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Materials Compatibility and Aging for Flux and Cleaner Combinations

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Background

Most common and harmful contamination sources

- flux residues
- cleaning agent residue

Potential interactions with moisture and voltage

- corrosion
- dendrite growth
- electrical leakage

Background

Defluxing process must be:

- compatible with the materials on the PWA
- compatible with the structure of the PWA
  - Low standoff, tight spacing, fragile components
- achievable for production agency
  - Acceptable hazard level for facility requirements
  - Applicable to cleaning method/equipment in place
  - Reasonable timeline for validation

Goal for Initial Compatibility Study

Determination of which fluxes and cleaning agents pose a greater risk of corrosion and damage to circuit boards and their assemblies for high reliability, long-life electronics.

NOTE: Fluxes are selected by program, so this study was limited to fluxes already under consideration, and is inclusive of defluxers in use and under consideration.

Process

Phase 1: test for corrosion or damage from excess fluxes and defluxers on circuit board materials.

A small amount of reflowed flux and is combined with each defluxer and placed with coupons in a silicone oil environment and aged, to determine which combinations present the higher risk in use.

Process (con.)

Phase 2: test the same fluxes and defluxers under typical hand soldering conditions.

Each fluxed coupon is treated with mild cleaning, or a very brief cleaning, and PWBs cleaned with more extended vapor defluxing, then all aged in air, with heat and humidity to accelerate chemical reaction.

Process (con.)

Visual inspection of coupons and boards from both cases at the termination of four weeks aging allows comparison of damaging effects on the materials involved. Inspection includes signs of corrosion, staining, and pitting in all materials of the assembly. Ionic residue measured for soldered Cu and PWB.

Materials: Fluxes

Flux Types:

- A: water soluble paste, ORH0
- B1 & B2: no-clean liquid, ORL0
- C: water soluble liquid, ORH1
- D1 & D2*: mildly activated rosin, RMA, ROL0

*****_RMA fluxes may be reported together, as response approximately same in all cases_

Materials: Substrates

Metal Coupon Materials:

- OFE Copper
- Kovar
- Paliney 7
- 304 Stainless Steel

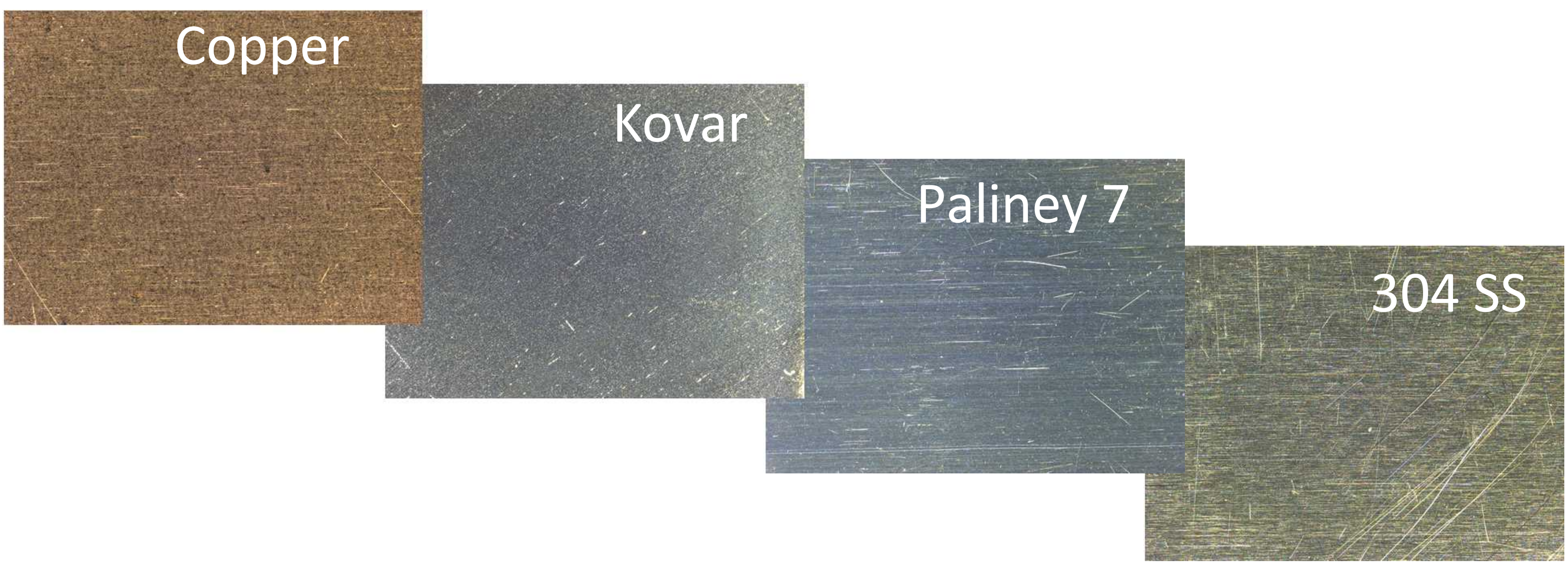
Materials: Defluxers

Cleaning Agents

- S1: solvent, ethanol
- S2: solvent, d-Limonene
- A1: DI water, >16 MOhm-cm
- A2: aqueous defluxer # 2
- A3: aqueous defluxer #3
- V1: vapor defluxer, AK-225
- V2: vapor defluxer # 2
- V3: vapor defluxer #3

Method

Metal coupons are prepared by cleaning in 10% Brulin™ 815GD with 40 kHz ultrasonics at 60 ^{O}C, and rinsed in DI water of > 16 MOhm-cm resistivity. The Cu is also treated with a 15 second acid dip with DI water rinse. Pre-treatment images were taken of all materials.



Method, Phase 1

- 0.18 mL flux applied by droplet or brush onto Cu coupons
- Coupons placed on hot plate at a temperature selected to mimic the typical soldering process on the high heat end:
  - in excess of lead-free solder (370 – 450 ^{O}C)
  - in excess of tin-lead solder (230 – 280 ^{O}C)
- Cool to ambient, place coupons in jars.
- Add 6.0 mL silicone oil & 0.18 mL defluxer
- Gently agitate, cover
- Store at ambient temperature for 4 weeks

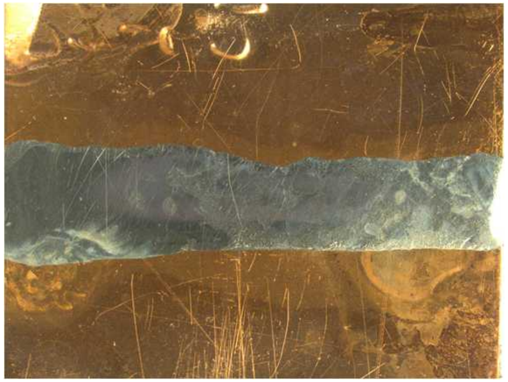
Method, Phase 2

Cu coupons hand solder and flux. Repeat of most fluxes & defluxers. Half treated by each cleaning method:

- Clean A: 3 – 5 minute soak, manual agitation and/or ultrasonics cleaning, 3 minute rinse where appropriate
- Clean B: 1 minute dip with gentle manual agitation, followed by brief rinse where appropriate

PWB hand solder, RMA flux, vapor defluxing of 3 & 6 cycles

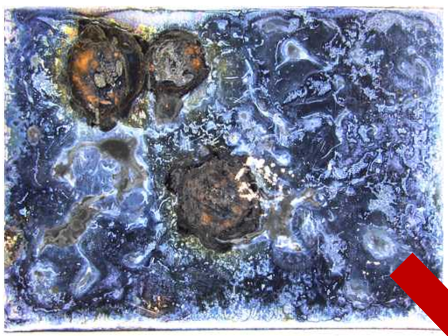
Ionic residue is measured with an Ionograph before parts begin the 4 week 65 % humidity at 30 ^{O}C exposure .



Method (con.)

Inspect

- Coupons inspected first time immediately upon removal
- Again after cleaning by scrub in ethanol (in some cases copper was also acid dipped in order to view substrate)



Phase 1 with scrub and acid etch dip

Phase 2 with scrub only

Comparison Rating

- Rating system to compare amount of residue and corrosion
- The number scale increases with the amount of residue or damage by corrosion
- Post-clean rating used for Phase 1* & Phase 2**

KEY	Rating Description, Cases 1 &2 Post-Clean
0	no discoloration or pitting
1	very slight stain, no residue or pitting
2	visible stain, little residue, no pitting
3	visible stain and residue, slight pitting
4	heavy stain and residue, visible pitting
5	heavy stain, residue and pitting

*The rating reported for each jar is a sum of the ratings given by each material for Phase 1.

Rating (con.)

**Phase 2 incorporates a scale for amount of corrosion residue seen before cleaning, as well as a scale based on Ionograph results. The rating reported for each coupon is a total of all three ratings.

KEY	µg NaCl equivalent, Phase 2 Ionograph
0	<0
0.5	0-75
1	76-150
1.5	151-225
2	226-300
2.5	300+

KEY	Rating Description, Phase 2 Pre-Clean
0	No Discoloration/Residue
0.5	Slight Discoloration/Residue
1	Discoloration/Residue on <25%
1.5	Discoloration/Residue on 25% to 50%
2	Discoloration/Residue on 50% to 75%
2.5	Discoloration/Residue on >75%

Results

- Figures 1 – 4: Examples of best and worst ratings for each temperature group for Phase 1, post-clean
- Figures 5 – 8: Examples of best and worst rated fluxes and cleaning agents for each cleaning type in Phase 2, post-clean

It is noted that all coupons in Phase 1 were in aging solution solution stacked, thus it is possible that galvanic corrosion accelerated or decelerated coupon damage.

Phase 1 Results: Best

Figure 1: Best of Low Temperature; RMA flux D2 with vapor defluxers

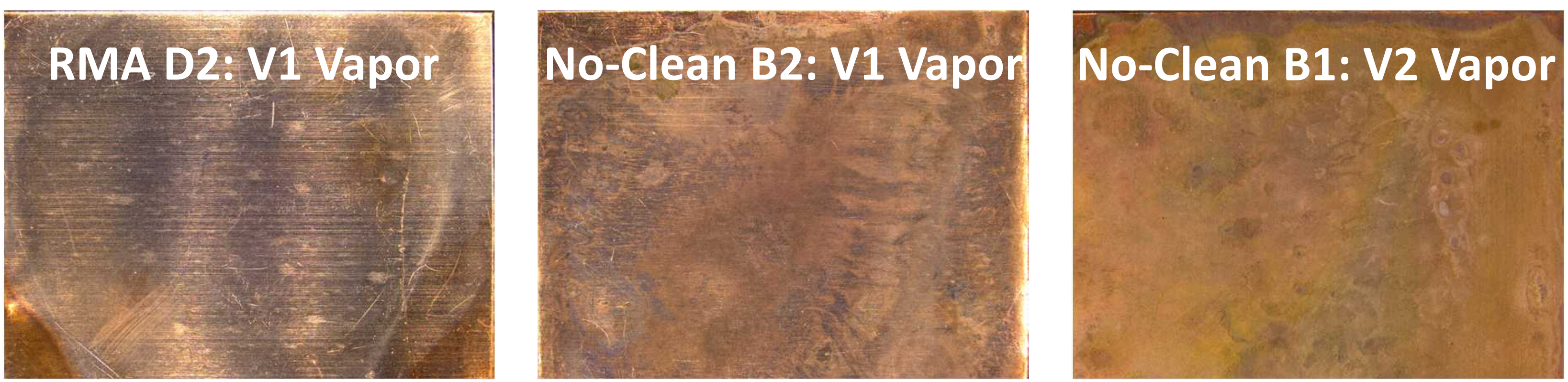


Figure 2: Best of High Temperature, no-clean flux B1 & B2 or RMA Flux D2

Phase 1 Results: Worst

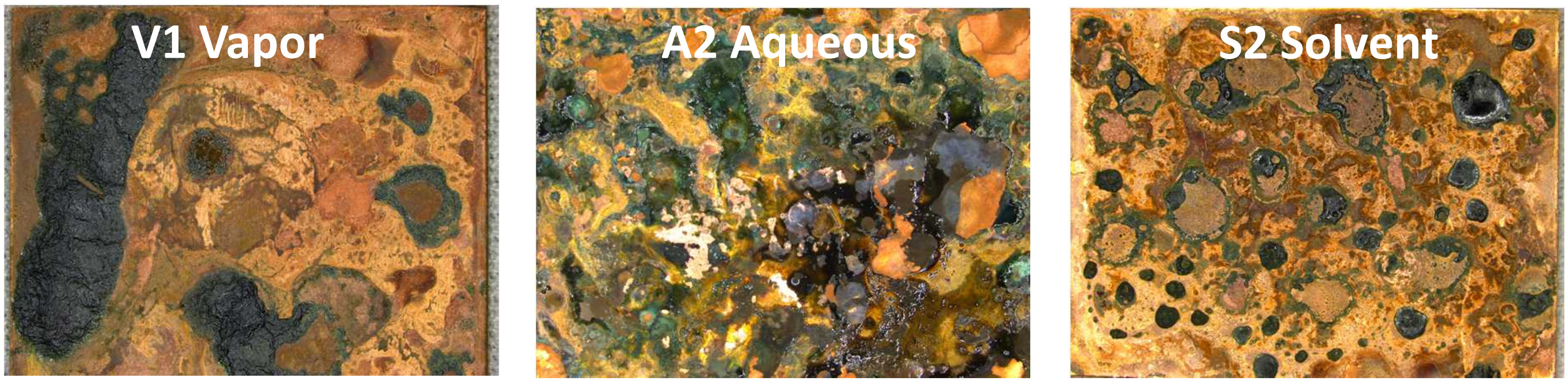


Figure 3: Worst of Low Temperature, C1 water soluble ORL1 flux

Figure 4: Worst of High Temperature, C1 water soluble ORL1 flux

Phase 2 Results

Figure 5: Clean A, BEST, RMA flux D, defluxer A3

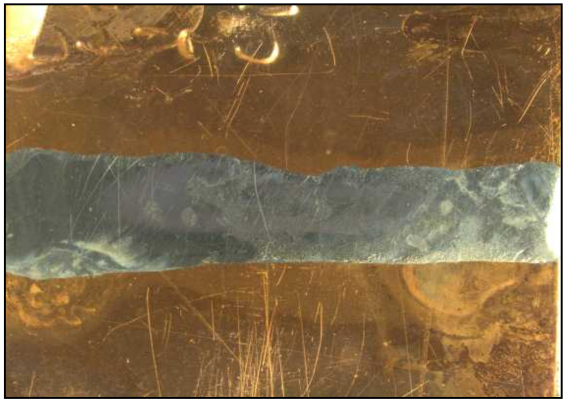


Figure 6: Clean A, WORST, ORH1 flux, defluxer V3

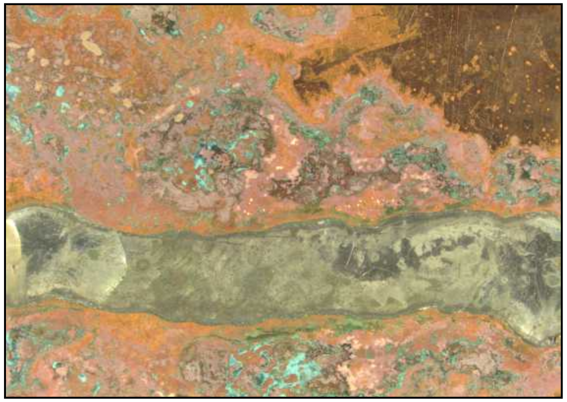


Figure 7: Clean B BEST, RMA flux D, DI water defluxer A1

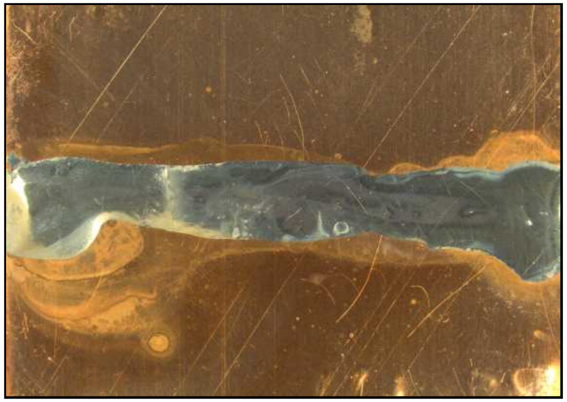
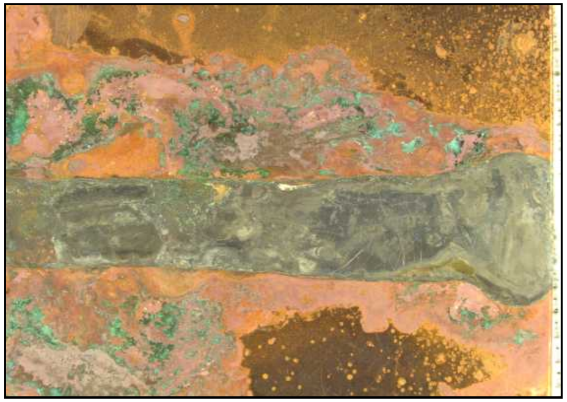


Figure 8: Clean B, WORST, ORH1 flux, AK-225 defluxer V1



Results, con.

- Figures 9 and 10: rating results graph for Phase 1
- Figures 11 and 12: rating results graph for Phase 2
- Figure 13: Average of ratings for all cleaner and flux combinations for Phase 2
- Figure 14: Hand soldered PWBs with vapor clean, Ionograph results
- Figure 15: residue from least effective vapor defluxer

Phase 1 Corrosion Ratings

Figure 9: High Temperature

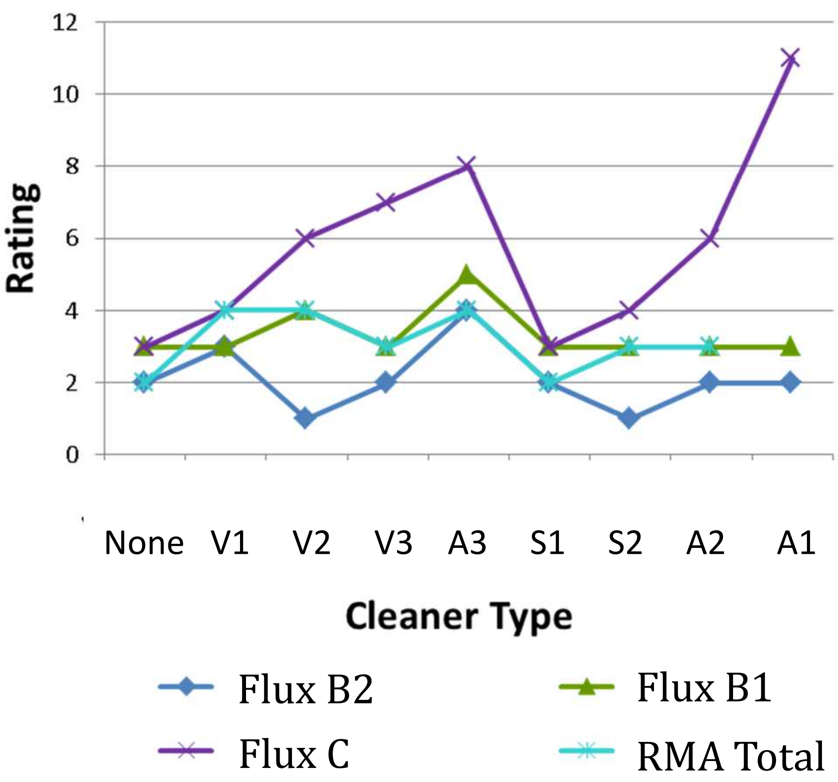
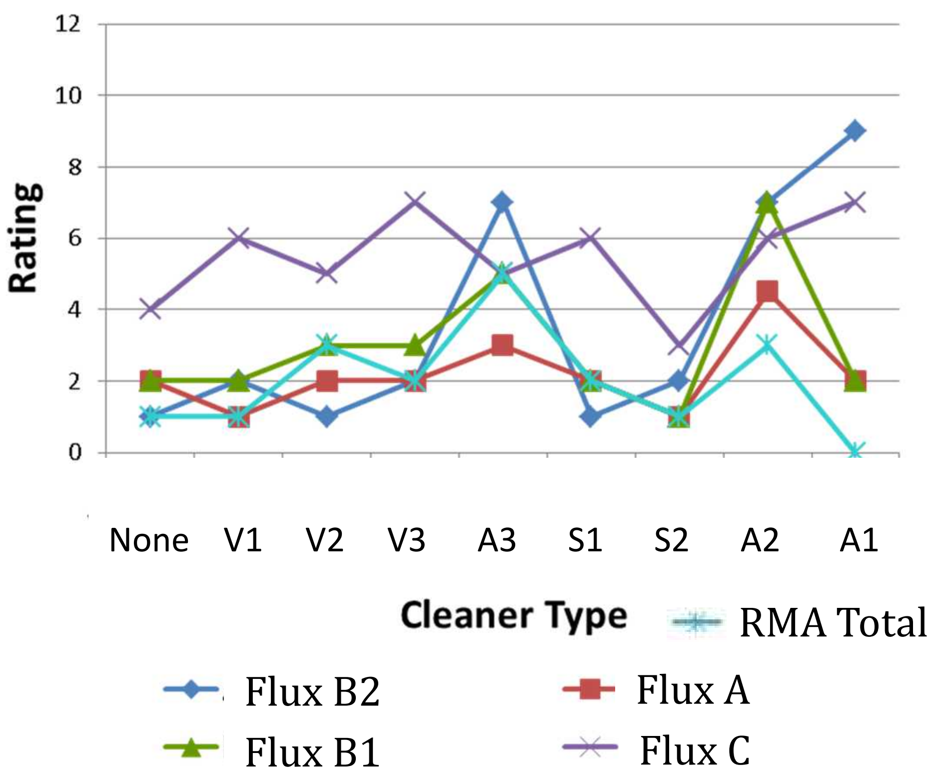


Figure 10: Low Temperature



Phase 1 Corrosion Ratings

Figure 9: High Temperature

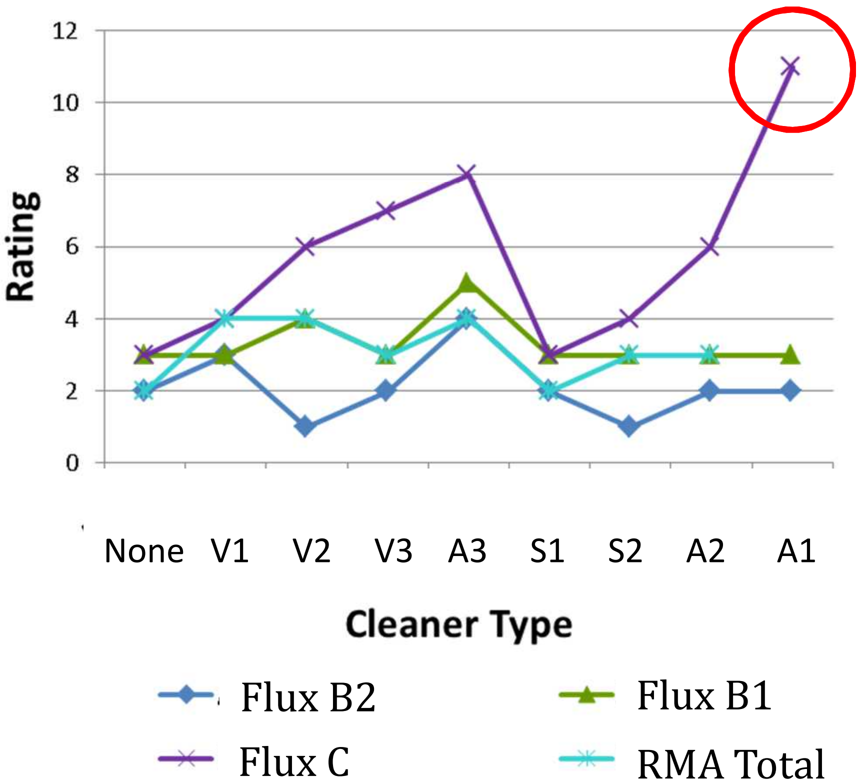
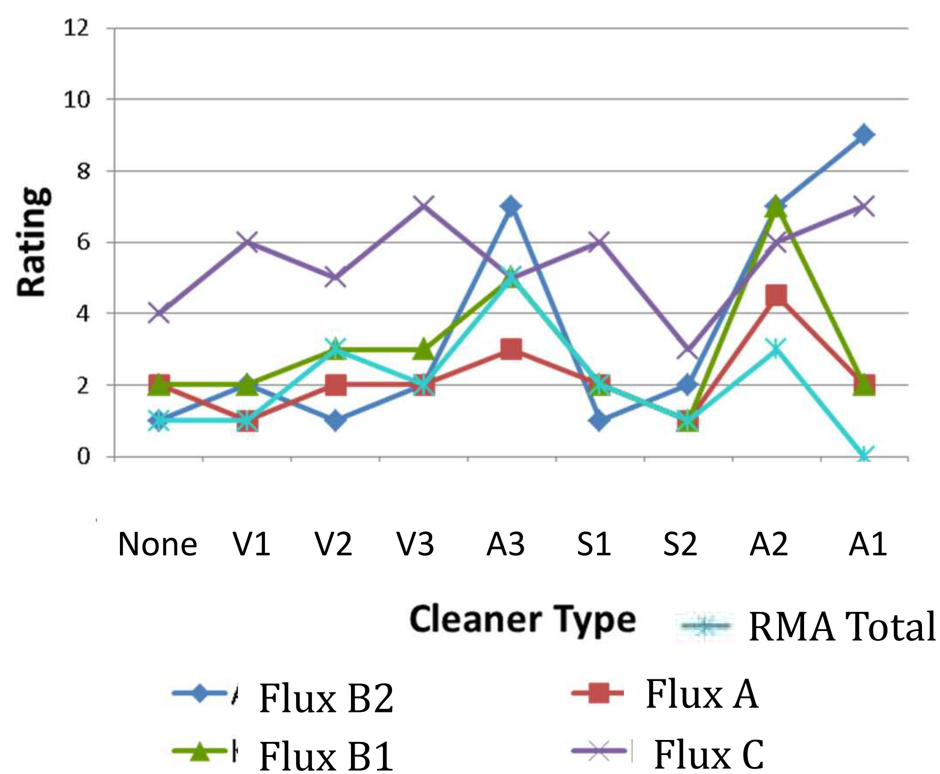
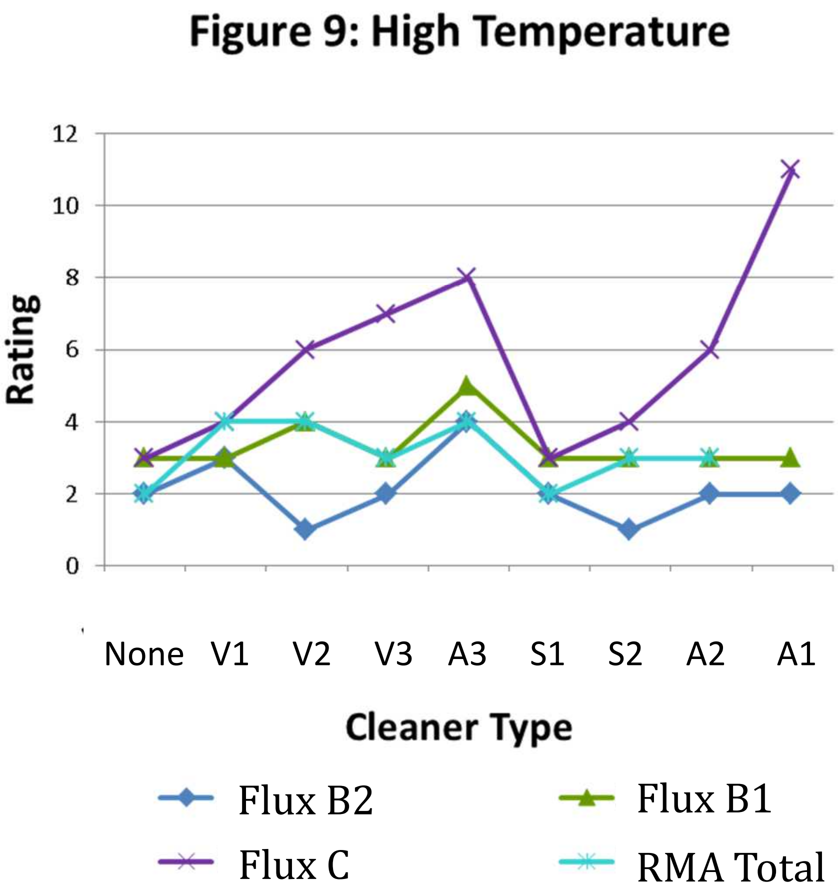


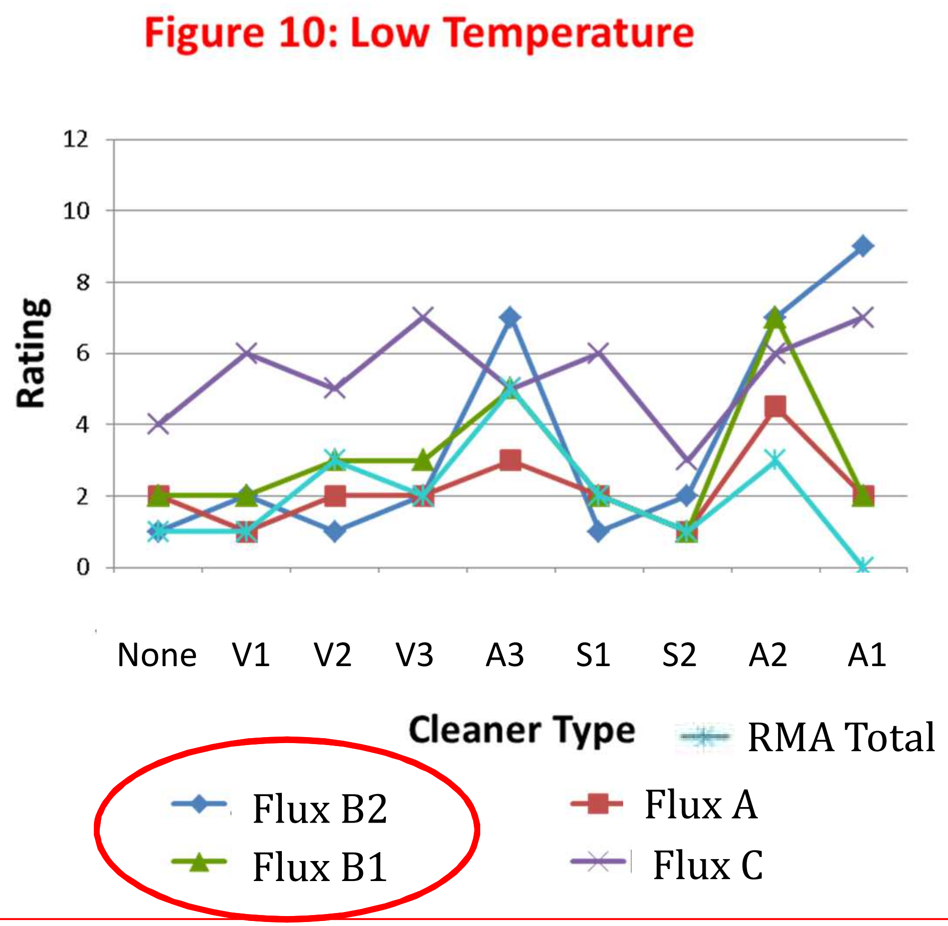
Figure 10: Low Temperature



Note: Flux C, water-sol ORH1, and Cleaner A1 rating is higher due to staining on other coupon materials

Phase 1 Corrosion Ratings





Note: Fluxes B1 & B2, no-clean, most dependent on cleaner, Flux C, ORH1, worst for both temperatures.

Phase 2 Corrosion Ratings

Figure 11: Clean A

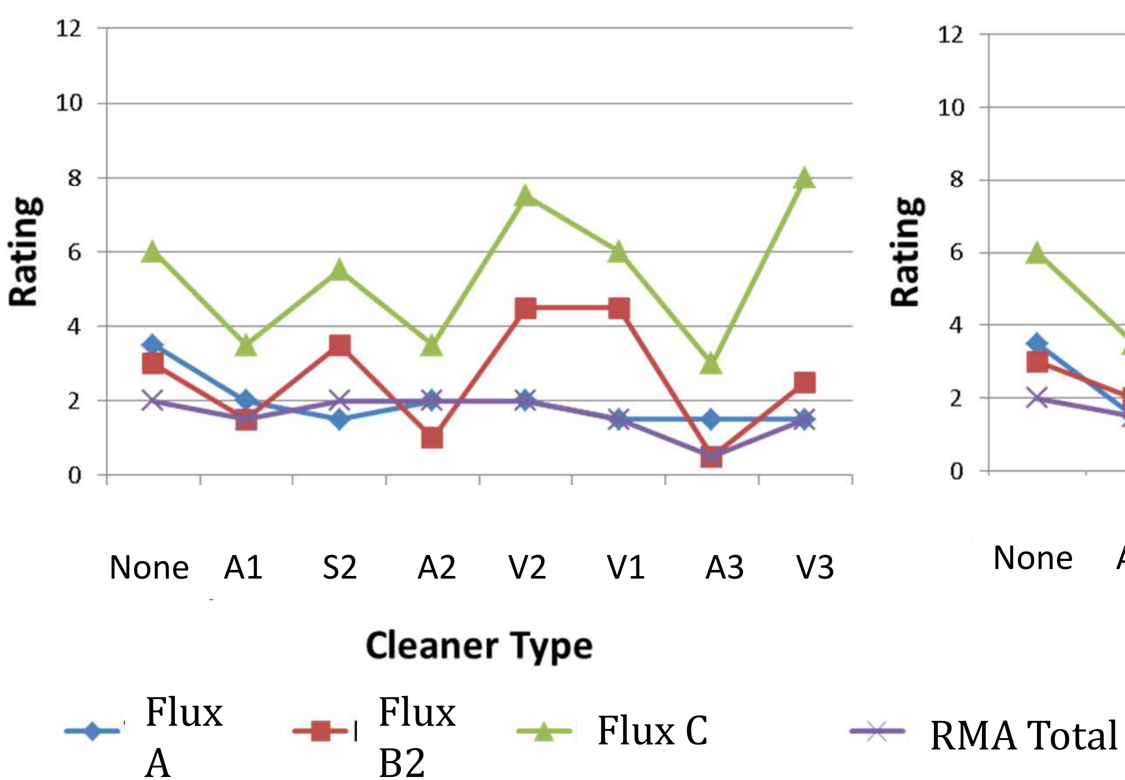
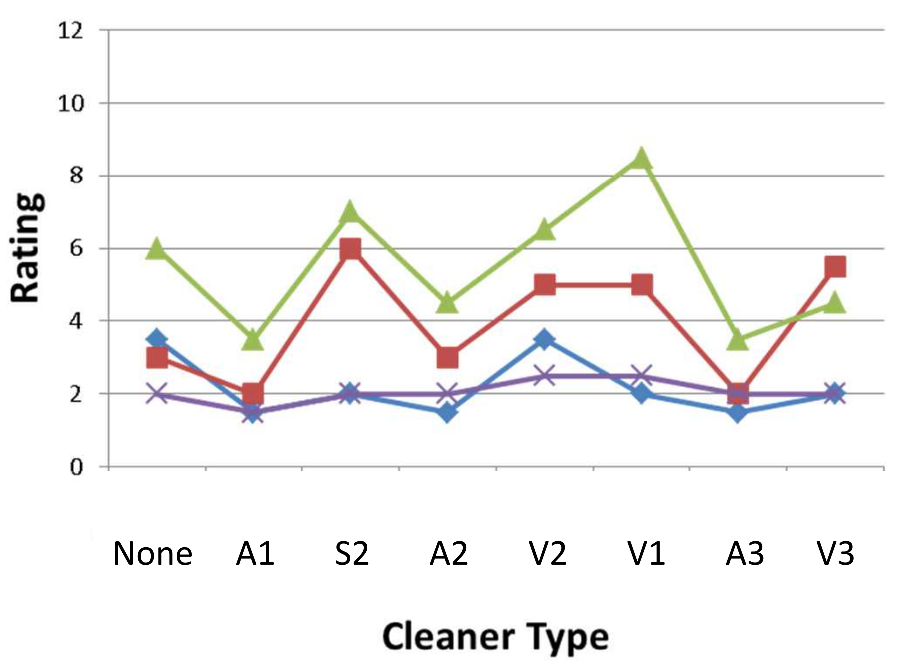


Figure 12: Clean B



Phase 2 Corrosion Ratings

Figure 11: Clean A

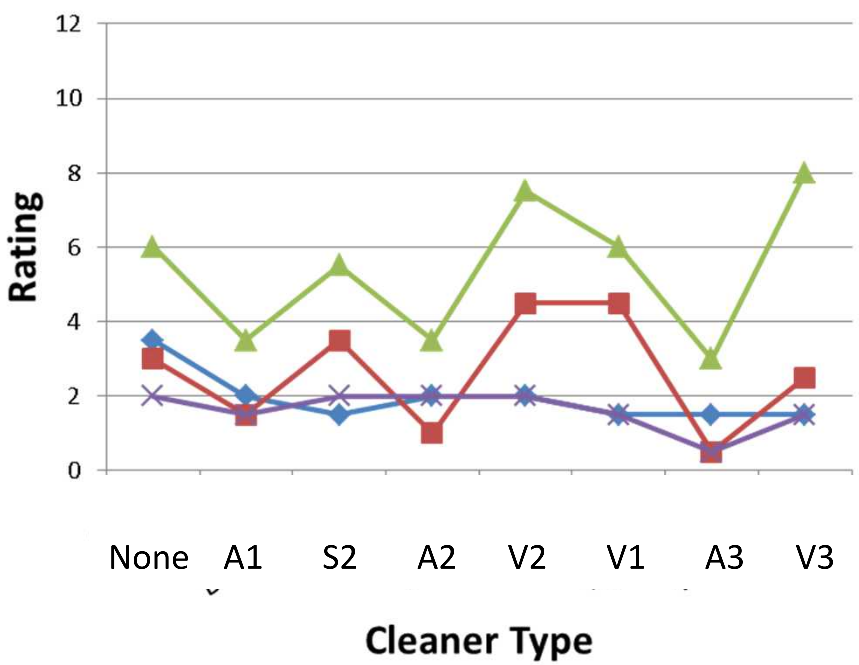
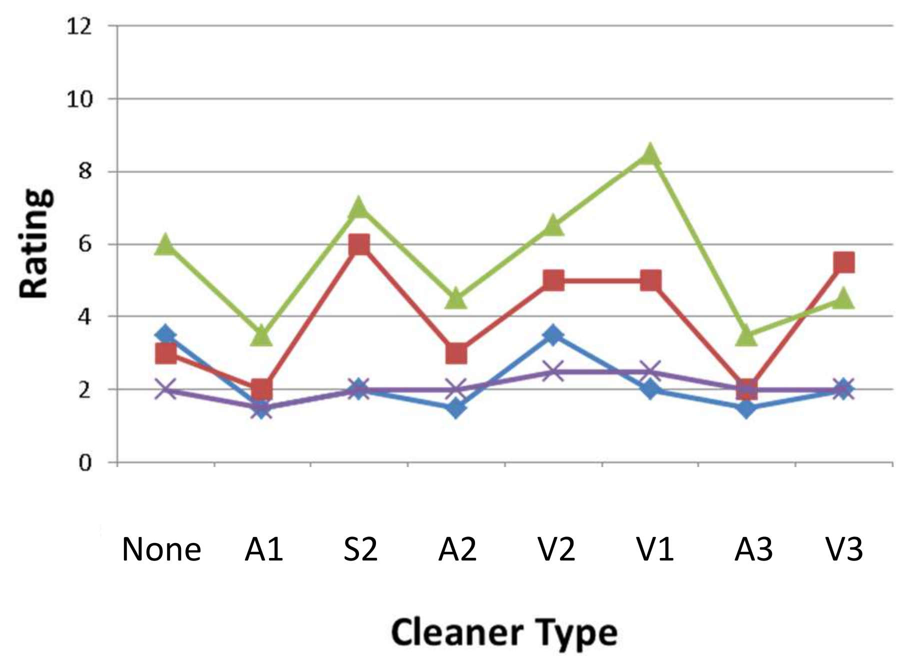


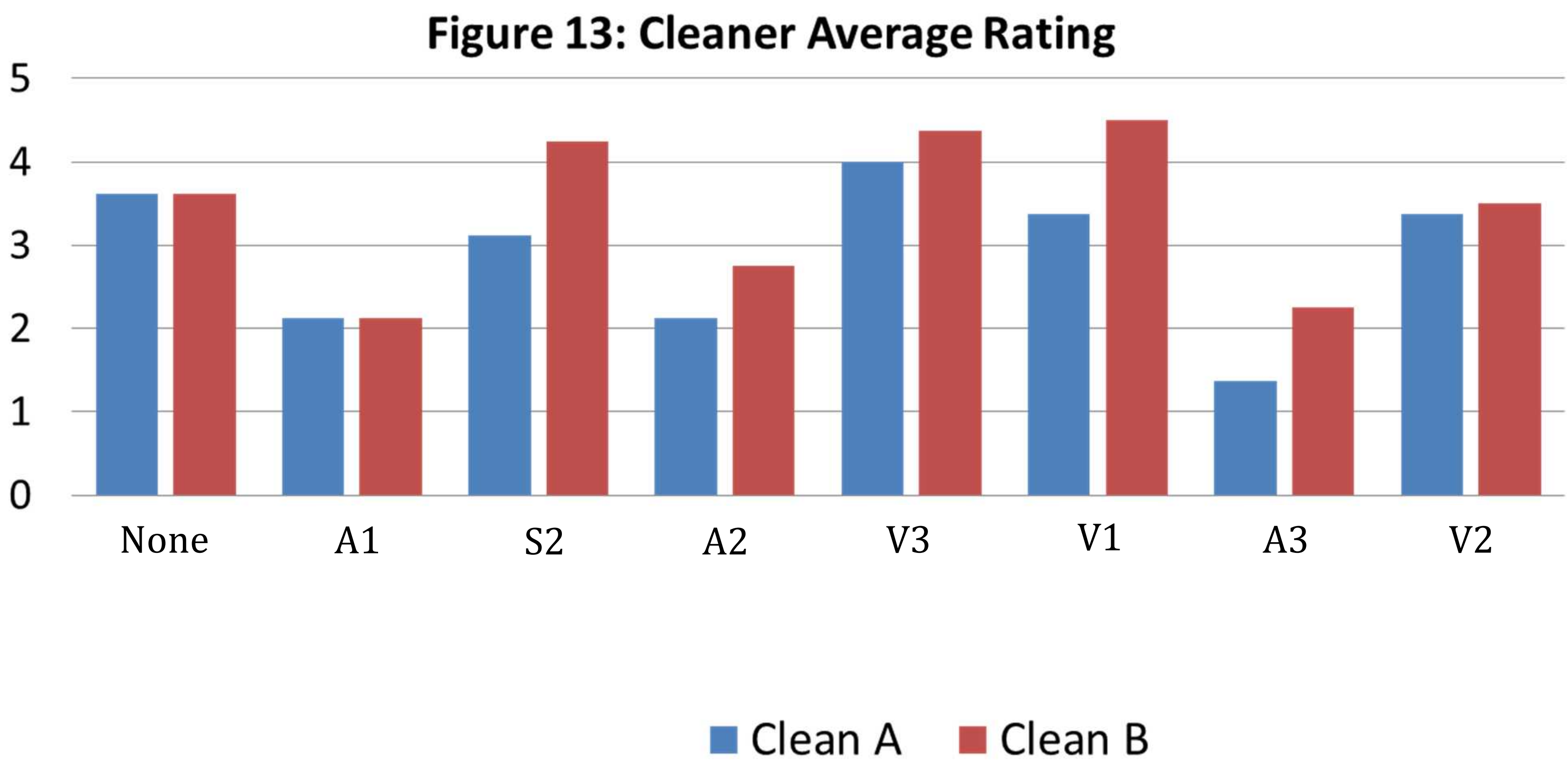
Figure 12: Clean B



Flux A Flux B2 Flux C RMA Total

Note: A very minimal clean and rinse was little different from a more thorough clean and rinse, when little physical cleaning action is present (no impingement spray, etc.)

Phase 2 Combined Results (con.)



Result: Vapor Clean of PWBs

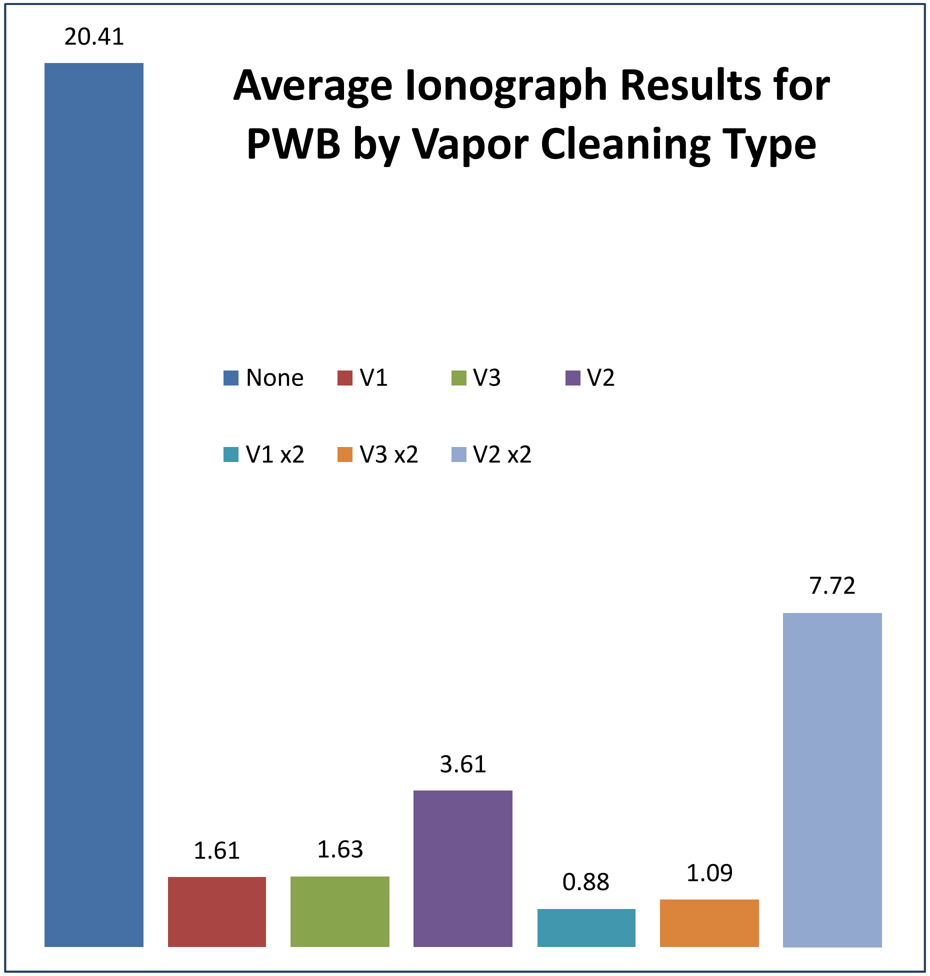
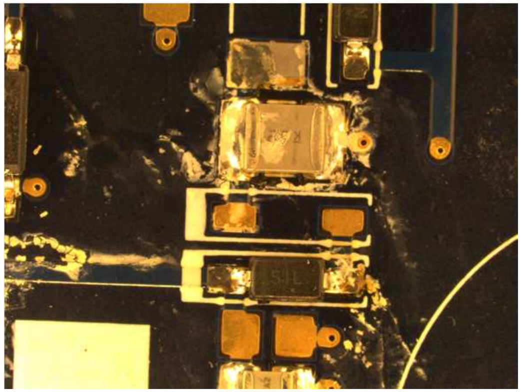


Figure 14: PWB Ionic Residue

One set of boards was cleaned by a typical vapor cleaning, the second set cleaned with a double amount of cleaning cycles. All used RMA flux at typical Sn-Pb temperatures.

Result: Worst Board Clean



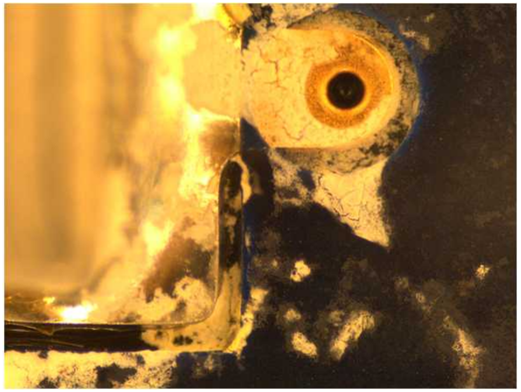


Figure 15: PWB Flux Residue

One PWB example had substantial visible residue: V2 Vapor defluxer

Conclusion, Phase 1

No removal of flux or rinsing of defluxer was attempted.

- Substantial corrosion appeared across all types of defluxers. This less than optimal performance is likely due to insufficient (no) rinsing. The results of the first phase demonstrate the need for appropriate rinsing to achieve low corrosion risk.
- Observations confirm that higher halide fluxes are more likely to result in corrosion.

Conclusion, Phase 2

- Most corrosion occurred with the vapor defluxers.
- Performance of the vapor defluxers on Cu coupons may be due to lack of physical pre-clean, or insufficient repetitions of vapor condensation. The PWB cleaning helped demonstrate better result.
- The need for appropriate cleaning method to achieve low corrosion risk.
- Confirms that higher halide fluxes are more likely to result in corrosion.

Path Forward

- Test for cleaning efficacy with physical cleaning.
  - Test boards with BGA, QFN and miniature components.
  - Clean with each defluxer identified for flux/solder type.
  - Clean with physical method required for process type.
  - Evaluate rinse capability for various defluxers.
- Determine cleanliness level validation methods.
  - Destructive testing
  - DI resistivity
  - Extended time and flow for ROSE or IC
  - Other?

Thank You

Acknowledged for their contributions:

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Sam Lucero, SNL

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W88/B-61 PWA-PWG

C8 Enhanced Surveillance

Flux Key for Phase 1

- A= Alpha WS809 water soluble paste, 230 C, 250 C
- B1= Kester 979 no-clean liquid, 280 C, 400 C, 450 C
- B2= Alpha NR330 no-clean liquid, 280 C, 400 C, 450C
- C1= Kester 2331-ZX water soluble, 280 C, 400 C, 450 C
- D1= Kester 185 RMA, 280 C, 450 C
- D2= Kester 197 RMA, 280 C, 370 C

Flux Key for Phase 2

A= Alpha WS809 water soluble paste, 380C

B2= Alpha NR330 no-clean liquid, 380 C

C1= Kester 2331-ZX water soluble, 380 C

D1= Kester 185 RMA, 380 C

Defluxer Key

- S1: solvent, ethanol
- S2: solvent, d-Limonene
- A1: DI water
- A2: aqueous defluxer # 2, A4241
- A3: aqueous defluxer #3, Vigon N600
- V1: vapor defluxer, AK-225
- V2: vapor defluxer # 2, Vertrel SDG
- V3: vapor defluxer #3, Precision V