Utilizing SIR and Analytical Tools to Determine Impact to Reliability for Process Improvements

"Presented at SMTA International 2023"

Denis Barbini, Ph.D.,
ZESTRON Corporation, Manassas, VA
Denis.Barbini@zestronusa.com

Jamie Boutwell
Cirtronics, Milford, New Hampshire
JBoutwell@Cirtronics.com

ABSTRACT
Implementation of a new process, machine, or material triggers a qualification event for that change under the new H revision of IPC-J-Std-001.

When changing specific materials or cleaning solutions, one must determine and provide objective evidence that the improvement does not increase the risk of unused material or flux residues. Rather, it should improve the efficacy of removing the residues. The consequence of flux residues remaining on the PCBA may lead to electrochemical reactions that result in product failure while in use.

To quantify the risk, the CM or OEM is required to acquire quantitative data prior to the implementation of the process change. This presentation focuses on the importance of incorporating the specific tools and analytical measurements developed to ensure the product's reliability, such as SIR, Ion Chromatography, and Rose testing. This presentation provides insight into a real-life implementation of a material change and the subsequent qualification.

Keywords: IPC-J-Std-001, Electronics Industry, Implementation, Product Failure, Electrochemical Reactions, Qualification, SIR, Ion Chromatography, Rose Testing, IPC-TM-650

INTRODUCTION
In the quest to improve, define and quantify process controls and product reliability, the electronics assembly ecosystem has evolved over the decades to develop guidelines, test methods and standards. These tools lead to the innovation of technologies and techniques while updating familiar analytical tools to provide quality based. When focused on qualifying a cleaning process qualification, one is required to conduct testing that includes visual analysis in the form of 10x and 30x as required; electrical testing in the form of SIR testing and/or electromigration; chemical testing in the form of Ionic Cleanliness levels 1 and 2, component compatibility, residue analysis and others. All these protocols require equipment, materials and expertise. Currently, the onus for implementing these quality safeguards and providing the objective evidence that the change planned, whether it be a minor or major change, will not impact product quality or reliability falls to the assembly house or contract manufacturer. Consequently, the manufacturer is responsible for documenting the change, run the required testing for qualification and for continuous process controls. The challenge for the contract manufacturer is to work with their OEM to establish which tests and protocols to put in place to be compliant with standards and test methods. This will take a significant undertaking that requires significant time, resources, and preparation to meet the standards and required objective evidence. In this paper, the collaboration between the contract manufacturer and supplier provides a method for delivering the objective evidence for qualification of a cleaning chemistry in an efficient and timely manner.

Experimental SIR Testing
A total of thirty-two (32) IPC-B-52 boards were submitted for SIR testing. These boards were classified as follows:

- Fifteen (15) boards were cleaned with Cleaning Chemistry A
- Six (6) boards were cleaned with DI-water.
- Nine (9) boards were cleaned with Cleaning Chemistry B
- Two (2) bare boards

The following components were populated on these boards:

- 0402 chip capacitors
- 0603 chip capacitors
- 0804 chip capacitors
- 1206 chip capacitors
- CABGA256
- TQFP80
- QFP160
- SO16
- Conn-TH-Horizontal
- Conn-TH-Vertical
- Conn-SMT

PROCESS CONDITIONS
Based on standard manufacturing processes, seven different manufacturing processes were chosen for SIR testing and characterization. These manufacturing process include the characterization of two cleaning chemistries labeled

Cleaning Chemistry A and Cleaning Chemistry B respectively. The SIR testing was split up into consecutive tests to accommodate 16 IPC-B-52 boards in each test. Table 1 lists the first grouping of processes for qualification labeled "Chamber 1" while the second grouping of processes for qualification is labeled "Chamber 2."

Table 1. SIR Chamber 1 with Six Cells and Five Independent Process

CHAMBER 1									
Cell 1		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy	Flux	Cleaning Process
Board	1	SnPb Type 4	SMT top	CC A	N/A	Selective Solder	SnPb	N/A	CC A
Board	2	SnPb Type 4	SMT top	CC A	N/A	Selective Solder	SnPb	N/A	CC A
Board	3	SnPb Type 4	SMT top	CC A	N/A	Selective Solder	SnPb	N/A	CC A
Cell 2		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	N/A	N/A	N/A	N/A	Selective Solder	SnPb	N/A	CC A
Board	2	N/A	N/A	N/A	N/A	Selective Solder	SnPb	N/A	CC A
Board	3	N/A	N/A	N/A	N/A	Selective Solder	SnPb	N/A	CC A
Cell 3		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SnPb Type 4	SMT top	CC A	N/A	N/A	N/A	N/A	N/A
Board	2	SnPb Type 4	SMT top	CC A	N/A	N/A	N/A	N/A	N/A
Board	3	SnPb Type 4	SMT top	CC A	N/A	N/A	N/A	N/A	N/A
Cell 4		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SAC305 - OA	SMT top	DI water	N/A	N/A	N/A	N/A	N/A
Board	2	SAC305 - OA	SMT top	DI water	N/A	N/A	N/A	N/A	N/A
Board	3	SAC305 - OA	SMT top	DI water	N/A	N/A	N/A	N/A	N/A
Cell 5		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SAC305 - OA	SMT bottom	N/A	SMT top	N/A	N/A	N/A	DI water
Board	2	SAC305 - OA	SMT bottom	N/A	SMT top	N/A	N/A	N/A	DI water
Board	3	SAC305 - OA	SMT bottom	N/A	SMT top	N/A	N/A	N/A	DI water
Cell 6		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Bare Board	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 2. SIR Chamber 2 with Six Cells and Five Independent Processes

CHAMBER 2									
		ASSEMBLY FLOW							
Cell 1		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy	Flux	Cleaning Process
Board	1	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC - A
Board	2	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC - A
Board	3	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC - A
Cell 2		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SAC305 Type 4	SMT top	CC - A	N/A	Selective Solder	SAC 305		CC - A
Board	2	SAC305 Type 4	SMT top	CC - A	N/A	Selective Solder	SAC 305		CC - A
Board	3	SAC305 Type 4	SMT top	CC - A	N/A	Selective Solder	SAC 305		CC - A
Cell 3		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SnPb Type 4	SMT top	SKIP	N/A	Selective Solder	SnPb		CC- B
Board	2	SnPb Type 4	SMT top	SKIP	N/A	Selective Solder	SnPb		CC- B
Board	3	SnPb Type 4	SMT top	SKIP	N/A	Selective Solder	SnPb		CC- B
Cell 4		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC- B
Board	2	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC- B
Board	3	SAC305 Type 4	SMT bottom	N/A	SMT top	N/A	N/A	N/A	CC- B
Cell 5		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Board	1	SnPb Type 4	SMT top	CC- B	N/A	N/A	N/A	N/A	N/A
Board	2	SnPb Type 4	SMT top	CC- B	N/A	N/A	N/A	N/A	N/A
Board	3	SnPb Type 4	SMT top	CC- B	N/A	N/A	N/A	N/A	N/A
Cell 6		Paste	Assembly Process	Cleaning Process	Assembly Process	Liquid Soldering	Liquid Soldering Alloy		Cleaning Process
Bare Board	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

SIR Test Equipment

- ESPEC Temperature & Humidity Chamber (Model: PSL-2J)
- Gen3 AutoSIR2+
- Fluke Digital Multimeter

Test Parameters

Test Parameters	Set Values
Test Conditions	40°C & 90% R.H.
Test Duration	168 hours
Bias Voltage	5 volts DC
Measurement Voltage	5 volts DC
Measurement Frequency	Every 10 min

Test Procedure & Sample Handling

Chamber Control Board Preparation:
One IPC B-52 test board (bare copper on FR4) was used as chamber control.

- Bare board was cleaned in ionic contamination tester containing 75% IPA + 25% DI water till all the ionics are removed.
- Cleaned bare board was dried for two hours at 50°C in a vacuum oven.
- If the control board readings are less than 1000 MΩ (9 Log ohms) at any point after the initial 24 hours of SIR exposure, a new set of test coupon shall be obtained, and the entire test repeated.

Chamber Preparation:

- The interior of the chamber was wiped with IPA and left to dry by keeping the chamber door open for 30 min.
- Fresh deionized water was filled in 'water supply tank' of ESPEC Chamber. This water supplies the humidity to the chamber.
- All boards were screened for solder bridges and shorts prior to being placed into the chamber using the Fluke Digital Multimeter.
- The test fixture/rack was visually inspected for loose and/or broken wires.
- Checker card was also used to check wiring on test rack. Checker card was inserted into each slot on the test rack to ensure wiring is intact.
- The test samples were inserted into test fixture/rack. The boards were positioned such that the airflow is parallel to the boards.
- Temperature & Humidity Chamber was sealed and ramped from laboratory ambient conditions to 25°C and 50% R.H. Dwell for one hour. The electrical system setup was verified by taking a series of measurements at these specified conditions. Measurements need not be reported unless ''shorts'' are observed and therefore deemed inappropriate for test.
- The temperature was increased to 40°C while maintaining the humidity at 50% R.H. ± 3% R.H. and maintained at this temperature for 15 minutes. After this period, within 0.5 hour, the relative humidity was increased gradually to 90% R.H. ± 3 % R.H. The temperature of the samples was not allowed to drop below the dew point.
- Chamber was allowed to stabilize at set point for one hour.
- All SIR measurements (every unique channel) were recorded at least once every 10 minutes for total duration of 168 hours.
- After 168 hours of conditioning at 40°C & 90% R.H., temperature and humidity were ramped down slowly to 25°C & 50% R.H in two hours and final resistance measurement were recorded.

Upon completion of the test, samples were removed from chamber and visually inspected.

Results

The following results are from the IPC-B-52 boards monitored by Surface Insulation Resistance testing in Chamber 1 and Chamber 2.

The SIR Chamber held the temperature and humidity throughout the SIR testing as required for both Chamber 1 and Chamber 2. Figure 1 shows the stability of the temperature and humidity throughout the testing and is representative of both testing chambers.

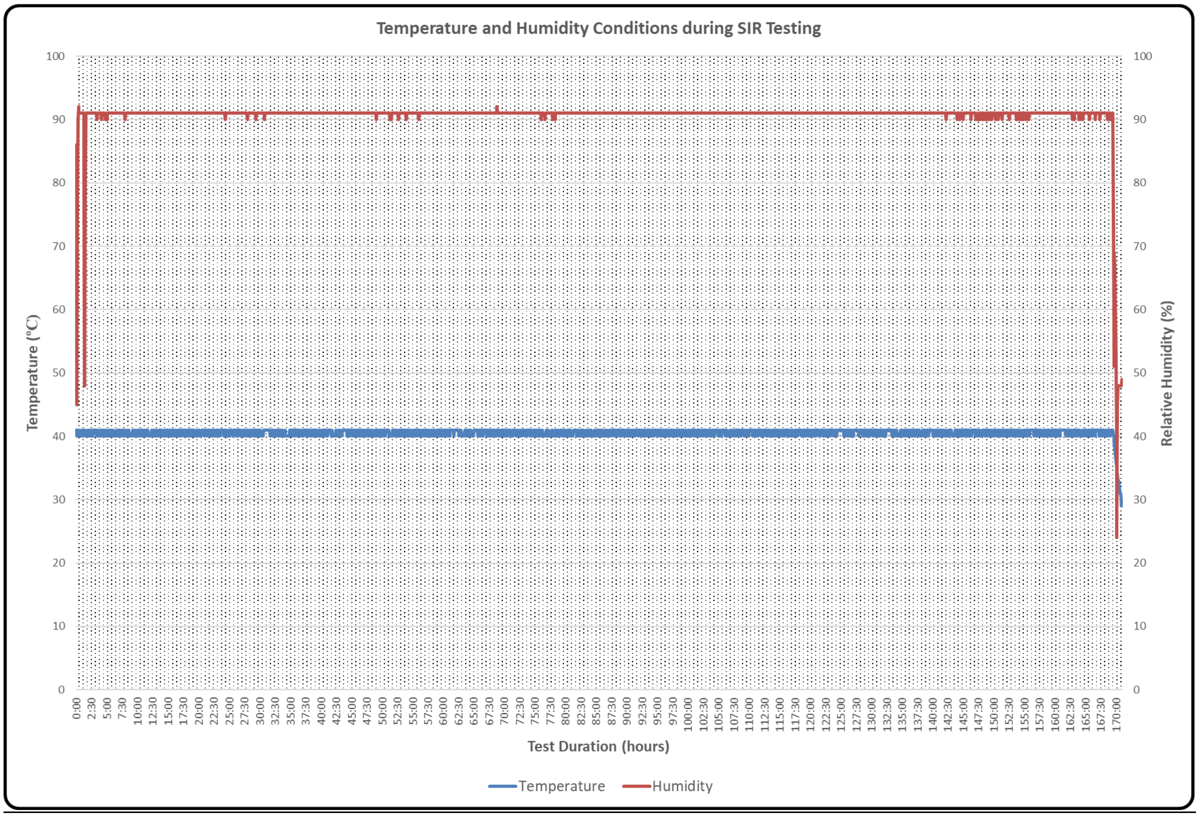

Figure 1. Temperature / Humidity Condition in Test Chamber 1

<u>Cleaning with DI- Water</u>

The following two cells are related to DI Water cleaning of Organic Acid flux.
The board that represented the process for SAC305, SMT Bottom, SMT TOP, DI Water is shown in Figure 2

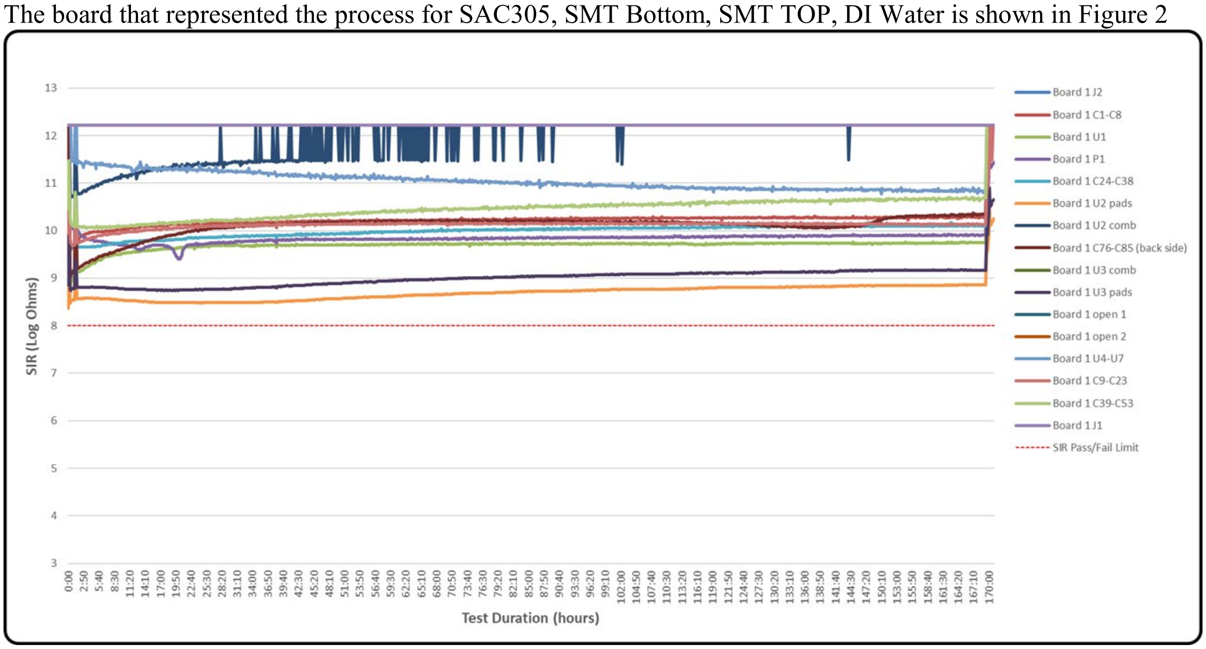

Figure 2. The Representative SIR results for Chamber 1 Cell 5

The board that represented the process for SAC305, SMT TOP, DI Water is shown in Figure 3.

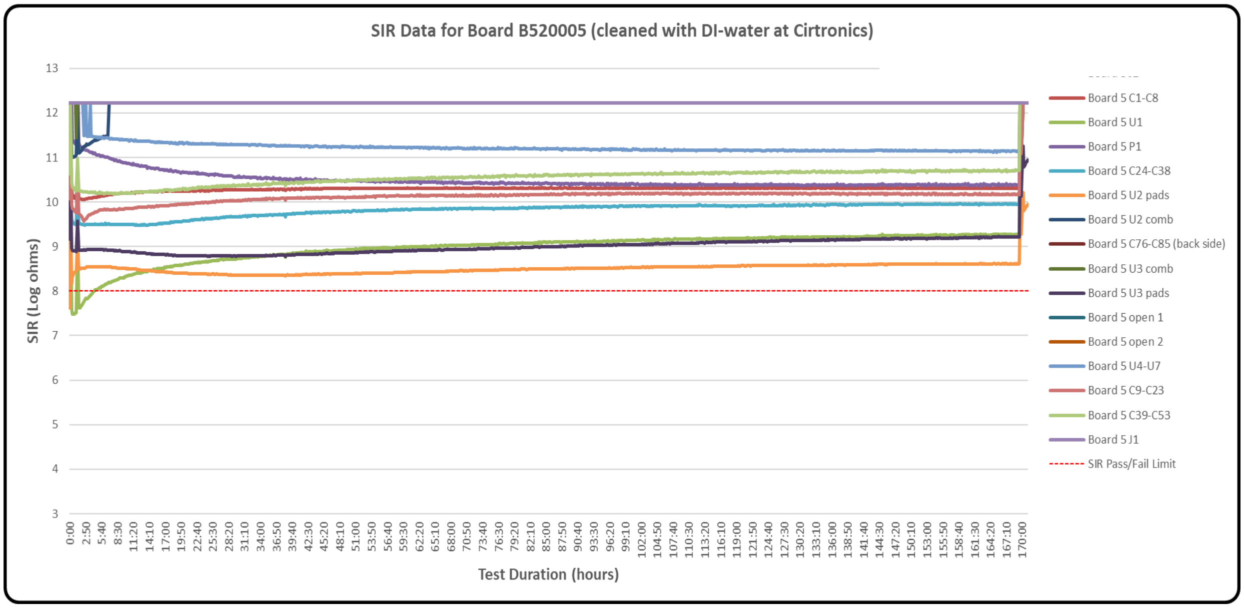

Figure 3. The Representative SIR results for Chamber 1 Cell 4.

Cleaning with CC-A Cleaning

Cleaning of the selective soldering process that is representative for SnPb, Through Hole Insertion, Flux soldering n Figure 4.

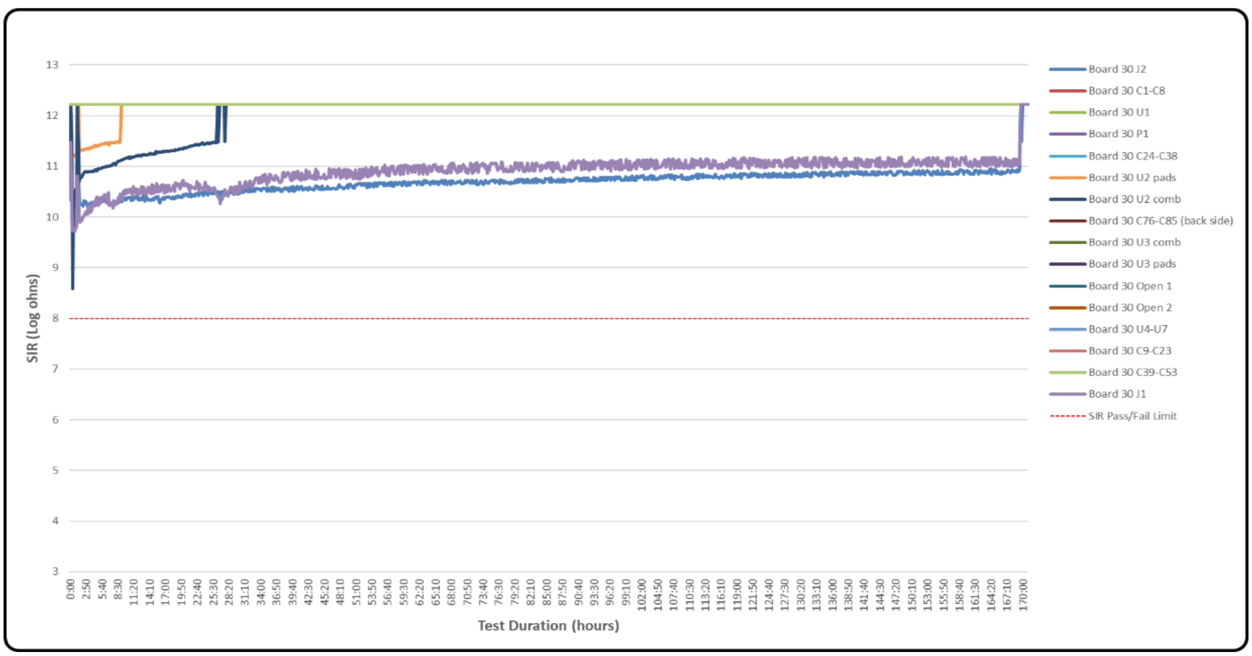

Figure 4. The Representative SIR results for Chamber 1 Cell 2.

The board that is representative for the assembly process SnPb, SMT Top, CC-A, through Hole Insertion, CC-A Figure 5.

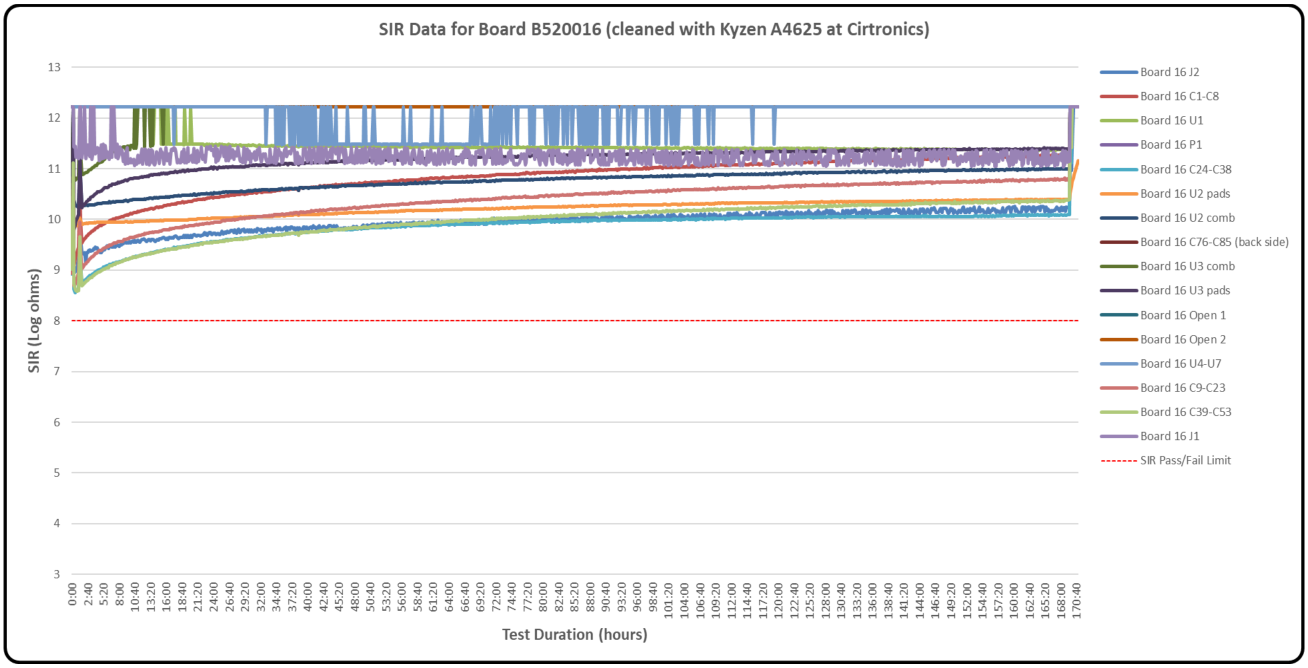

Figure 5. The Representative SIR results for Chamber 1 Cell 1**.**

The board that is representative for the assembly process SnPb, SMT Top, CC-A, through Hole Insertion, CC-A Figure 6.

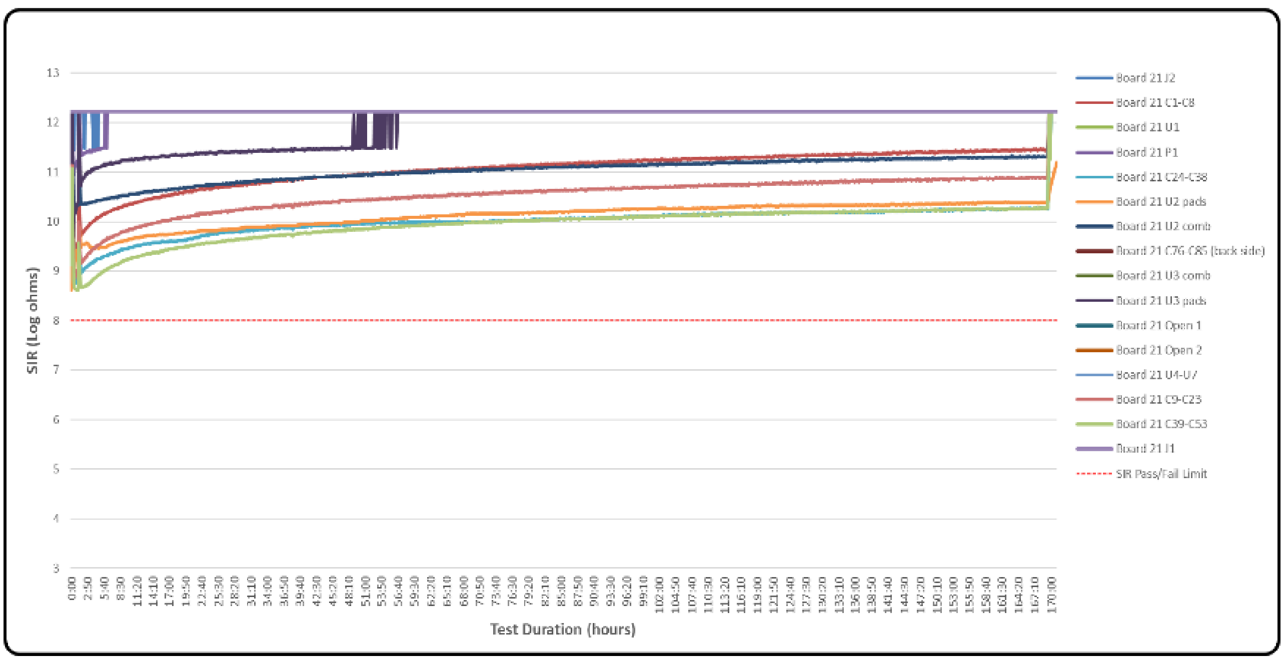

Figure 6. The Representative SIR results for Chamber 1 Cell 3.

The board that is representative for the assembly processSAC305, SMT Bottom, SMT Top, CC-A is illustrated in Figure 7.

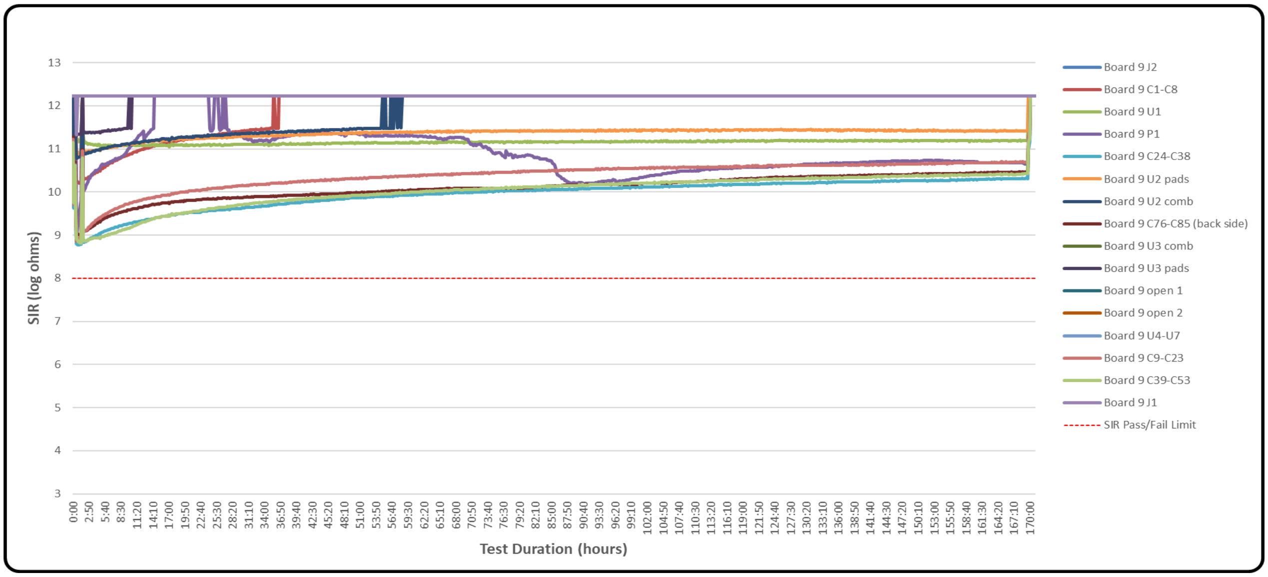

Figure 7. The Representative SIR results for Chamber 2 Cell 1.

The board that is representative for the assembly process SAC305, SMT TOP, CC-A, Through Hole Insertion. SAC 305 Selective Soldering, CC-A is illustrated in Figure 8.

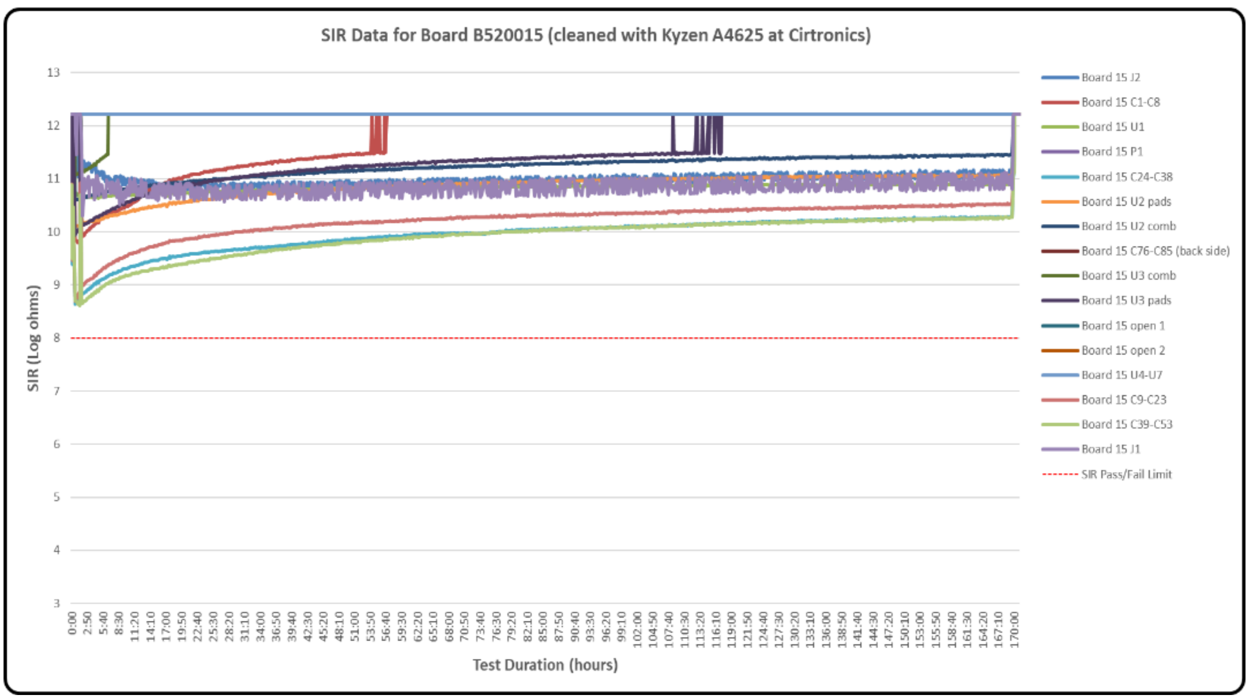

Figure 8. The Representative SIR results for Chamber 2 Cell 2.

Cleaning with CC-B Cleaning

The board that is representative for the assembly process SnPB, SMT TOP, Through Hole Insertion. SnPb Selective Soldering, CC-B is illustrated in Figure 9.

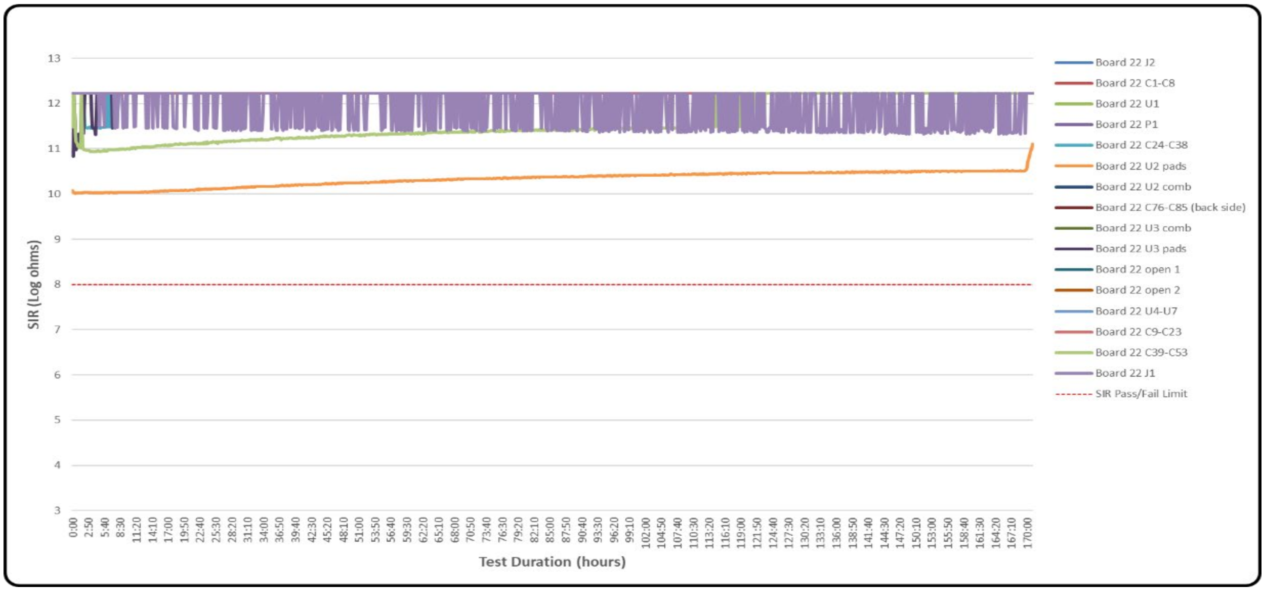

Figure 9. The Representative SIR results for Chamber 2 Cell 3.

The board that is representative for the assembly process SAC305, SMT Bottom, SMT Top, CC-B is illustrated in Figure 10.

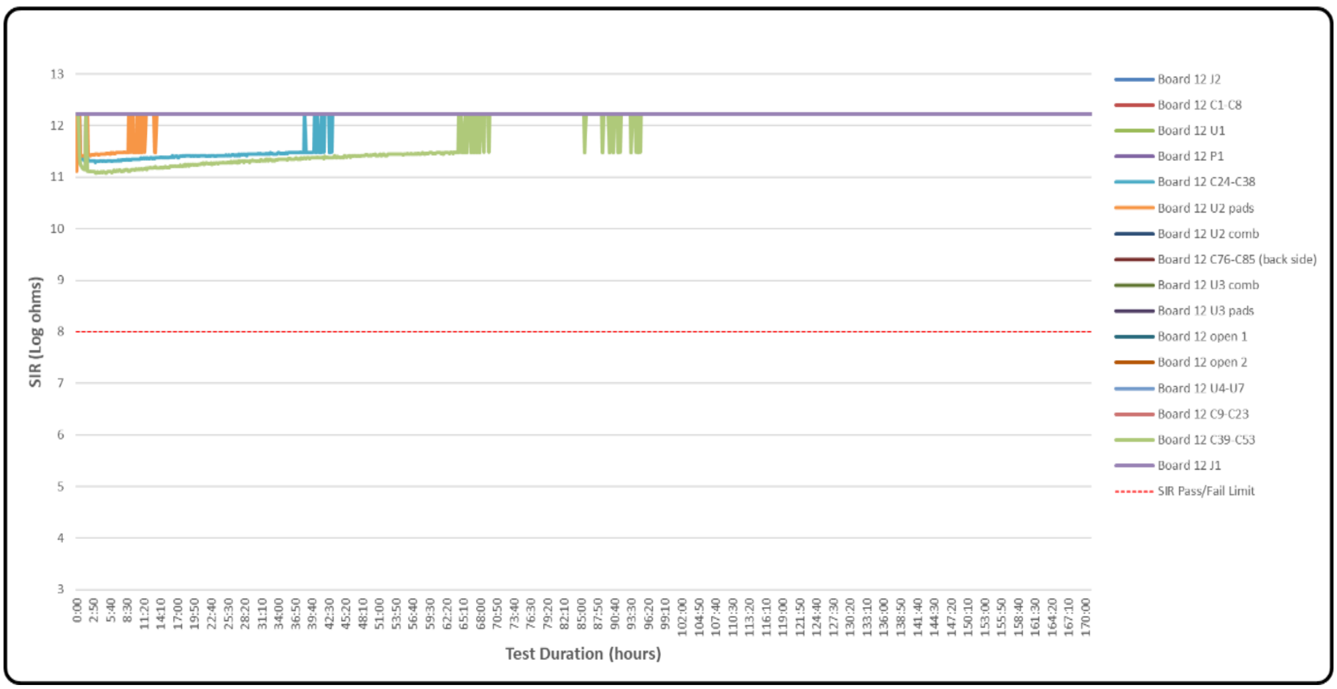

Figure 10. The Representative SIR results for Chamber 2 Cell 4.

The board that is representative for the assembly process SnPb, SMT Top, CC-B is illustrated in Figure 11.

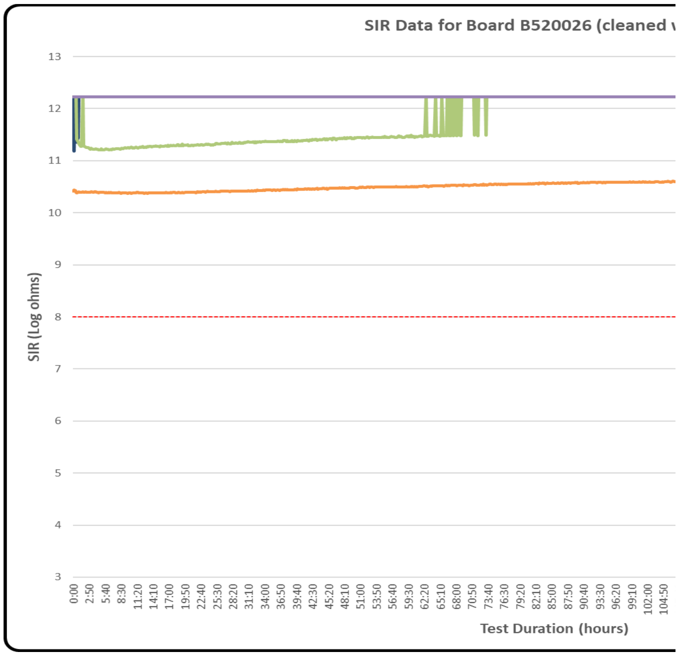

Figure 11. The Representative SIR results for Chamber 2 Cell 5

Discussion

Cleaning with DI- Water

In the two cells, Chamber 1-Cell 4 and Chamber 1-Cell 5, exhibited residue remaining on U2 and U3 components respectively. For the board in Chamber 1-Cell 4, the resistance dropped below SIR pass/fail limit of 8 Log Ohms for a short duration of time and completed the SIR test above the Pass/Fail limit. The residue was observed post testing inspection as shown in Figure 12.

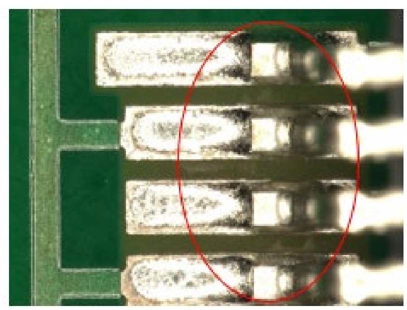

Figure 12. Residue remaining on U2 pads.

However, for the Chamber 1-Cell 5, the residue caused the resistance to drop below the Pass/Fail limit at the conclusion of the SIR testing. The residue was observed post testing inspection as shown in Figure 13.

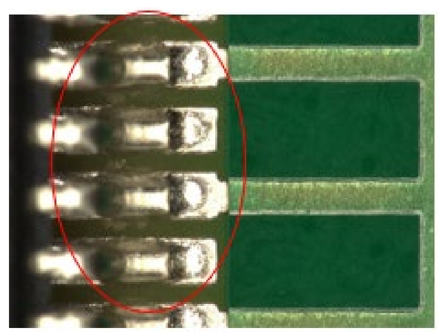

Figure 13. Residue remaining on U3 pads.

Lessons Learned

Process improvements and optimization were implemented at various parts of the assembly to ensure assembly quality and product reliability. These improvements included the utilizing of a flux test which is designed to visually indicate any remaining active flux on the board post assembly. The second improvement utilized is the ROSE test for a given product build/lot. In addition, SIR testing capability was installed in the factory for the purpose of qualifying of a given material, manufacturing step or process as well to ensure the quality of the products manufactured.

Cleaning with Cleaning Chemistry

Board ID	Cleaning Chemistry A	Board ID	Cleaning Chemistry B
	Minimum Resistance Values Recorded (LogOhms)		Minimum Resistance Values Recorded (LogOhms)
Chamber 1 Cell 1 Board 1	8.74	Chamber 2 Cell 3 Board 1	10.02
Chamber 1 Cell 1 Board 2	8.7	Chamber 2 Cell 3 Board 2	10.02
Chamber 1 Cell 1 Board 3	8.74	Chamber 2 Cell 3 Board 3	9.94
Chamber 2 Cell 3 Board 1	8.77	Chamber 2 Cell 5 Board 1	10.19
Chamber 2 Cell 3 Board 2	8.79	Chamber 2 Cell 5 Board 2	10.37
Chamber 2 Cell 3 Board 3	8.68	Chamber 2 Cell 5 Board 3	10.08
Chamber 2 Cell 1 Board 1	8.56	Chamber 2 Cell 4 Board 1	10.97
Chamber 2 Cell 1 Board 2	8.69	Chamber 2 Cell 4 Board 2	10.96
Chamber 2 Cell 1 Board 3	8.85	Chamber 2 Cell 4 Board 2	11.08

Table 3. Final Log ohms From SIR Testing Between Cleaning Chemistries A and B for Comparative Assembly Processes

Chemistry A averages 8.72 Log ohms over three manufacturing processes while Chemistry B averages 10.4 Log ohms over the three manufacturing processes. It is important to note that while the manufacturing processes where exactly the same for the materials used, reflow and selective soldering processes, it was not for the cleaning process. For the three cells utilizing Cleaning Chemistry B, the cleaning process was delayed by four days. In addition, the IPC-B52 boards in Chamber 2 Cell 3 were cleaned with Cleaning Chemistry B only once after both soldering steps. While the IPC-B52 boards in Chamber 1 Cell 1 utilizing Cleaning Chemistry A were cleaned twice.

Testing Anomalies

As with any given test, the potential for a given defect in materials, deviation in process, mishandling or other quality related issue is omnipresent. In one the IPC-B-52 boards that was assembled and subjected to SIR testing, a latent board defect resulted in very low resistance. The root cause analysis is due a mechanical disturbance between traces of the U2 component as illustrated in Figure 14. The low resistance commenced at the very beginning of the SIR testing and was consistent throughout the test.

For both Cleaning Chemistries A and B, the resistance did not fall below the 8.0 Log ohms at any time during the SIR testing. The final resistance was above the pass limit of 8.0 Log ohms. During the post inspection of the IPC-B52 boards, there were no observations of dendrites, discoloration between conductors, water spots or subsurface metal migration.

The analysis of the Log ohms between Cleaning Chemistry A versus Cleaning Chemistry B provides a distinct difference in the absolute value of Log ohms as listed in Table 3.

Table 3. Final Log ohms From SIR Testing Between Cleaning Chemistries A and B for Comparative Assembly Processes

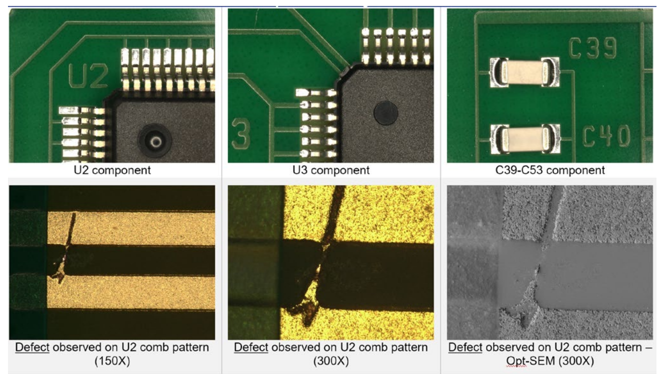

Figure 14. Mechanical Defect Between Traces of the U2 Component

Conclusion

This investigation into the qualification to improve, define and quantify process controls and product reliability, has provided objective evidence for the manufacturer to implement new materials while also improving product quality using existing systems and collaborating with suppliers. In working together, the onus for implementing these quality safeguards and providing the objective evidence that the change planned whether it be a minor or major change will not impact product quality or reliability, is ultimately the responsibility of the assembly house or contract manufacturer but is aided by the expertise of a supplier. In this paper, the collaboration between contract manufacturer and supplier to provides a method for providing the objective evidence for qualification of a cleaning chemistry in an efficient and timely manner.