Cleaning Qualification Methodology for Inline Aqueous Assembly Process

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EXECUTIVE SUMMARY

An assessment to measure the cleanliness of the area underneath a component has been completed. The assessment uses an 8”×9”×0.093” test vehicle with FR4 laminate, OSP surface finishing, and 21 package types. The test vehicles went through a Pubs assembly process and inline aqueous cleaning. The two test methodologies used are Ion Chromatography (IC) and Electron Migration (EM). Based on the test results, most of components pass the criteria, except three high pin count LBGA’s on Bromide level of Paste B. No significant differences between the low stand-off components group and other groups. Among the four low stand-off components, LGA133, which has the lowest stand-off, shows a higher Total Anion level. The test results also verified that, within the similar package types, the ionic level is likely proportional to the stencil paste volume. It also shows there is no statistical differences among the three Time-To-Wash cases. In other words, if the board is washed within 72 hours, there is no significant difference on ionic level. EM test results are still under analysis. It will be available at conference.

Components Spot Cleaning Assessment For Inline Aqueous Process

STEVEN PERNG, CISCO SYSTEM INC.

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OBJECTIVE

- Where Are We Now –
  To investigate how current aqueous cleaning process is correlated to J-STD-001 and other published industrial criteria.
- Where Can We Be In The Future –
  To investigate the risks of using low stand-off components, such as 0.4mm CSP, LGA, and QFN.
- How To Get There –
  Design a Cleanliness Test Kit to be used for New Site Line Qualification and Line Stop investigation.

Action Plan

1. Survey and review current industrial standards, test methodologies, and publications on PCA aqueous cleanliness
2. Contact industrial partners for current activities and active projects, including paste suppliers, equipment suppliers, IPC work group, CM's, and other OEM's.
3. Define a Cleanliness Test Methodology for PCA aqueous cleaning process
4. Design a Test Vehicle using current and near future component technology
5. Consolidate the Test Methodology and Test Vehicle into a Cleanliness Test Kit for new facility qualification or quality alert audit

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Test Methodology

Measure or quantify the residues underneath a component on a printed circuit board, which may impact the electrical performance in long run

Ion Chromatography (IC)

- Chemical Measurement (µg/ml)
- Extraction Basis
- One time
- Based on IPC-TM-650, 2.3.28

Electronmigration (EM)

- Electrical Measurement (Ω)
- In-situ Measurement
- 500-hr Continuous
- Based on IPC-TM-650, 2.6.14.1

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Ion Chromatography

Equipment

- Dionex 500
- AS-40 Auto Sampler
- IonPac AS 11-HC 2mm (10-32)
- ASRS suppressor

Process

- 10% isopropanol in DI H2O
- 80°C water bath for 1-hr
- Cool down for 1-hr

Calibration

(µg/ml)	Detection Limit	Working Standard Concentration			
		1	2	3	4
Chloride	0.05	0.10	0.113	0.20	0.40
Bromide	0.10	0.18	0.23	0.45	0.90
Sulfate	0.10	0.17	0.22	0.34	0.68

Calculation

$(\mu g/cm^2) = (C \times V \times D) / A$

C : extract concentration (µg/ml)
V : volume of extraction solution (ml)
D : dilution factor
A : surface area of sample (cm^2)
(L x W x 2)

Maximum Concentration For Cleaning Assembly

							ug/in^2	
	4.5	0.7						
					3.0	0.47	5	3.88
			6.45	1.0			24.52	3.80

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Comparison Chart of SIR/EM Test

		SIR		EM
		GR-78-Core 13.1.3	**J-STD-001D** p. 46 **IPC-TM-650** 2.6.3.3	**GR-78-Core** 13.1.4 **IPC-TM-650** 2.6.14.1
Stencil THK		8mil	6mil	8mil or agreement
Pre-condition or Stabilization		23°C, 50%RH for 24 hr	85±2°C, 20%RH for 3 hrs	85°C, 65%RH for 96 hrs
Temperature		35±2°C	85±2°C	65°C
Humidity		85%	85±2%	85%
Voltage	Bias	45 ~ 50 V DC	45 ~ 50 V DC	10 V DC
	Measurement	-100 V DC	-100 V DC	45~50 V DC
Criteria	[1 + 4] day	> 10^5 MΩ (50mil) > 2×10^4 MΩ (12.5mil)		
	7-day		> 108 Ω (100MΩ)	
	500-hr (21-day)			$R_{final} > R_{initial}/10$
Test Pattern / Square Count		Bellcore / 440 IPC B-25	IPC-B-24 / 1000	Bellcore / 440 IPC B-25
Dendrite Growth		Not Specified	< 20% of Spacing (10X ~ 30X)	< 20% of Spacing (10X)

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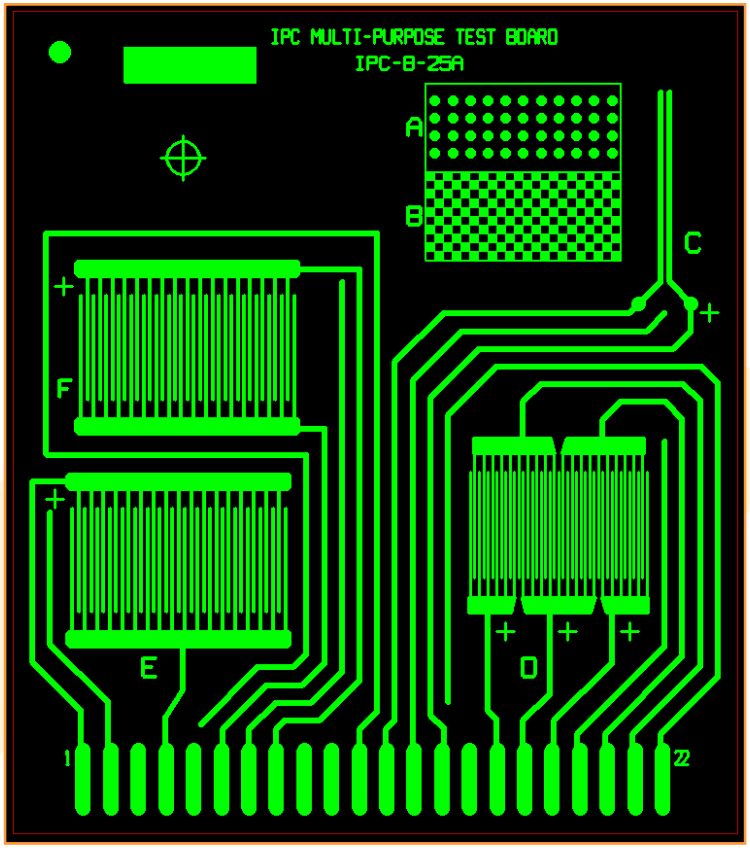
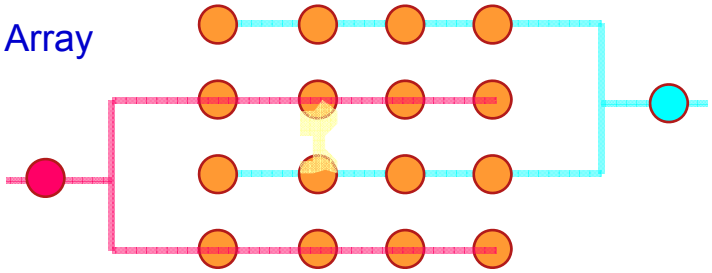
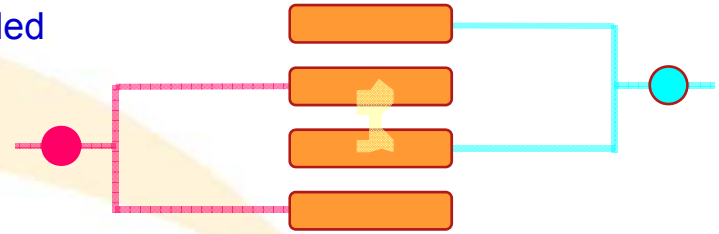
SIR Pattern Design for Component



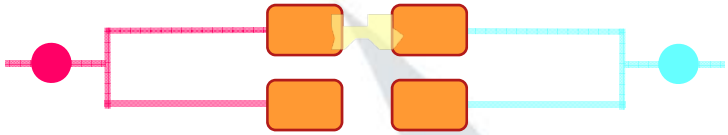
Area Array



Leaded



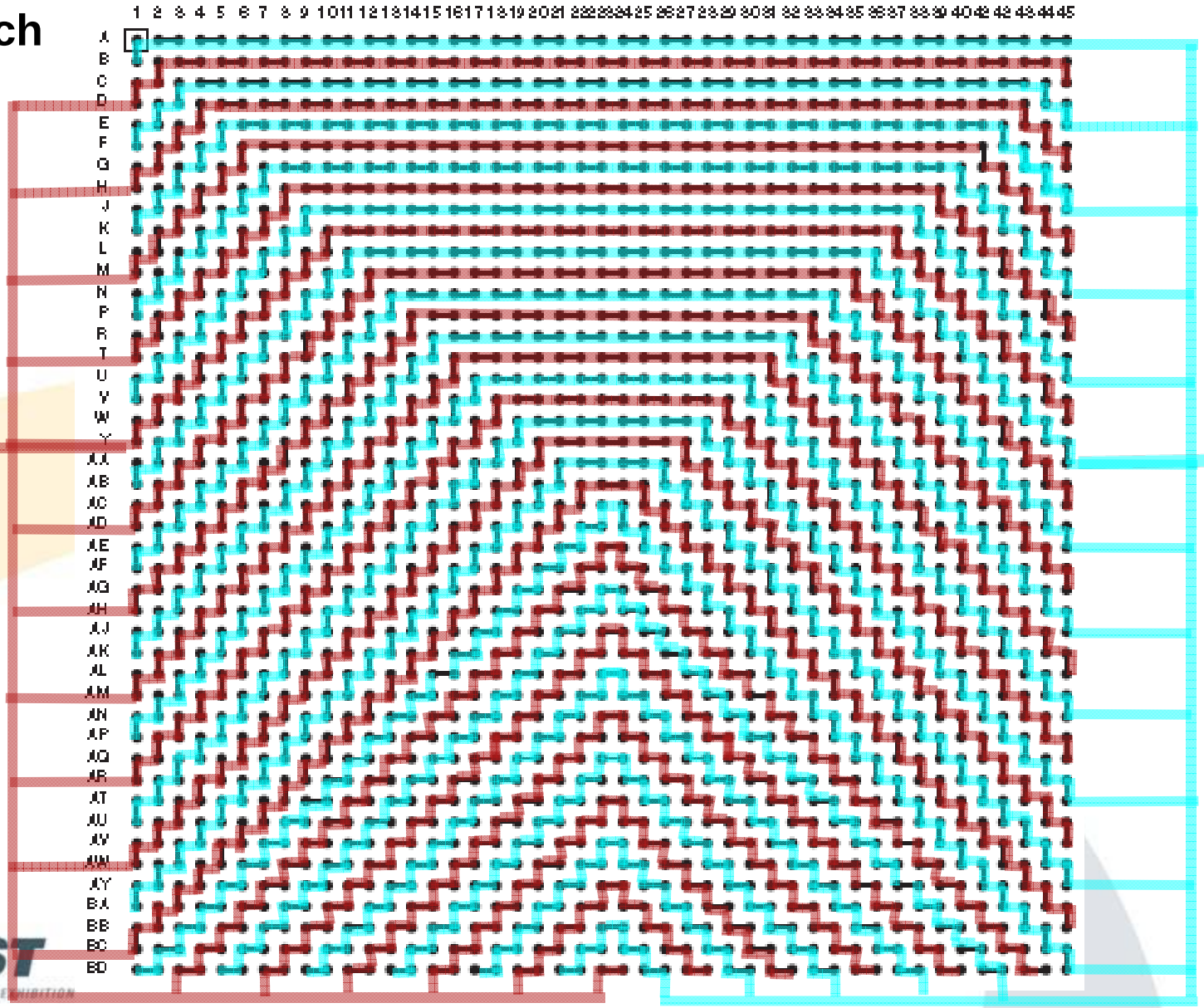
Chips



1. Prefer to have no daisy chain in the component
2. If component is built-in with daisy chain, the SIR pattern routing has to be changed accordingly.
3. For array area components, if all 4 neighborhood pads are the same polarity, the shortage or contamination within the area is not detectable.

LBGA2025
0.8mm Pitch
&
0.5mm Pitch
Final

Bottom Side (Top X-Ray View)



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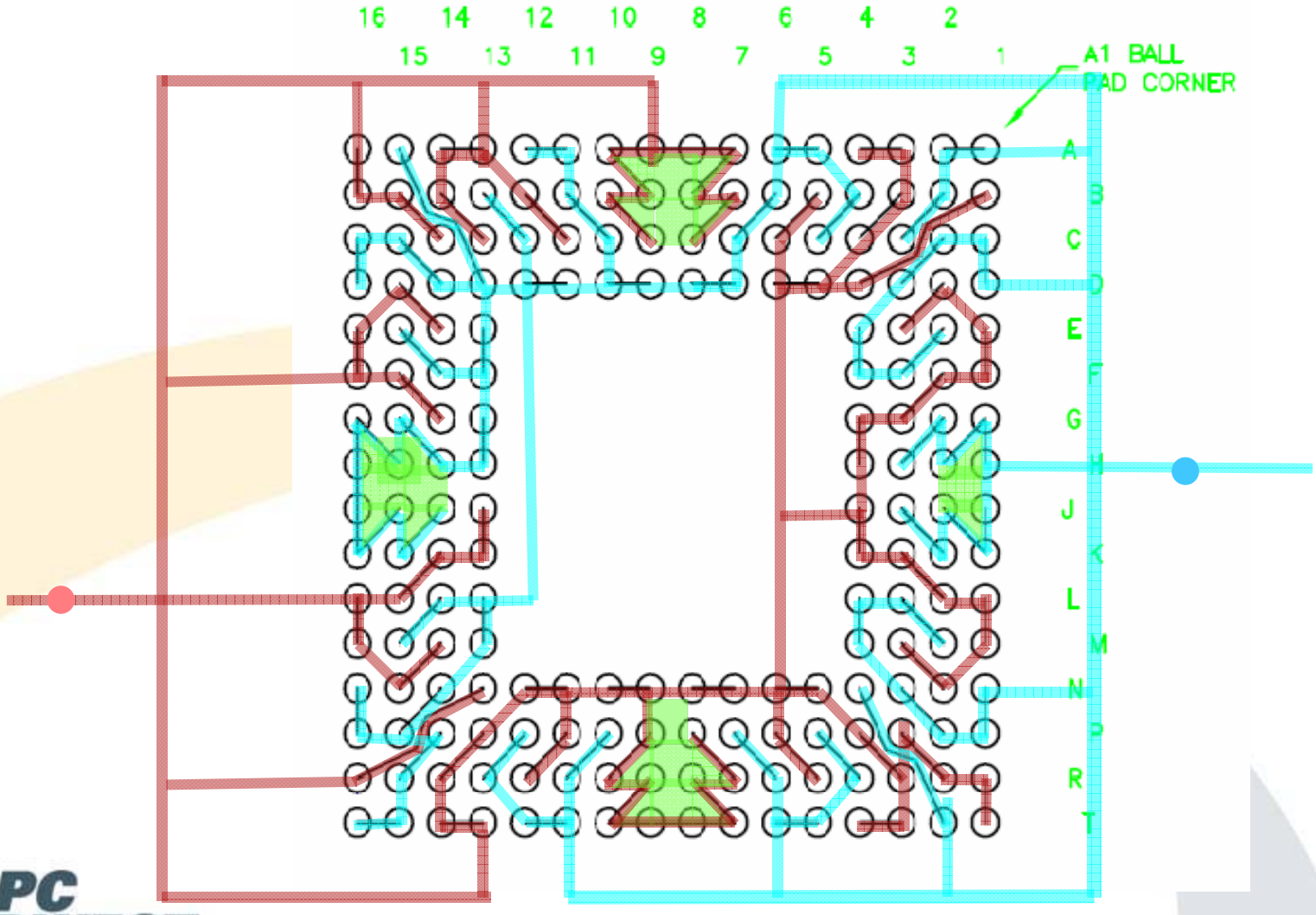
CSP192
0.4mm Pitch
Final

Area not covered



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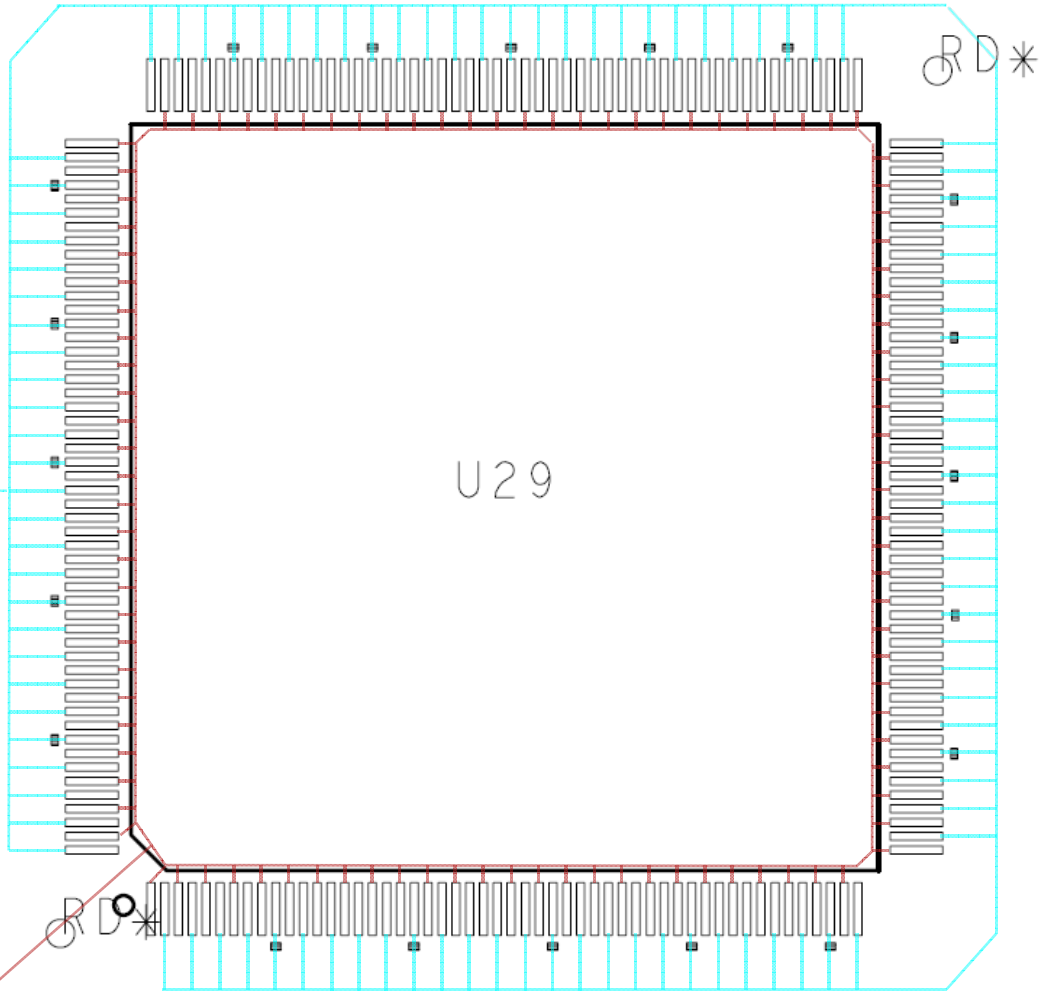
QFP208
0.5mm Pitch
Final

Area not covered



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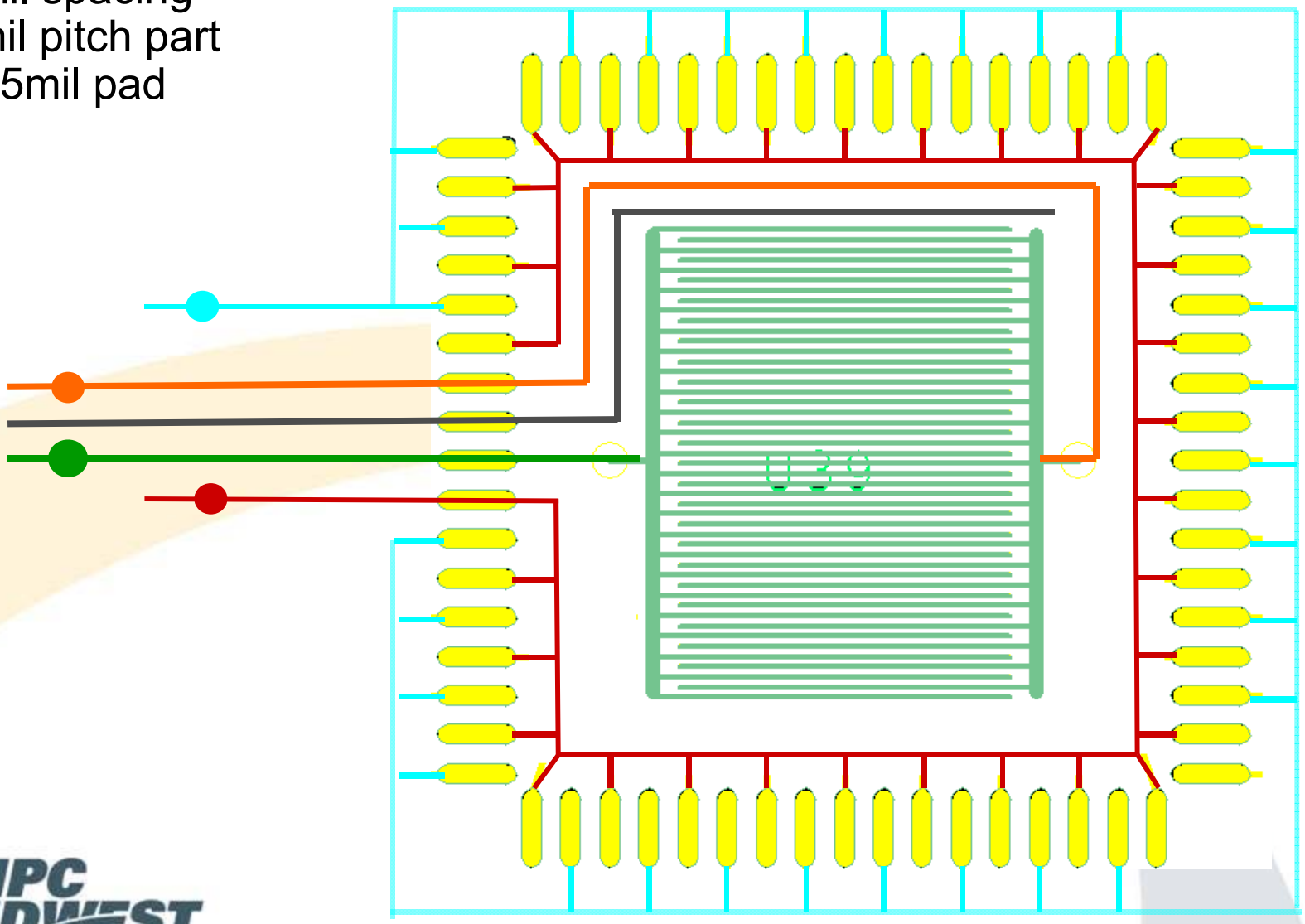
IPC-B-36

7mil width
6mil spacing
50mil pitch part
25mil pad



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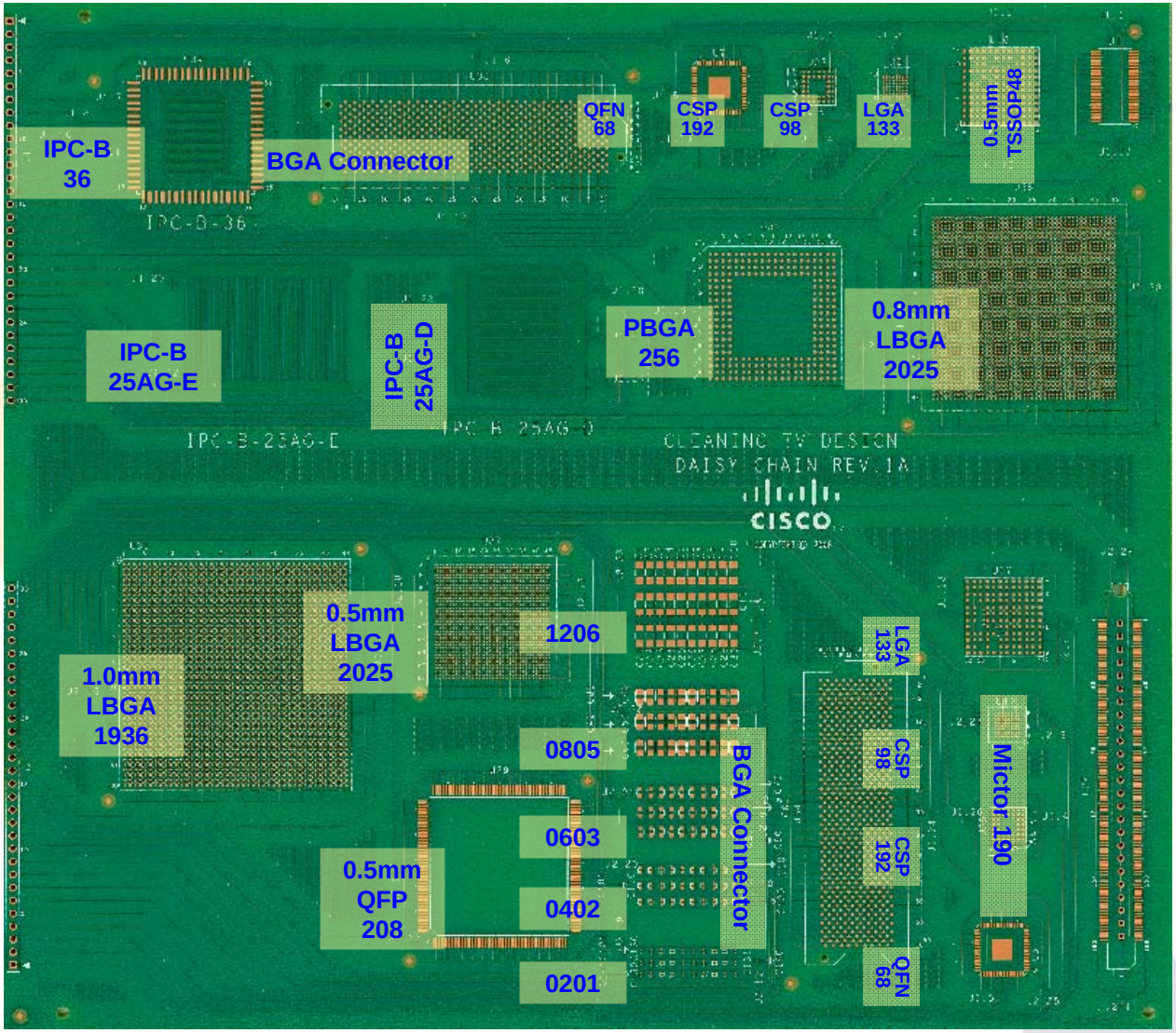
Test Vehicle for EM Test

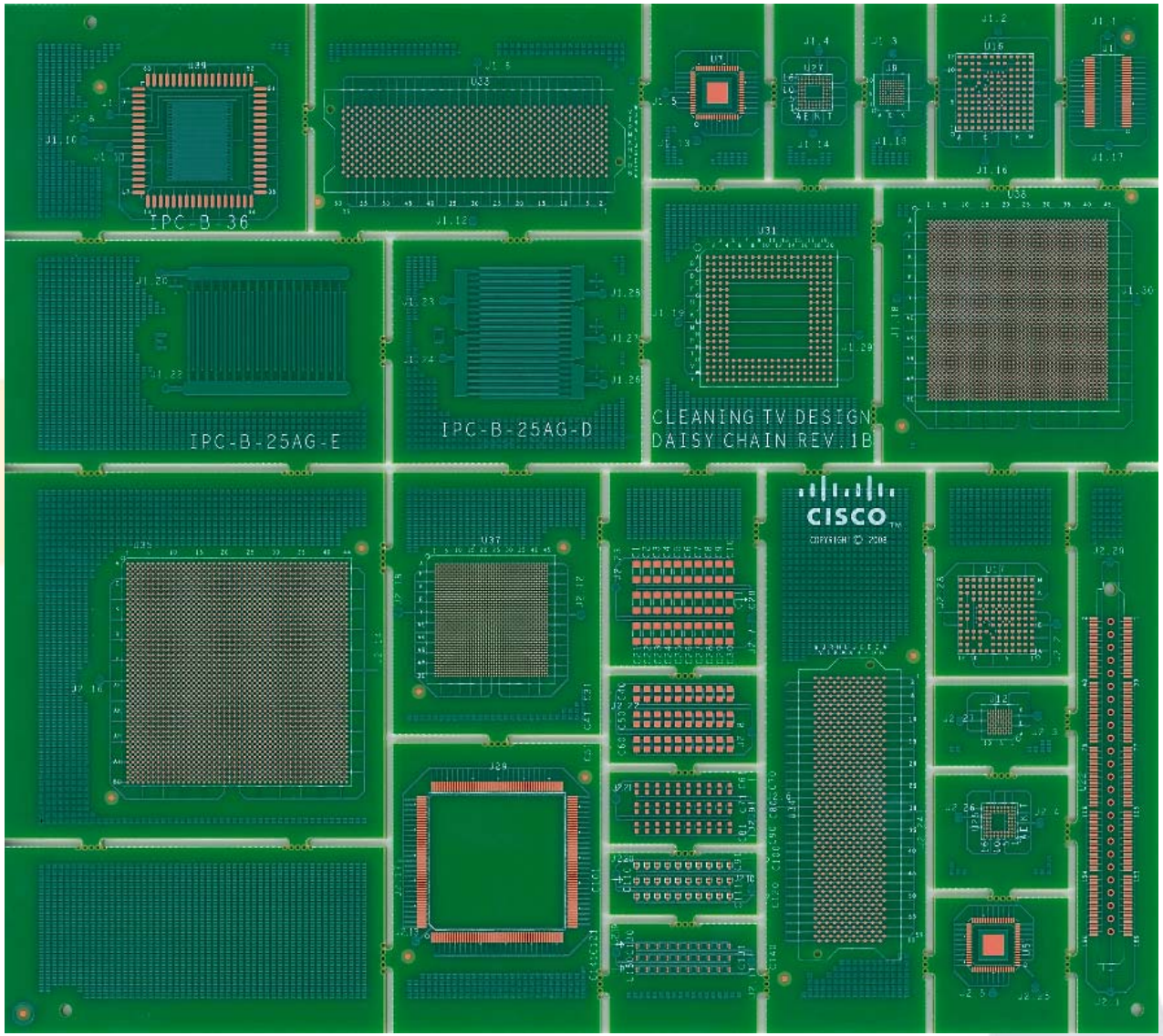
- w/ Traces & no Break-away



IPC MIDWEST CONFERENCE & EXHIBITION

Test Vehicle for IC Test

- w/o Traces & w/ Break-away



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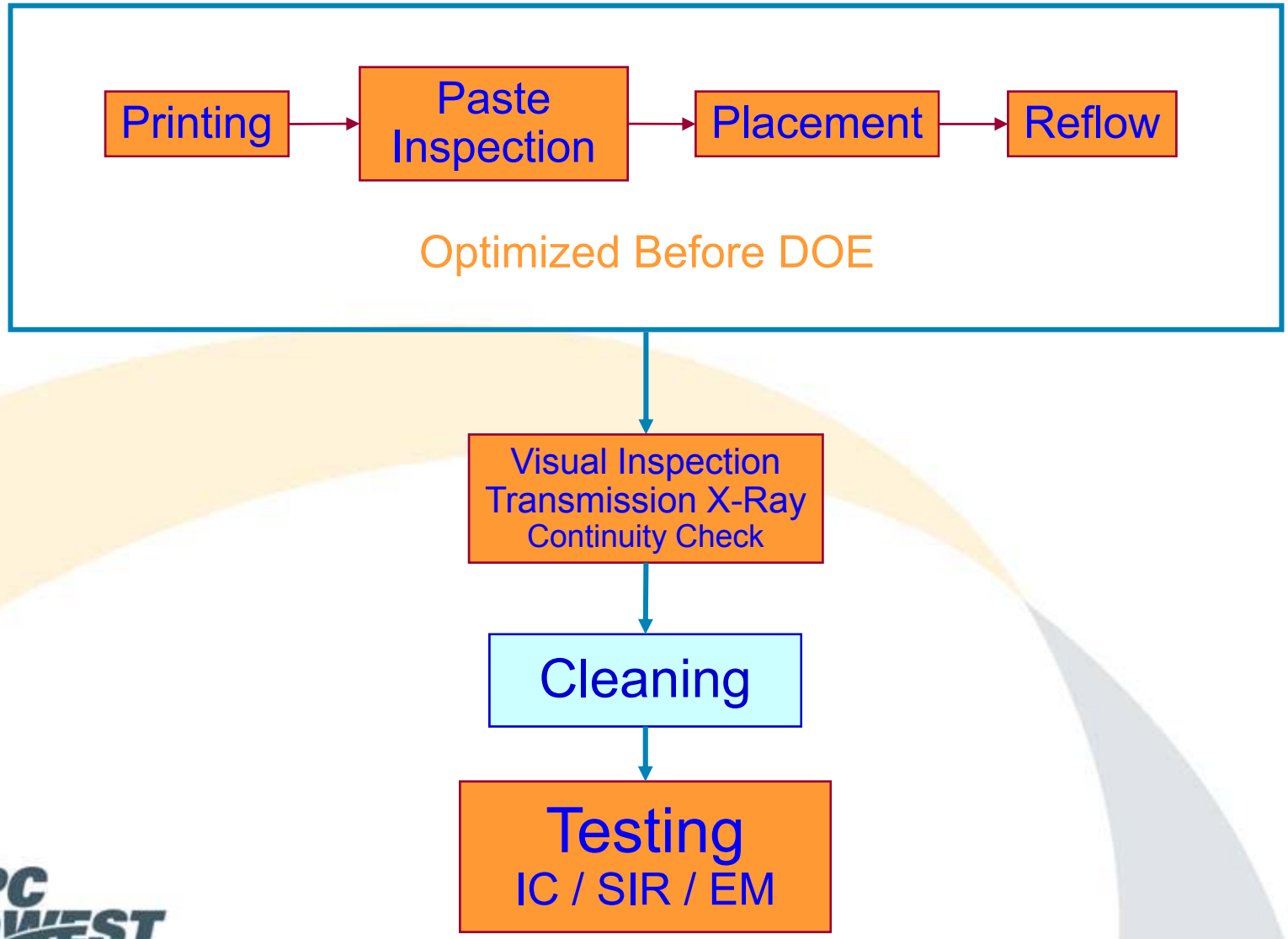
Process Flow



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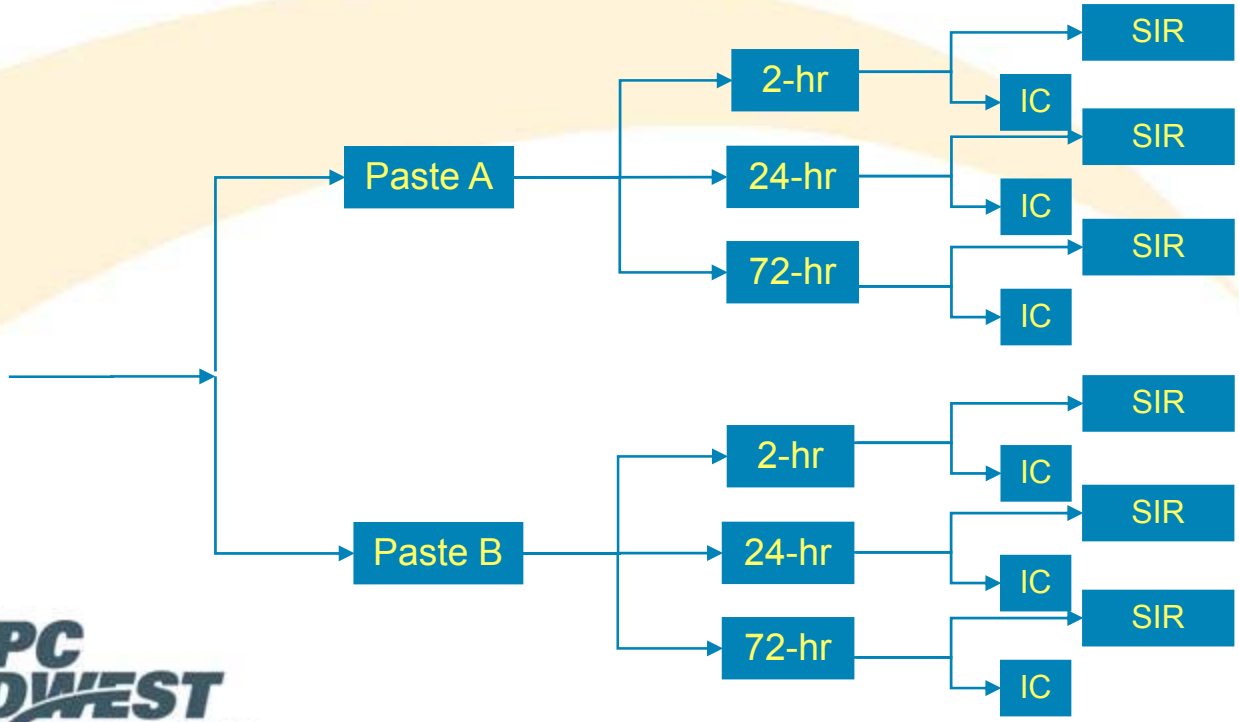
Test Matrix

PbSn Paste	Reflow	Time-To-Wash	Wash	Test
1. A	198 / 237 °C	1. 2-hr	Wash 140°F	1. SIR/EM
2. B	132 / 95 sec	2. 24-hr	Rinse 150 °F	2. IC
		3. 72-hr	Drying 160 °F	



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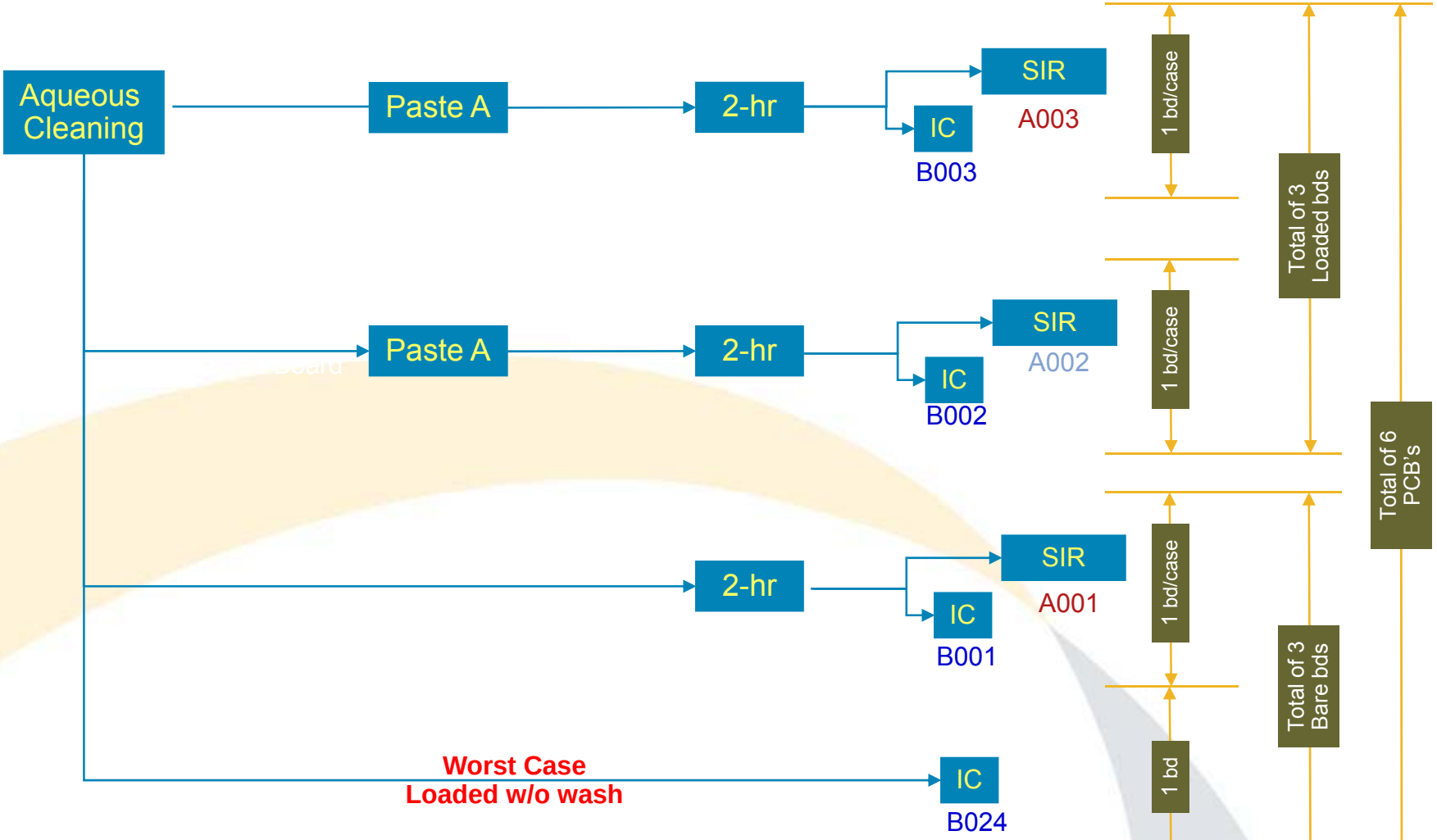
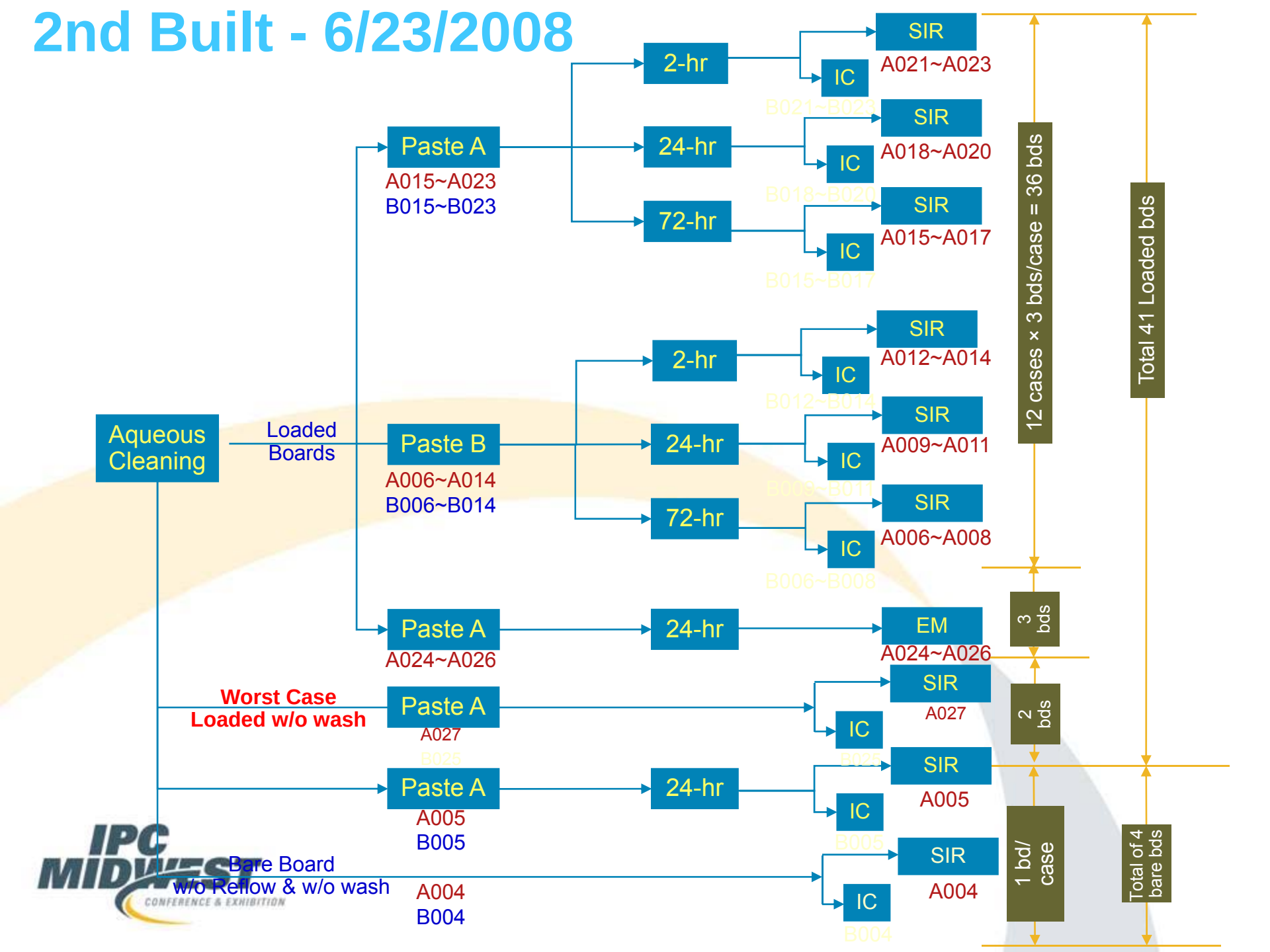
1st Built Pilot Run - 4/28/2008



A001: denotes the S/N of Configuration A PCB

B001: denotes the S/N of Configuration B PCB

2nd Built - 6/23/2008



IC Data

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IC Test Matrix

Low Stand-Off

LGA133 ×2
CSP98 ×2
CSP192 ×2
QFN68 ×2

BGA

BGA Connector ×2
0.8mm LBGA2025
PBGA256
0.5MM LBGA2025
1.0mm LBGA1936

Chips

1206
0805
0603
0402
0201

Leaded

TSSOP56
MICTOR
QFP208

Bare

IPC-B-36
IPC-B-25D
IPC-B-25E
BARE

PbSn Paste

1. A
2. B

Time-To-Wash

1. 2-hr
2. 24-hr
3. 72-hr

Ion Chromatography

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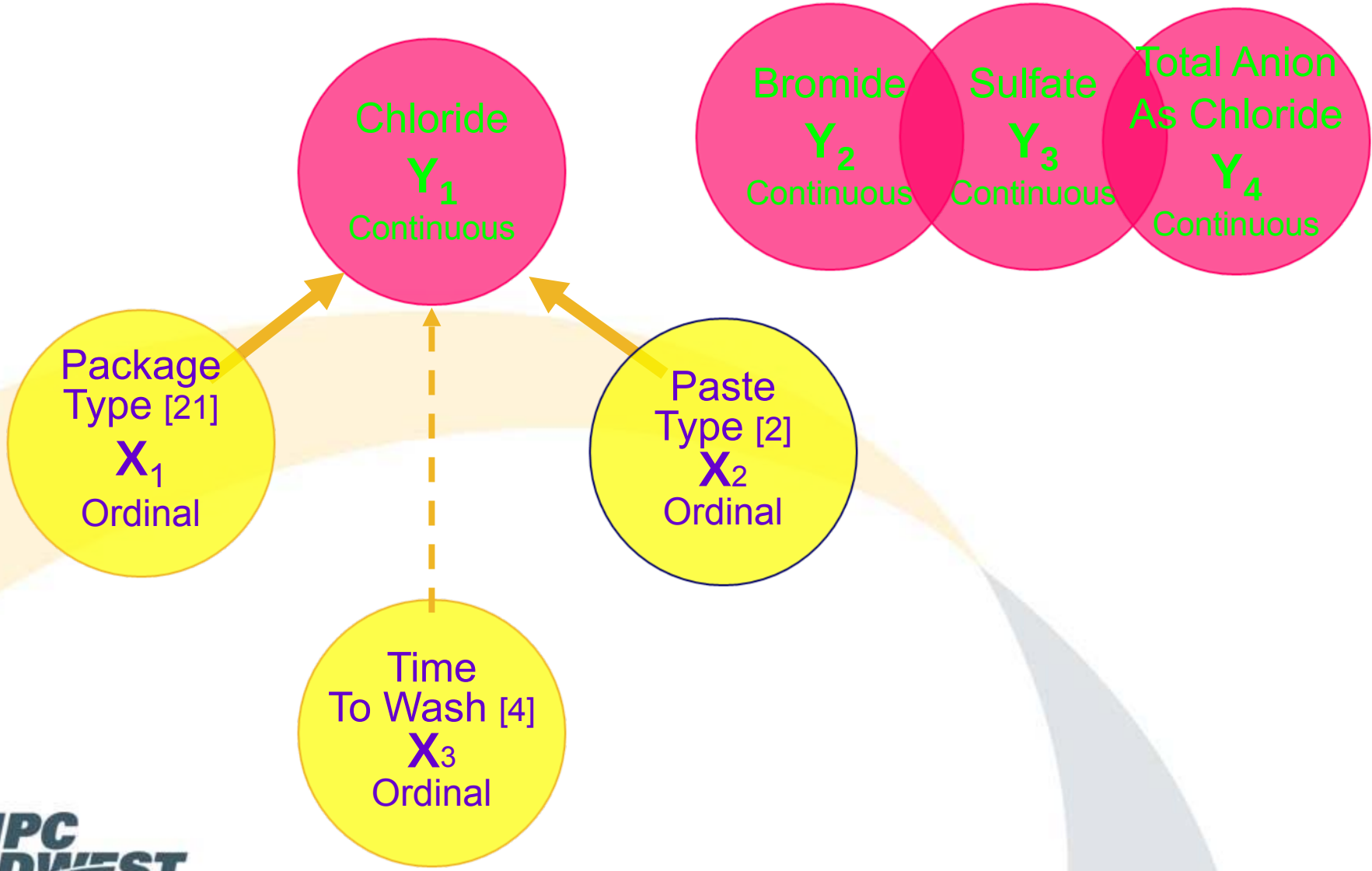
Identify the Factors (X) & Responses (Y)



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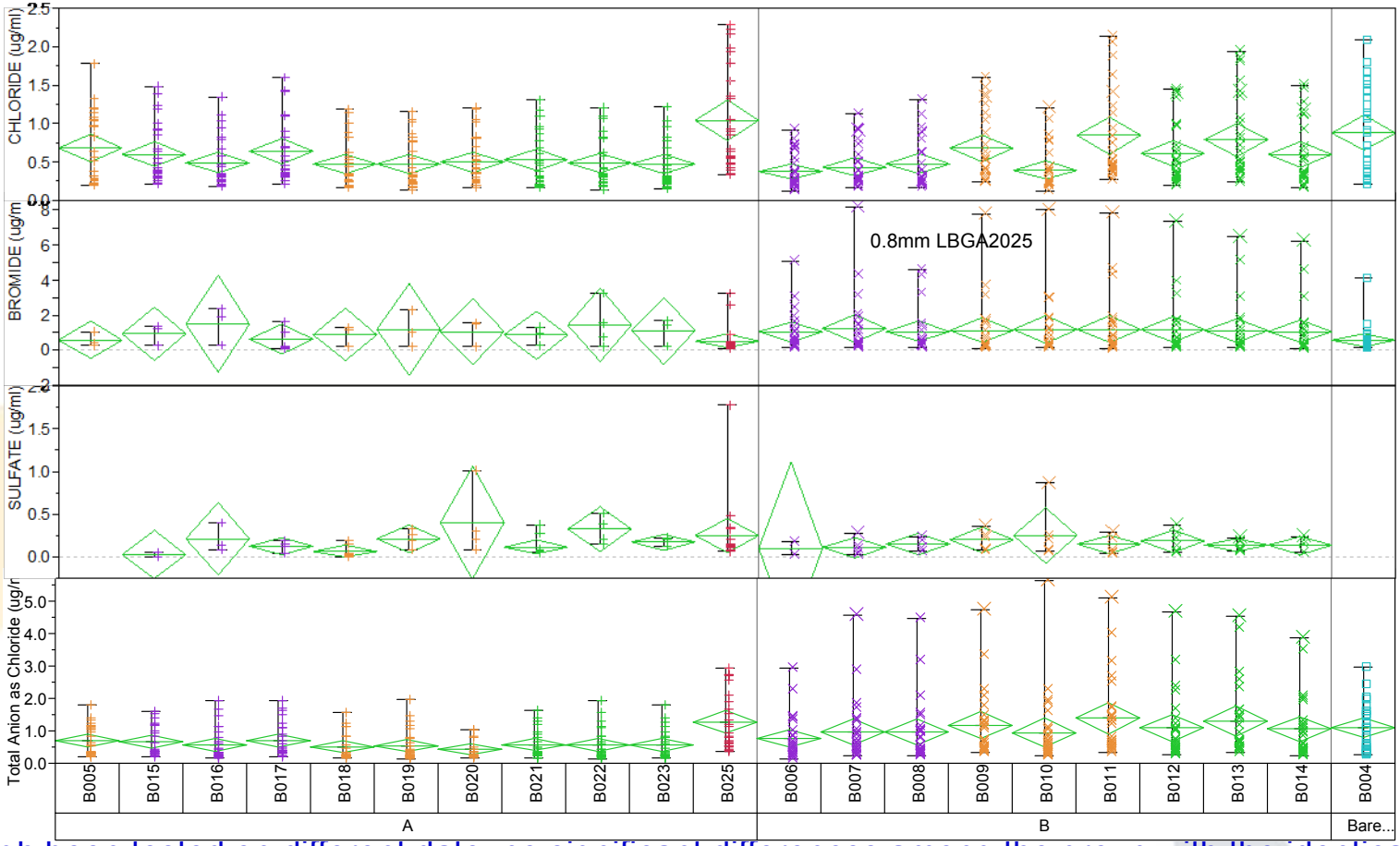
Variability (Volume Concentration µg/ml)
- From Day-To-Day & From Board-To-Board

Green : 2hr
Yellow : 24 hr
Purple : 72 hr
Red – Loaded No Wash
Blue – Bare No Wash

- This chart is to check if there is a significant variation due to day-to-day extraction process which has been randomized based on S/N.
- B024 is a verification board with 4 packages only, including CSP98, CSP192, LGA133, and BGA Connector.
- Based on the distribution and board mean, it shows no significant Day-To-Day & Board-To-Board variation.

Variability (Distribution, 95% CI, & Group Mean) - From Paste To Paste & From Board To Board

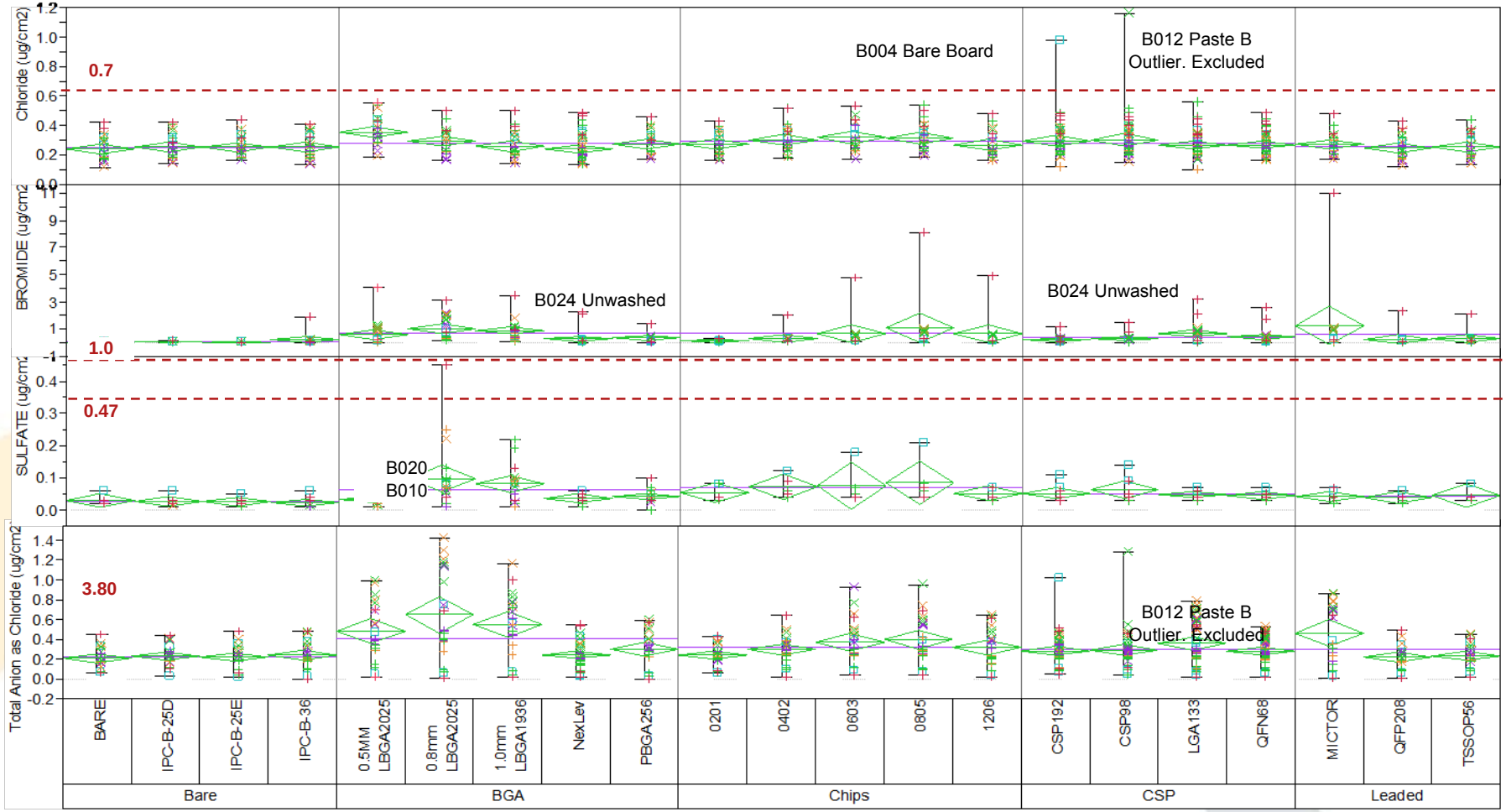
Green : 2hr
Yellow : 24 hr
Purple : 72 hr
Red – Loaded No Wash
Blue – Bare No Wash



- Though been tested on different date, no significant differences among the group with the identical test conditions (same Paste Type & Time-To-Wash). Test Date does not have significant impact on data.
- For the 3 boards Within the identical test condition, the 95% CI Diamond does not overlap with each other. It indicates no significant differences from board to board.
- The p-values are all much larger than 0.05, typically above 0.7.

Variability (Area Concentration µg/cm²)

- By Package, divided by de-panelized board area



- The plot includes bare boards, pasted boards, and loaded boards. Both washed and unwashed.
- The two failed 0.7 Chloride criteria are unloaded CSP192 and 2-hr Paste A CSP98, which are considered as outliers and are excluded from the following analysis.

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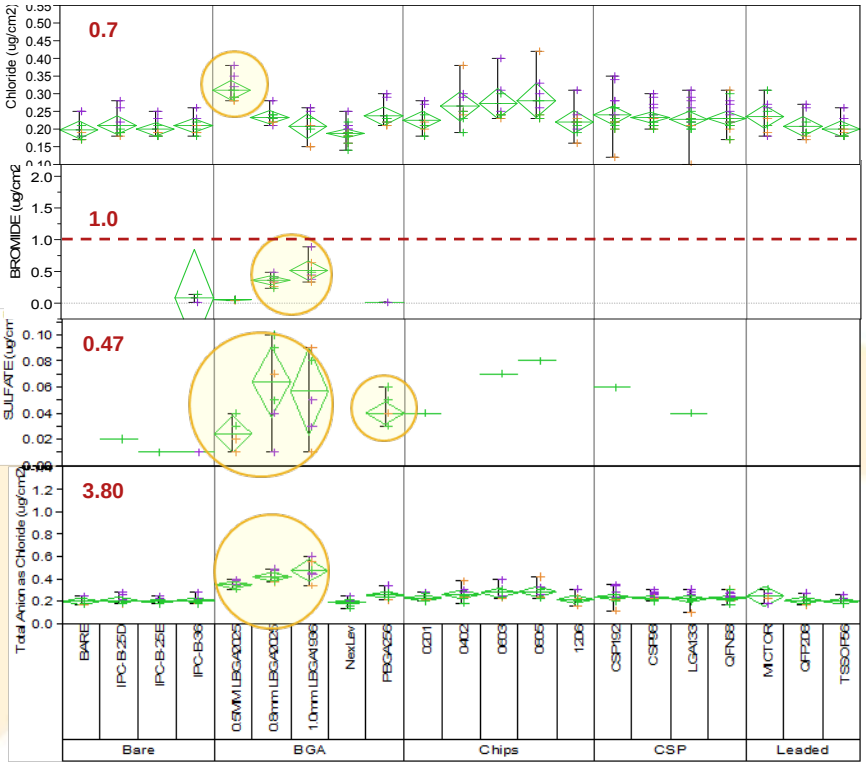
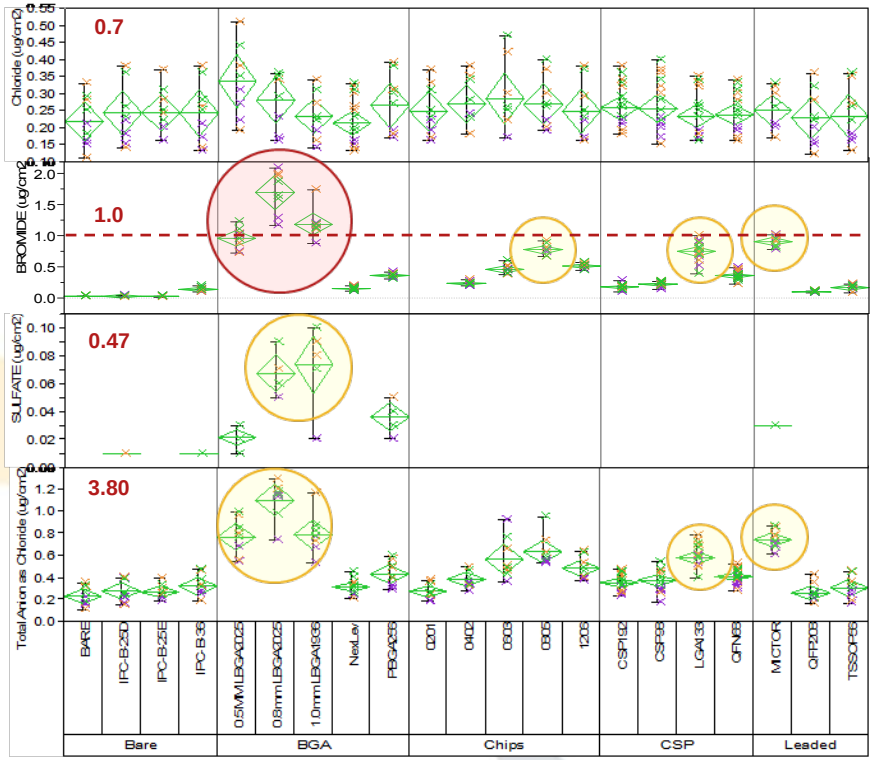
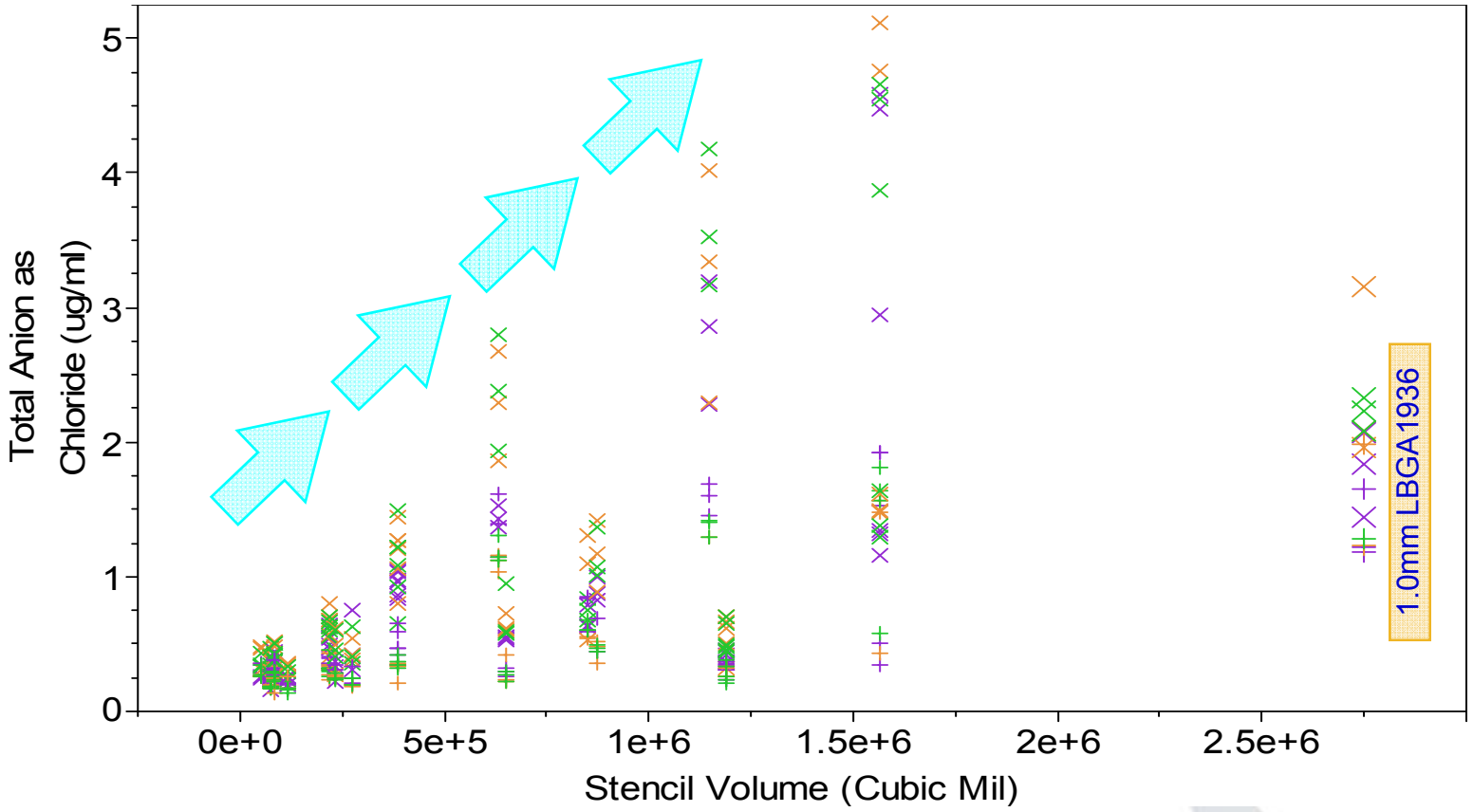
Variability (Data Reduction)
- 2nd Run loaded & Washed boards only.





- Everything passed except the Bromide level on 3 LBGA locations.
- For Paste A, all three LBGA's are statistically higher from others (95% CI).
- For Paste B, the three LBGA's single out again. Mictor and LGA133, are higher as well.

Contamination Level vs. Stencil Volume



- All of the data points are on the lower triangle of the plot. It may indicate there is a trend of contamination level vs. paste volume.
- The cleaning mechanism depends on the component structure, such as size, pitch, hidden or exposed joints, BGA or leaded. The plot should be refined to take package type into consideration.

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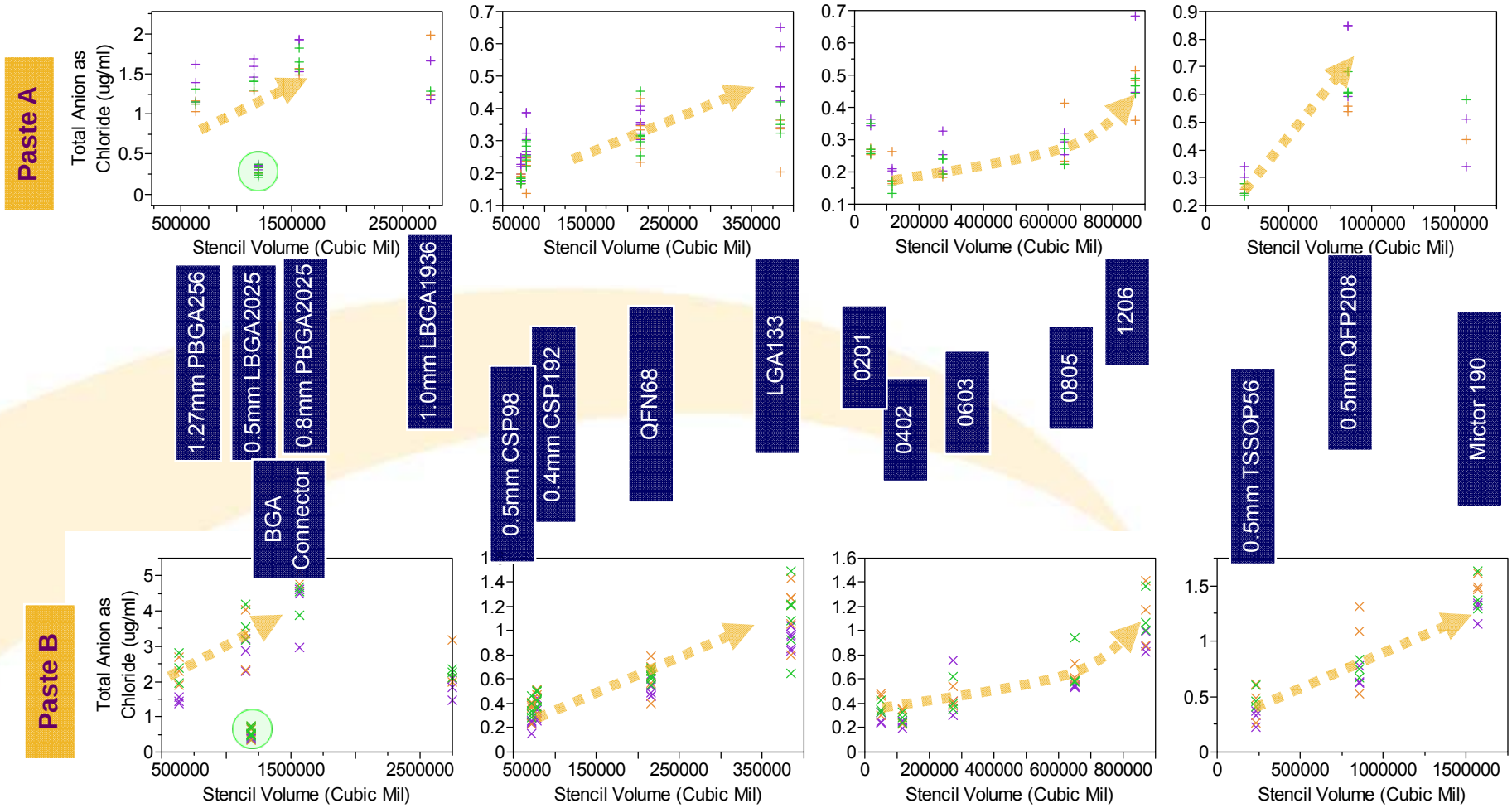
Contamination Level vs. Stencil Volume

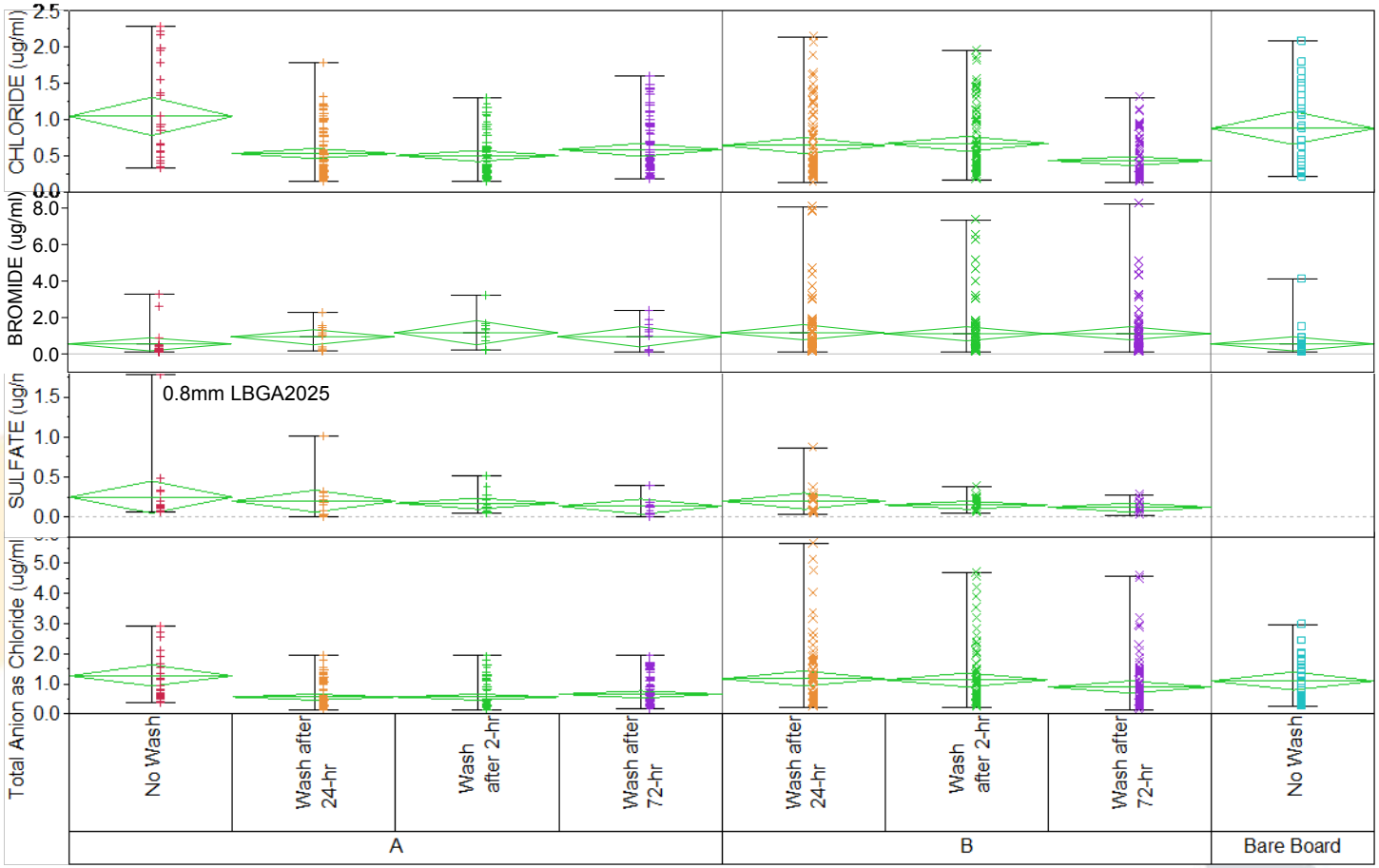
- by Package & Paste



- BGA Connector is not encapsulated on top, which may allow water jet pressurized into the slot and clean up the flux underneath.
- A trend of increasing contamination level can be observed in each of the component category.

Variability (Volume Concentration µg/ml)
- Time To Wash (2hr, 24hr, 72hr, and No Wash)

Green : 2hr
Yellow : 24 hr
Purple : 72 hr
Red – Loaded No Wash
Blue – Bare No Wash



- + is Paste A. × is Paste B. □ is virgin bare board w/o wash and reflow.
- Based on the 95% CI Diamond of Total Anion, the unwashed loaded board is statistically different from other groups in Paste A.
- Within the same Paste group, the 95% CI Diamonds overlap with each other. Which indicates the Time-To-Wash does not have significant impact on contamination level.

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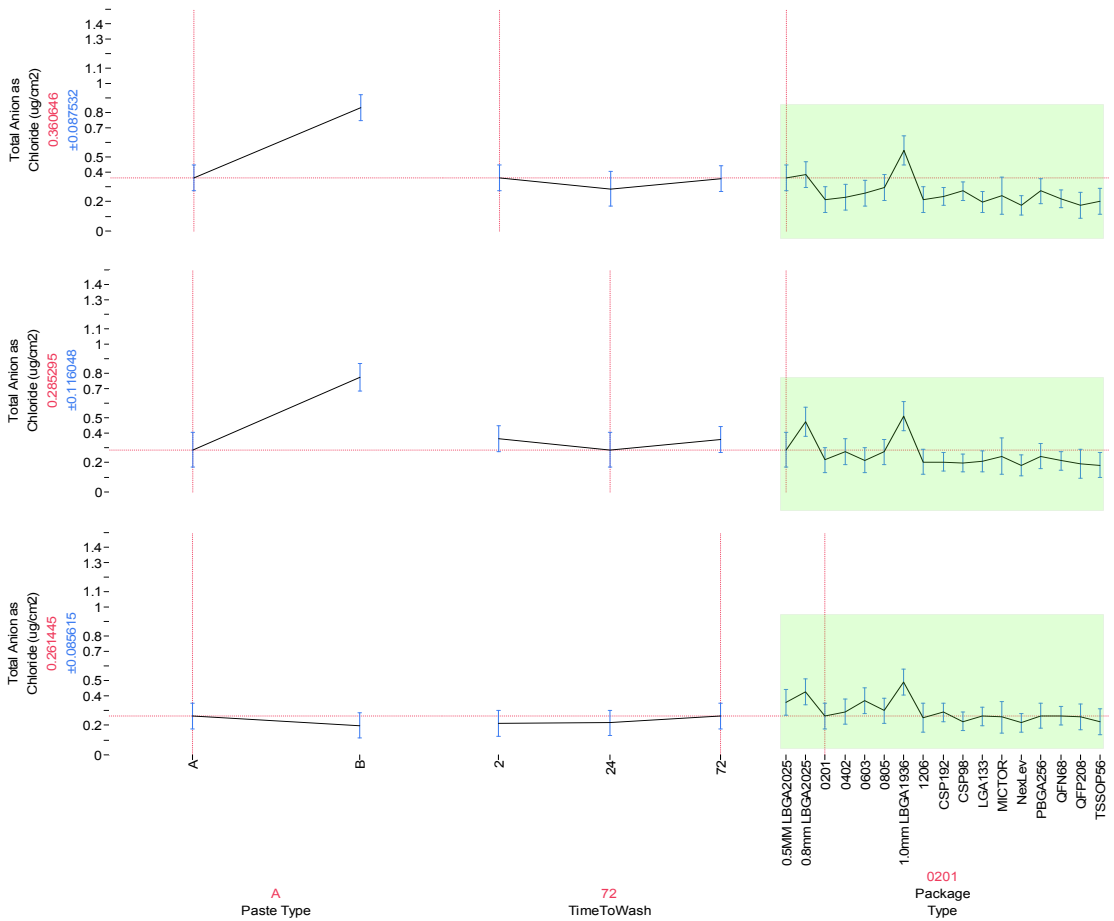
Profiler - Paste A

- 2nd Run loaded & Washed boards only.



2-hr

24-hr

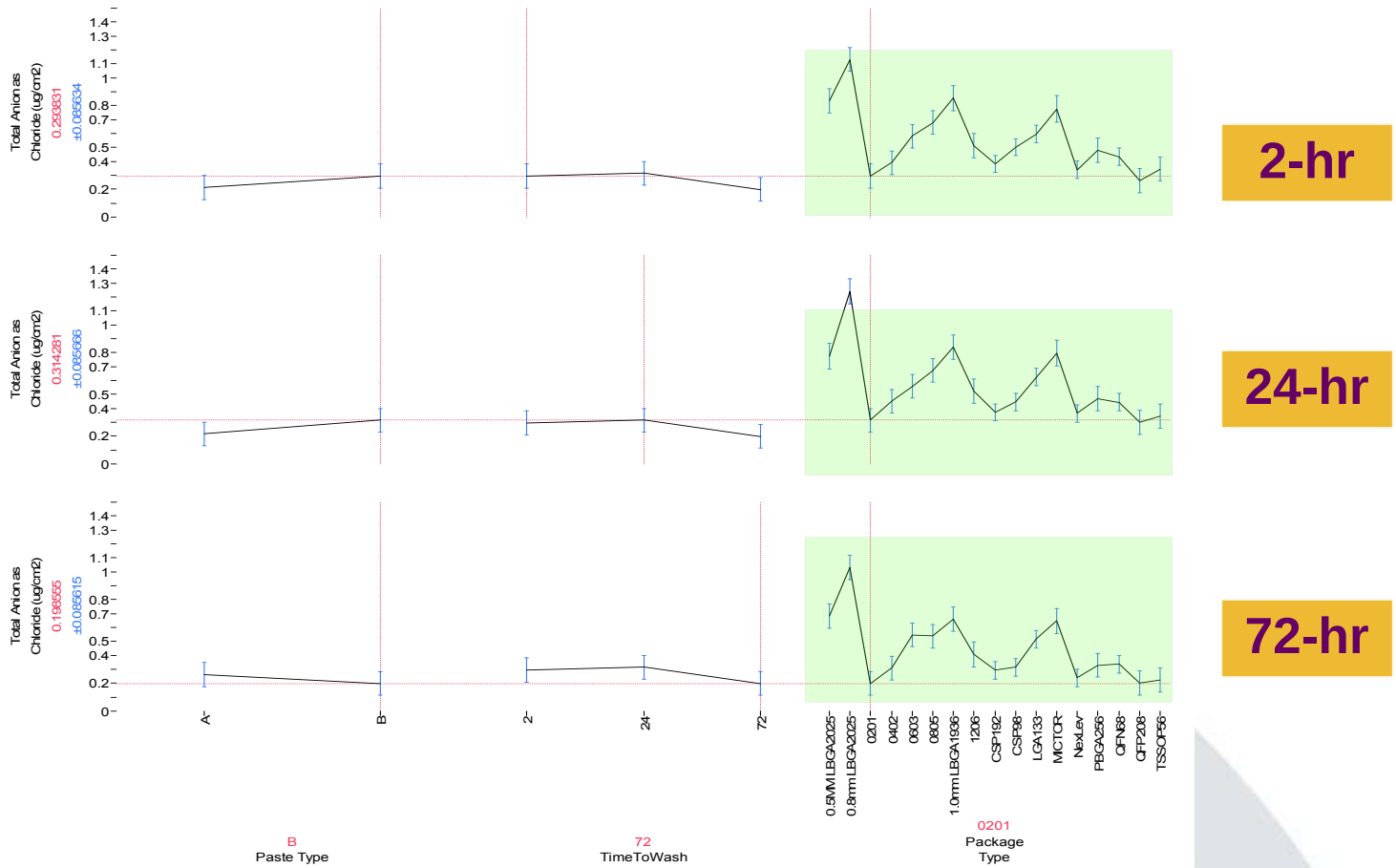
72-hr

The Profiler plot also indicates the Time-To-Wash does NOT have significant impact on Paste A contamination level.

IPC MIDWEST CONFERENCE & EXHIBITION

Profiler - Paste B

- 2nd Run loaded & Washed boards only.



2-hr

24-hr

72-hr

The Profiler plot also indicates the Time-To-Wash does NOT have significant impact on Paste B contamination level.

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Conclusion

- 25 boards with 21 Package types on each board are analyzed by Ion Chromatography on Chloride, Bromide, Sulfate, and Total Anions As Chloride.

- The 3 Factors are Time-To-Wash, Package Type, and Paste Type.

- Based on the published industrial criteria, most packages **PASS** the contamination level specified.

- The only FAILS are on *Bromide* level of *0.5mm LBGA2025, 0.8mm LBGA2025, and 1.0mm LBGA1936*. All three packages are from the same manufacturer. However, all three pass Total Anion As Chloride (as WOA).

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Conclusion (cont'd)

- Based on 95% CI, Time-To-Wash does NOT have significant effect on contamination level.
- By Paste Type, Paste A has slightly lower contamination level than Paste B.
- By narrowing down to package categories, the data indicates there is a proportional trend between contamination level and stencil volume.
- With similar amount of paste volume, the contamination level of BGA Connector is lower than the BGA's. It may due to the open-top wafer structure which allows water jet passing through and wash the PCB surface.

Conclusion (cont'd)

- The four low stand-off components (CSP192, CSP98, LGA133, & QFN68) are well within criteria for Paste A with no statistical differences from package to package. However, for Paste B, LGA133 distribution is higher than others with significance.

- The modeling of Total Anion by Package Types, Paste Types, and Time-To-Wash has RSquare value of 0.87 and Adj RSquare value of 0.83, which indicates the fit model with the 3 factors predict the response well.

Future Work

- SIR/EM 500-hr test will be completed on Aug. 18.
- Continue the analysis on SIR/EM data.
- Cross check SIR/EM data with IC data to find any correlation between these two tests.
- Review the industrial standards and test results to see if additional standards are needed for certain component categories.

Backup Slides

IPC MIDWEST CONFERENCE & EXHIBITION

Related Industrial Standards

J-STD-001

Appendix C – Material and Process Compatibility Testing

- C-5.1 Sample size

  10 vehicles
  combination (IPC-TR-467)

  It is recommended that additional unprocessed vehicles be tested as controls.

- C-6.1 Convert the min SIR values from each test vehicle to log10

  The average of these log values less 3 standard deviations needs to be at least 8.0 (100 MΩ or 10^8 Ω).

  Average - 3σ > 100 MΩ

- C-6.2 Visual Requirements

  All areas need to be inspected at 10X~30X for corrosion and dendritic formation.

  Dendritic formation cannot bridge more than 20% of the distance between conductors.

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Related Industrial Test Method

IPC-TM-650

- Method 2.3.27 Rosin Flux Residues Analysis (HPLC Method)
  - 10 ml/cm^2 (a volume correction is made in the calculation)
  - Flux residues < 100 mg/cm^2 (645 mg/cm^2)

- Method 2.3.25 Ionic Residues (ROSE Method)
  - NaCl residues < 10 µg/in^2 (1.56 µg/cm^2)
  - *[J-STD-001D, 8.3.6.3, P36 – For assemblies soldered with ROL0 or ROL1 fluxes, surface contamination shall be less than 10 µg/cm^2 ionic or ionizable flux residue.

- Method 2.3.39 Surface Organic Contamination ID Test (FTIR)
  - Based on mutual agreement

- Method 2.6.3.3 SIR, Fluxes (section 5.7.3, p3)
  - If the dendrite spans 25% or more of the original spacing, It constitute a failure.

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Related Industrial Standards

J-STD-004 *Requirements for Soldering Flux*

- J-STD-004A, 3.4.5.1 Required SIR Test
  - *"All SIR measurements on all test patterns shall exceed the 100MΩ (10^8 Ω) requirements when measured at 96 and 168 hours."*

- IPC-TM-650,

  Method 2.6.3.3 *SIR, Fluxes*

  - 85±2°C, 20%RH chamber stabilizing for 3 hrs
  - Ramp to 85±2% over a min of 15min.
  - Equilibrium for at least 1 hr.
  - Apply a 45~50v DC bias voltage to all specimens
  - At 24, 96, and 168 hours, remove the 45~50V DC, apply a -100vDC, and measure the resistance.
  - All specimens shall also be examined under a 10x~30x microscope using backlighting within 24 hours of completing the testing. If dendritic growth spans 25% or more of the original spacing is observed, it is a failure.


IPC-TM-650
TEST METHODS MANUAL

IPC MIDWEST CONFERENCE & EXHIBITION

Related Industrial Standards

GR-78-CORE *Generic Requirements for the Physical Design and Manufacture of Telecommunications Products and Equipment*

13.1.4 SIR Test

- Square Count - the length of the parallel conductors in the test pattern divided by their separation
- PCB – untreated bare copper finishing, dry film photo resist to optimize conductor edge definition.
- SMT – 8mil stencil THK
- SIR Test Equipment – 35±2°C, 85%RH chamber. Max range up to $10^{13}\Omega$ meter with ±5% accuracy at $10^{12}\ \Omega$/100Vdc.
- SIR Test Procedure – Measure @100Vdc for 1 min after
  1. 24-hr unbiased stabilization period..
  2. After applying a dc bias of 45~50V for a 4-day (96hrs) period.
- Criteria - The average insulation resistance (megohms), for each sample group, taken at 24 hours and again at 4 days, shall be

$IR_{MIN} > 1\times10^{5}$ MΩ ($10^{11}\ \Omega$), for 50mil spacing pattern

$IR_{MIN} > 2\times10^{4}$ MΩ ($2\times10^{10}\Omega$), for 12.5mil spacing pattern

Table 13-2. Sample Preparation - Solder Pastes

Sample Group	Print/Reflow	Post Clean	Test
A[a] (3 patterns)	No	No	SIR
B (3 patterns)	Yes	No	SIR
C[b] (3 patterns)	Yes	Yes	SIR
D[c] (3 patterns)	Yes	Yes	Electromigration

IPC MIDWEST CONFERENCE & EXHIBITION

Related Industrial Standards

- Electromigration Resistance Test

[GR78 13.1.4] or [IPC-TM-650 2.6.14.1 + IPC-TR-476A]

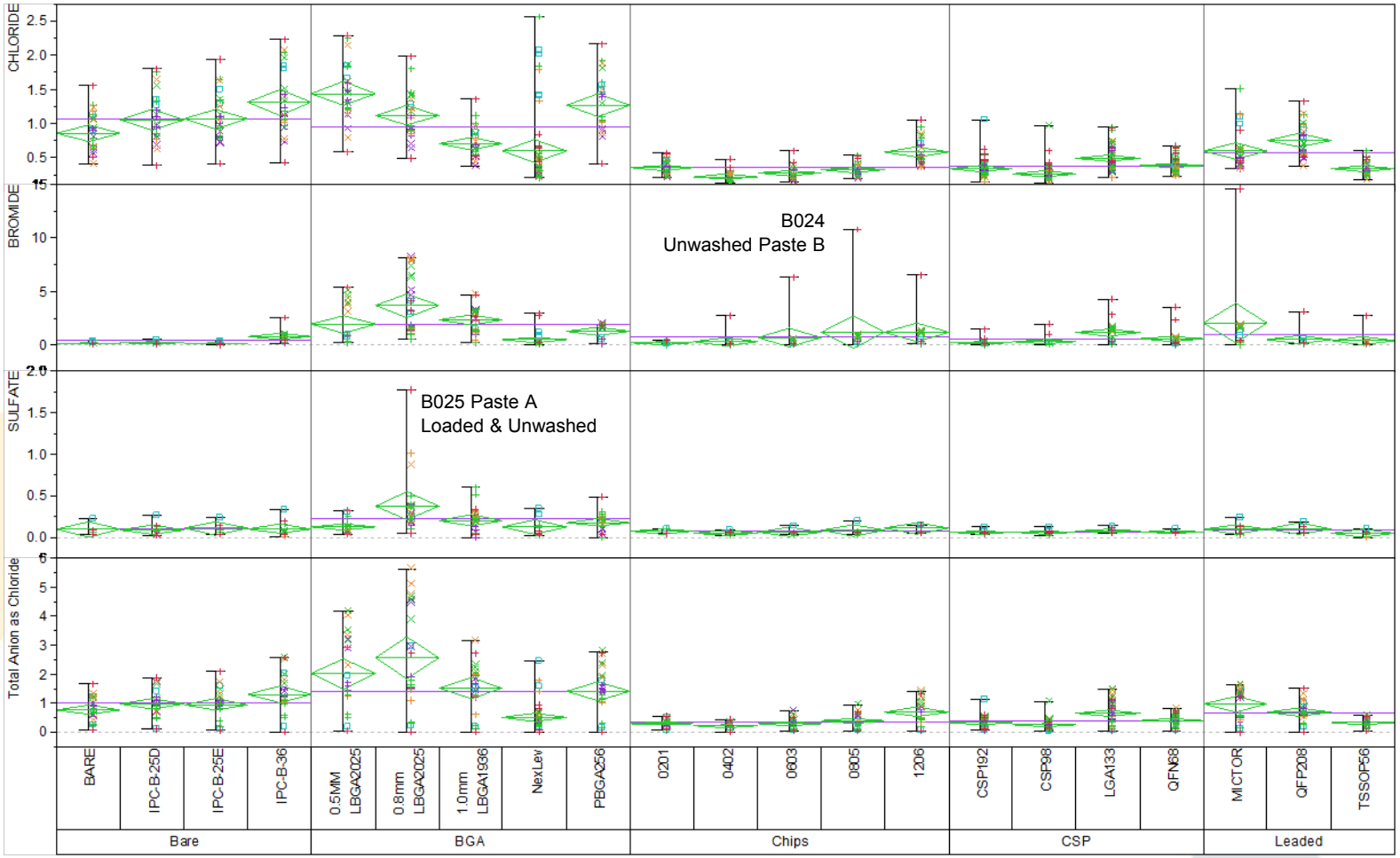
- **EM Test Equipment –** 65±2°C, 85%RH chamber. Max range up to 10Ω meter with ±5% accuracy at 10Ω/100Vdc. Twelve 1MΩ current limiting resistors.
- **Test Pattern:** IPC-B-25 B or E, or IPC-B-25A D (all are in same dimensions)
- **Test Procedure –**
  1. 96-hr stabilization period at 65±2°C, 85%RH
  2. Measure @45~100Vdc
  3. Apply 10Vdc for a 500-hr period
  4. Measure @45~100Vdc
- **Criteria -** The average insulation resistance value shall not degrade by more than a decade as a result of the applied bias

$$IR_{FINAL} \geq 0.1 \times IR_{INITIAL}$$

- **Visual Inspection -** After completion of the electro migration test, the test samples shall be removed from the test chamber and examined, with backlighting, at 10x magnification. There shall be no evidence of electro migration (filament growth) that reduces conductor spacing's by more than 20%.

Variability (Distribution, 95% CI, & Group Mean) - From Package-To-Package

Green : 2hr
Yellow : 24 hr
Purple : 72 hr
Red – Loaded No Wash
Blue – Bare No Wash



- Bare group shows high Chloride concentration. This group includes both bare board and loaded board.
- Other than the Bare group, it shows a proportional trend to paste volume (or pin count, or package size)

IPC MIDWEST CONFERENCE & EXHIBITION