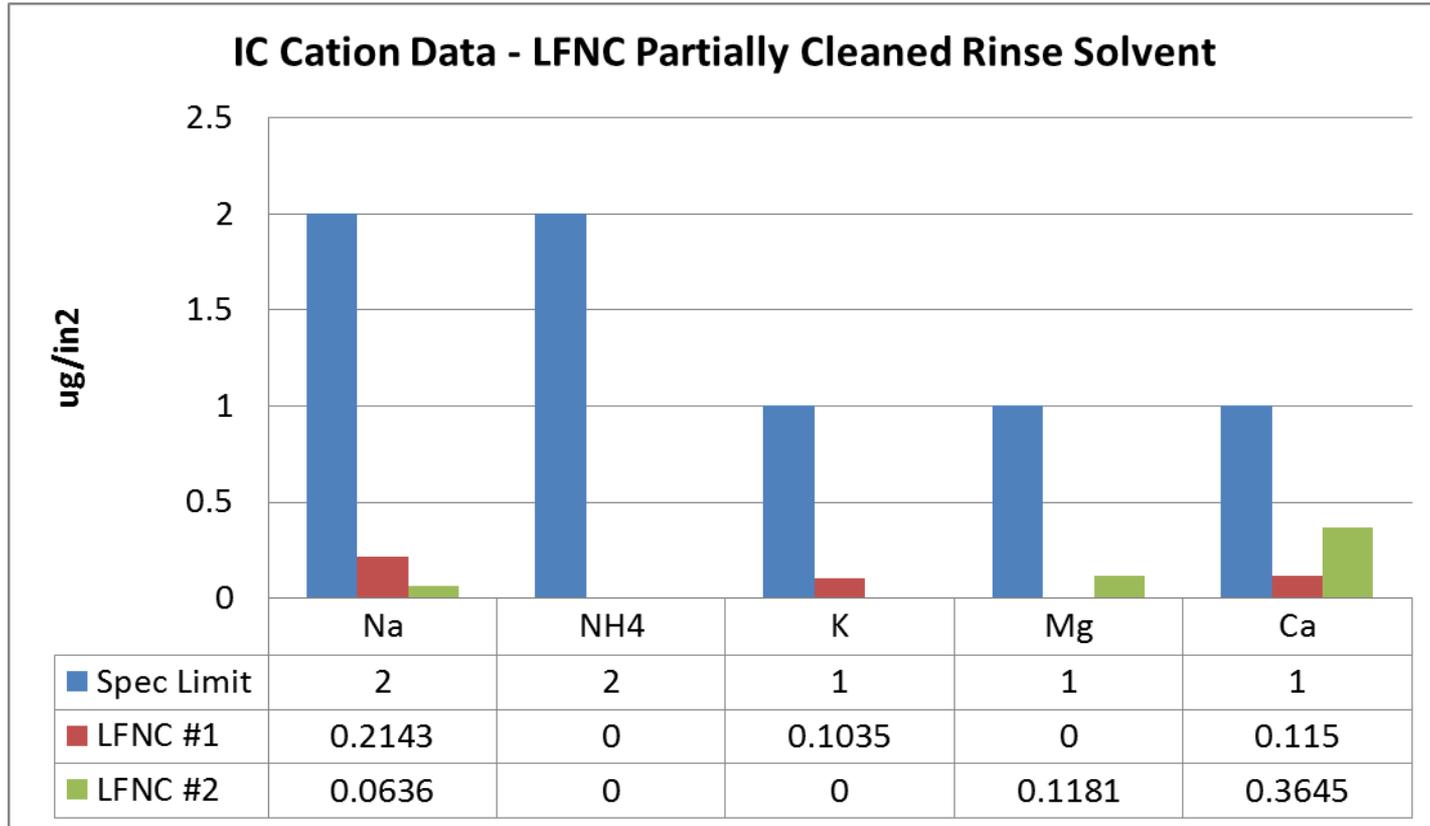
Lead Free NC ~ Not Cleaned



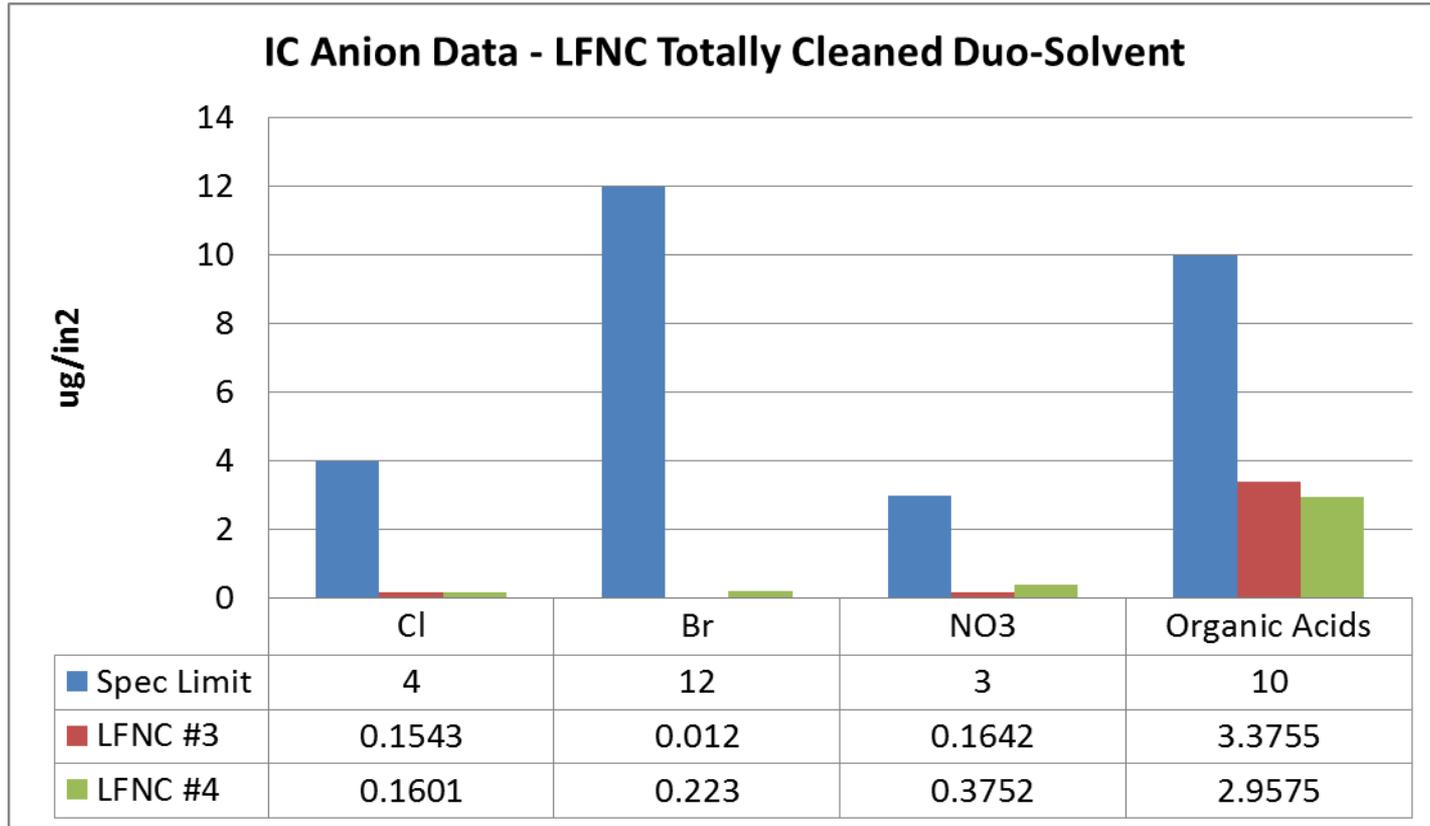
Partially Cleaned Rinse Solvent



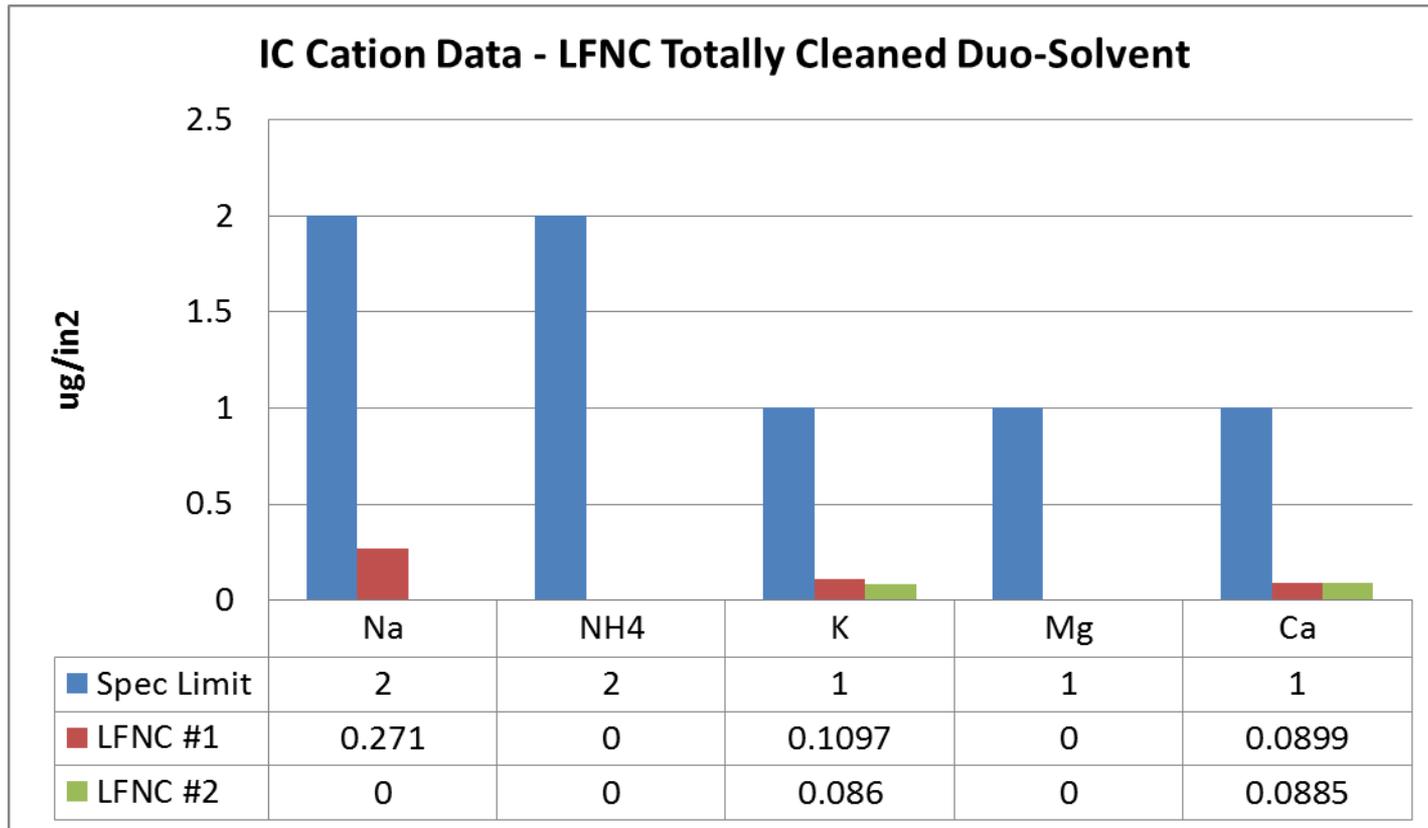
Partially Cleaned Rinse Solvent



Cleaned Duo-Solvent



Cleaned Duo-Solvent



Surface Insulation Resistance (SIR)



- Used to determine the propensity of a material and how the material is processed to lead to an electrochemical event (Ex. Corrosion, dendrites or leakage)
- Test is carried out under specified environmental and electrical conditions
 - Elevated temperature and humidity conditions ~ such as 85°C/85% RH and 40°C/90% RH with periodic insulation resistance (IR) measurements obtained
 - For this evaluation the test was performed using IPC-TM-650, method 2.6.3.7 with a slight modification.
 - (40 C / 90% RH; 5 VDC bias; 7 Day test and 14 Day test -20 minute measurement intervals)
 - Note: Two sets of test conditions are represented in this presentation. One set was ran from the traditional 7 days and other for 14 days

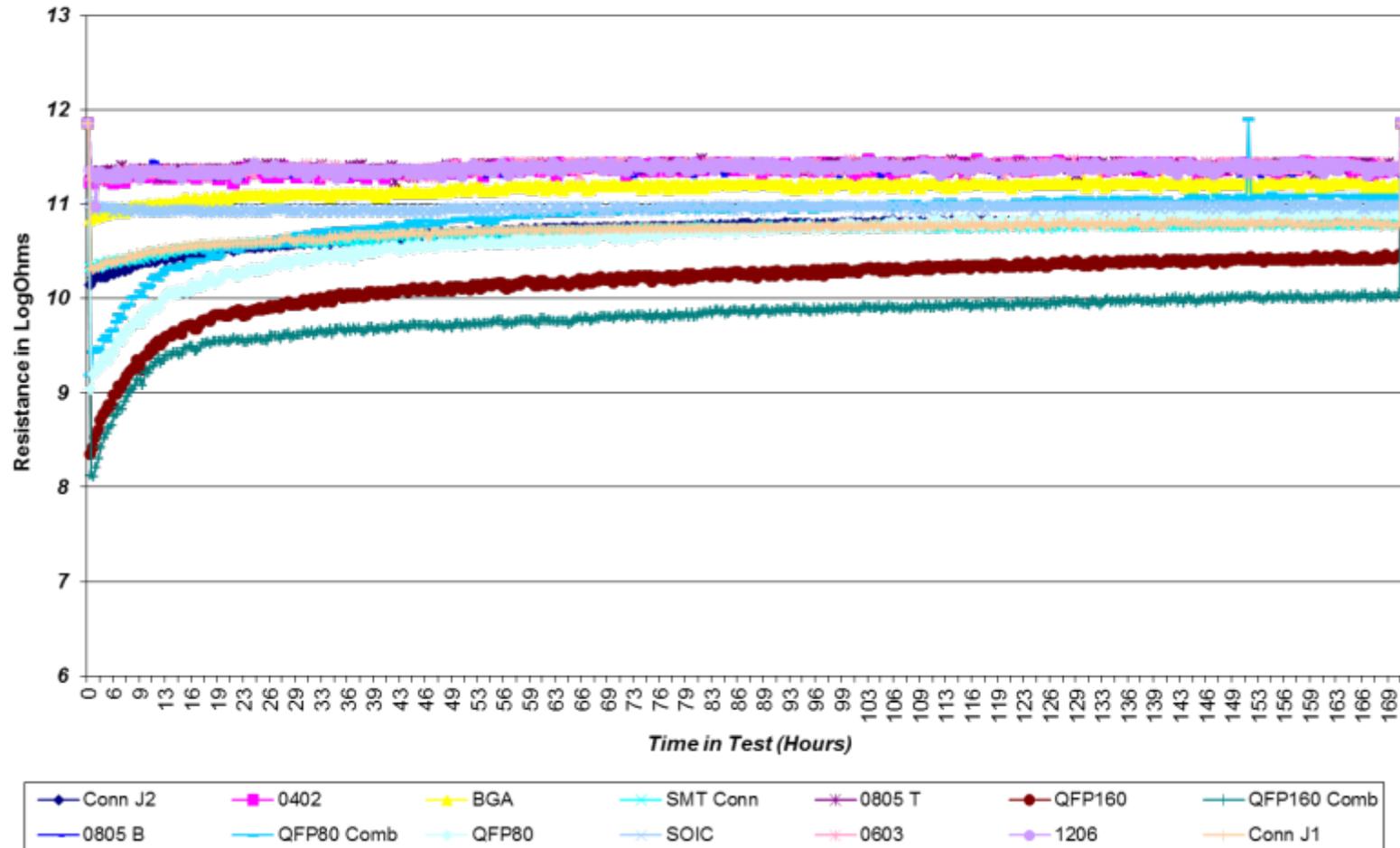
SIR Data Findings



- Important test in determining
 - Electrical reliability impacted by flux residues / ionic contaminants
 - Conductive / corrosive nature of residues
 - Formation of dendrites and/or leakage issues
- Passing measurements
 - Measurements exceeding 100 M Ω (1.0E+08 Ohms or 8.0 LogOhms) for processed test boards
 - Measurements exceeding 1000 M Ω (1.0E+09 Ohms or 9.0 LogOhms) for unprocessed control boards.

Unprocessed Control \sim 7 Days

B52 SIR - Board S/N 2 (Unprocessed Control)



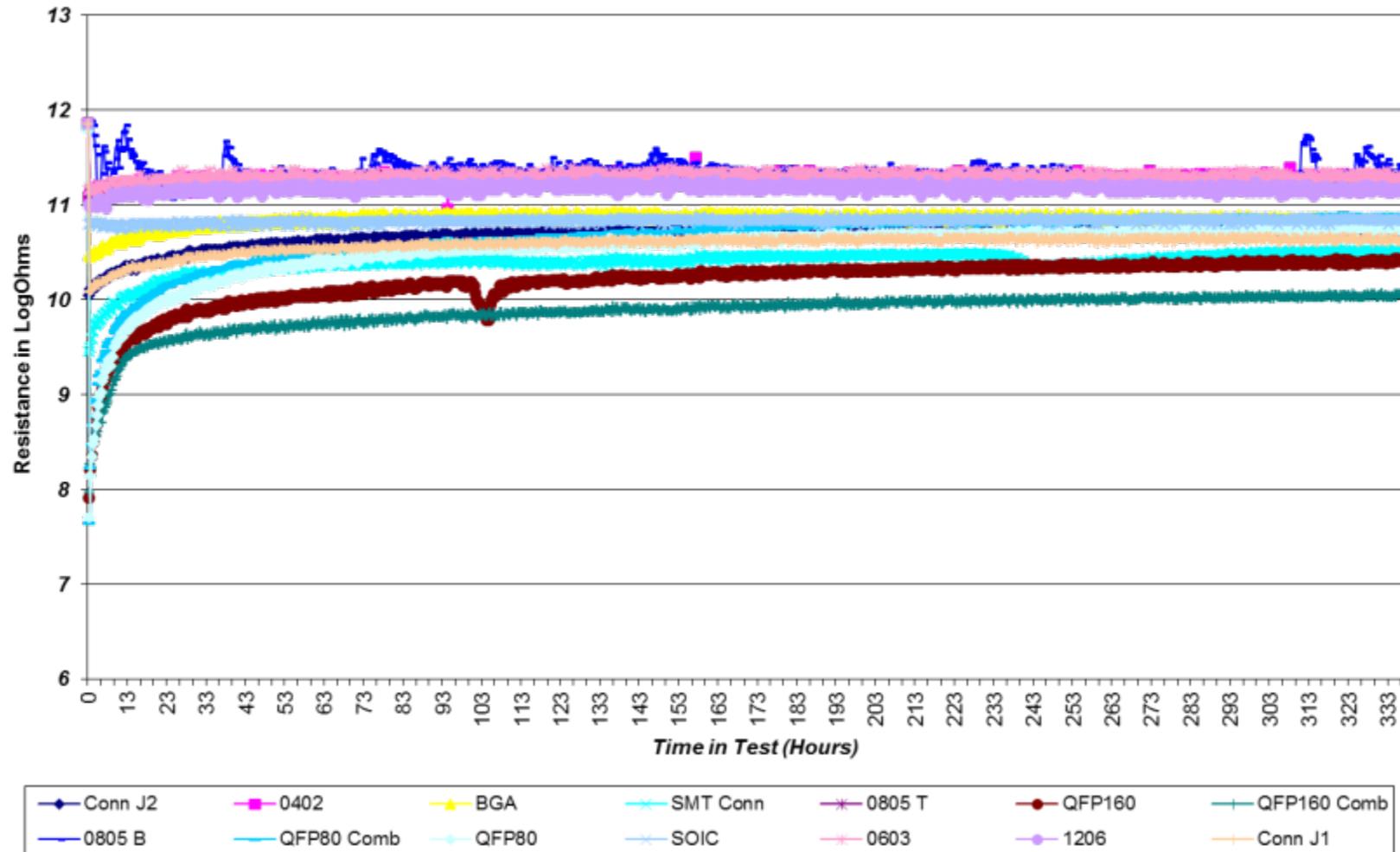
Unprocessed Control Data Findings



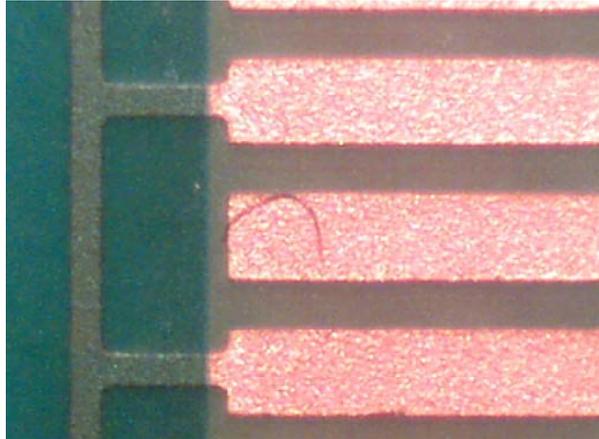
- All test patterns maintained well above 1000 M Ω limit
- Test board was adequately clean for use in this study
- Visual inspection is pending.

Unprocessed Control ~ 14 Days

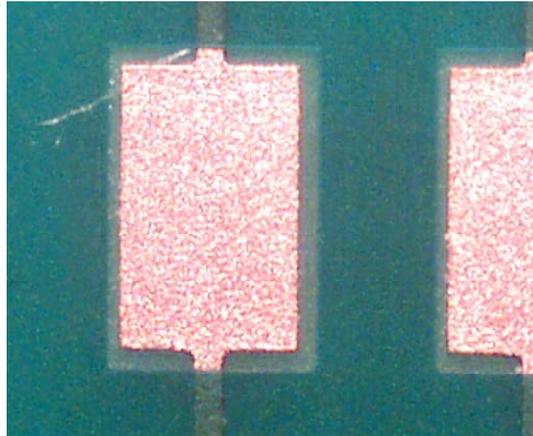
B52 SIR - Board S/N 1 (Unprocessed Control)



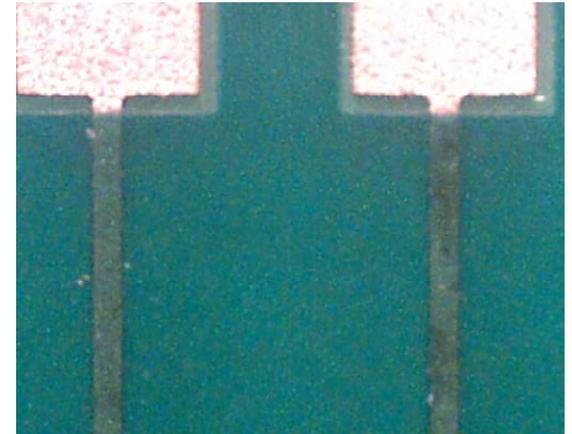
Unprocessed Control – Comments



A. QFP160 – Fiber



B. 0805T - Fiber

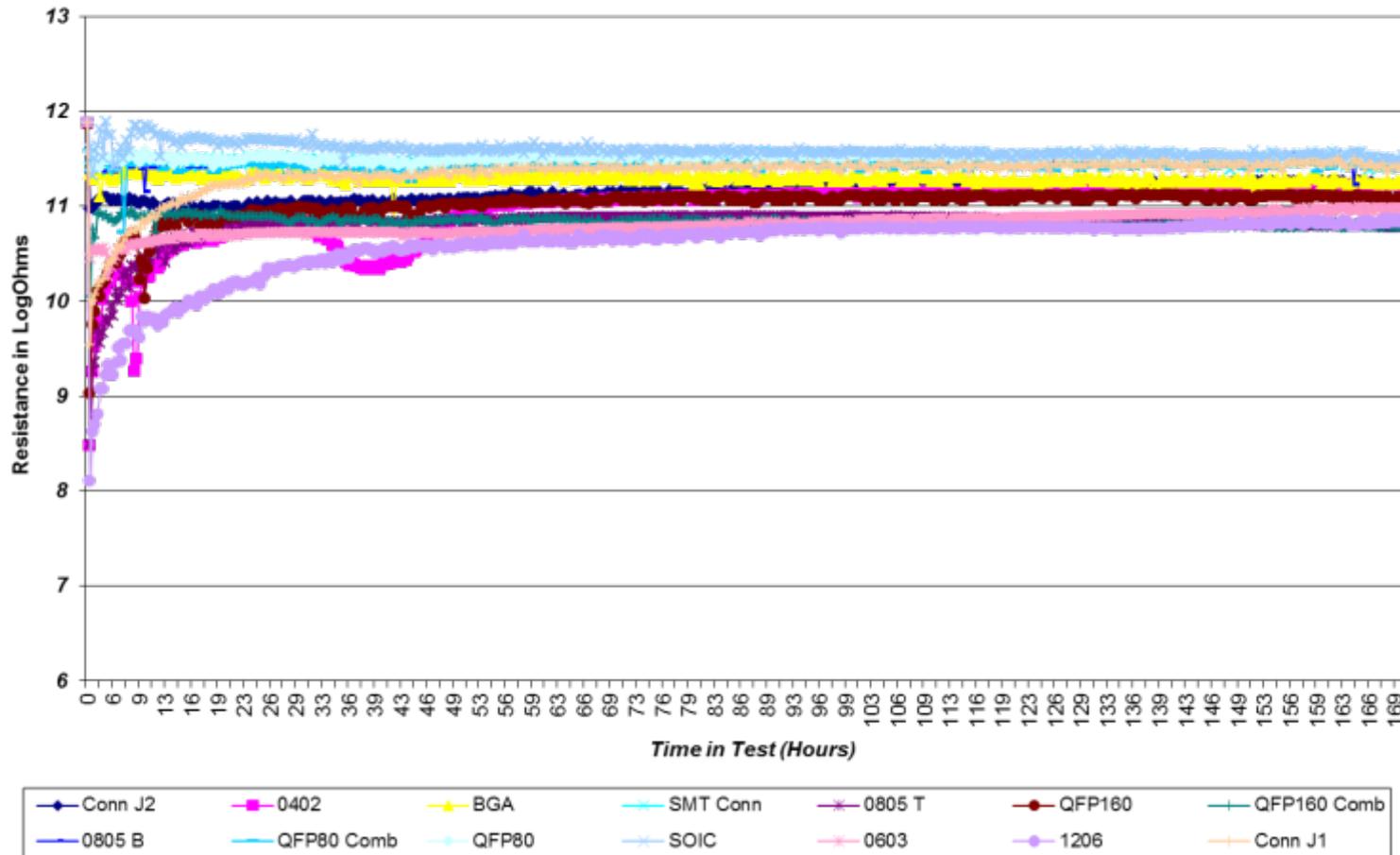


C. 0805T – Trace discoloration

- Overall SIR data for the control boards looks good. The data grouping was tight and maintained well above the 1000 M Ω limit.
- The QFP160 data dropped approx. 101 hours into test, but recovered. A fiber (A) was observed, but no other visual anomalies were noted.
- The 0805B (bottom side) showed erratic behavior throughout test. A fiber (B) was noted and was plated over. Additionally solder mask over traces was discolored (C) on one side of the pattern.
- No evidence of any water spotting, corrosion or dendritic activity.

Lead Free NC – Not Cleaned- 7 days

B52 SIR - Board S/N 4 (Lead-Free NC; Not Cleaned)



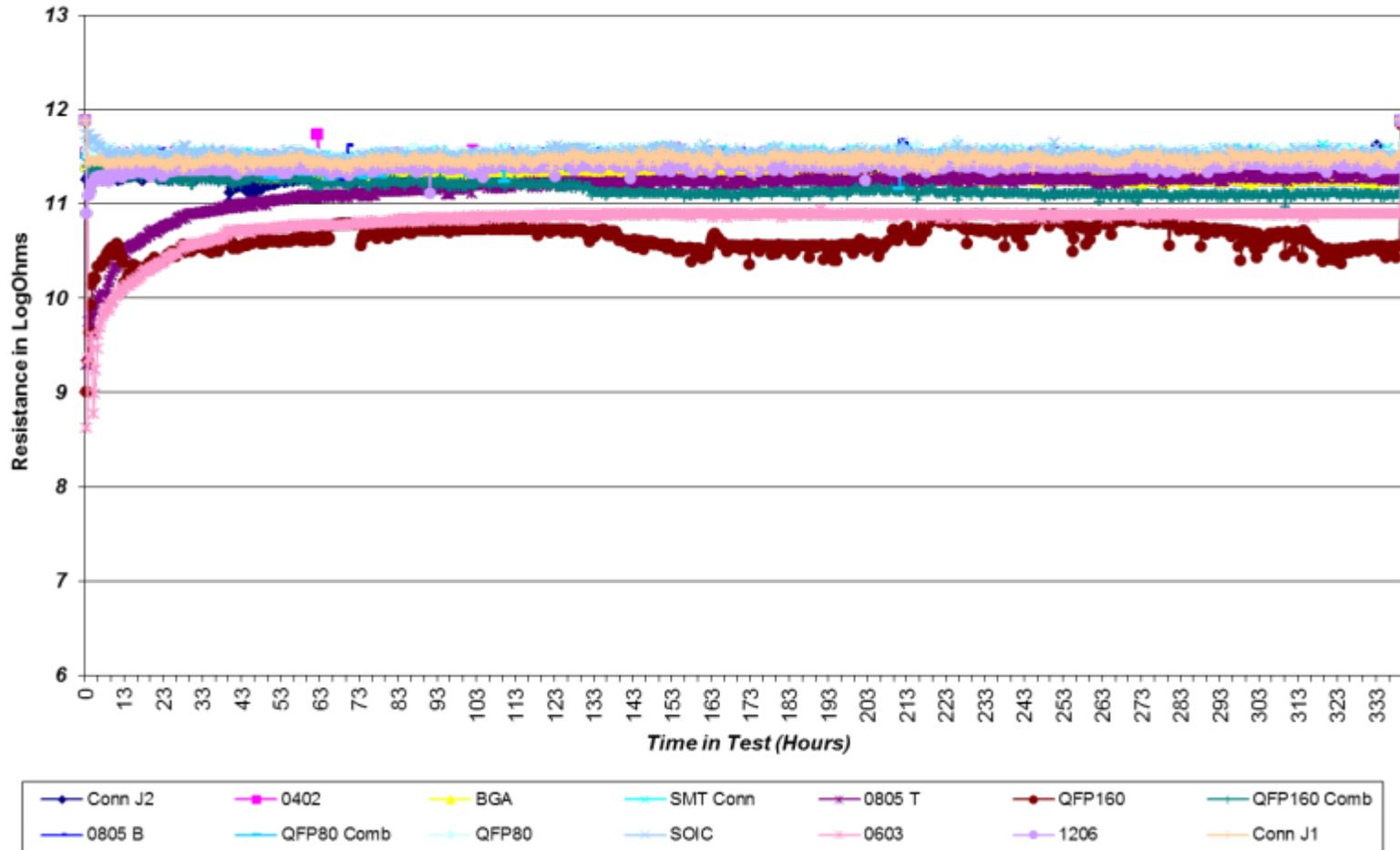
Lead Free Not Cleaned ~ 7 Days



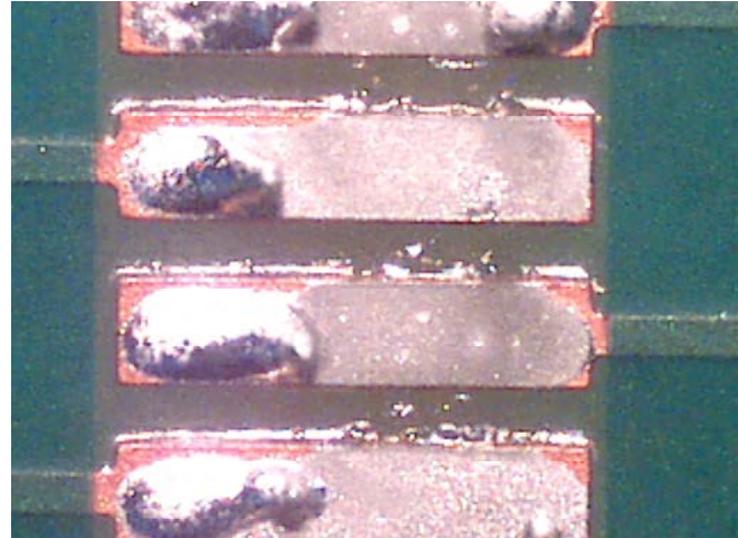
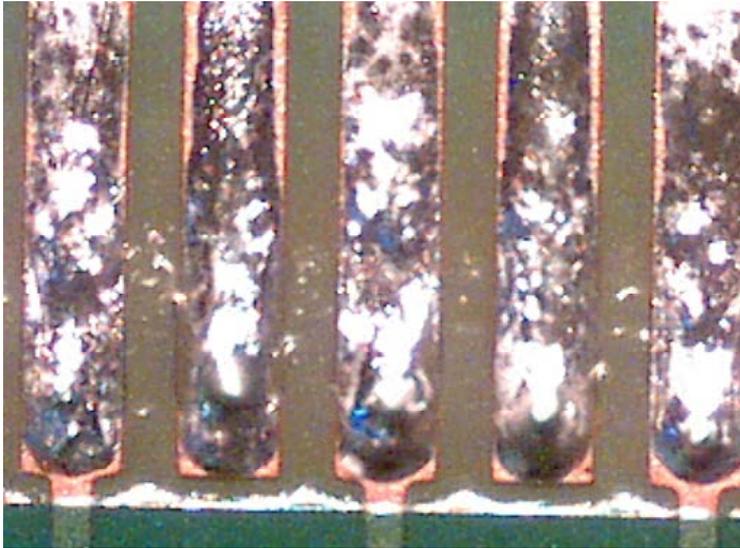
- All patterns maintained well above the 100 M Ω limit beyond 24-hour grace period
- Data variability that is observed during first few hours of test is due to acclimation of the test board and material. This is common.
- Data very tightly grouped beyond 49 hours and is very stable
- Visuals are pending.

Lead Free NC – Not Cleaned- 14 days

B52 SIR - Board S/N 3 (Lead Free NC; Not Cleaned)



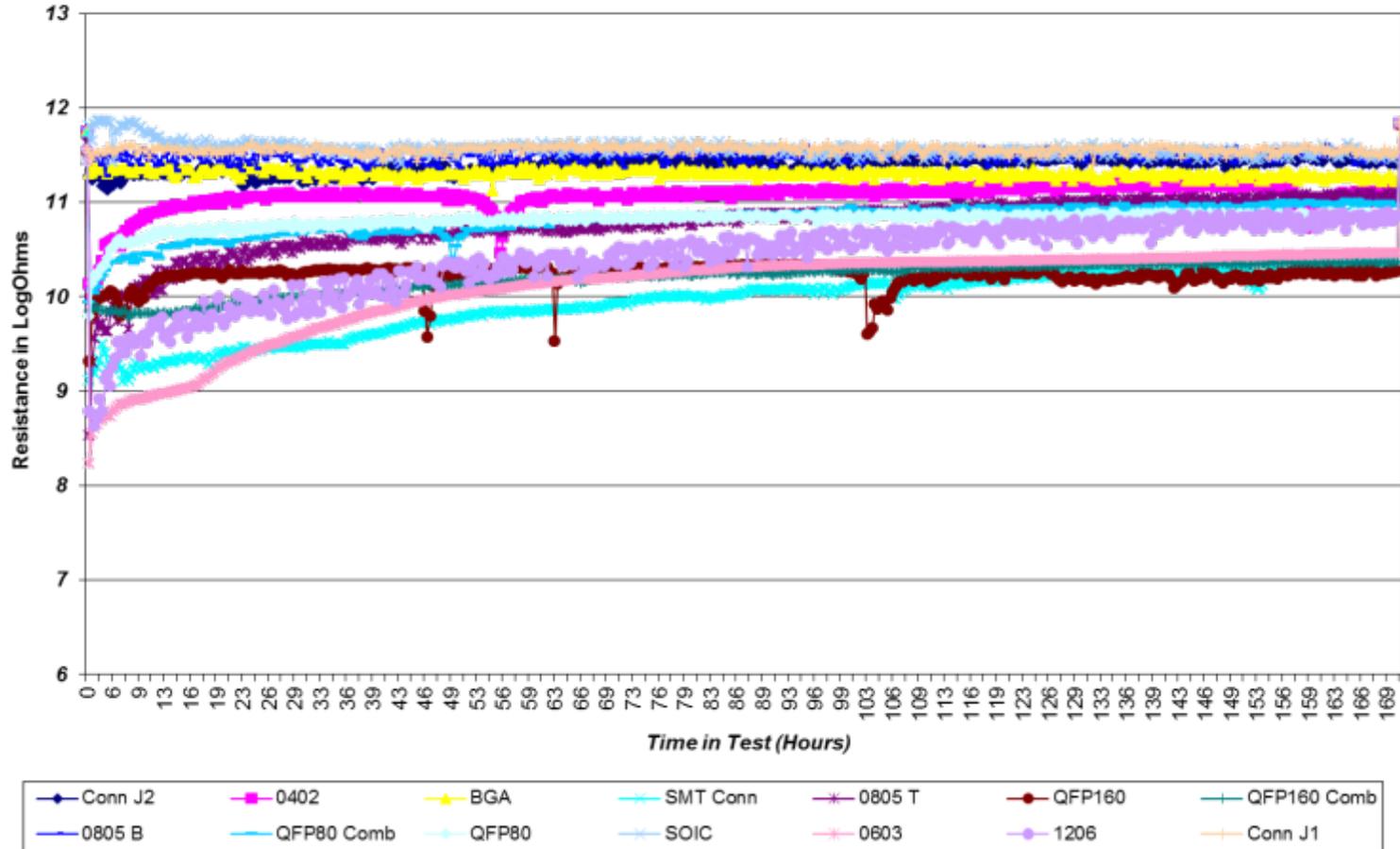
Lead Free NC (Not Cleaned) – Comments



- The uncleaned NC board showed good SIR levels overall well above the 100 M Ω limit. The data was somewhat erratic, which is likely due to the presence of flux residues.
- The QFP160 was the lowest trending pattern on the board and also showed the most pronounced erratic behavior.
- The photographs above show the flux residue that was observed and noted around the entire component.
- There was no evidence of any water spotting, corrosion or dendritic activity noted.

Solvent Rinsed – Partially Cleaned

B52 SIR - Board S/N 8 (Lead Free NC; Partially Cleaned, Solvent Rinse)

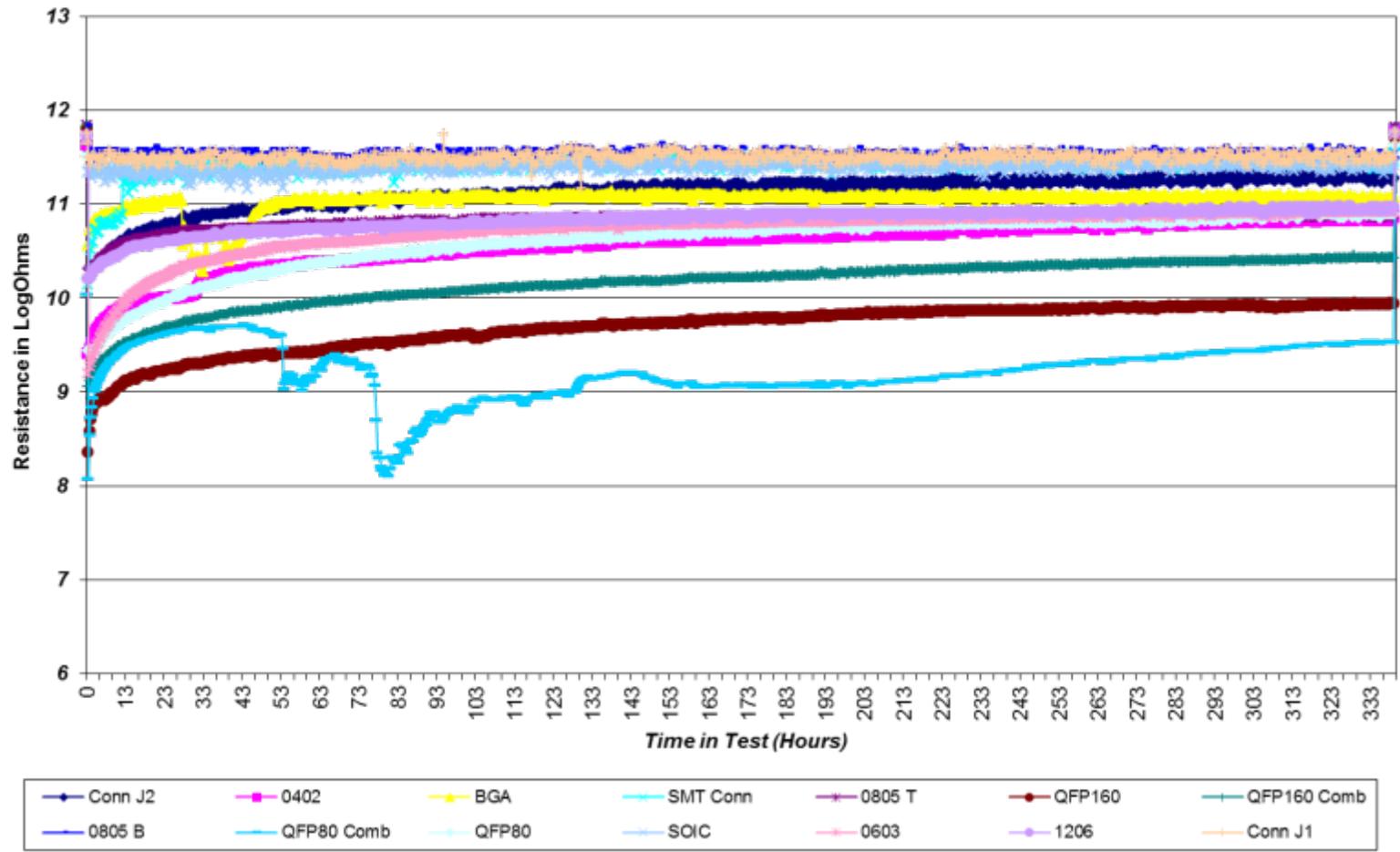


- Pattern data maintained above 100 M Ω limit.
- However, considerably more variability than previous aqueous.
 - Patterns QFP160 comb, 1206 cap field and 0402 cap field show more erratic performance.
 - Since the parts were rinsed only in the solvent and not cleaned in solvating agent, more white residue remained. White residues contributed to erratic performance.
- Visuals are pending.

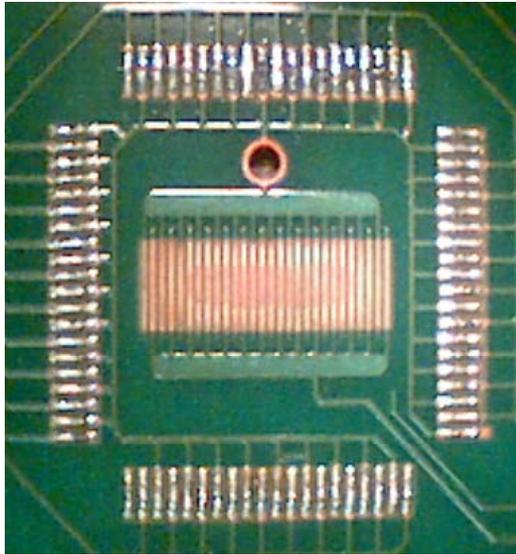
Duo Solvent 14 Days Rinsed – Partially Cleaned



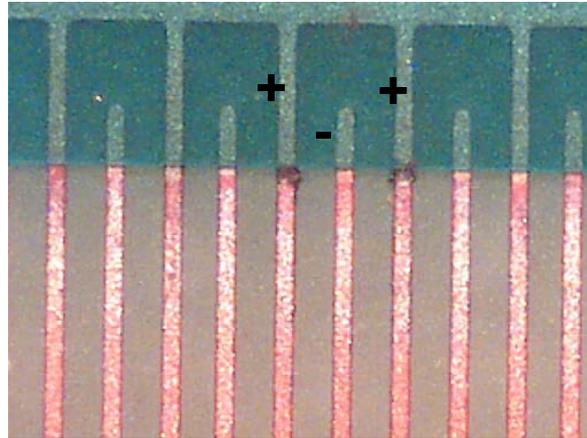
B52 SIR - Board S/N 7 (Lead Free NC; Partially Cleaned, Solvent Rinse)



Rinse Solvent Cleaned Comments



A. QFP80 Comb



B. QFP80 Comb
Possible Dendrites

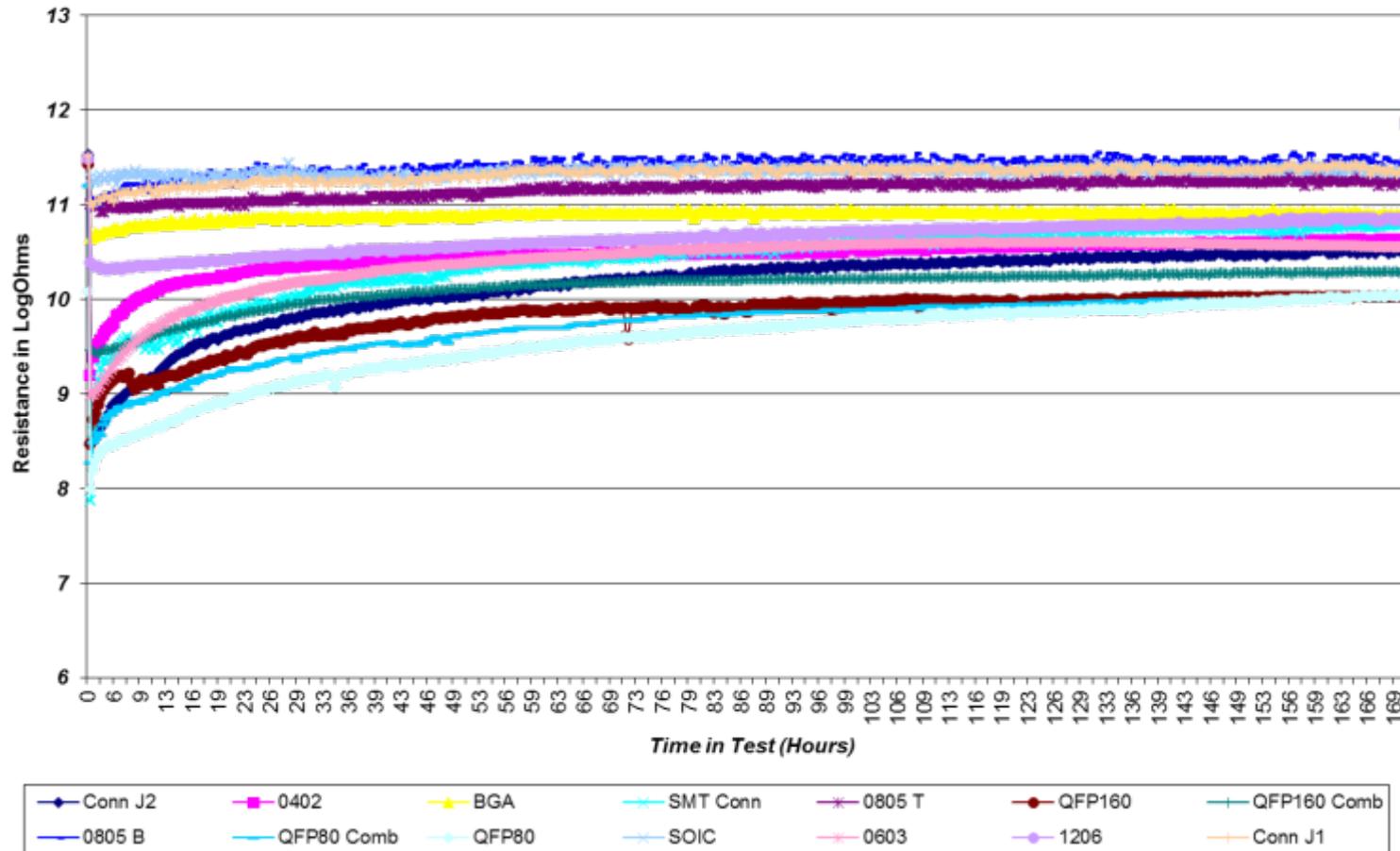


C. QFP80 Comb
Possible Dendrites
(Backlighting)

- Overall the board showed good SIR performance, except for the QFP80 comb.
- Visually, there was evidence of white residue left under the part. Photograph A shows an outline in the middle of the comb.
- Visually, there appeared to be possible dendrites present. The direction of the growths further suggests dendritic activity (See photo's B and C)

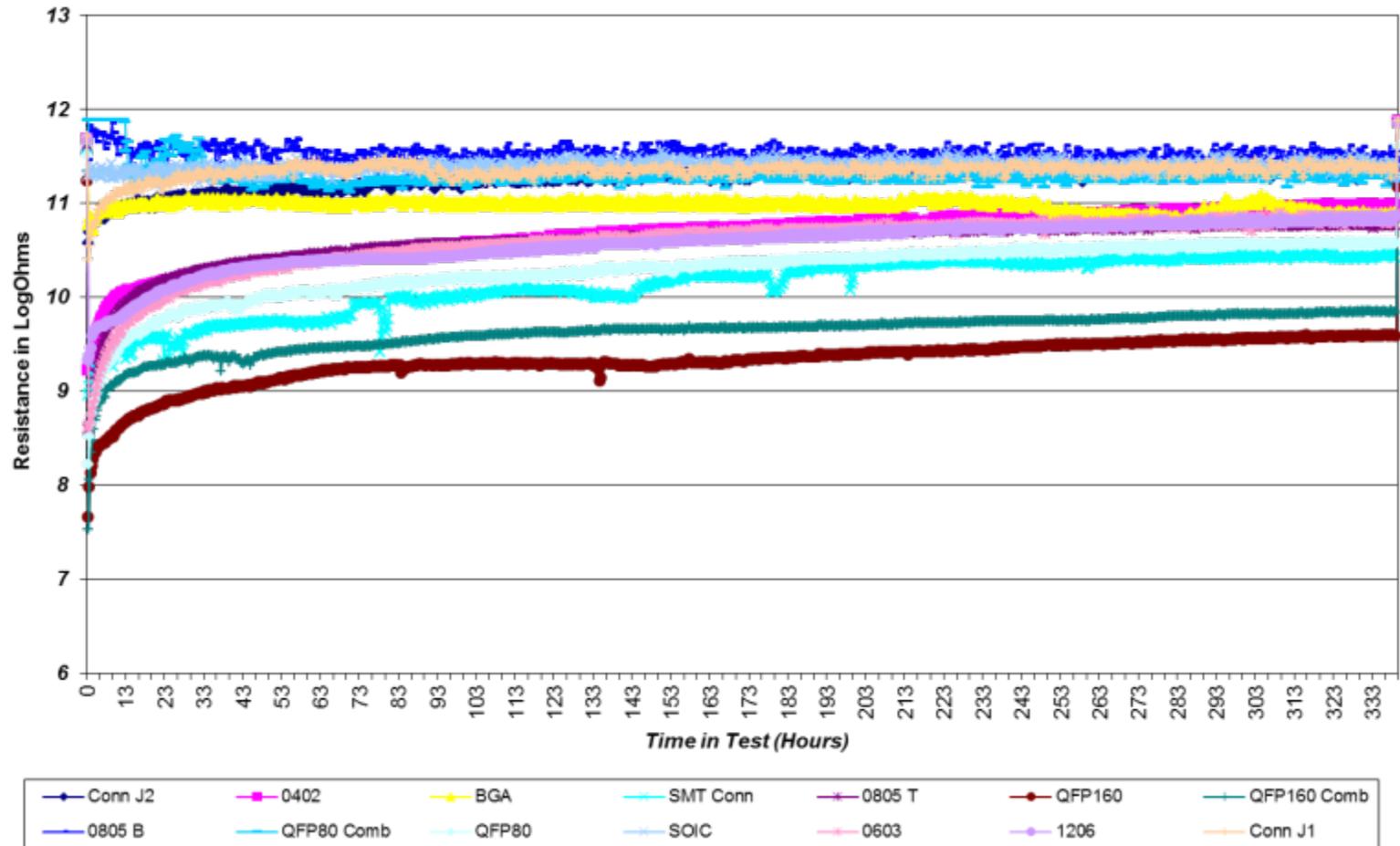
Duo Solvent – Clean – 7 days

B52 SIR - Board S/N 12 (Lead Free NC; Totally Cleaned, Duo Solvent)



Duo Solvent – Clean – 14 days

B52 SIR - Board S/N 11 (Lead Free NC; Totally Cleaned, Duo Solvent)



Duo Solvent – Clean Comments



- Overall the data was good and maintained well above the 100 M Ω limit.
 - S/N 12 showed better data stability. The variation observed in the two samples may be an indication of process / material variability. Starting board cleanliness may also be at work in the data.
- The SMT Connector on S/N 11 had some intervals where the data jumped around. Visually, the only item observed was some very mild process debris (see the photo above). There was no evidence of any water spotting, corrosion or dendritic growth.

INFERENCES FROM DATA FINDINGS

SIR Electrical Testing



1. Unprocessed boards
 - Both were adequately clean
 - Met the minimum SIR requirements to pass the test.
2. Lead Free NC ~ not cleaned
 - Overall good electrical resistivity when left uncleaned. Some data variability observed, especially in the QFP160 location.
 - The second board (S/N 4) showed better overall SIR performance, less data variability. This suggests potential process variability.
 - Met the minimum SIR requirements to pass the test.

Duo-Solvent



1. Duo-Solvent Rinse cleaned
 - The QFP80 comb of S/N7 saw some loss in resistivity but recovered
 - The cause appeared to be white residue next to component terminations. Possible dendritic activity led to lower resistance levels.
 - Most patterns met the minimum SIR requirements to pass the test.
2. Duo-Solvent Totally cleaned
 - Some data variability was observed across several components. The SMT Connector showed the most pronounced variability, but maintained above the defined limit.
 - QFP160 values passed but trended lower than other values
 - Met the minimum SIR requirements to pass the test.

RESEARCH CONCLUSIONS

Summary



- Duo Solvent Process
 - Flux compositions are multi compositional soils
 - Cleaning fluids require a combination of dispersive, polar and hydrogen bonding forces
 - Engineered cleaning fluids designed to
 - Clean multi-compositional flux residues
 - Rinse with a high vapor pressure solvent composition
 - Provides a waterless solvent-based process for cleaning today's electronic assemblies
 - Effective at *removing* no-clean/Pb free flux residues
 - Rinse fluid is effective at
 - Removing drag-out from wash process
 - Removes ionic residues during the rinse process

Thank You

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Appendix

- Solder Pastes on Slides 26 & 27

Alpha OM 338-PT

Alpha OM 340

AIM NC 258 R-15

Senju 1

Senju 2

Indium 8.9 HF1

AIM NC 258

Indium 9.72

Alpha RMA 390

Cobar SC5-XM55

Indium SMQ92J

Alpha RMA 9086

Indium 8.9 HF

AIM 520

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Thank you!

Questions