Divergence in Test Results Using IPC Standard SIR and Ionic Contamination Measurements

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Abstract

Controlled humidity and temperature controlled surface insulation resistance (SIR) measurements of flux covered test vehicles, subject to a direct current (D.C.) bias voltage are recognized by a number of global standards organizations as the preferred method to determine if no clean solder paste and wave soldering flux residues are suitable for reliable electronic assemblies. The Association Connecting Electronics Industries (IPC), Japanese Industry Standard (JIS), Deutsches Institut fur Normung (DIN) and International Electrical Commission (IEC) all have industry reviewed standards using similar variations of this measurement.

Ionic contamination testing is recognized by the IPC as a standard for evaluating the cleanliness of assemblies that have subjected to a cleaning process. IPC J-STD001F standard calls for a cleanliness level of < 1.56 µg/cm² NaCl equivalent after the cleaning processes. Historically, this threshold originated from the cleanliness specifications of military and aerospace original equipment manufacturers (OEMs). These applications used rosin-based wave soldering fluxes, such as RMAs, and cleaned with now presently banned fluorocarbon solvents. Many of these applications have subsequently implemented water soluble soldering processes. Several automotive and consumer electronic OEMs still use this standard, to qualifying assemblies built with no-clean materials using mixed SMT and PTH assembly technologies.

IPC-TM-650 Method 2.3.25 contains standard test methods for extracting contaminants from circuit boards using heated isopropanol (IPA) / water mixtures. Test method 2.3.25 is commonly referred to as the ROSE (Resistivity of Solvent Extract) test. Previous work [1,2] has shown poor correlation between the presence of extractable, corrosive weak organic acids and results from IPC-TM-650 2.3.25 test results, partially due to the lack of solubility of materials found in no-clean fluxes, and the higher SIR values imparted by rosins and resins in modern no-clean soldering materials.

This study will compare the results from testing two solder pastes using the IPC-J-STD-004B, IPC TM-650 2.6.3.7 surface insulation resistance test, and IPC TM-650 2.3.25 in an attempt to investigate the correlation of ROSE methods as predictors of electronic assembly electrical reliability.

Introduction

Ionic contamination testing has been traced back to work done at the United States Naval Avionics Center in Indianapolis in the early 1970's by Hobson and DeNoon [3]. This work eventually led to the development of the 1.56µg/cm2 (10µg/inch²) NaCl equivalent standard for ionics extracted using an IPA/water mixture. High volume circuit assembly at the time used only wave soldering processes, employing foam fluxers to apply RMA flux followed by post soldering cleaning process with fluorocarbon solvents. A schematic diagram of the original ionic contamination test method is depicted in Figure 1.

This ionic contamination limit became part of now defunct Mil Spec P-28809 [4] and Mil STD-2000A, but has been carried through versions A through F of IPC ANSI/J-STD-001 standard. This manual procedure has become more automated with the invention of production test equipment. Although these measuring devices improve the efficiency and accuracy of measuring ionic contamination soluble in alcohol/water mixtures, they also increase the amount of ionic material measured. [5, 6]

IPC-9202 describes a procedure for qualifying a process for electrical reliability by measuring SIR using IPC TM-650 2.6.3.7 and IPC TM-650 2.3.28 by using the IPC-B-52 test coupon. This coupon is shown in Figure 2. The standard calls for a minimum SIR value of 100MΩ, but only calls for a measure and report of the ionic contamination. The reported ionic contamination then becomes a benchmark for "future trouble shooting or process improvement efforts."

The experiments carried out in this work were designed to use methodology derived from IPC-9202 to determine if it is possible to have a solder paste that passes SIR standard of >100 MΩ, but fails the ionic contamination level of ANSI/J-STD-001F, and determine if a second solder paste fails the SIR test and passes the ROSE test standard.

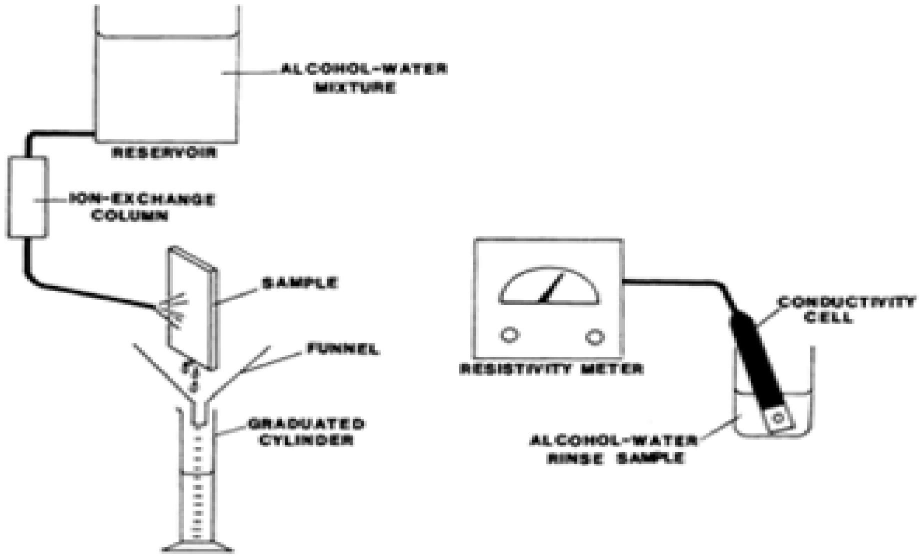

Figure 1. Schematic diagram of the original ionic contamination method.

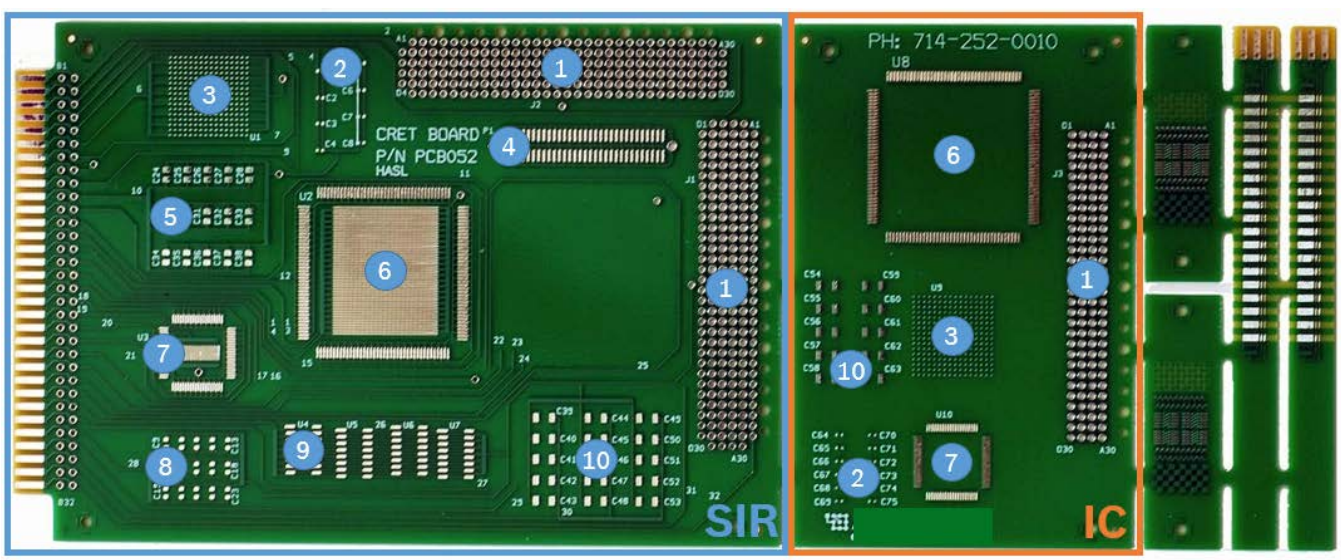

Figure 2. IPC B-52 test coupon comprising a SIR test coupon (SIR) and a section for ionic contamination measurements (SIR). Component ID: 1 – TH connector 4 x 24 pins, 2 – Capacitor, 10 pF, 0402 package, 3 – BGA, 256 IO, 1mm pitch, isolated, 4 – SM connector IEEE 1386, 2 x 16 pins, 5 – Capacitor, 10 pF, 0805 package, 6 – QFP160, 0.65 mm pitch, isolated, 7 – QFP80, 0.5 mm pitch, isolated, 8 – Capacitor, 10 pF, 0603 package, 9 – SOIC16, 1.27 mm pitch, isolated, 10 – Capacitor, 10 pF, 1206 package.

Methodology

Two different SAC305 solder pastes were printed and reflowed on IPC B-52 test coupons (Figure 2). The assembled coupons were broken into 2 separate test vehicles after the solder pastes were printed, populated and reflowed. The section of the board on the center right was used to measure ionic contamination. The left portion of the test vehicle was used to measure SIR. The four smaller panels on the far right were discarded. A schematic diagram of Production Test Equipment A that was used is depicted in Figure 3. Production Test Equipment A is considered a “dynamic” ROSE measurement in which the extraction solution is continuously passed through ion exchange columns that remove the ionic material in the solution. A conductivity bridge detects ions in solution, and a flow meter measures the volume of solution passing by the conductivity bridge, allowing ionic contamination to be integrated with extraction solution volume.

A second measurement using three IPC-B-24 coupons (usually used for single material SIR measurements) for each of the two pastes was made.

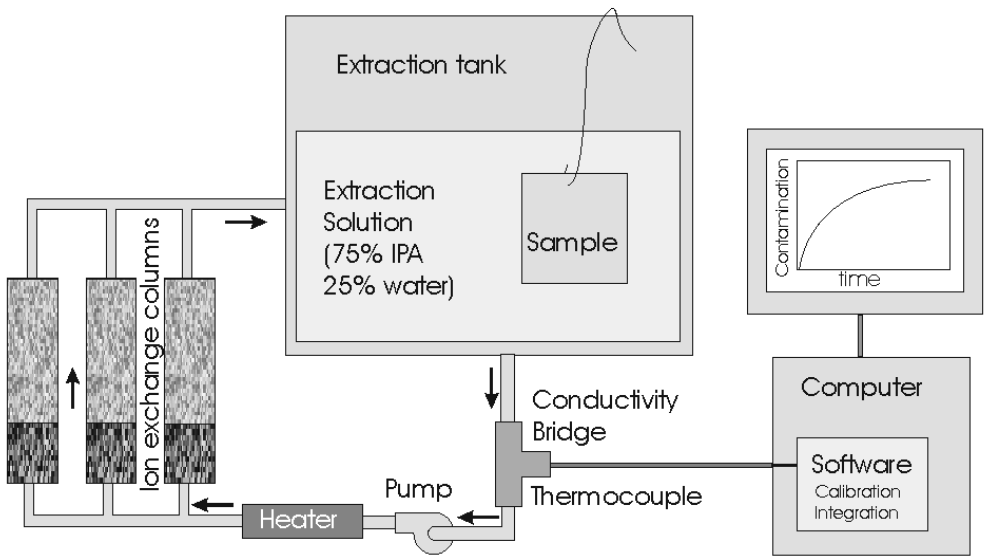

Figure 3. Schematic Diagram of Production Test Equipment A.

Experimental Procedure

1. IPC-B-52 Coupon Preparation

Ten IPC-B-52 coupons were processed for each of the two selected solder pastes. These coupons were used as delivered from the board fabricator; no further cleaning was done. The pastes were printed using a 0.125 mm (5 mil) stencil. Positions 2, 3, 5, 7, 8 and 10, as shown in Figure 2, were populated with dummy components. The coupons were then reflowed using a production reflow oven with a 1.1 °C/s straight ramp to a peak temperature of 243°C with a time above liquidus of 53s using a nitrogen atmosphere (600-800ppm O2), see Figure 4.

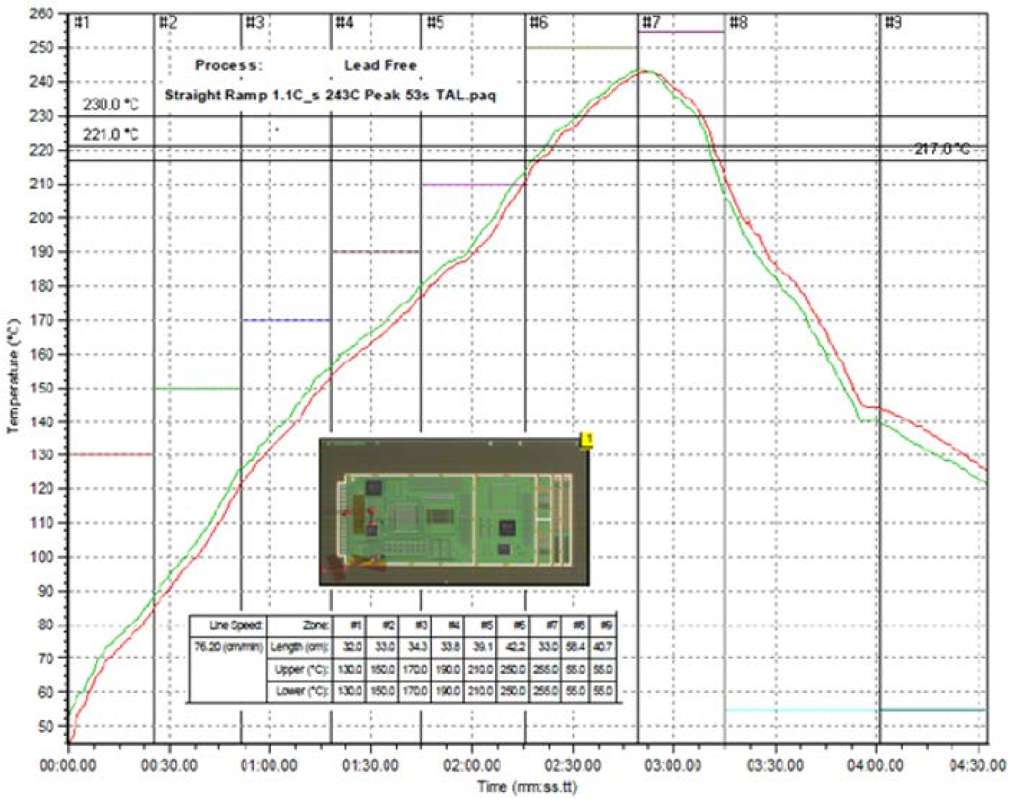

Figure 4. Applied reflow profile comprising a straight ramp to 243°C under nitrogen (1.1 °C/s, 53 s TAL).

2. SIR measurements

The SIR portion of twenty coupons and two unprocessed control coupons were mounted in a temperature-humidity chamber. Teflon insulated leads were hand soldered to the coupons. The chamber was programmed to run at 40°C +-1°C and 90-93% RH, and production monitoring equipment for measuring SIR was programmed to apply 12V bias and to measure SIR at bias voltage every 20 minutes for 7 days.

SIR data were recorded for pattern No. 5, 6, 7 and 8 (see Figure 2). The boards were mounted in the temperature/humidity chamber and connected to the production monitoring equipment for measuring the SIR. The chamber was programmed to record SIR readings at 12 V every 20 minutes. No edge card connectors were used. Teflon-insulated wires, were soldered with ROL0 flux cored wire.

3. Ionic Contamination Measurements of IPC-B52-coupons

Ten IPC B 52 ionics break away with three populated patterns were measured for each of the two pastes. Production test equipment A was used to measure the ionic contamination of each sub coupon. A 75% isopropanol 25% water extraction solution heated to 45°C was used. A dwell time of 15 minutes in the equipment was used. This time was a balance between complete removal of ionic contamination, versus CO2 absorption increasing the apparent conductivity of the solution from a source other than the test vehicle. A PCB surface area of 65 cm^2 was used in the calculations.

4. IPC-B-24 Coupon preparation

A. Pre-cleaning

Modified IPC-B-24 test coupons, with bare copper FR4 were immersed in a 75% isopropanol / 25% water solution in Production test equipment A. The solution was heated and circulated. The boards remained in the solution until a solution resistivity of > 300 ohm-cm was achieved. The boards were then baked at 50°C for one hour.

B. Coupon assembly

The solder paste was printed on three test coupons per paste using a 150µm (6 mil) stencil. The coupons were then exposed the temperature profile similar to that shown in Figure 4 below using a production reflow oven in N2 (600-800ppm O2).

Results and Discussion

Log SIR results for solder paste A and solder paste B measured on the leads around the small QFP on the IPC-B-52 coupons are depicted in Figures 5 and 6 respectively. Figure 7. shows the mean Log SIR values for all 6 patterns measured for both solder pastes. As can be seen from the 7 day test, paste A has a consistent SIR reading of 3 orders of magnitude greater than paste B. Paste B is a marginal fail if 100MΩ is used as the pass/fail standard.

Figure 8 compares the results for ionic contamination measured on the IC part of the B-52 test vehicles with solder paste A and B. Contrary to the SIR readings, the test coupons processed with solder paste A exhibit an ionic contamination level that were three times larger than solder paste B. The discrepancy is a result of the easy extraction of benign ionics in the alcohol/water mixture from solder paste A, and insoluble contributors to reduced surface insulation in solder paste B. A detailed analysis of the chemical nature of the ionic residues was not performed. The results are a borderline pass for solder paste A with high SIR values and a pass with a wide margin for the samples that used solder paste B that failed to consistently maintain a SIR above 100 MΩ during the constant climate test.

Log SIR per J-STD-004C is shown for pastes A and B in Figure 9. In this case, SIR values are 4.5 orders of magnitude higher for paste A than paste B.

Conclusions

These divergent test results emphasize why a ROSE test should be used as a relative test to qualify a process, and to use the baseline SIR/Ionic contamination measured using the dual purpose test as a benchmark for “future trouble shooting or process improvement efforts.” Test coupons with ionic equivalent measurements just below the 1.56µg/cm2 NaCl equivalent limit used in IPC ANSI/J-STD-001F standard were shown to have 3 orders of magnitude greater Surface Insulation Resistance, but still have 3X measured ionic contamination. Thus, the ionic contamination of a PCBA does not predict any reliability of the electronic control unit under high temperature and high humidity conditions. It is highly recommended that the IPC 5-22A task group review and amend IPC ANSI/IPC-J-STD-001F standard to account for the known divergence in SIR and Ionic contamination results on the electrical reliability in SMT assemblies.

References

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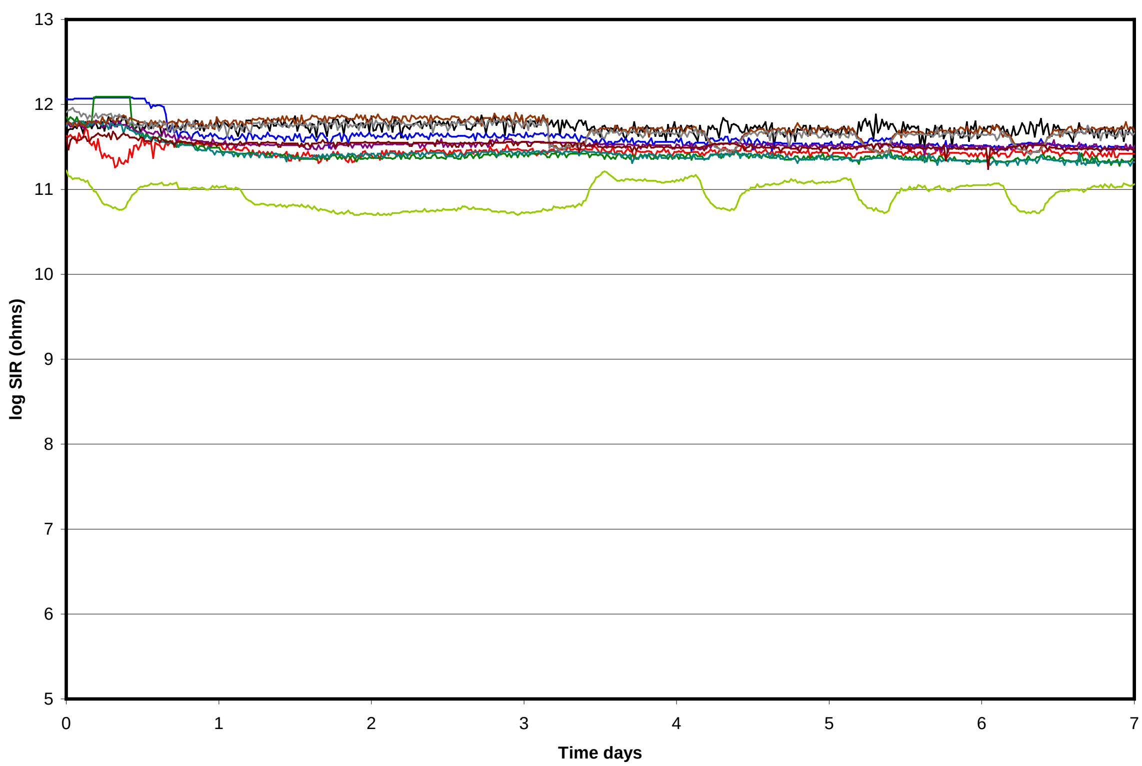

Figure 5. IPC-B-52 SIR test results of Paste A at small QFP leads

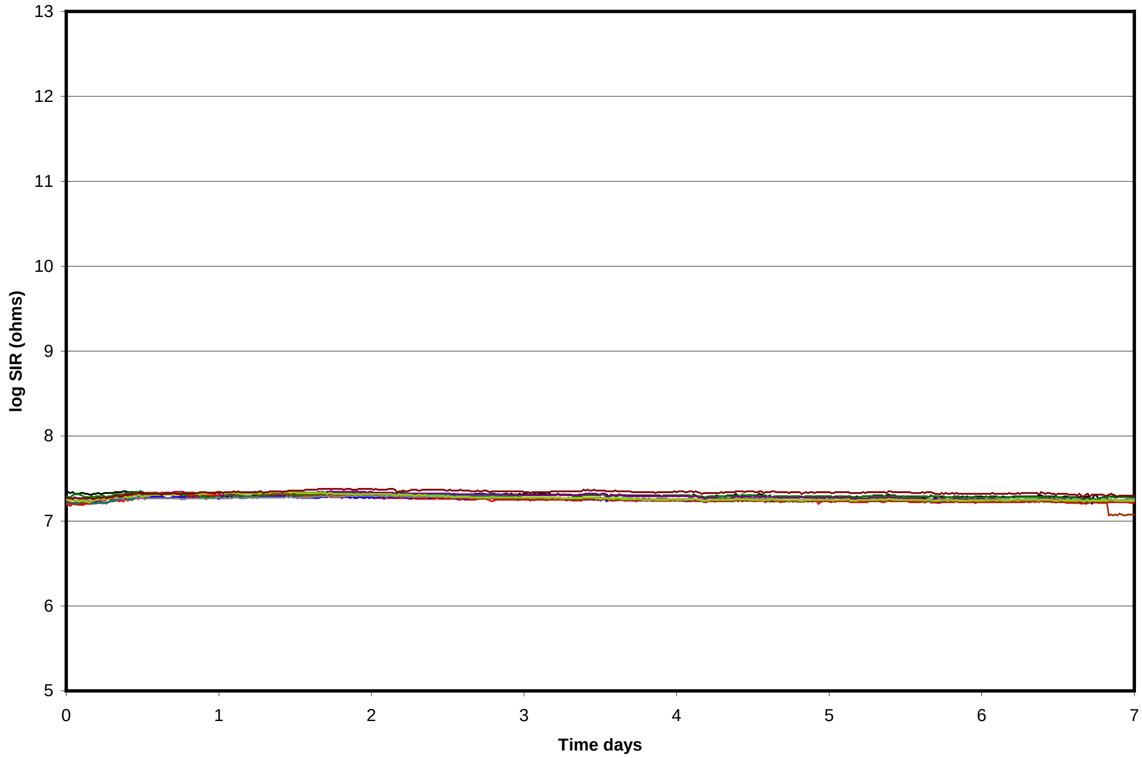

Figure 6. IPC-B-52 SIR test results of Paste B at small QFP leads

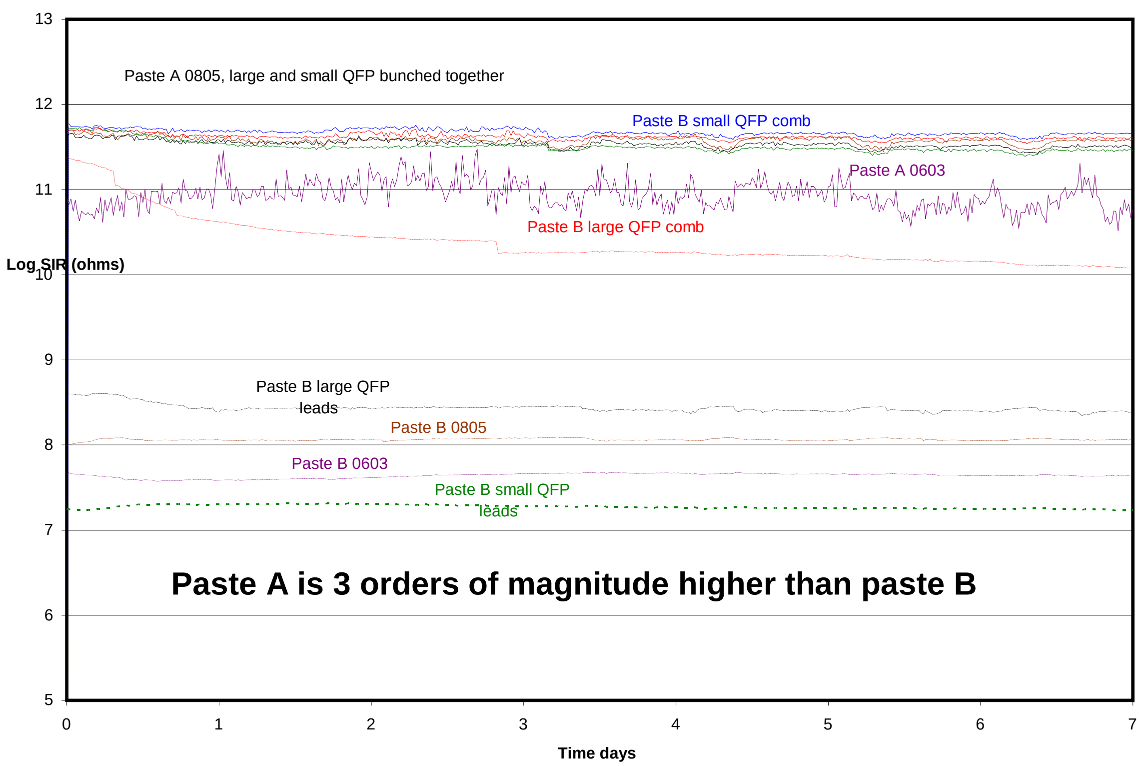

Figure 7. Mean B52-SIR all patterns Paste A and Paste B

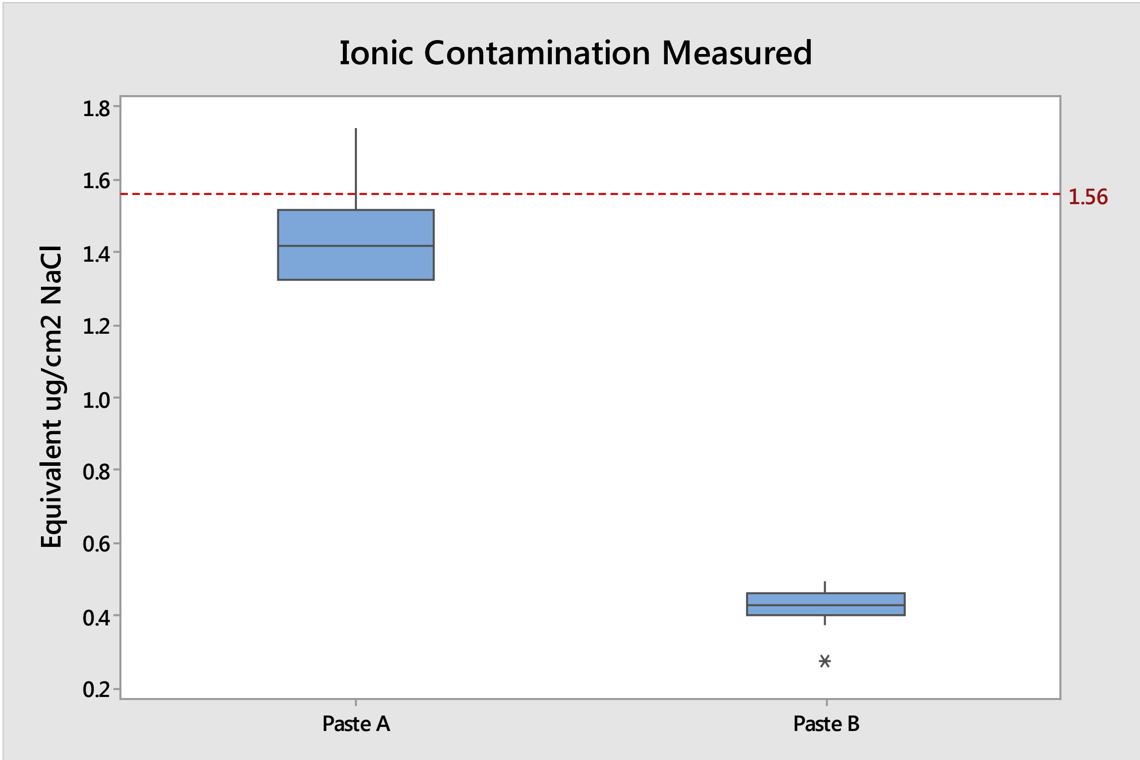

Figure 8. Box plots of ionic contamination measurements of the IC part of B-52 test vehicles processed with Solder pastes A and B.

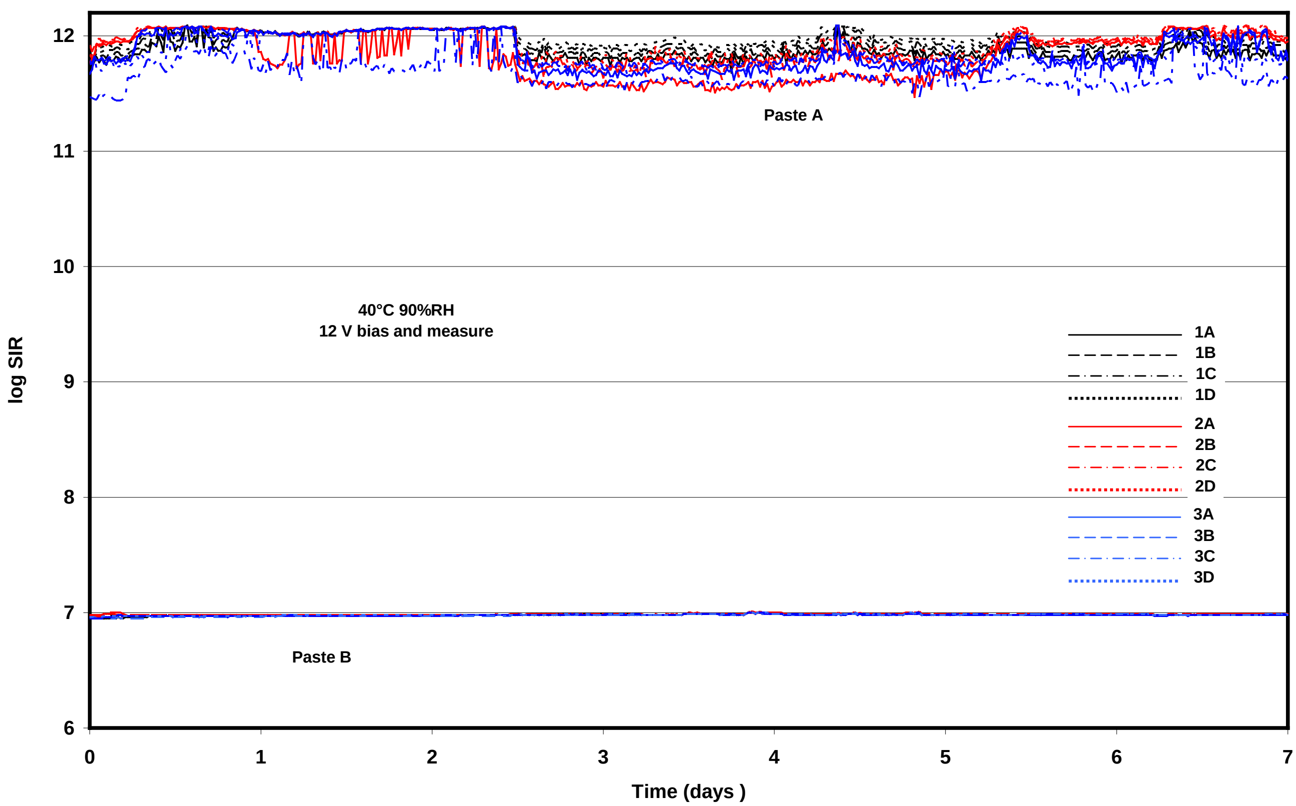

Figure 9. Paste A and Paste B SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7

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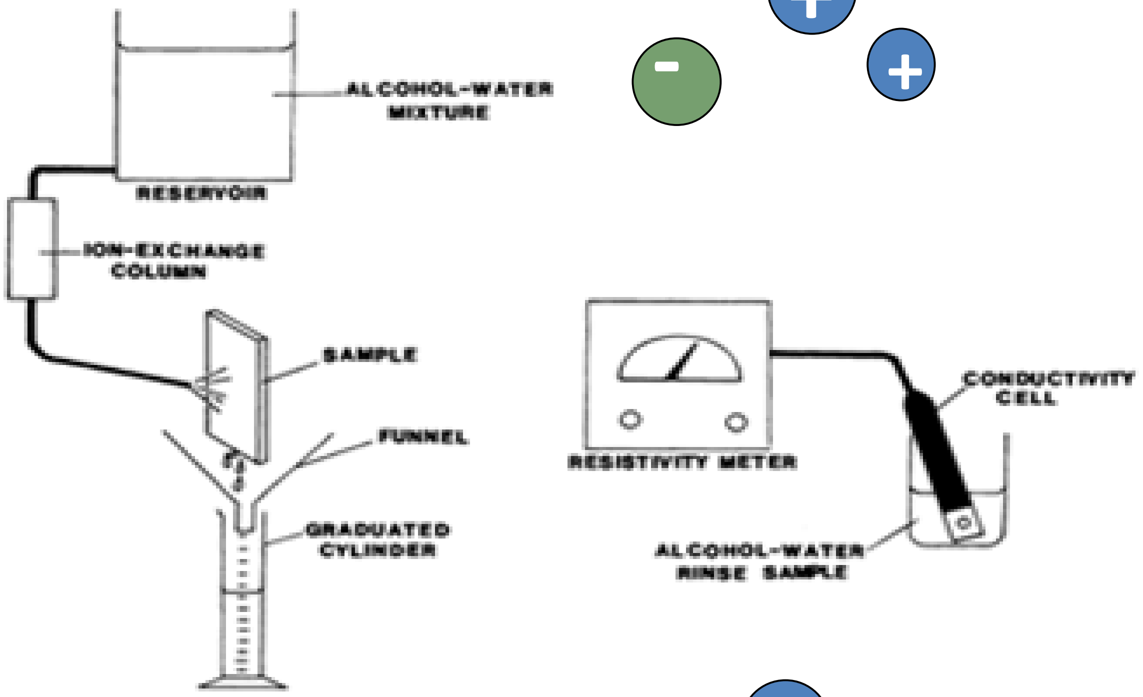
Introduction

- Ionic contamination testing of PWB's began in the 1970's
  - Hobson and DeNoon
    - At this time, most PWB assembly used RMA fluxes and wave soldering.
    - Cleaned with fluorocarbon solvents.
  - Adopted in military specifications
    - Mil Spec P-28809 and Mil STD-2000A
  - Evolved into the 1.56 eq µg NaCl limit found in cleaned electronic assemblies

Original Resistivity Of Solvent Extract Test

- PWB rinsed with deionized isopropanol water mixture.
- The ionic conductivity measured and compared to NaCl solution.
- Newer methods are automated:
  - Bathtub – Keep same extraction solution, just circulated.
  - Shower – Solution passed through ion exchange filter
  - Usually extract more ionic contamination



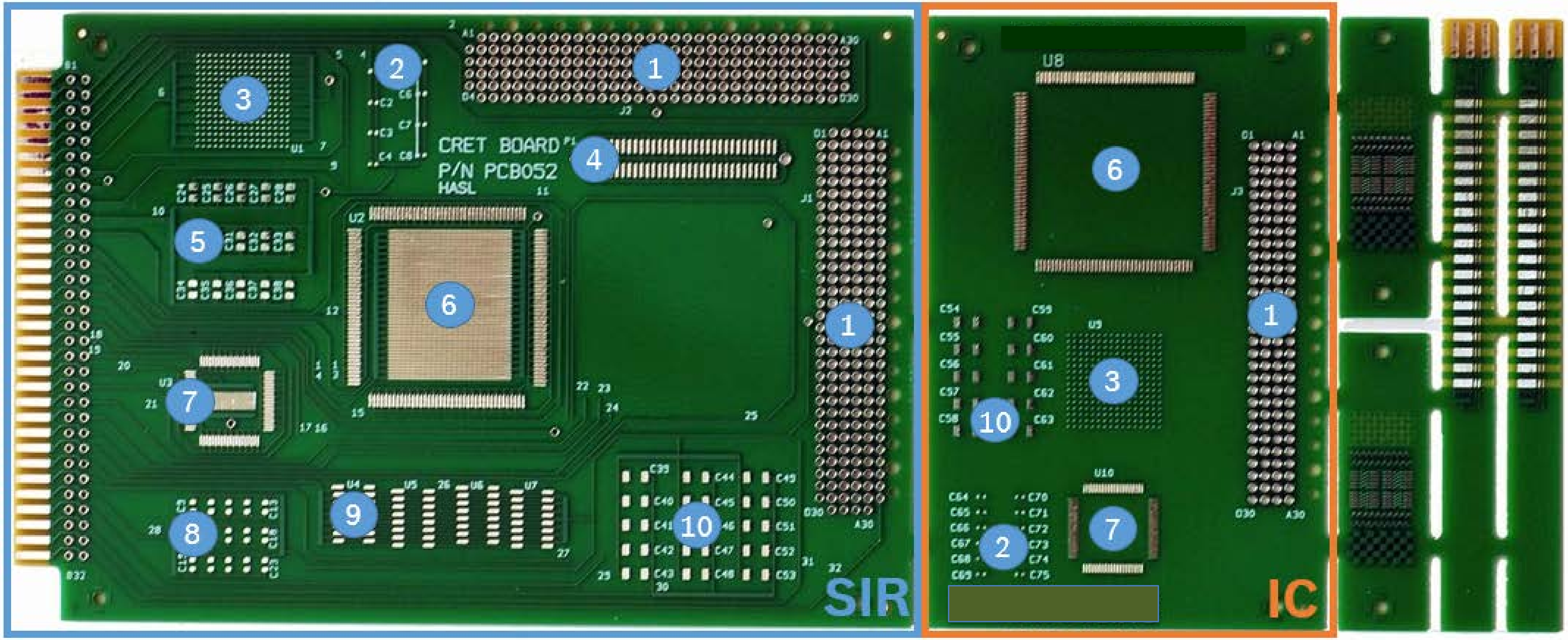
Introduction

- Some automotive and consumer electronic OEM's still use the 1.56µg/cm^2 to qualify assemblies built with **no-clean** materials.
  - This limit is given only for **cleaned** assemblies in J-STD-001F.
  - This limit may not even be adequate for PWBs cleaned with some modern processes.
    - Originally intended for RMA fluxes cleaned with fluorinated hydrocarbons.
  - Ionic contamination levels may not necessarily predict electrochemical reliability.

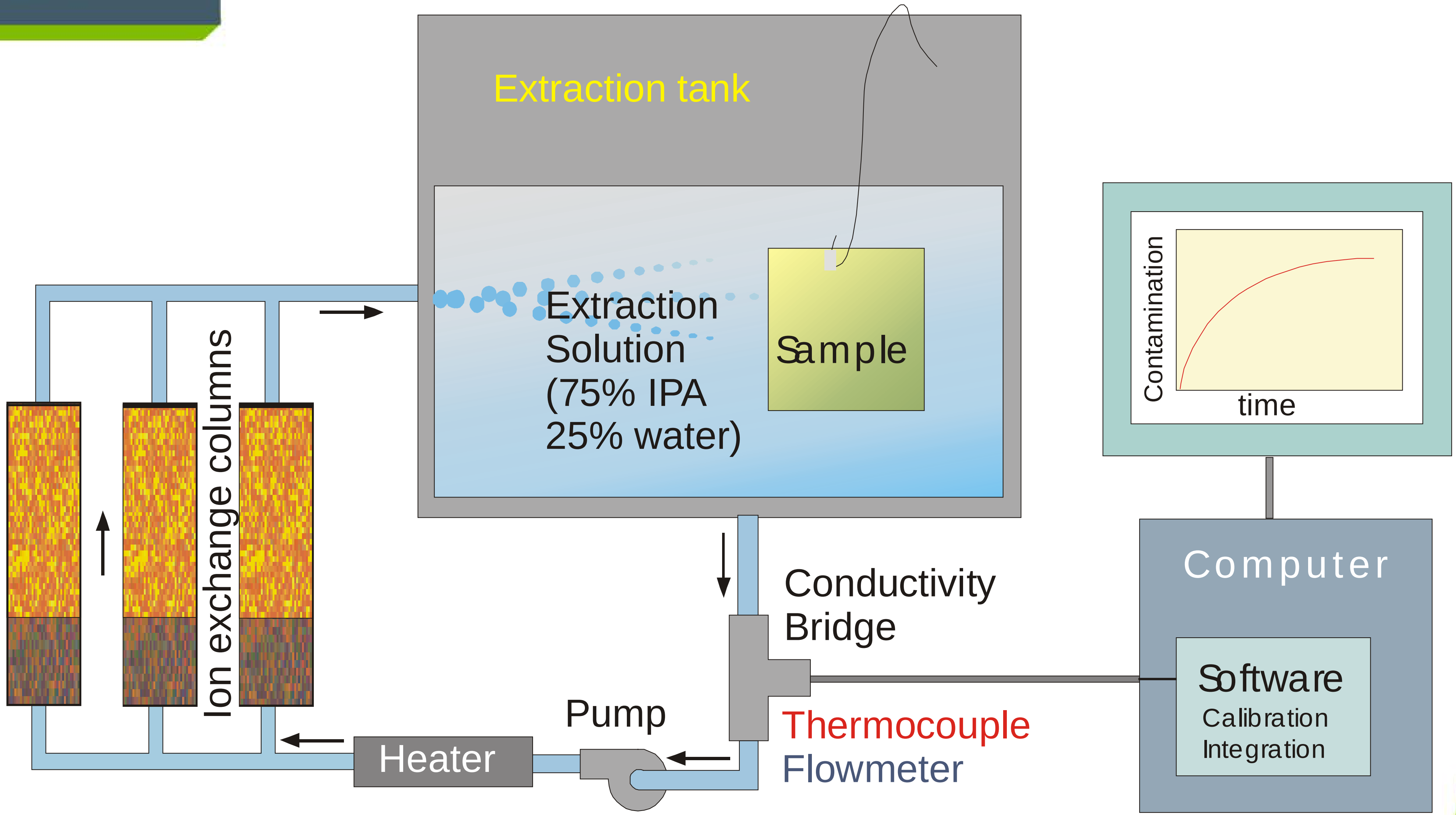
Introduction

- IPC 9202 provides a better way to evaluate PWB reliability for a given process.
  - As close to actual assembly as possible, fabrication and assembly
  - SIR measurements using model components.
  - ROSE testing can be then referenced to SIR results.
  - Ionic measurements can then be used as a benchmark for “future trouble shooting or process improvement efforts” and process control.

IPC-B-52 Test Vehicle

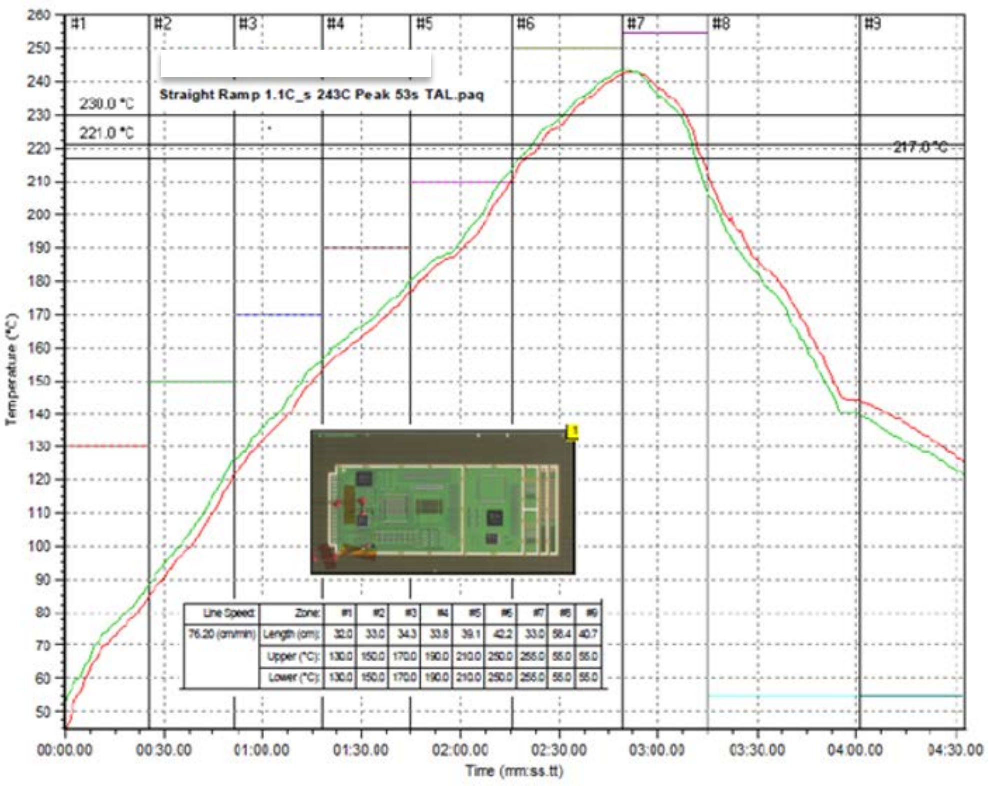


Shower-type automated ROSE test



IPC-B-52 Coupon Preparation

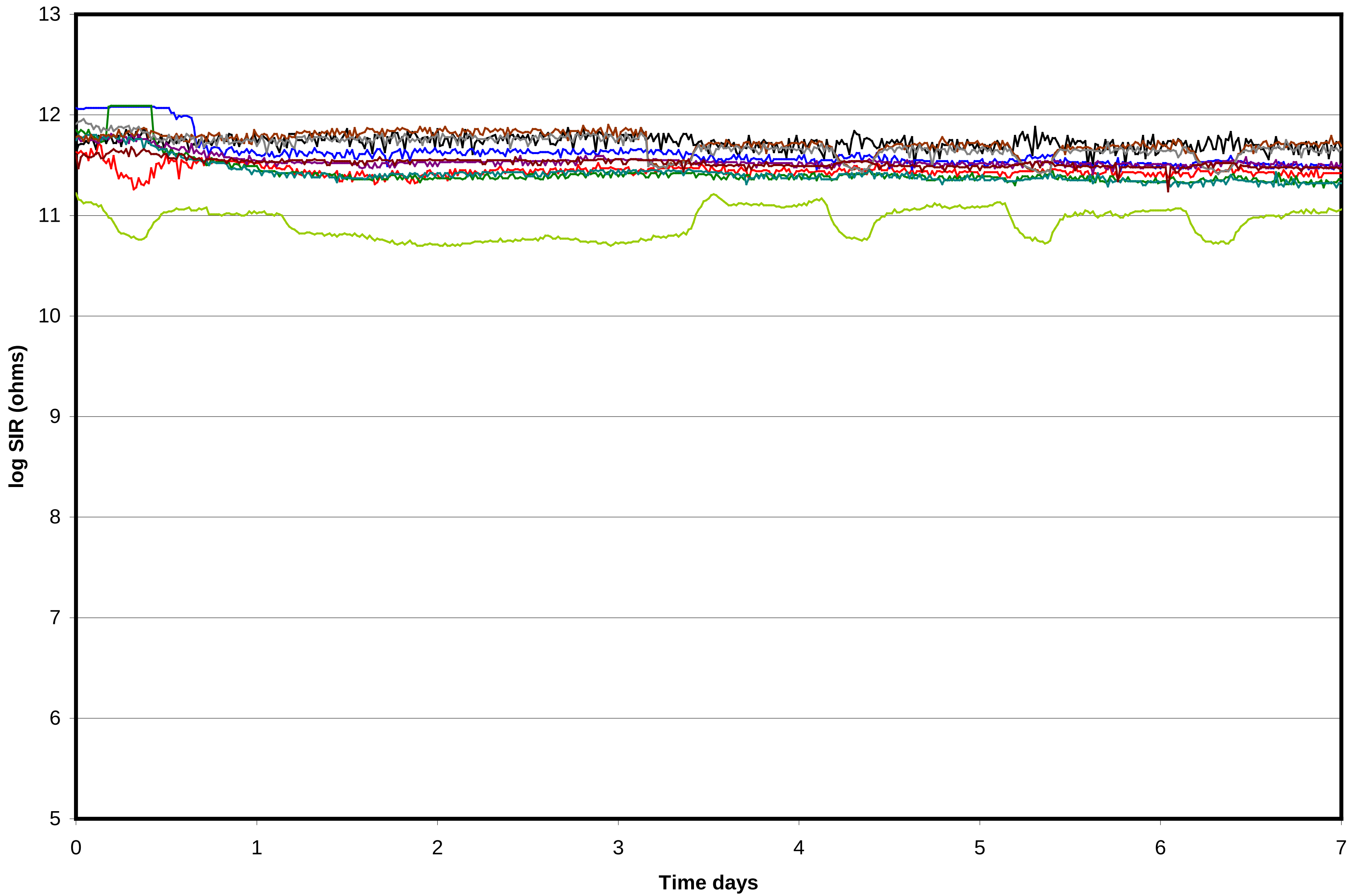
- 2, 3, 5, 7, 8 & 10 populated
- Two solder pastes, A & B
  - SAC305
- Reflow straight ramp in N_2
  - 1.1 C/s 243° C peak 53 s TAL
- SIR per IPC TM 650 method 2.6.3.7, 40° C 90% RH 12V bias and measure for 7 days.
  - Pattern 5, 0805's
  - Pattern 6, unpopulated large QFP comb and leads
  - Pattern 7, populated small QFP comb and leads
  - Pattern 8, 0603's



Line Speed:	Zone:	#1	#2	#3	#4	#5	#6	#7	#8	#9
76.20 (cm/min)	Length (cm):	32.0	33.0	34.3	33.8	39.1	42.2	33.0	58.4	40.7
	Upper (°C):	130.0	150.0	170.0	190.0	210.0	250.0	255.0	55.0	55.0
	Lower (°C):	130.0	150.0	170.0	190.0	210.0	250.0	255.0	55.0	55.0

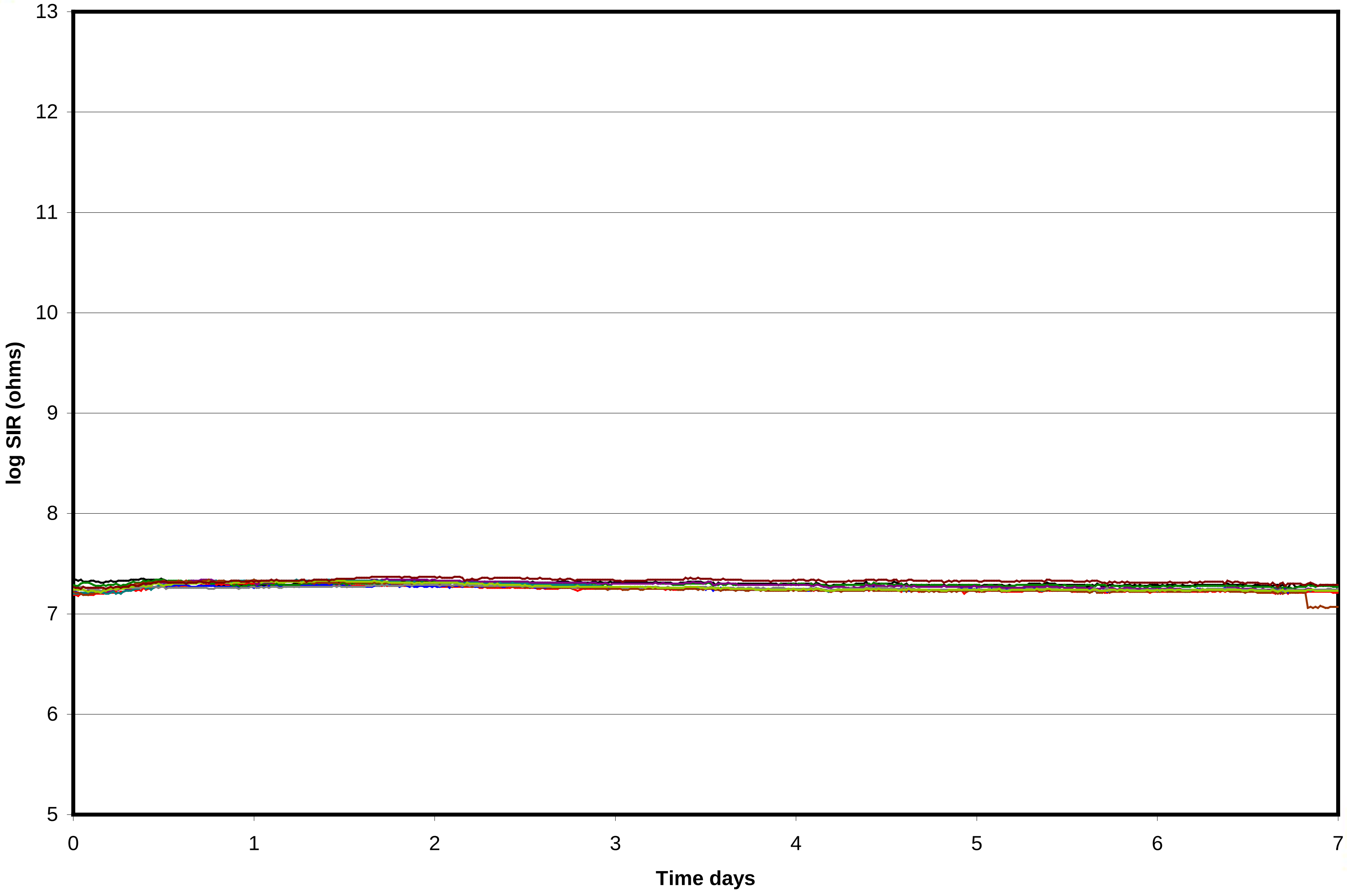
Log SIR Paste A at small QFP leads

- High SIR

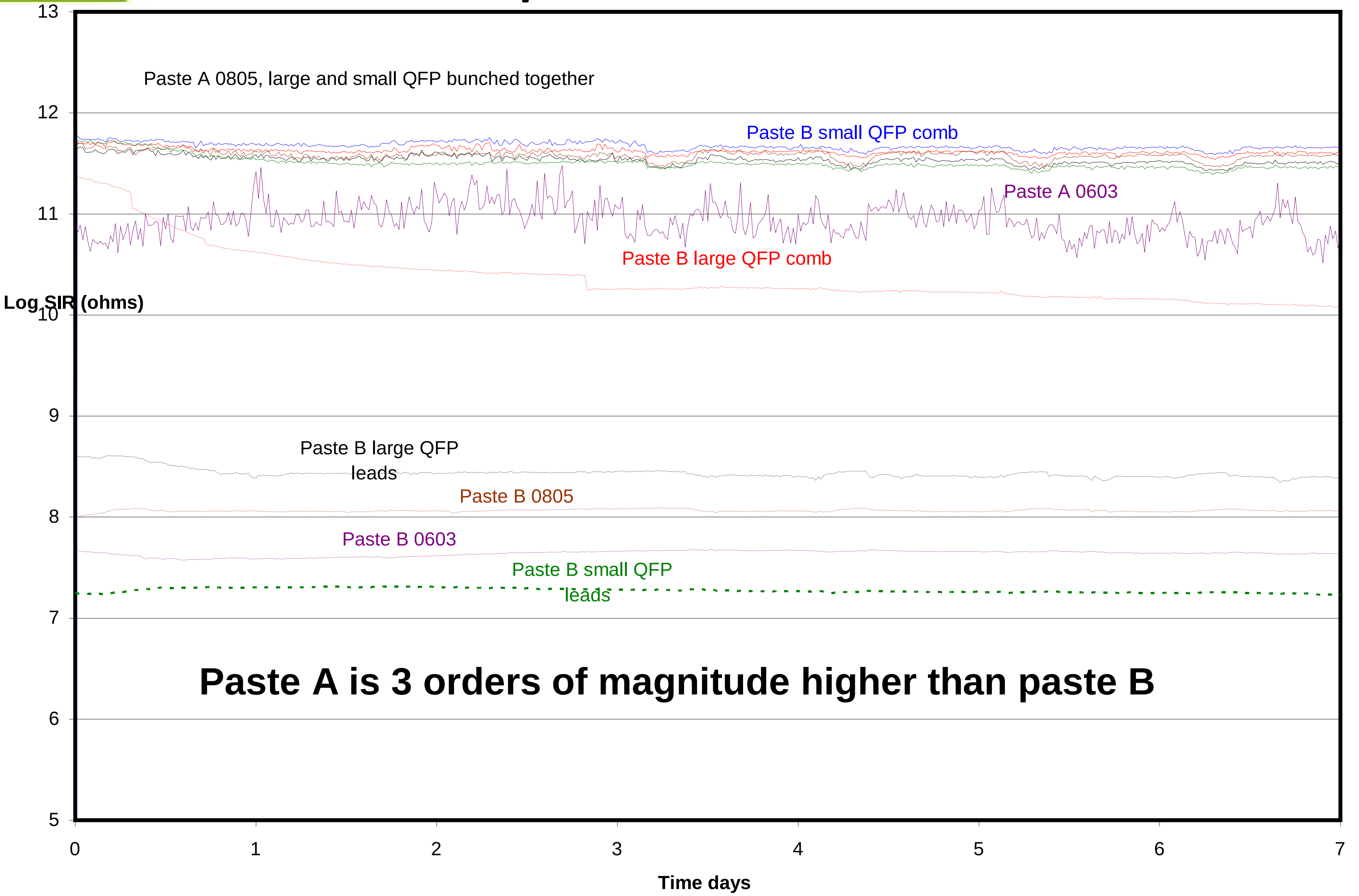


Log SIR Paste B at small QFP leads

- Low SIR

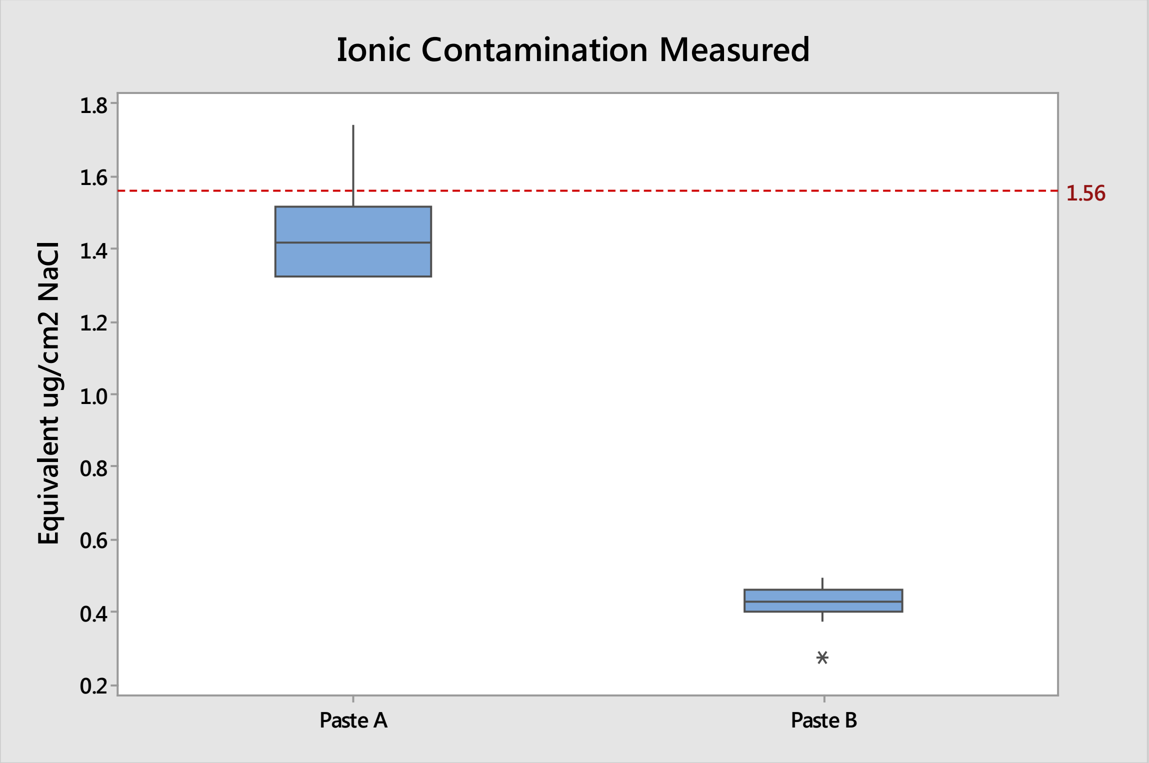


Mean IPC-B-52 SIR all patterns tested pastes A and B



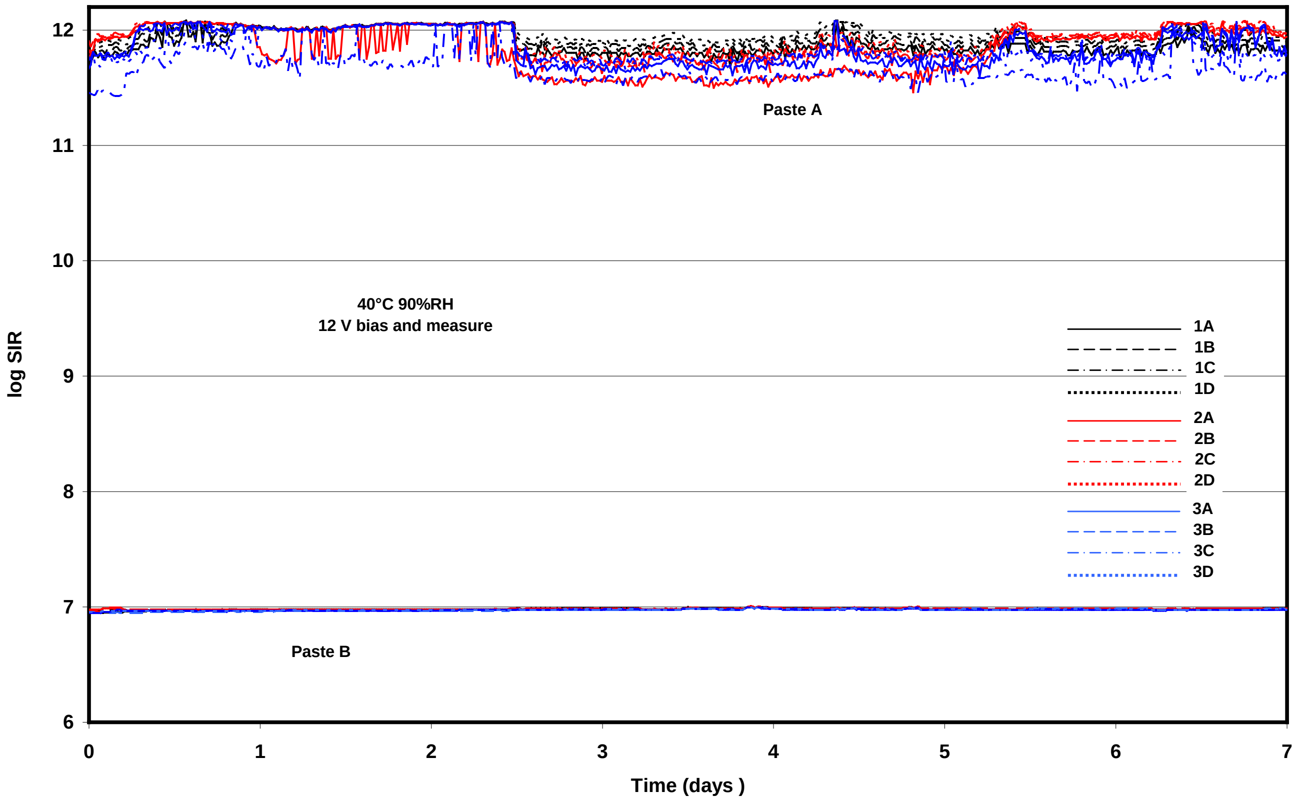
Ionic Contamination Measurements Pastes A and B

- Paste A has 4X the extractable contamination that paste B has!
- Paste A has much better SIR.
- Which method better predicts PWB reliability?



Paste A and Paste B SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7

- IPC-B-24 coupons, bare copper on FR-4.
- Cleaned in 75%IPA/25% water before printing and reflowing paste.
- Paste A SIR is nearly 5 orders of magnitude higher than paste B.



Conclusions

- We have demonstrated that a paste with high SIR can have much more extractable ionic contamination than a paste with much lower SIR.
- ROSE measurements should be benchmarked with SIR evaluation of an PWB assembly process.
  - These measurements should be considered relative to the SIR evaluation.
- ANSI/IPC J-STD-001F should be amended to account for the divergence in SIR and Ionic contamination results on electrical reliability

Thank you!

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