SIR Test Vehicles – Comparison from a Cleaning Perspective

Naveen Ravindran, Umut Tosun
ZESTRON Americas
Manassas, VA

Abstract
PCB design has evolved greatly in recent years becoming ever more complex. Board density is increasing, component standoff heights are decreasing and long term reliability requirements are greater than ever, particularly for Class III products. Given the quality and reliability demands for complex PCBs, manufacturing processes are qualified; that is, the PCB design, including component and solder paste/flux selection, material compatibility and process steps, must meet the long term reliability requirements demanded and quality standards desired. As a result, cleaning is becoming a mandatory step within the manufacturing process.

Analytical tests are key elements to any qualification process. Through the IPC, numerous tests have been developed and have been added to industry standards. In particular, IPC-TM-650, method 2.6.3.7 or SIR (Surface Insulation Resistance) is frequently used regardless of the solder paste/flux type. Per the specification, this test can quantify the deleterious effects of fabrication, process or handling residues on SIR in the presence of moisture. Measuring changes in surface resistance is a standard way of testing cleanliness and long-term reliability of a test board or complete process assembly based on industry standards.

There are numerous test vehicle options available to the industry for conducting SIR analysis. This study was designed to compare different SIR test vehicles, from a cleaning perspective, in order to determine which, test vehicle is tougher to clean and therefore challenge the cleaning process.

The three (3) test vehicles selected were the IPC-B-52, IPC-B-36 and the SMTA Saber. Each test vehicle was populated with specific components. The authors chose to reflow the test vehicles with water soluble solder paste only, since the high activity flux in the water soluble paste would increase the chance of SIR failure if left partially cleaned.

Multiple test vehicles were prepared. Cleanliness verification and validation was completed by visual inspection underneath all components as well as by performing SIR tests. All test vehicles were cleaned prior to reflow and ion chromatography was conducted on selected test vehicles initially to ensure they were free of any ionics. An inline cleaning process was used for all cleaning trials.

Keywords:
Surface Insulation Resistance, Qualification Process, PCB Cleanliness Assessment, Reliability

Introduction
Why employ SIR testing in the first place? As the complexity of PCBs increases, so does required product reliability. As an OEM or CM, SIR has become a standard test mechanism by which to qualify a process. Essentially, SIR testing is performed for one of three reasons [1]:

- As part of a qualification or classification of a product
- To evaluate or control a process
- To compare materials or processes

Considering the purpose of SIR, and the fact that numerous vehicles are available for conducting the test, what criteria should be used to select the SIR test vehicle? One must note that each vehicle includes different component types and in one case, enables evaluating through hole fluxes in addition to surface mount solder paste/flux.

Even though numerous SIR test vehicles are available, only a select few are used to assess effectiveness of a cleaning process. In order to provide the best opportunity for a differentiating result, the authors chose a high activity water soluble flux. Furthermore, they chose to clean the boards using a spray-in-air inline cleaning system with DI-water. As the selected solder paste was water soluble, using DI-water for the cleaning media was expected to result in cleanliness assessment meeting industry standards.

The study was designed in two phases whereby through Phase 1, the authors would establish cleaning process operating parameters and through Phase 2, utilize the Phase 1 cleaning parameters to prepare the vehicles for the SIR analysis. In Phase 1, the authors chose to assess cleanliness by visual inspection underneath all component types. In order to ensure variation in the cleaning results, the test protocol developed included operating the conveyer belt at speeds ranging from 1 ft/min to 4 ft/min. Ideally, it was attempted to establish cleaner operating parameters resulting in a “best case” or fully cleaned under all component types and “worst case” or partially cleaned residues under all component types.

In the Phase 1 trials, the authors anticipated that DI-water alone would not fully clean underneath the components at the accelerated conveyor belt speeds [2]. Thus, as a comparator, we chose to duplicate the cleaning trials using an engineered aqueous based cleaning agent within the cleaning process.

Within the Phase 2 trials, the best case and worst case cleaning trial parameters was chosen to prepare the test vehicles for the SIR analysis.

Methodology
The main objective of the study was to compare three commonly used SIR test vehicles that are available within the industry focusing on the ease and/or difficulty of cleaning them under similar process conditions. Based on the cleanliness results achieved, the effect if any on SIR test results for each vehicle type would be assessed.

The SIR test vehicles used were the IPC-B-52 (Figures 1-3), IPC-B-36 (Figures 4-6) and the SMTA Saber (Figure 7). Each vehicle was screened using lead-free water soluble solder paste, 6 mil thick stencil and reflowed per the manufacturer’s recommendation. Figures 2 and 3 are representative pictures of low standoff chip cap components. For the SIR evaluation, each coupon type was populated as follows:

1. IPC-B-52 Rev B populated with:
   a. QFP160
   b. 0402SMC
   c. 0603SMC
   d. 0805SMC
   e. 1206SMC

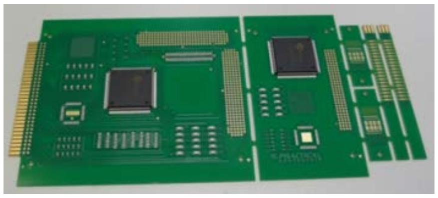


Figure 1. IPC-B-52

Figure 2. 0402 component

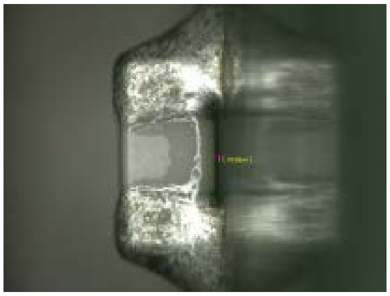


Figure 3. 0402 component standoff: 20 microns or 0.8 mil

2. IPC-B-36 populated with:
Four (4) 68LCC components

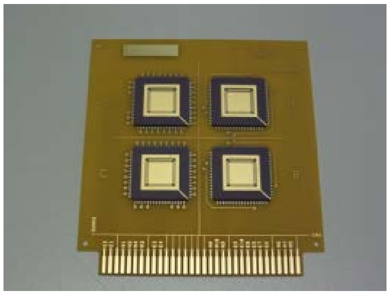


Figure 4. IPC-B-36 populated with 68LCC components

68LCC components

i. The 68LCC components were chosen for this board. The PLCC68 has a much higher standoff height and will not challenge the cleaning process.
ii. Patterns 1, 3, 5, 7 are comb structures located in the middle of the LCC component area.
iii. Patterns 2, 4, 6, 8 are external locations which could be on the perimeter of the component or between the leads of the component.

Figures 5 and 6 are representative pictures of standoff heights of PLCC and LCC components:

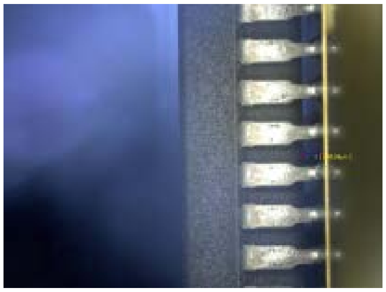


Figure 5. PLCC68 component standoff: 550 microns or 22 mil

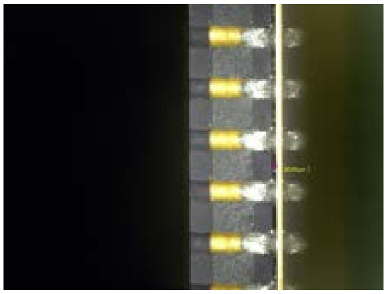


Figure 6. 68LCC component standoff: 80 microns or 3.2 mil

3. SMTA Saber Test board (Rev E) populated with:
a. QFP208
b. QFP100
c. 0402SMR
d. 0603SMR
e. 0805SMR
f. 1206SMR
g. PLCC68

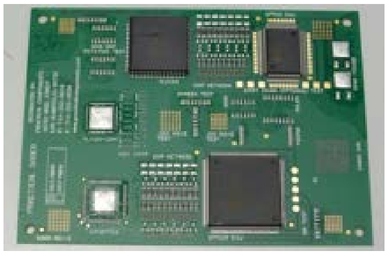


Figure 7. SMTA Saber Test Board

Standoff measurements could not be made on the SMTA Saber board due to the orientation of the chip components.

All SIR test vehicles were populated at an outside Institute and returned to the company technical center for cleaning and evaluation. All SIR tests were completed by an independent outside testing lab.

The study was conducted in two phases:

- Phase 1 Trials: Determine cleaning process operating parameters resulting in fully cleaned and partially cleaned coupons as verified through visual inspection underneath all components
    - Eight (8) coupons of each type or 24 coupons in total
- Phase 2 Trials: Utilize results from Phase 1 trials for best case and worst case cleaning scenarios and assess cleanliness through SIR analysis for each coupon type
    - Three (3) coupons of each type or 9 coupons in total

Phase 1 Visual Analysis

Through these trials, the authors identified the wash process parameters that would result in partially and fully cleaned vehicles as determined through visual analysis. In order to assess cleanliness, all components were sheared off enabling visual assessment underneath the components.

The cleaning process parameters were selected based on the authors' field experience. With the exception of conveyor belt speed, all inline cleaning parameters remained constant for all trials. Reference Table 1 for cleaning process parameter details:

Table 1. Cleaning Process Parameters

Wash Stage	
Equipment	Spray-in-air inline cleaner
Cleaning Agent	• DI-water • Dynamic Surfactant Cleaning Agent (5%) concentration
Wash Spray Configuration	8 spray bars standard intermix
Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI
Wash Pressure (Top/Bottom)	75 PSI / 60 PSI
Wash Hurricane Pressure (Top/Bottom)	40 PSI / 40 PSI
Wash Temperature	140°F / 60°C
Chemical Isolation Pressure (Top/Bottom)	30 PSI / 25 PSI
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	80 PSI / 70 PSI
Rinse Hurricane Pressure (Top/Bottom)	40 PSI / 40 PSI
Rinse Temperature	140°F / 60°C
Final Rinse Pressure (Top/Bottom)	25 PSI / 25 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Temperature (D1)	160°F
Drying Temperature (D2)	180°F
Drying Temperature (D3)	180°F

Four (4) conveyor belt speeds were considered for each vehicle type. Thus, a total of twenty-four (24) populated test vehicles were required for this phase of the study. In total, eight (8) trials were conducted. Reference Table 2 for details.

Table 2. Belt Speeds

Trial #	Cleaning Agent	Wash Temperature (°F)	Belt Speed (ft/min)	Board Type
1	DI-water	140	1	IPC-B-52
				IPC-B-36
				SMTA Saber
2			2	IPC-B-52
				IPC-B-36
				SMTA Saber
3			3	IPC-B-52
				IPC-B-36
				SMTA Saber
4			4	IPC-B-52
				IPC-B-36
				SMTA Saber
5	Chemistry A (5%)	140	1	IPC-B-52
				IPC-B-36
				SMTA Saber
6			2	IPC-B-52
				IPC-B-36
				SMTA Saber
7			3	IPC-B-52
				IPC-B-36
				SMTA Saber
8			4	IPC-B-52
				IPC-B-36
				SMTA Saber

Within Phase 1 of this study, eight (8) fully populated vehicles of each type were cleaned utilizing the spray-in-air inline cleaning system. Four (4) coupons were cleaned with DI-water and four (4) with aqueous based cleaning agent.

Phase 1 Results

The components were sheared off of all test vehicles followed by an evaluation of cleanliness underneath components. Overall cleanliness percent of the board was taken as the percent of components that were completely clean underneath. Thus, a fully cleaned surface was determined to be "best case" and highest percent residues remaining underneath the component were determined to be "worst case."

- Best case: Settings that yield 100% cleanliness result for all test vehicle types
- Worst case: Settings that yield the lowest cleanliness result for all test vehicle types

Once determined, the "best case" and "worst case" process settings were used for cleaning each vehicle type for Phase 2 of the study.

Visual Inspection Results

Once cleaned, all components were sheared off and through visual inspection, each test vehicle was graded for the percent cleanliness achieved. Reference Table 3.

Table 3. Visual Inspection Results

Trial #	Cleaning Agent	Temperature (°F)	Belt Speed (ft/min)	IPC-B-52 Test Vehicle		IPC-B-36 Test Vehicle		SMTA Saber Board	
				Surface	Under Components	Surface	Under components	Surface	Under Components
1	DI-water	140°F	1	++	100.00%	++	87.50%	+	100.00%
2		140°F	2	++	100.00%	++	31.25%	+	97.25%
3		140°F	3	++	94.81%	-	0.00%	-	91.74%
4		140°F	4	++	62.34%	-	0.00%	-	66.06%
5	Aqueous Cleaning Agent (5% conc.)	140°F	1	++	100.00%	++	100.00%	++	100.00%
6		140°F	2	++	100.00%	++	100.00%	++	100.00%
7		140°F	3	++	100.00%	++	100.00%	++	100.00%
8		140°F	4	++	100.00%	++	100.00%	++	100.00%

It was observed, that all the boards cleaned using the low concentration cleaning agent (Trials 5-8) were fully clean. However, differences in cleaning performance could be noted with boards cleaned using only DI-water (Trials 1-4) as depicted in Figure 8:

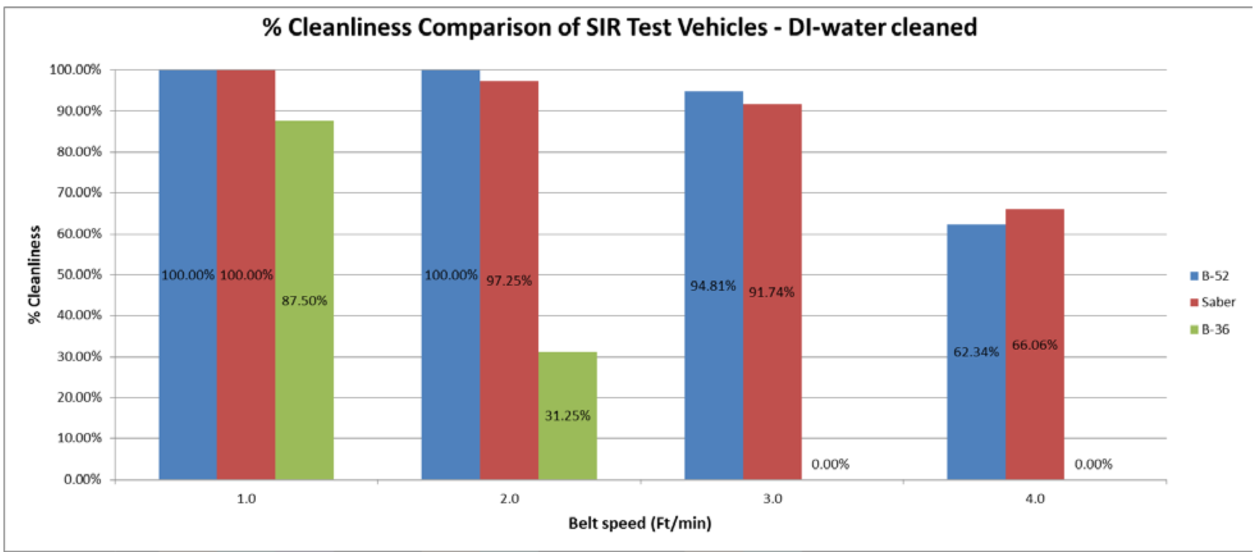


Figure 8. Cleaning Comparison of SIR Test Vehicles: Cleaned with DI-water

Representative pictures of the residues noticed in Trial 4 on all the board types are below:

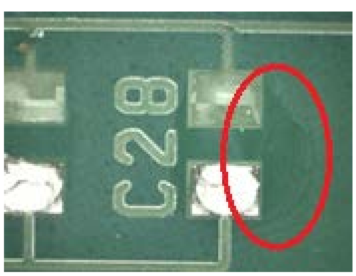


Figure 9. IPC-B-52: 0805 Components

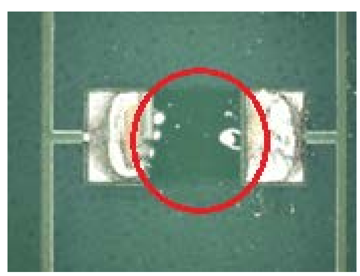


Figure 10. IPC-B-52: 1206 Components

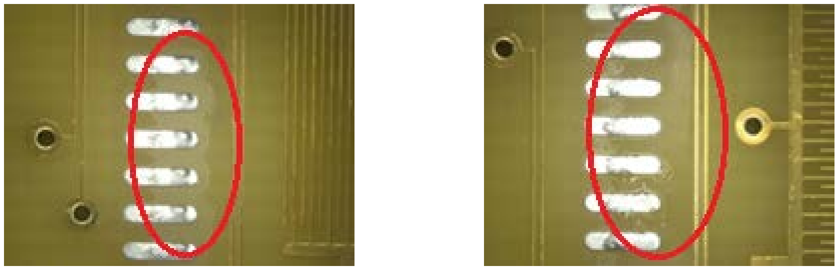


Figure 11. IPC-B-36 Boards

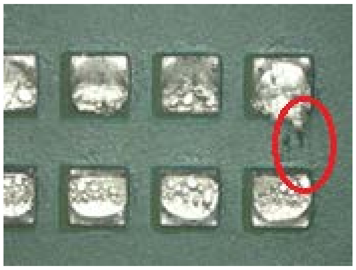


Figure 12. SMTA Saber Boards – 0603 Components

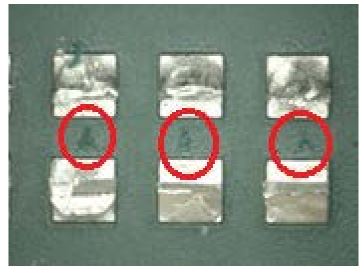


Figure 13. SMTA Saber Boards – 0805 Components

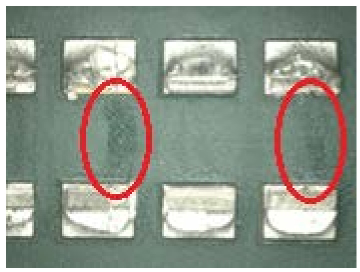


Figure 14. SMTA Saber Boards – 1206 Components

Observations – Visual Inspection Results

- The IPC-B-52 test vehicles were the easiest to clean, with no residues noticed on the surface, even at the fastest belt speed. Underneath components, residues were mainly noticed on the 1206 and 0805 components in Trials 3 and 4. Complete cleanliness under components could be attained at belt speeds as high as 2 ft/min with the B-52 boards.
- The IPC-B-36 board is the most difficult to clean. Thus, 100% cleanliness could not be achieved even at the reduced conveyor belt speed of 1 ft/min with just DI-water. Additionally, residues could be seen on the surface at the faster belt speeds.
- The SMTA Saber boards showed signs of staining on the solder mask even at 1 ft/min. However, this could be paste dependent and is not considered as a measure of the difficulty of cleaning this board. Underneath components, residues were noticed mainly on the 1206, 0805 and some 0603 components. Results indicated 100% cleanliness under components with DI-water at 1 ft/min.
- 100% cleanliness was achieved for all trials with all vehicles using aqueous cleaning agent

Phase 2 – SIR Testing

Prior to proceeding with the Phase 2 trials, and preparing the coupons for SIR analysis, the bare test vehicles were cleaned utilizing the inline cleaning system and the engineered aqueous based cleaning agent. A cleanliness assessment was conducted on two (2) test vehicles of each type using ion chromatography to ensure they were free of any ionics. All cleaned vehicles were placed in ESD bags until processing.

Following cleaning, two (2) test vehicles of each type were sent to the outside Institute for assembly and returned to the company technical center for cleaning and further analysis. One (1) cleaned bare test vehicle of each type was not populated and used as a control for the SIR comparison tests.

The fully populated vehicles, two (2) of each type, were cleaned utilizing the best case and worst case scenarios and subjected to SIR analysis. SIR analysis was conducted in accordance with IPC TM-650 Method 2.6.3.7.

Phase 2 Results

Phase 2 results include both IC and SIR analysis. Ion chromatography was completed using full board extraction (results detailed in Table 4).

Table 4. Ion Chromatography Results

	Ionic Species	Maximum Contamination Levels	B-36 #1	B-36 #2	Saber #1	Saber #2	B-52 #1	B-52 #2
ANIONS	Fluoride (F^-)	3	0	0.0850	0	0	0.0016	0
	Acetate ($C_2H_3O^-_2$)	3	ND	ND	ND	ND	ND	ND
	Formate (CHO^-_2)	3	ND	ND	ND	ND	ND	ND
	Chloride (Cl^-)	3	0.1617	0.0341	0.2219	0.2388	0.1479	0.1250
	Nitrite (NO_2^-)	3	ND	ND	ND	ND	ND	ND
	Bromide (Br^-)	2.5	0.0431	0.0507	0.0028	0.0072	0.0268	0.0277
	Nitrate (NO_3^-)	3	0.0448	0.0501	0.8946	0.7664	0.0713	0.0926
	Phosphate (PO_4^{2-})	3	ND	ND	ND	ND	ND	ND
	Sulfate (SO_4^{2-})	3	0.0262	0.0329	0.1196	0.1092	0.0704	0.0957
	WOA (Weak Organic Acid)	N/A	ND	ND	ND	ND	ND	ND
CATIONS	Lithium (Li^+)	2	0.0006	0.0003	0.0007	0.0003	ND	ND
	Sodium (Na^+)	2	0	0	0.4280	0.3574	0.1308	0.0923
	Ammonium (NH_4^+)	3	0.0209	0.0140	0.6782	0.6572	0.3968	0.4041
	Potassium (K^+)	2	0	0	0	0	0	0
	Magnesium (Mg^{2+})	1	0	0	0.6000	0.3077	0.0202	0.0028
	Calcium (Ca^{2+})	1	0.0116	0	0.5045	0.2323	0	0

As all test vehicles passed IC analysis, we were assured that the test vehicles were ready to be populated in preparation for SIR analysis. Two (2) vehicles of each coupon type were populated and one unpopulated test vehicle of each was set as "control" for SIR analysis. Based on the results of the Phase I testing, the cleaning process operating parameters from Trial 4 and Trial 5 were selected to represent the "worst case" and "best case" scenarios respectively. SIR results are detailed in Table 5 and Figures 15-32. The Saber board passed the SIR test even under worst case settings. This is due to the fact that the SIR measurements are taken on the QFP component of the Saber board which is an easier component to clean as compared to other components on the board.

Table 5. SIR Results

Board Type	Process settings	Overall Results
IPC-B-52	Control	Pass
	Best Case settings (Aqueous Cleaning Agent)	Pass
	Worst Case settings (DI-water)	Some failures. SIR values lower than Control and Best Case boards in general.
IPC-B-36	Control	Pass
	Best Case settings (Aqueous Cleaning Agent)	Pass
	Worst Case settings (DI-water)	Some failures. SIR values lower than Control and Best Case boards in general.
SMTA Saber	Control	Pass
	Best Case settings (Aqueous Cleaning Agent)	Pass
	Worst Case settings (DI-water)	Pass

IPC-B-52 Test Vehicles

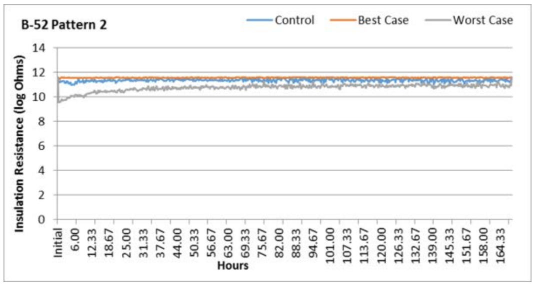


Figure 15. IPC-B-52 Vehicle: Pattern 2 – Passed

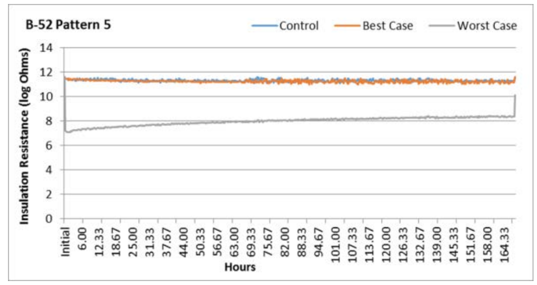


Figure 16. IPC-B-52 Vehicle: Pattern 5 – Failed (Worst Case)

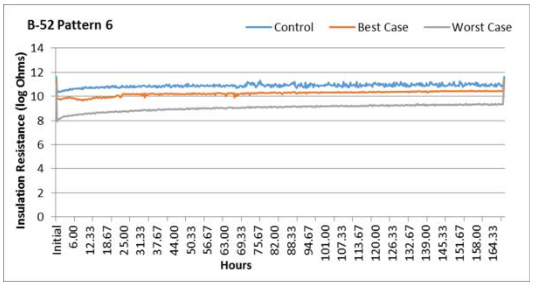


Figure 17. IPC-B-52 Vehicle: Pattern 6 – Passed

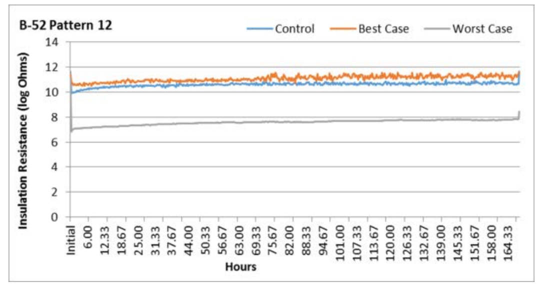


Figure 18. IPC-B-52 Vehicle: Pattern 12 – Failed (Worst Case)

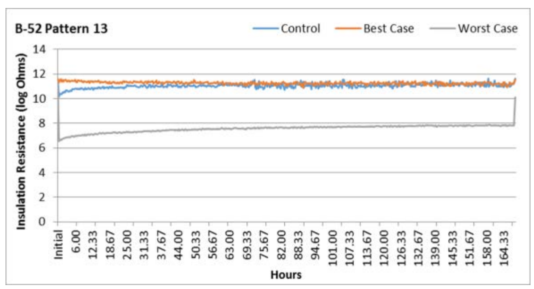


Figure 19. IPC-B-52 Vehicle: Pattern 13 – Failed (Worst Case)

IPC-B-36 Test Vehicles

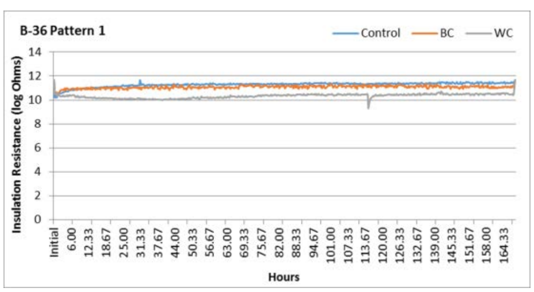


Figure 20. IPC-B-36 Vehicle: Pattern 1 – Passed

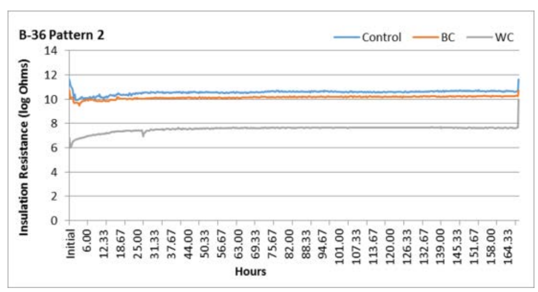


Figure 21. IPC-B-36 Vehicle: Pattern 2 – Failed (Worst Case)

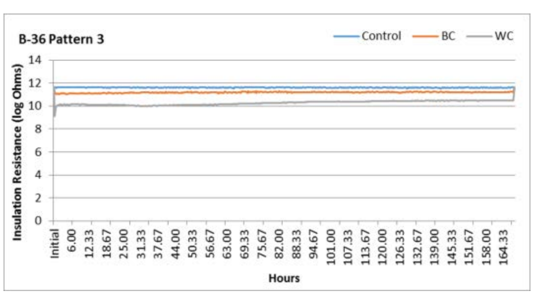


Figure 22. IPC-B-36 Vehicle: Pattern 3 – Passed

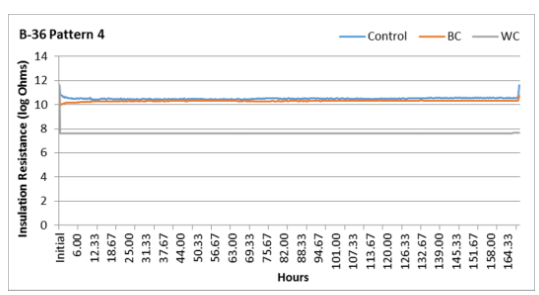


Figure 23. IPC-B-36 Vehicle: Pattern 4 – Failed (Worst Case)

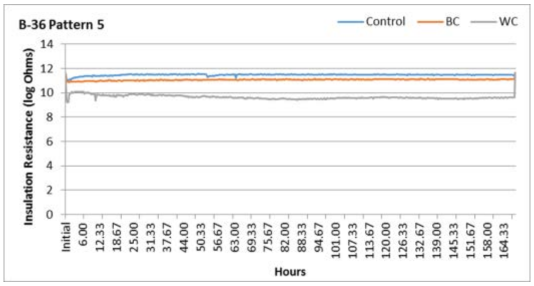


Figure 24. IPC-B-36 Vehicle: Pattern 5 – Passed

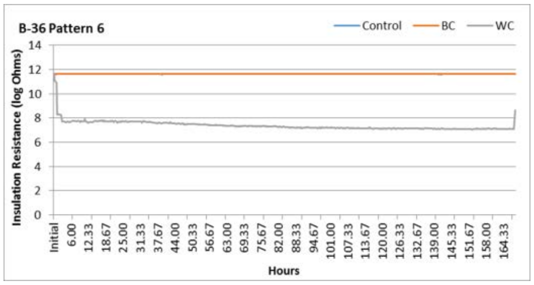


Figure 25. IPC-B-36 Vehicle: Pattern 6 – Failed (Worst Case)

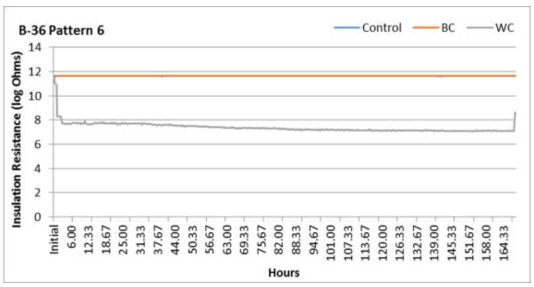


Figure 26. IPC-B-36 Vehicle: Pattern 6 – Failed (Worst Case)

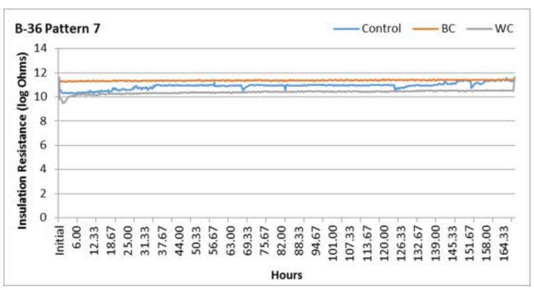


Figure 27. IPC-B-36 Vehicle: Pattern 7 – Passed

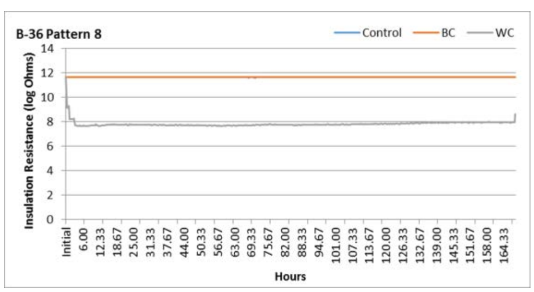


Figure 28. IPC-B-36 Vehicle: Pattern 8 – Failed (Worst Case)

SMTA Saber Boards

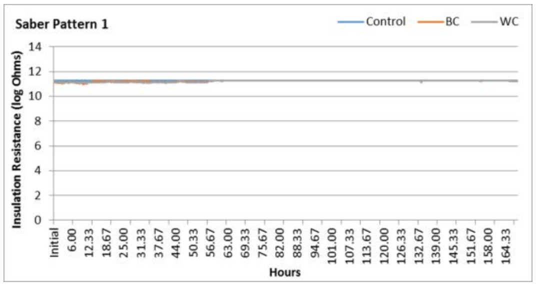


Figure 29. SMTA Saber Vehicle: Pattern 1– Passed

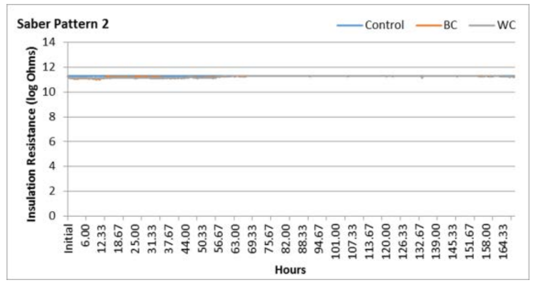


Figure 30. SMTA Saber Vehicle: Pattern 2– Passed

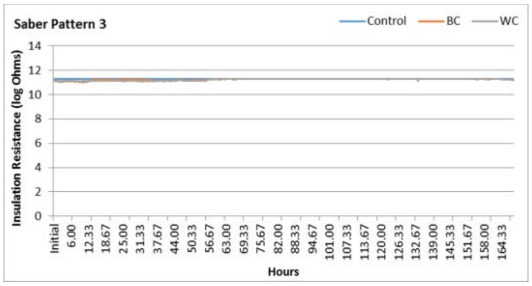


Figure 31. SMTA Saber Vehicle: Pattern 3– Passed

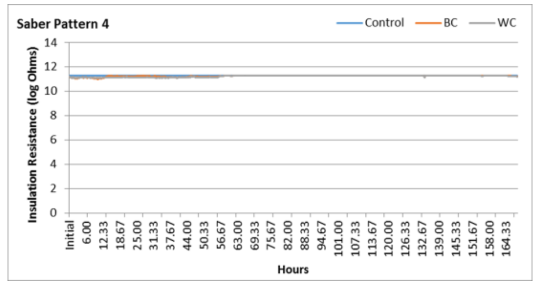


Figure 32. SMTA Saber Vehicle: Pattern 4– Passed

Conclusions

Conducting this study using water soluble solder paste enabled the authors to differentiate achievable cleanliness levels of the three (3) different SIR test vehicles. As expected, if residues remain on the board surface, SIR tests yielded failed results. As mentioned in the introduction, the purpose of SIR testing should influence SIR coupon selection. It is interesting to note that utilizing the low concentration aqueous cleaning agent yielded passing SIR results for all coupons cleaned under the "best case" scenario whereas the DI-water cleaned coupons yielded failed SIR results under "worst case" scenarios for IPC-B-52 and IPC-B-36. Additionally, the following was noted:

- Differences in visual cleaning results could be noted on boards cleaned with DI-water only.
- The IPC-B-36 test vehicles were found to be the most difficult to clean with residues noticed underneath components even at 1 ft/min with DI-water. Using the aqueous cleaning agent, all coupons were clean at 4 ft/min.
- SMTA Saber boards required a conveyor belt speed of 1 ft/min to be 100% clean, whereas the IPC-B-52 test vehicles were completely cleaned at 2 ft/min with DI-water.
- SIR test results showed failures on the IPC-B-52 and IPC-B-36 test vehicles cleaned under "worst case" settings, which was to be expected since these settings resulted in residues under components.
- The SMTA Saber board passed the SIR test even under worst case settings. This is due to the fact that the SIR measurements are taken on the QFP component of the Saber board which is an easier component to clean as compared to other components on the board.
- In general, the SIR values for test vehicles cleaned with "best case" settings (with chemistry) were higher than boards cleaned with "worst case" settings (DI-water only).

Recommendations

As a result of this study, the authors recommend using the IPC-B-36 test vehicles for projects where the goal is to compare cleaning processes. This board provides the most challenging environment to test cleanliness. This can include comparing cleaning agents, cleaning equipment or a combination of both.

Once a cleaning process is established, the IPC-B-52 test vehicles can subsequently be used for the process qualification step since it has various components that may be more representative of the components used on actual production boards. An additional advantage with the IPC-B-52 test vehicles is that the board can be used for testing through-hole fluxes as well.

Although, the SMTA Saber boards are not ideal for SIR tests, from a cleaning perspective, the authors recommend that the boards could still be used for visual analysis.

References

[1] Renee Michalkiewicz, Janet Green, and Scott Opperhauser, "Surface Insulation Resistance Testing of Soldering Pastes and Fluxes," Pan Pacific Microelectronics Symposium, February 2001.

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

Acknowledgements

The authors would like to thank Rochester Institute of Technology(RIT) for populating all SIR coupons and StenTech for providing the stencils used in the study.

SIR Test Vehicles – Comparison from a Cleaning Perspective

Ravi Parthasarathy

ZESTRON Americas

Agenda

- Introduction
- Methodology
- Phase 1
- Phase 2
- Conclusions and Recommendations
- Questions

Introduction

- Surface Insulation Resistance (SIR) has become one of the standard test protocols to qualify a process
  - *Quantifies the effects of fabrication, process or handling residues on SIR in the presence of moisture*
  - *Current leakage due to contamination may cause unacceptably low insulation resistance between conductors or solder joints*
- Testing is performed for one of three reasons:
  - *Part of a qualification or classification of a product*
  - *Evaluate or control a process*
  - *Compare materials or processes*

Methodology

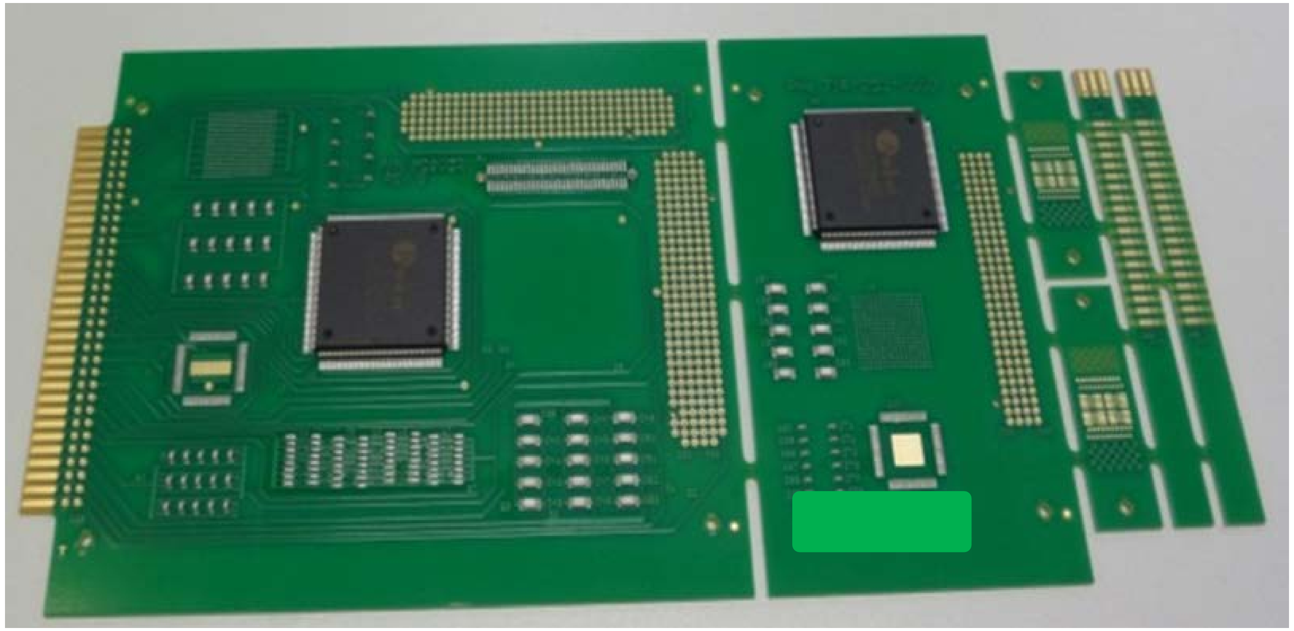
- Study designed to compare SIR test vehicles and determine which test vehicle is most challenging to clean
- Study was designed in two phases:
  - *Phase 1 – Determine cleaning process operating parameters resulting in fully cleaned and partially cleaned vehicles as verified through visual analysis of underneath components*
  - *Phase 2 – Utilize results from Phase 1 trials for best case and worst case cleaning scenarios and assess cleanliness through SIR analysis for each test vehicle type*

Methodology

- Main focus:
  - *Water soluble flux*
  - *DI-water and dynamic surfactant cleaning agent*
  - *Spray-in-air inline cleaner*
- Established cleaner operating parameters resulting in:
  - *Best case scenario – fully cleaned underneath components*
  - *Worse case scenario – partially cleaned underneath components*

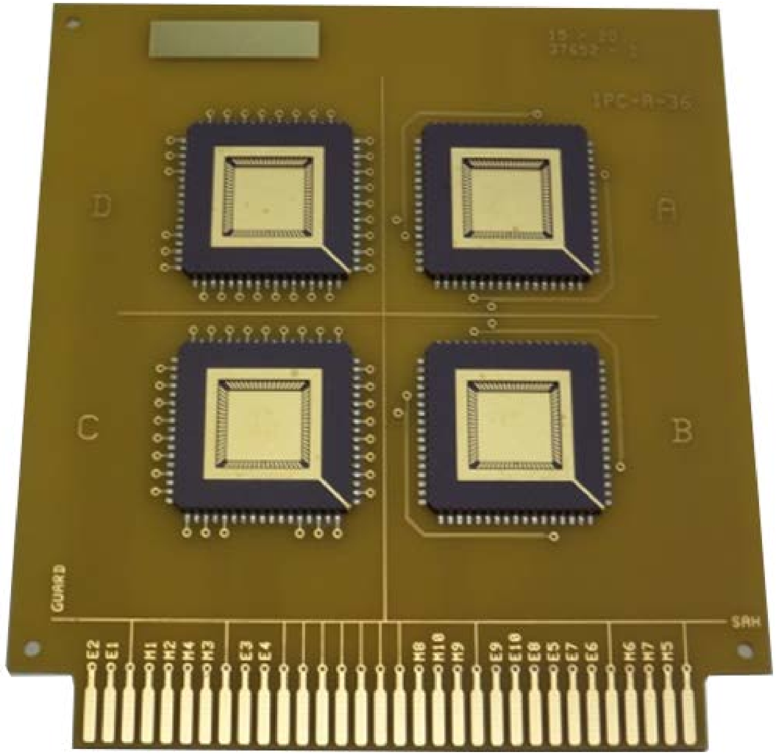
Methodology – Substrates Tested

- IPC-B-52 Test Vehicle
  - *QFP160*
  - *0402SMC*
  - *0603SMC*
  - *0805SMC*
  - *1206SMC*

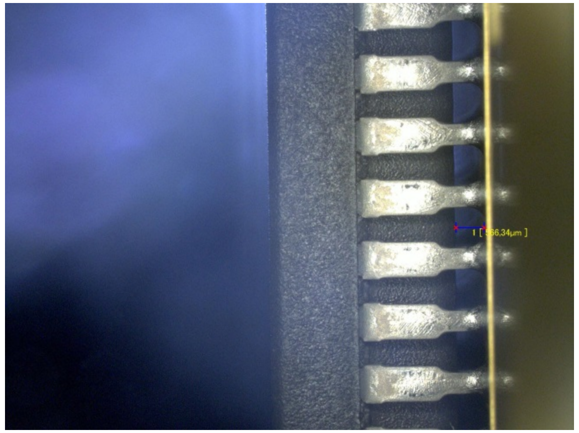


Methodology – Substrates Tested

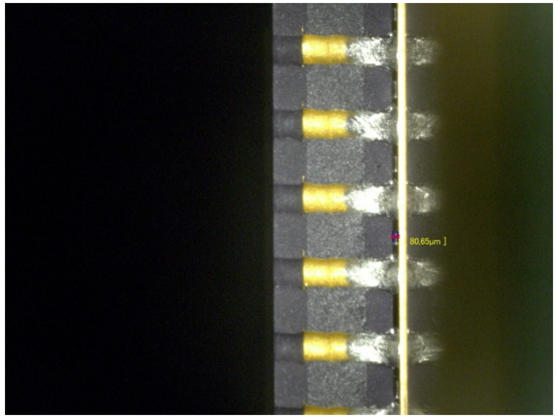
- IPC-B-36 Test Vehicle
  - *LCC68 components (ceramic)*
  - *PLCC68 not recommended*



IPC-B-36 with LCC68 components



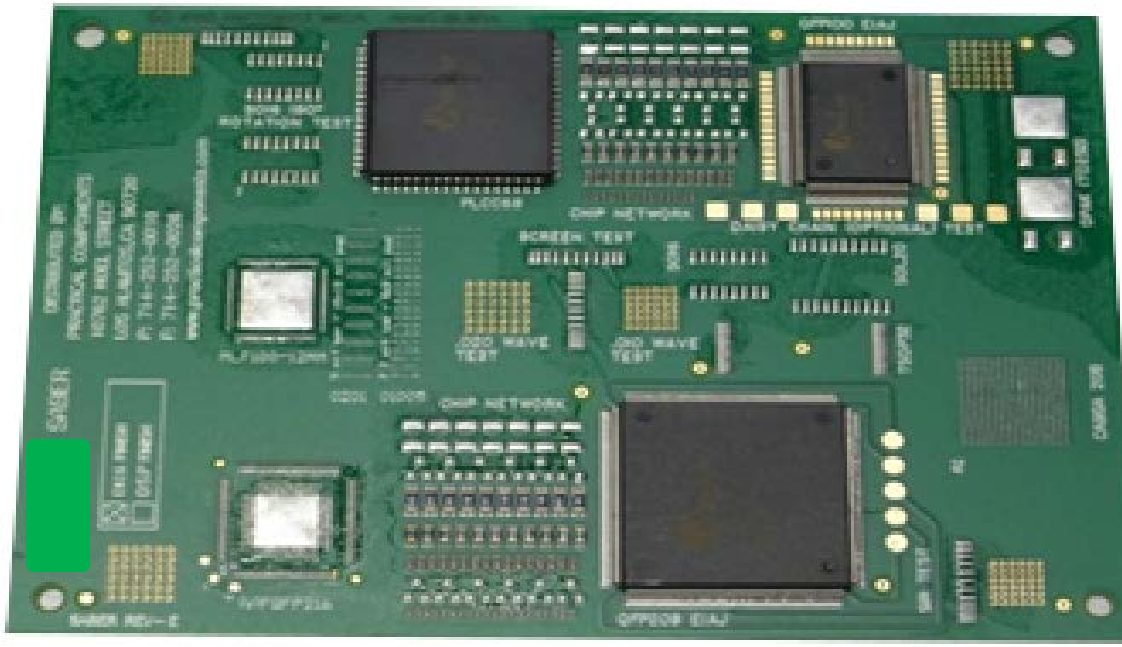
PLCC68 component standoff: 550 microns or 22 mil



LCC68 component standoff: 80 microns or 3.2 mil

Methodology – Substrates Tested

- SMTA Saber test board (Rev E) populated with
  - *QFP208*
  - *QFP100*
  - *0402SMR*
  - *0603SMR*
  - *0805SMR*
  - *1206SMR*
  - *PLCC68*



Phase 1 – Objective

- Compare three commonly used SIR test vehicles and focus on the difficulty of cleaning under similar process conditions
  - *IPC-B-52*
  - *IPC-B-36*
  - *SMTA Saber*
- Identify cleaning process parameters resulting in partially and fully cleaned vehicles as determined through visual analysis
- Anticipated DI-water would not fully clean board surface underneath the components
  - *Authors chose engineered aqueous based cleaning agent for comparison purposes*

Phase 1 – Cleaning Process Parameters

Wash Stage	
Equipment	Spray-in-air inline cleaner
Wash Spray Configuration	8 spray bars standard intermix
Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI
Wash Pressure (Top/Bottom)	75 PSI / 60 PSI
Wash Hurricane Pressure (Top/Bottom)	40 PSI / 40 PSI
Wash Temperature	140°F / 60°C
Chemical Isolation Pressure (Top/Bottom)	30 PSI / 25 PSI
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	80 PSI / 70 PSI
Rinse Hurricane Pressure (Top/Bottom)	40 PSI / 40 PSI
Rinse Temperature	140°F / 60°C
Final Rinse Pressure (Top/Bottom)	25 PSI / 25 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Temperature (D1)	160°F
Drying Temperature (D2)	180°F
Drying Temperature (D3)	180°F

Phase 1 – Design of Experiment (DOE)

Trial #	Cleaning Agent	Wash Temperature (°F)	Belt Speed (ft/min)	Board Type
1	DI-water	140	1	IPC-B-52
				IPC-B-36
				SMTA Saber
2			2	IPC-B-52
				IPC-B-36
				SMTA Saber
3			3	IPC-B-52
				IPC-B-36
				SMTA Saber
4			4	IPC-B-52
				IPC-B-36
				SMTA Saber
5	Aqueous based cleaning agent (5%)	140	1	IPC-B-52
				IPC-B-36
				SMTA Saber
6			2	IPC-B-52
				IPC-B-36
				SMTA Saber
7			3	IPC-B-52
				IPC-B-36
				SMTA Saber
8			4	IPC-B-52
				IPC-B-36
				SMTA Saber

Phase 1 – Visual Inspection

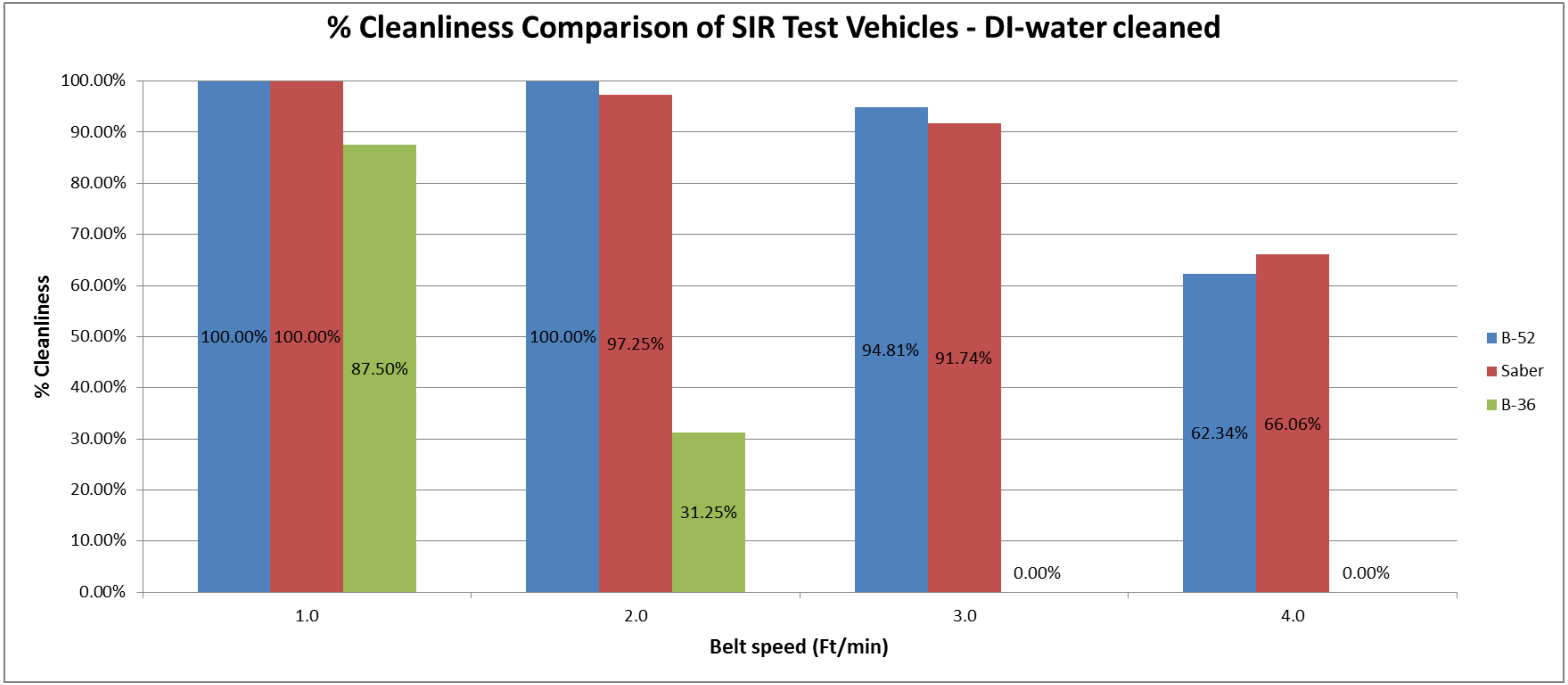
- Visual inspection:
  - *Components were sheared off*
  - *Cleanliness % defined as total # of components that are fully clean underneath*
- Best case: Settings that yield 100% results for all three (3) test vehicle types
- Worst case: Settings that yield the lowest cleanliness % among all test vehicle types
- Best case and worst case settings were used for in Phase 2 trials

Phase 1 – Visual Inspection Results

Trial #	Cleaning Agent	Temperature (°F)	Belt Speed (Ft/min)	IPC-B-52 Test Vehicles		IPC-B-36 Test Vehicles		SMTA Saber	
				Surface	Under components	Surface	Under components	Surface	Under components
1	DI-water	140°F	1	++	100.00%	++	87.50%	+	100.00%
2		140°F	2	++	100.00%	++	31.25%	+	97.25%
3		140°F	3	++	94.81%	-	0.00%	-	91.74%
4		140°F	4	++	62.34%	-	0.00%	-	66.06%
5	Aqueous based cleaning agent @ 5%	140°F	1	++	100.00%	++	100.00%	++	100.00%
6		140°F	2	++	100.00%	++	100.00%	++	100.00%
7		140°F	3	++	100.00%	++	100.00%	++	100.00%
8		140°F	4	++	100.00%	++	100.00%	++	100.00%

++: Clean *– : Not Clean*

Phase 1 – Results

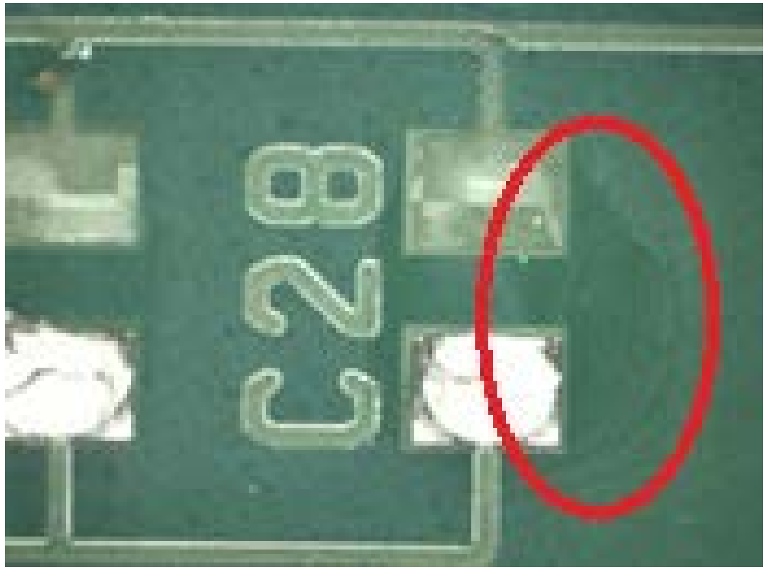


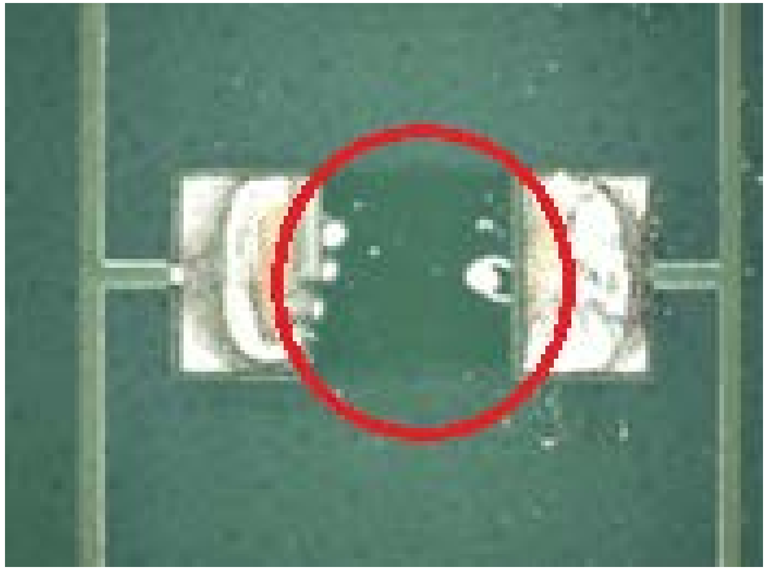
Phase 1 – Results

- Observations
  - *Difference in cleaning results observed on test vehicles cleaned with DI-water*
    - IPC-B-36 test vehicles were most difficult to clean
      - *Didn't clean 100% even at 1 ft/min*
    - SMTA Saber boards were 100% clean at 1 ft/min
    - IPC-B-52 test vehicles were 100% clean at 2 ft/min
  - *Chemistry cleaned under components on all test vehicles for all settings tested*

Phase 1 – Results

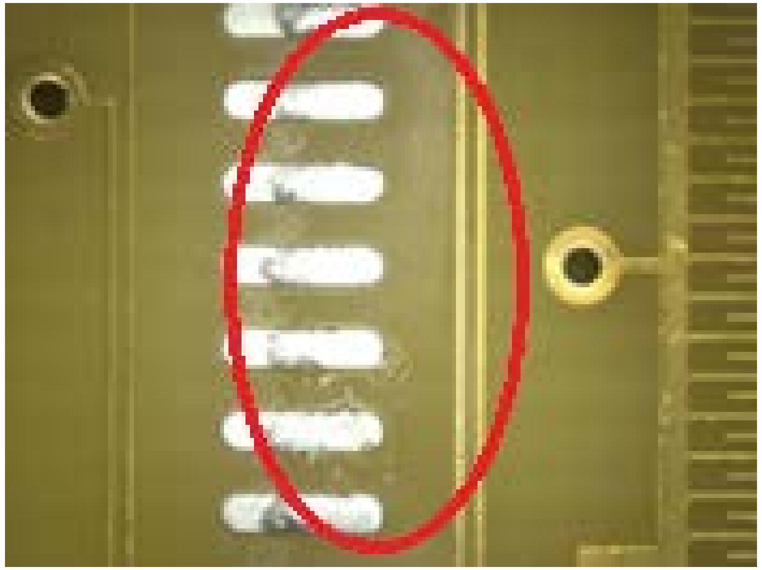
- IPC-B-52 Test Vehicles: Residues noticed in Trial 4





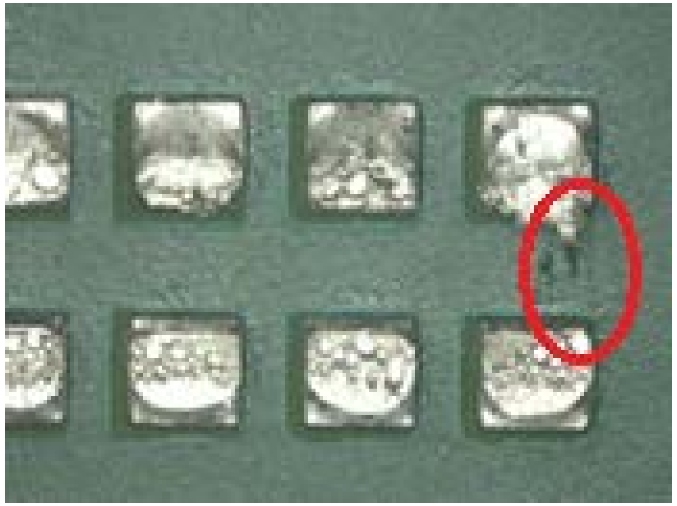
Phase 1 – Results

- IPC-B-36 Test Vehicles: Residues noticed in Trial 4

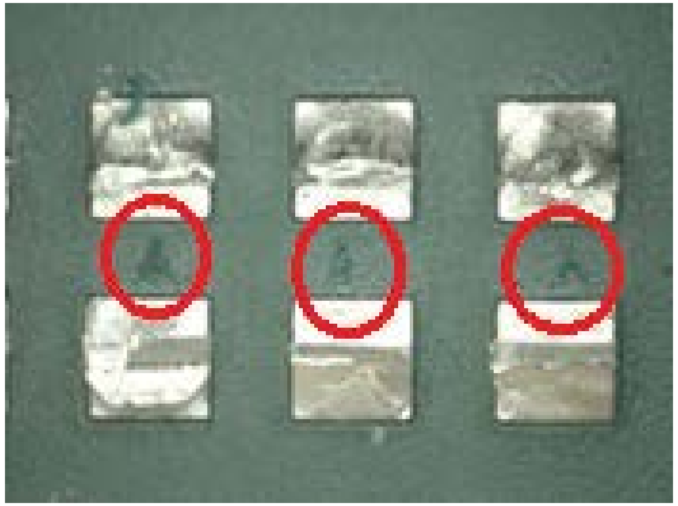


Phase 1 – Results

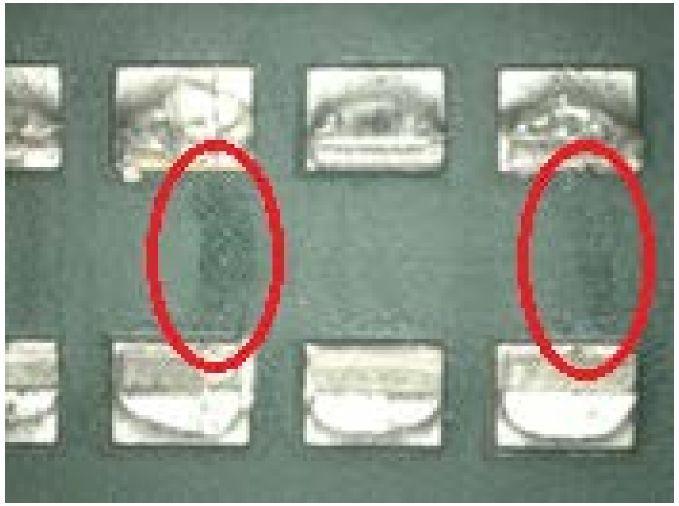
- SMTA Saber Test Vehicles: Residues noticed in Trial 4



0603 Components



0805 Components



1206 Components

Phase 2 – Objective

- Authors chose “best case” and “worst case” cleaning trial parameters to prepare the test vehicles for the SIR analysis
- Unpopulated test vehicles cleaned using chemistry initially to remove any contamination from the fabrication process
  - *Ion Chromatography tests conducted on 2 unpopulated test vehicles from each vehicle type (baseline purpose)*

Phase 2 – Objective

- Two (2) test vehicles of each type were populated and cleaned as follows:
  - *Best Case: Using Trial #5 settings – 1 test vehicle of each type*
  - *Worst Case: Using Trial #4 settings – 1 test vehicle of each type*
- The above two (2) test vehicles + control (unpopulated) sent for SIR testing (Method 2.6.3.7) for each vehicle type
  - *40°C / 90 RH*
  - *168 hours*
  - *5V DC*

Phase 2 – Ion Chromatography Results

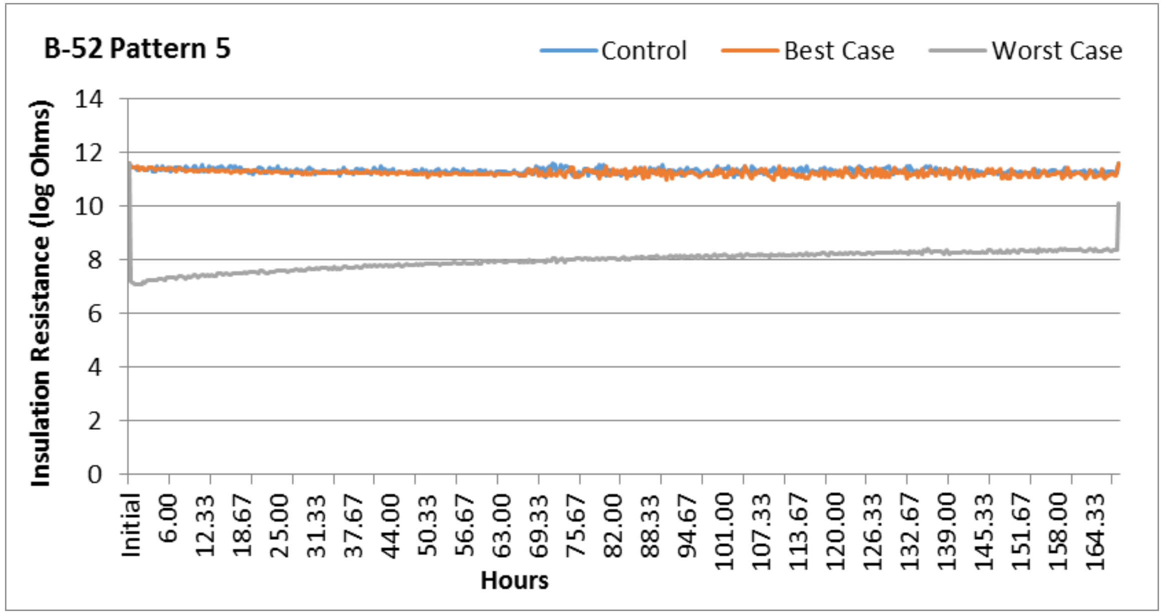
	Ionic Species	Maximum Contamination Levels	B-36 #1	B-36 #2	Saber #1	Saber #2	B-52 #1	B-52 #2
ANIONS	Fluoride (F^-)	3	0	0.0850	0	0	0.0016	0
	Acetate ($C_2H_3O^-_2$)	3	ND	ND	ND	ND	ND	ND
	Formate (CHO^-_2)	3	ND	ND	ND	ND	ND	ND
	Chloride (Cl^-)	3	0.1617	0.0341	0.2219	0.2388	0.1479	0.1250
	Nitrite (NO_2^-)	3	ND	ND	ND	ND	ND	ND
	Bromide (Br^-)	2.5	0.0431	0.0507	0.0028	0.0072	0.0268	0.0277
	Nitrate (NO_3^-)	3	0.0448	0.0501	0.8946	0.7664	0.0713	0.0926
	Phosphate (PO_4^{2-})	3	ND	ND	ND	ND	ND	ND
	Sulfate (SO_4^{2-})	3	0.0262	0.0329	0.1196	0.1092	0.0704	0.0957
	WOA (Weak Organic Acid)	N/A	ND	ND	ND	ND	ND	ND
CATIONS	Lithium (Li^+)	2	0.0006	0.0003	0.0007	0.0003	ND	ND
	Sodium (Na^+)	2	0	0	0.4280	0.3574	0.1308	0.0923
	Ammonium (NH_4^+)	3	0.0209	0.0140	0.6782	0.6572	0.3968	0.4041
	Potassium (K^+)	2	0	0	0	0	0	0
	Magnesium (Mg^{2+})	1	0	0	0.6000	0.3077	0.0202	0.0028
	Calcium (Ca^{2+})	1	0.0116	0	0.5045	0.2323	0	0

Phase 2 – SIR Results

Test Vehicle	Process Settings	Overall Results
IPC-B-52	Control	Pass
	Best Case Settings	Pass
	Worst Case Settings	Some failures. SIR values lower than Control and Best Case boards in general.
IPC-B-36	Control	Pass
	Best Case Settings	Pass
	Worst Case Settings	Some failures. SIR values lower than Control and Best Case boards in general
SMTA Saber	Control	Pass
	Best Case Settings	Pass
	Worst Case Settings	Pass

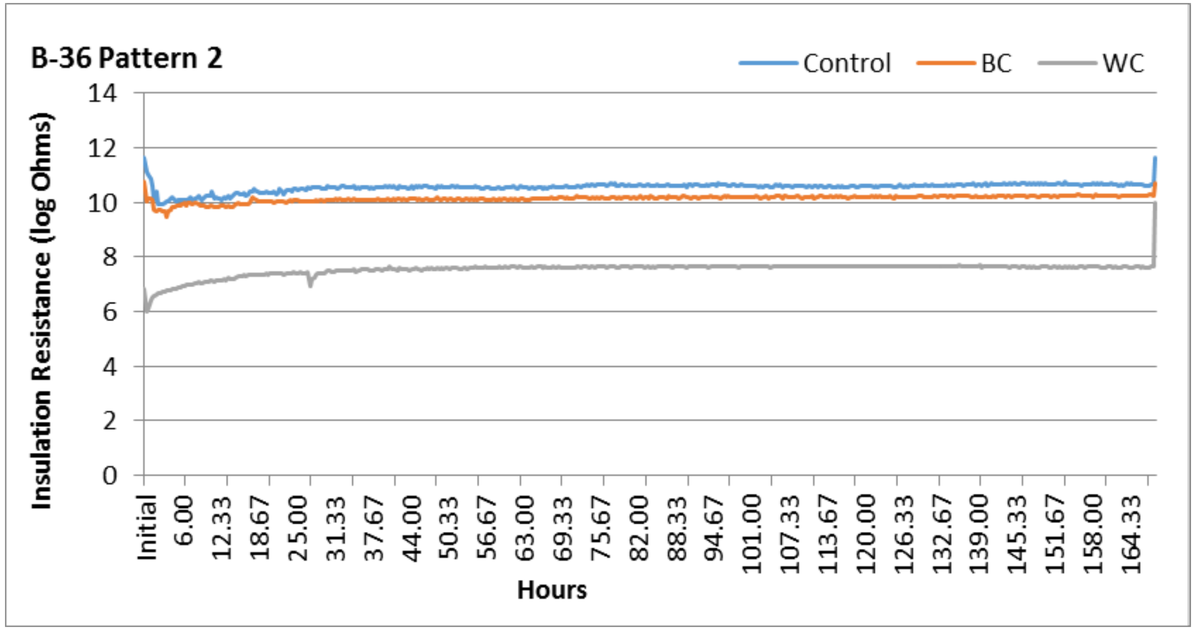
Phase 2 – SIR Results

- Examples of SIR Test Results – B-52 Test Vehicle
  - *Worst case settings resulted in failure while best case settings and control test vehicle passed*
- Pass/Fail requirement: SIR > 8 log Ohms



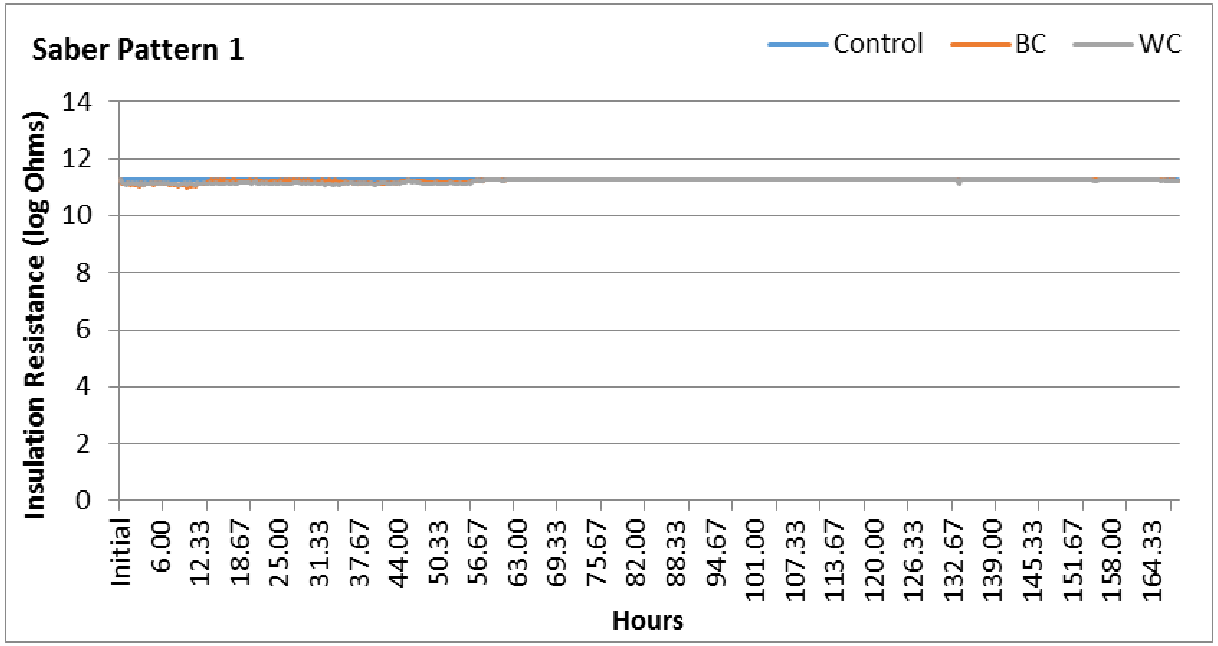
Phase 2 – SIR Results

- Examples of SIR Test Results – B-36 Test Vehicle
  - *Worst case settings resulted in failure while best case settings and control test vehicle passed*
- Pass/Fail requirement: SIR > 8 log Ohms



Phase 2 – SIR Results

- Examples of SIR Test Results– Saber Board
  - *All Saber boards passed the SIR Test*
- Pass/Fail requirement: SIR > 8 log Ohms



Conclusions

- Phase I testing proved
  - *Chemistry can clean 100% for all three (3) board types*
  - *DI-water shows varying levels of cleanliness for the three (3) test vehicle types*
  - *IPC-B-36 is hardest to clean even at 1 ft/min with DI-water*
    - Able to clean at 4 ft/min with aqueous based cleaning agent
  - *SMTA Saber board was fully clean at 1 ft/min with DI-water*
  - *IPC-B-52 test vehicle was fully clean at 2 ft/min with DI-water*

Conclusions

- Phase II testing showed that:
  - *IPC-B-52 and IPC-B-36 test vehicles exhibited SIR failures at the worst case settings*
    - Understandable since components/patterns where SIR was measured had residues
  - *SMTA Saber board passed the SIR tests even at worst case settings*
    - Since only QFP component is SIR test capable, the vehicles passed the test since QFP was fully clean even at worst case settings
  - *SIR values for boards cleaned with best case settings with (chemistry) were higher than boards cleaned with worst case settings (DI-water only)*

Recommendations

- Use IPC-B-36 test vehicles when
  - *Cleaning processes are to be compared*
  - *This includes comparing cleaning agents or cleaning equipment or combination of both*
- Use IPC-B-52 test vehicles when
  - *Cleaning process (chemistry and equipment) are already chosen*
  - *As a process qualification or verification tool*
- Use SMTA Saber boards
  - *Although not ideal for SIR, from a cleaning perspective the boards can still be used for visual analysis*

Thank you!

Questions?