Engineered Cleaning Fluid and Mechanical Impingement Optimization Innovations

IPC Midwest Conference

Mike Bixenman, Kyzen Corporation

9-26-07

KYZEN CORPORATION

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Electronic Interconnections Technology Trends

Situational Analysis

- Electronic interconnection industry experiencing rapid innovation to meet the ....
  - demand for greater functionality and performance
  - challenge of miniaturization and advanced designs
  - Never ending pressure for reduced cost
- Drivers for interconnection technology
  - Enhanced "System on a Chip" packaging
  - Higher Density
  - Better Reliability

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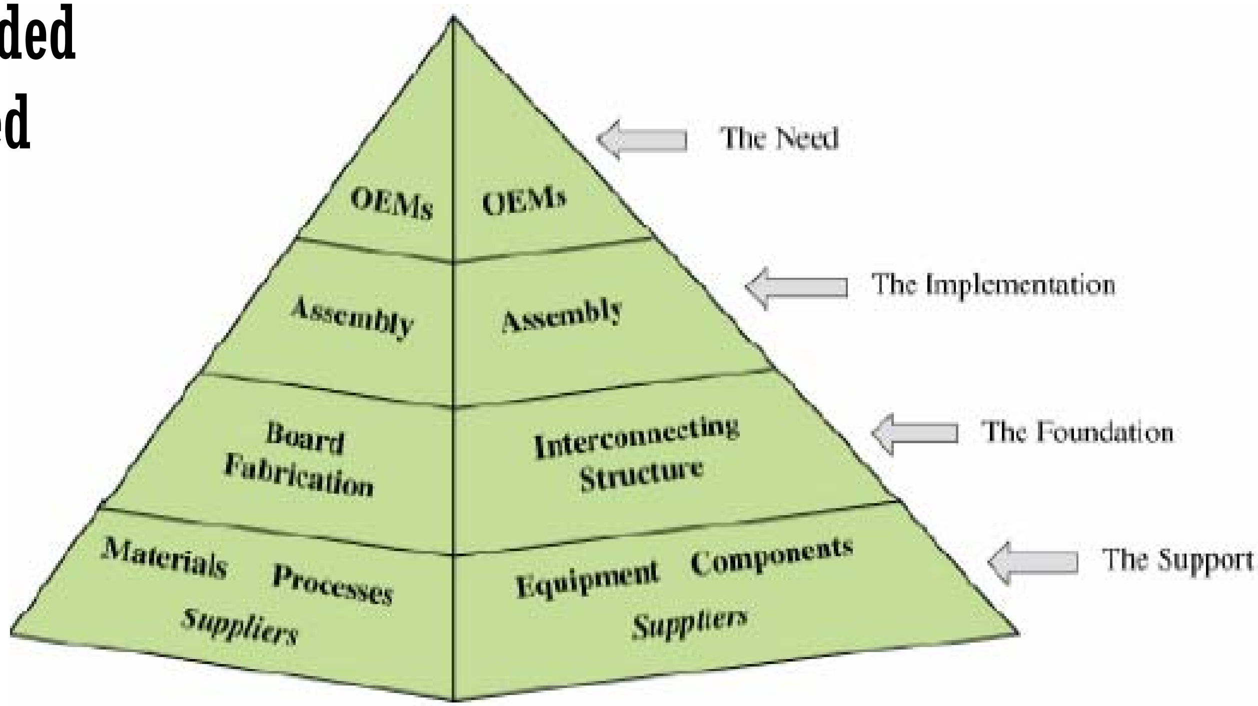
Needs Assessment

- Do products or processes need improvement to maintain market share?
- Do technologies exist to meet the needs of each level of the pyramid?
- What advancements or investments are needed to accomplish defined roadmap goals?



IPC International Technology Roadmap,2007

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What is driving cleaning technology development?

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Harsh Environments

- Automotive under the hood
- Military
- Avionics Electronics

Cleaning is a reliability driver

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Mid Range Performance Electronics

- High end personal computers
- High end games
- Networking telecommunications

Advanced packaging drives the need to clean

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High Performance Systems

- Mainframe
- Server
- Mass Storage
- RF
- Microwave

Bandwidth and signal impedance drive the need to clean.

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Hand Helds

- Cellular phones
- Sub-notebooks
- PDAs
- Hand held game

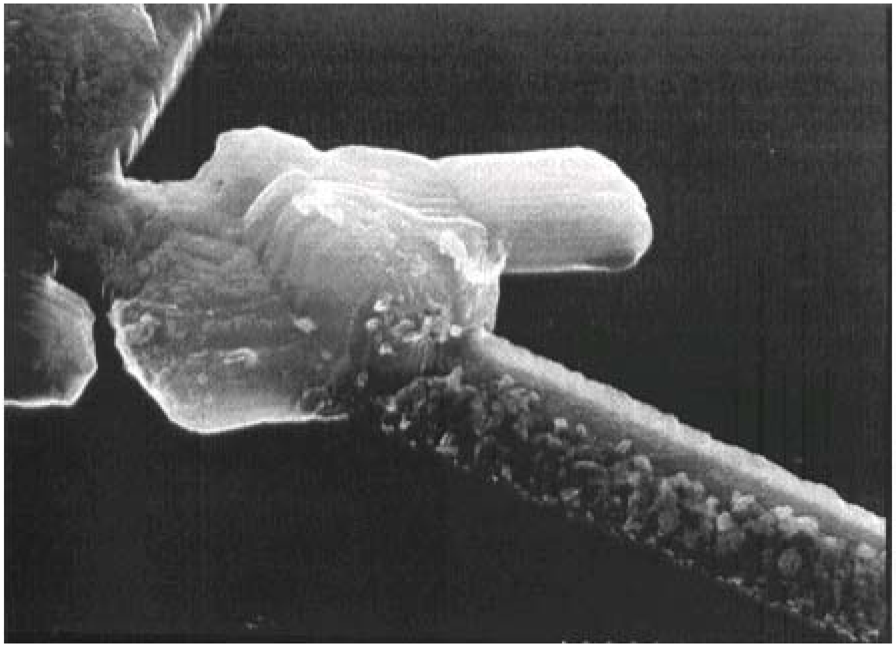
System in package
driving the need to clean exacerbated
by Pb-free marketing programs.

IPC International Technology Roadmap,2007

Failure Avoidance

This is why we are here today

Failures are bad
and cleaning can help
prevent failure at a systemic level



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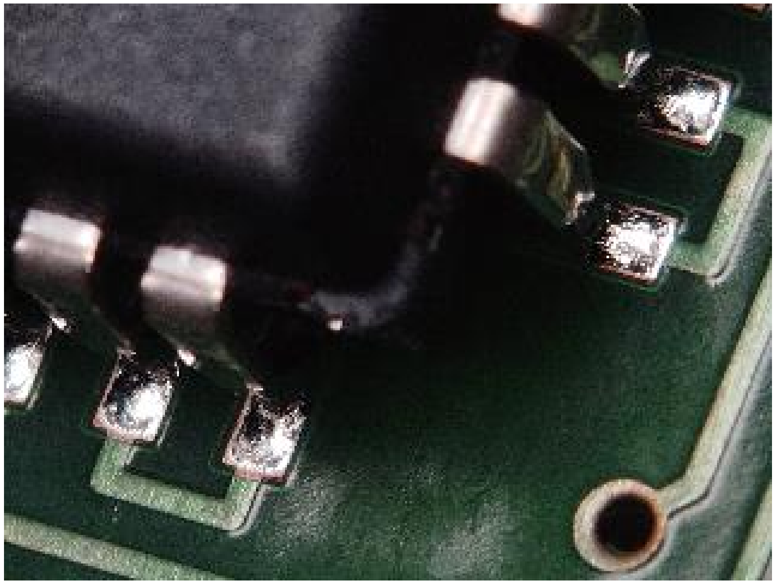
Cleaning equates to Customer Value

- Cleaning is a key part of the solution for each of these challenges
- They all share the need for:
  - Increased miniaturization
  - Higher processing speeds
  - High frequency
  - Lower cost, better yields

"A reliable assembly,
from a robust manufacturing environment"



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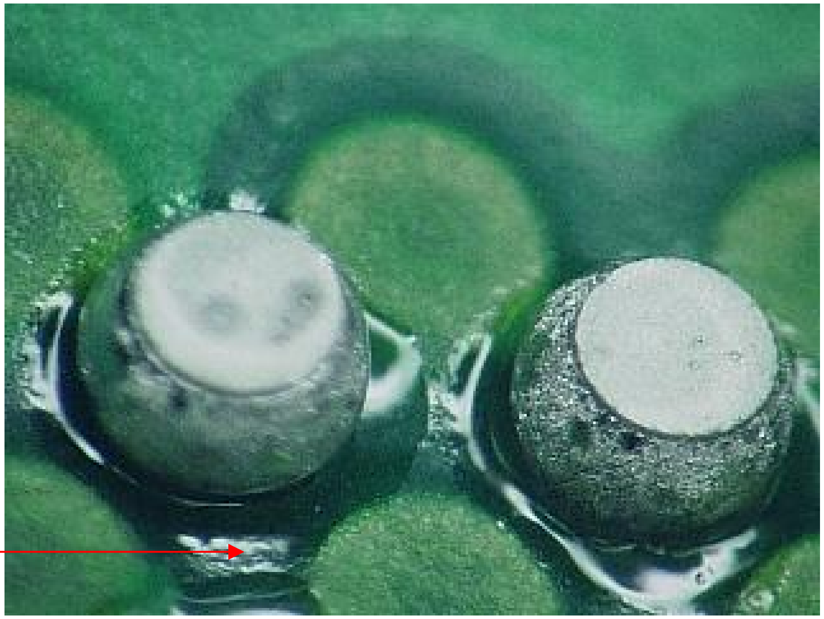
Electronic Interconnection Cleaning Technology

Cleaning Challenges have Evolved

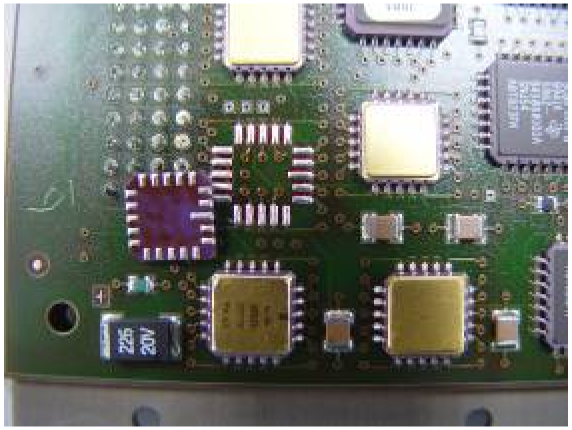
- Cleaning is increasingly more difficult due to:
  - Convergence of circuit board and advanced packaging technologies
  - Highly dense assemblies
  - Low standoffs
  - Pb-free flux is harder to clean

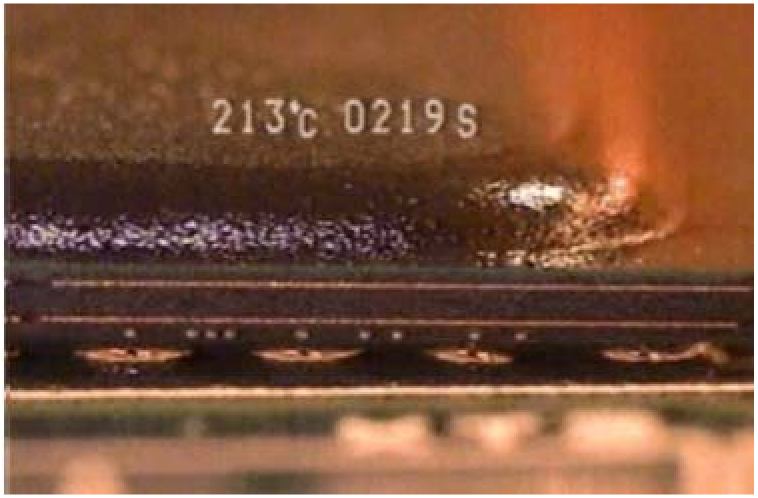
Flux Residue



Difficult Cleaning Challenges

- Leadless chip carriers
- Flush mounted chip caps
- Area array components
- Capillary action and surface tension fill the underside of the components flux residue





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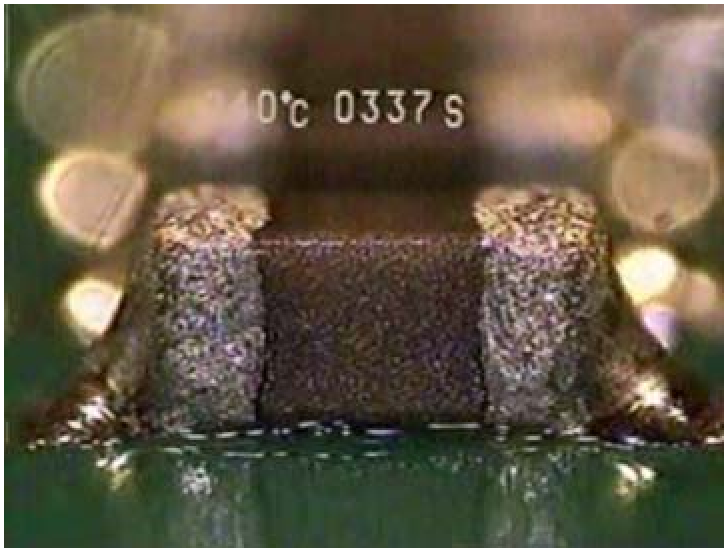
Problem Definition

- Average spacing under one of these devices is approximately 2-4 mils
  - Chip caps can be a low as 1 mil
- To clean under these components
  - Static and dynamic cleaning rates must
    - Break the flux dam
    - Impinge the leading edge with pressure and flow
    - Cleaning fluid that rapidly dissolves the residue
- Drivers for removing all flux residues
  - Cleaning fluid
  - Wash time
  - Wash temperature
  - Pressure, flow, and directional forces



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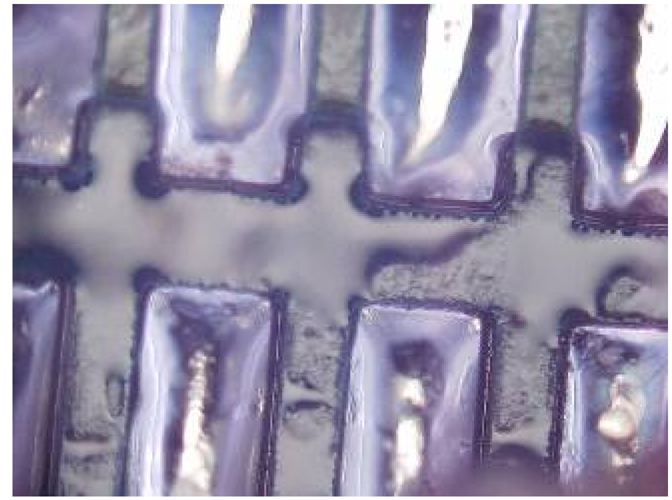
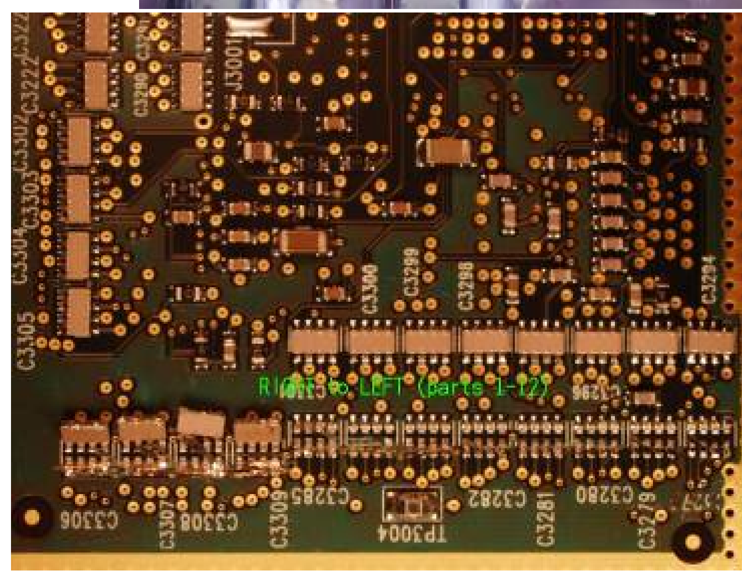
Approach to Solving Unmet Cleaning Needs

Optimizing the Cleaning Process

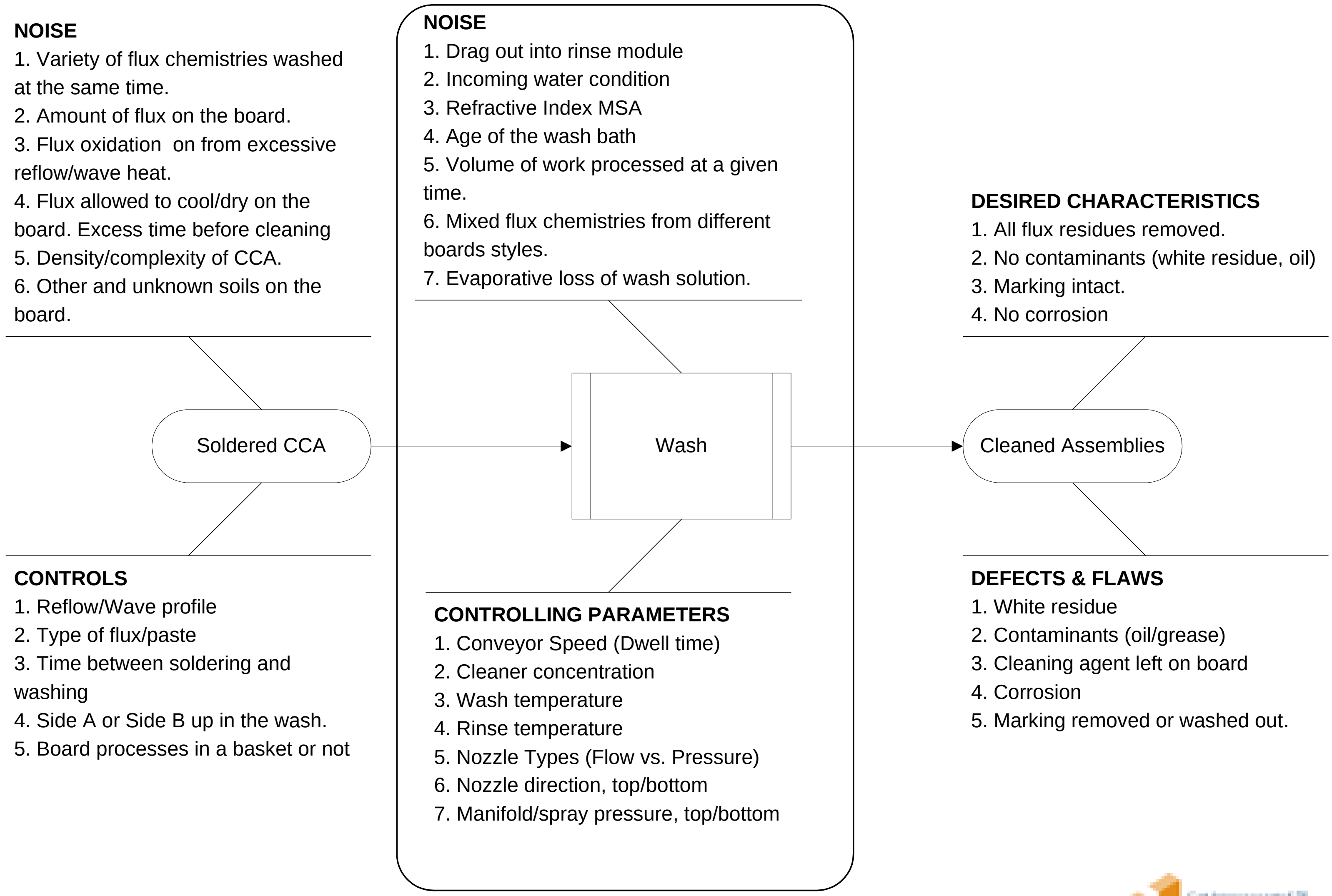
- Requires an understanding of …
  - Upstream considerations
  - Static driving forces
  - Mechanical driving forces
- As the component gap reduces
  - *Cleaning becomes more difficult*





Process Optimization

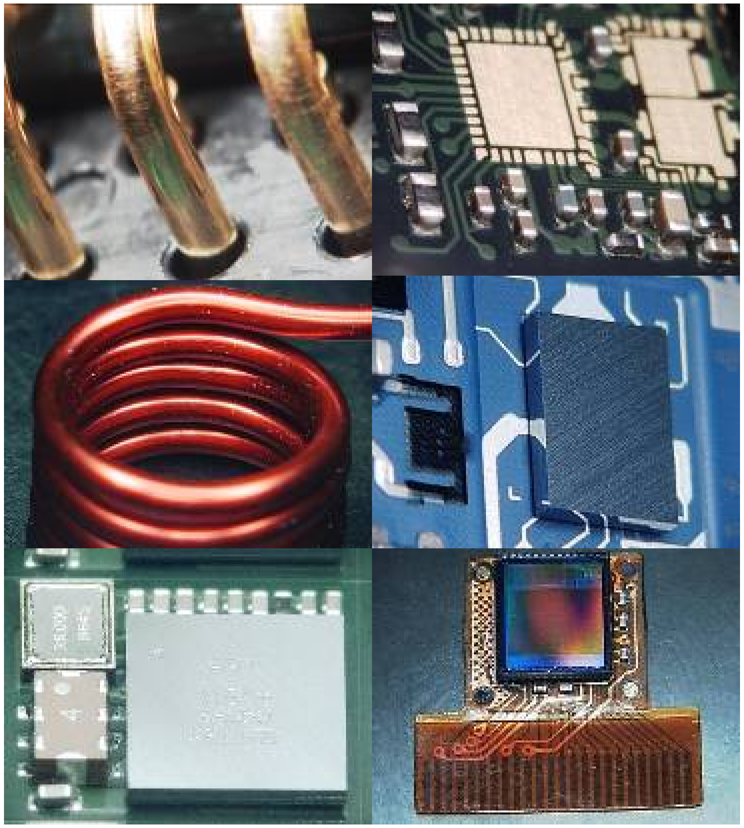
IDEAL FUNCTION DIAGRAM
WASH PROCESS



(Bixenman, Gervascio, Lasky, 2007)

Upstream Considerations

- Cleaning fluid must be designed
  - Around equipment types
  - For the soil
  - For the application
- Electronic cleaning needs
  - Rapid removal of soil
  - Low surface tension/wetting
  - Repeatability
  - Controllable
- Cleaning equipment
  - Building blocks must be matched to the specific cleaning requirement



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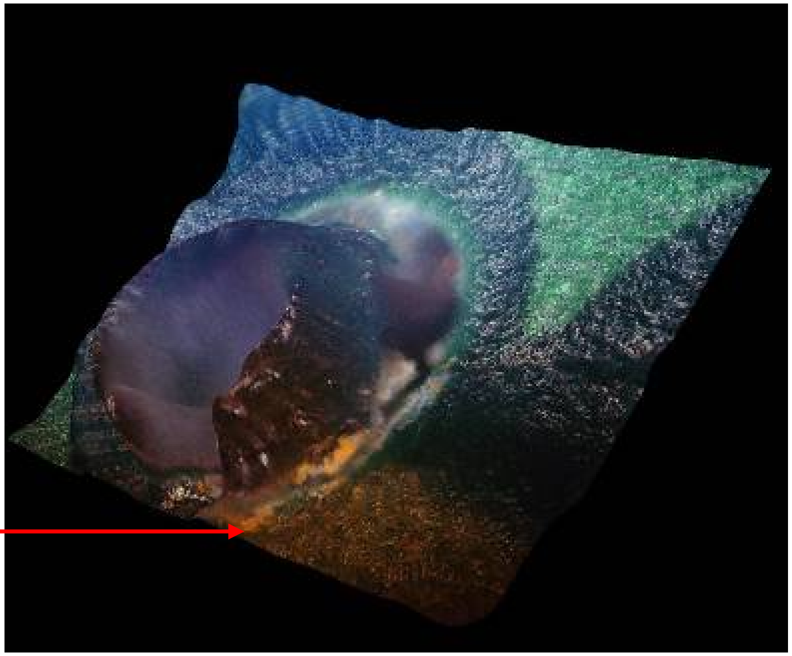
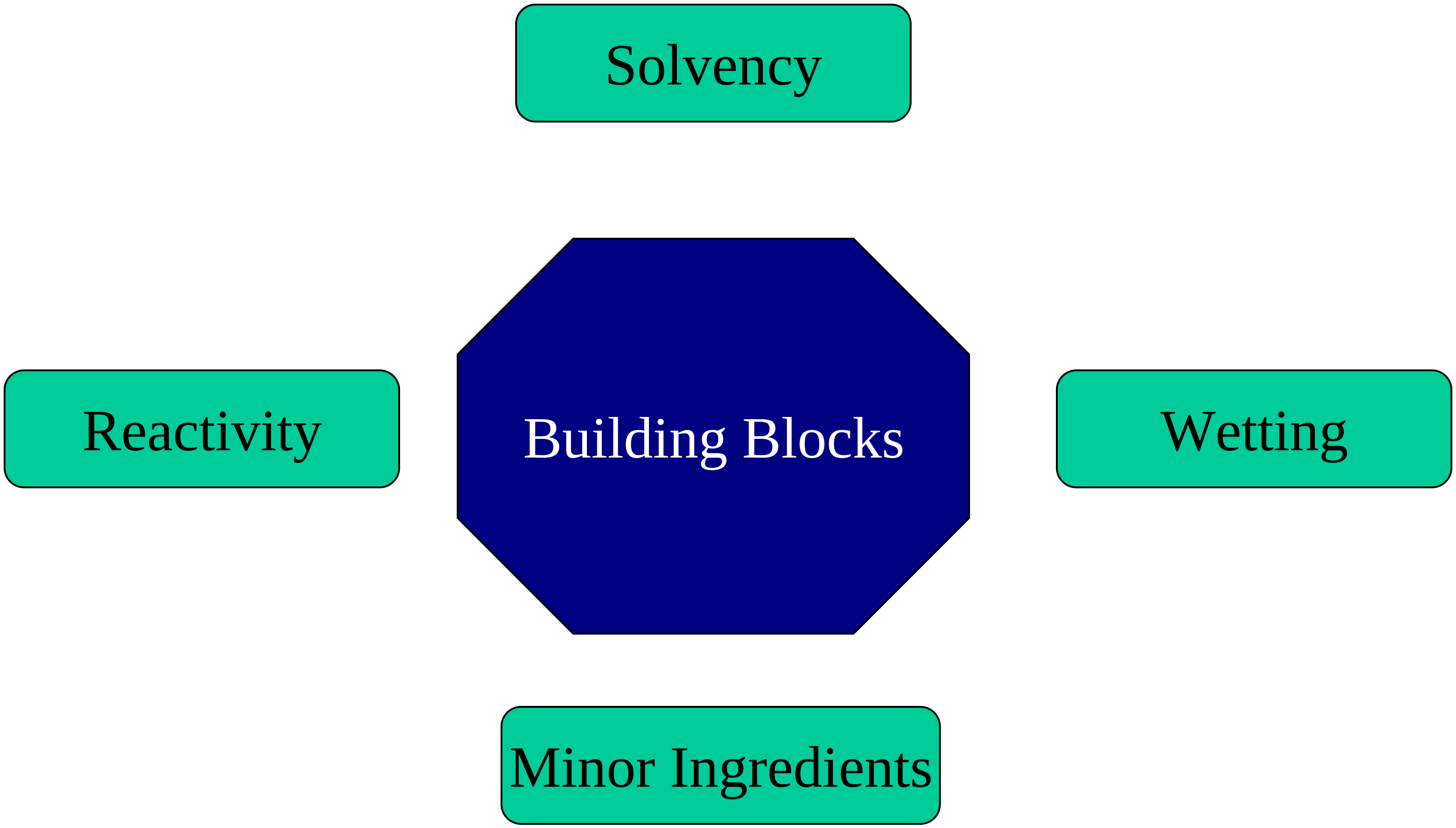
Influential Variables

- Many variables influence the process cleaning rate
  - Substrate
  - Contaminant
  - Wash Temperature
  - Wash time
  - Cleaning fluid
  - Mechanical impingement
  - Surface tension (capillary action)

White Residue



Cleaning Technology Basics



Cleaning Fluid Building Blocks

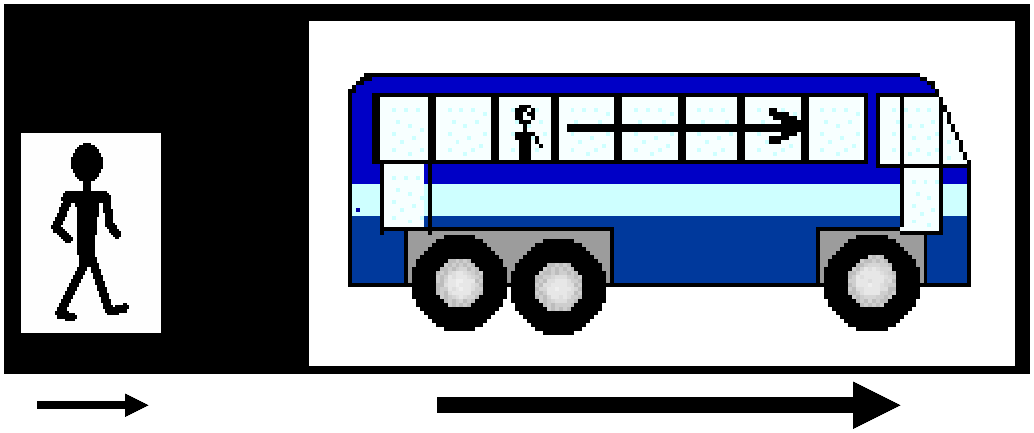
- Engineered aqueous materials that consist of:
  - solvating materials
    - dissolve resins, rosin and polymeric structures
  - wetting materials
    - reduce wash chemistry surface energy and droplet size
  - activators
    - rapidly softens resins, which allows dissolution in the wash media
  - minor ingredients
    - inhibition to prevent oxidation
    - destabilizing foam

Cleaning Fluid Goals

- Built on the principle of lean technology
- Product improvements are built from ....
  - Improved solvency to remove flux soils
  - Operate at lower concentrations ~ 5-15% range
  - Operate at lower wash temperatures ~ 110 -150ºF
  - Operational consistency
    - Long bath life
    - No foam
    - Controllable
  - Environmental improvements
  - Compatibility improvements

Rate Theory

"The over-all process cleaning rate is sum of the static rate plus the dynamic rate"



50 MPH + 50MPH = 100MPH

Static Rate + Dynamic Rate = Total Rate

Static Rate = Rate at which process will proceed on its own

Dynamic Rate = Rate increase attributable to machine

Stach, Bixenman (2005)

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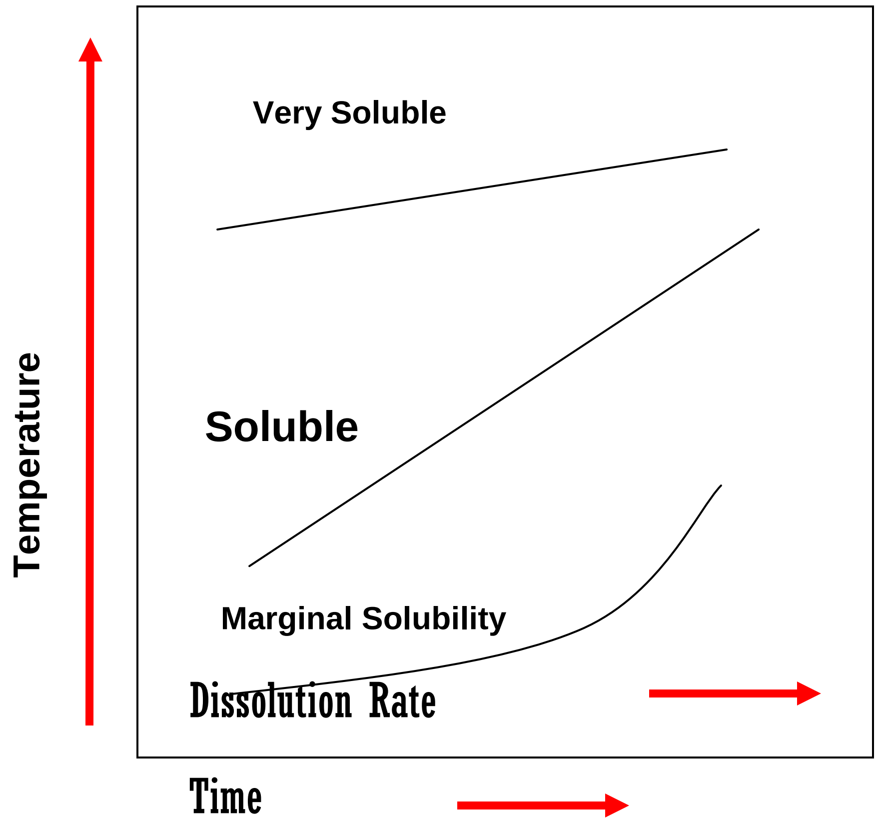
Cleaning Rate Theory Details

- Chemical Driving Forces
  - Dissolution rate
  - Temperature
  - Time
  - Cleaning fluid concentration
  - Surface Tension
  - Wetting
- Mechanical Driving Forces
  - Flow
  - Impingement
  - Direction
  - Fluid Pattern

Fluid Dynamics

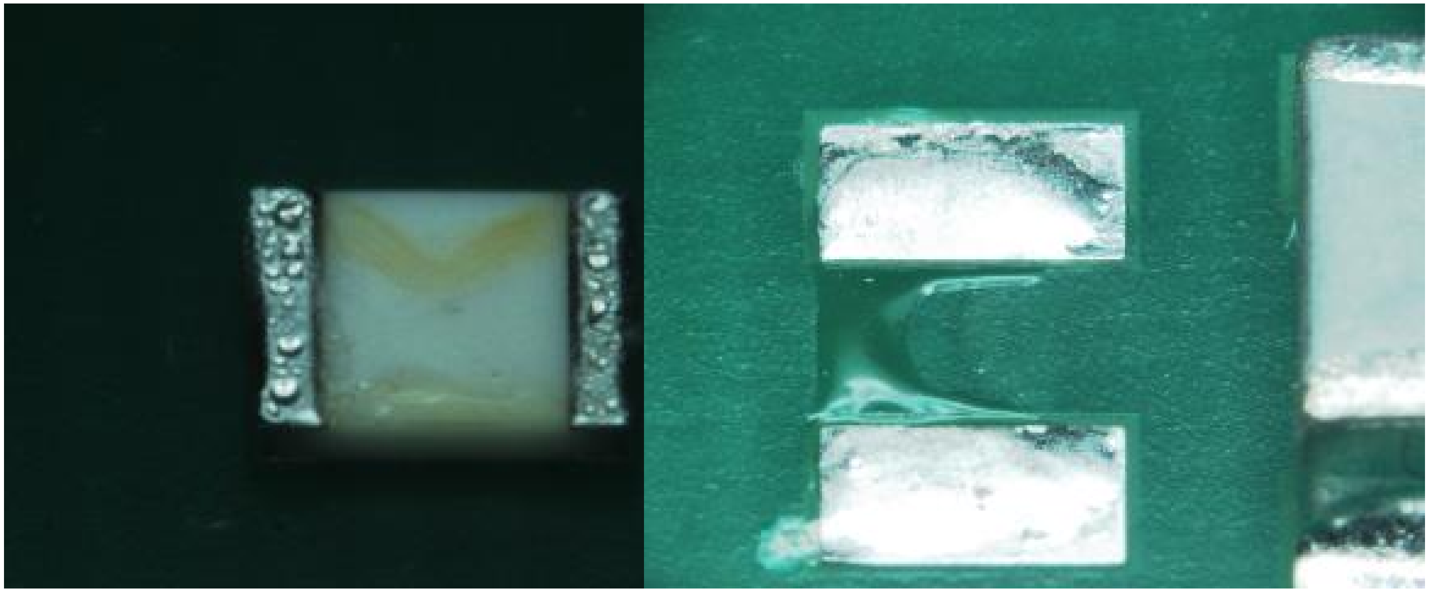


Process Implications of the Cleaning Rate Theory

- Concentration of the cleaning fluid
  - Higher concentration tends to improve cleaning performance
- Temperature
  - Solder flux tends to remove better at 130-160°F range
- Time
  - Longer time improve cleaning ~ especially under low standoffs
- Impingement
  - Combination of soak, flow and high pressure improve cleaning

Low Stand Offs: Complicate the Theory

- Rate theory fails to apply in all cases, specifically where penetration is required to reach the soil.
- The cleaning fluid must get to the soil before the cleaning fluid will dissolve or react

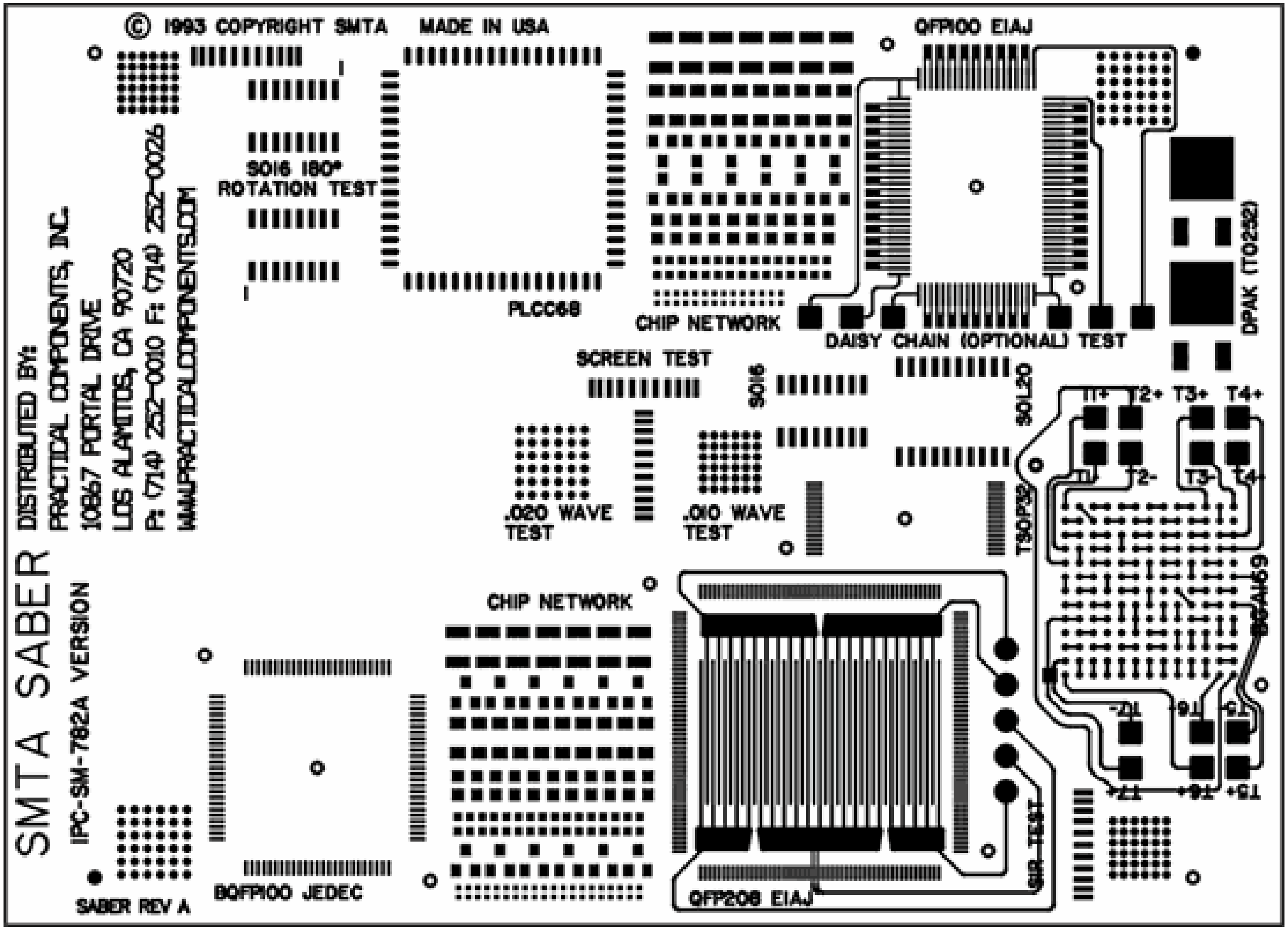


Methodology

- Static cleaning rate
  - SMTA Saber Board
    - Residue removal around fine pitch components
    - Factorial Design
    - Batch dishwasher style cleaning machine with low impinging forces
- Dynamic cleaning rate
  - Selection of cleaning fluid that provides highest static cleaning rate
  - Evaluate the design and layout of nozzles
    - Nozzle types for penetrating under low standoff components
    - Time under manifold to clean under low standoff components
    - Optimization of nozzles to facilitate cleaning under low standoff components

Static Cleaning Rate

Test Vehicle



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Factors

Factor Description	Level 1	Level 2
Reflow Profile	Low Thermal Load	High Thermal Load
Number of Reflows	1	2
Cleaning Residence Time	8 min	16 min
Cleaning Chemistry	Chemistry 1 @ 13% & 125F based on pre-test findings	Chemistry 2 @ 20% & 150F based on pre-test findings

DOE

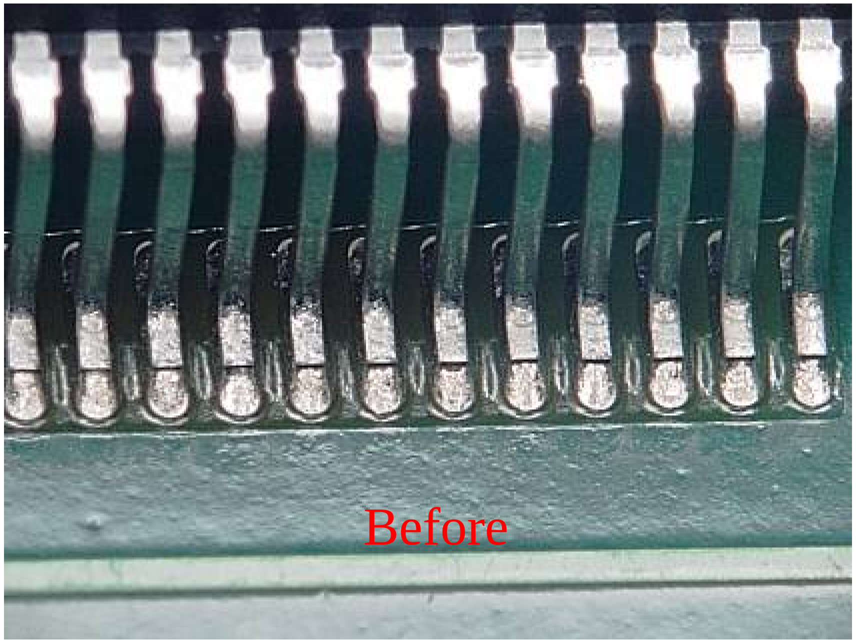
Run	Reflow Profile	No of Reflows	Cleaning Time	Wash Temp.	Conc.	Chemical
1	Low	1	8	125°F	13%	Chemistry 1
2	High	1	8	125°F	13%	Chemistry 1
3	Low	2	8	125°F	13%	Chemistry 1
4	High	2	8	125°F	13%	Chemistry 1
5	Low	1	16	125°F	13%	Chemistry 1
6	High	1	16	125°F	13%	Chemistry 1
7	Low	2	16	125°F	13%	Chemistry 1
8	High	2	16	125°F	13%	Chemistry 1
9	Low	1	8	150°F	20%	Chemistry 2
10	High	1	8	150°F	20%	Chemistry 2
11	Low	2	8	150°F	20%	Chemistry 2
12	High	2	8	150°F	20%	Chemistry 2
13	Low	1	16	150°F	20%	Chemistry 2
14	High	1	16	150°F	20%	Chemistry 2
15	Low	2	16	150°F	20%	Chemistry 2
16	High	2	16	150°F	20%	Chemistry 2

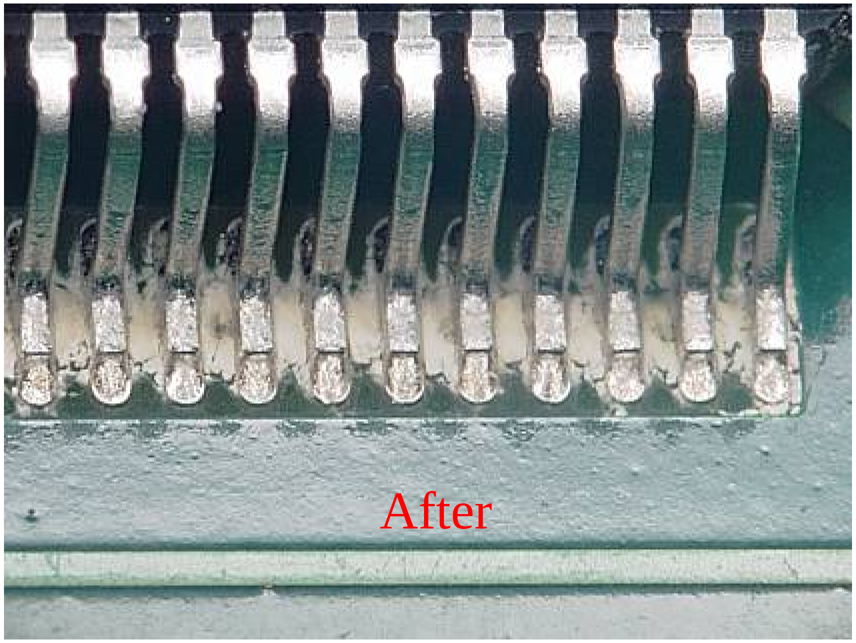
Responses

- The responses measured were visual examination of flux residues after reflow and cleaning processes. Printed circuit assembly was inspected around the QFP component. Two orientations were inspected and graded on a 1-10 scale.
- A "1" designated that no flux was removed. A "10" designated that 100% of flux residue was removed. Inspection was conducted under 10X magnification. On set of leads inspected was 90 degrees rotated from first set of leads.

Chemistry 1

- Low Reflow Profile (Peak 230°C)
- One reflow exposure
- 8 minute wash time, 125°F, 13%





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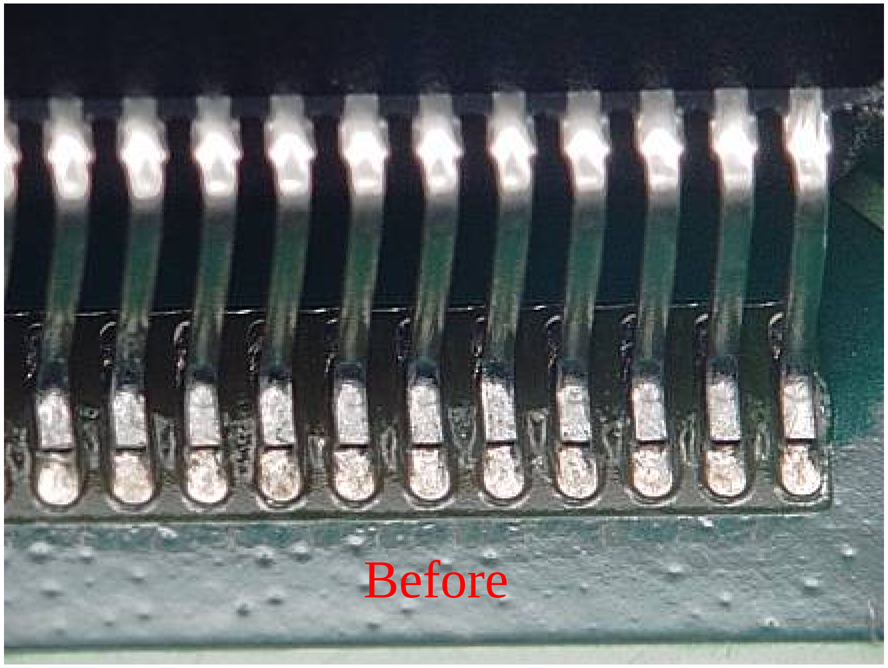

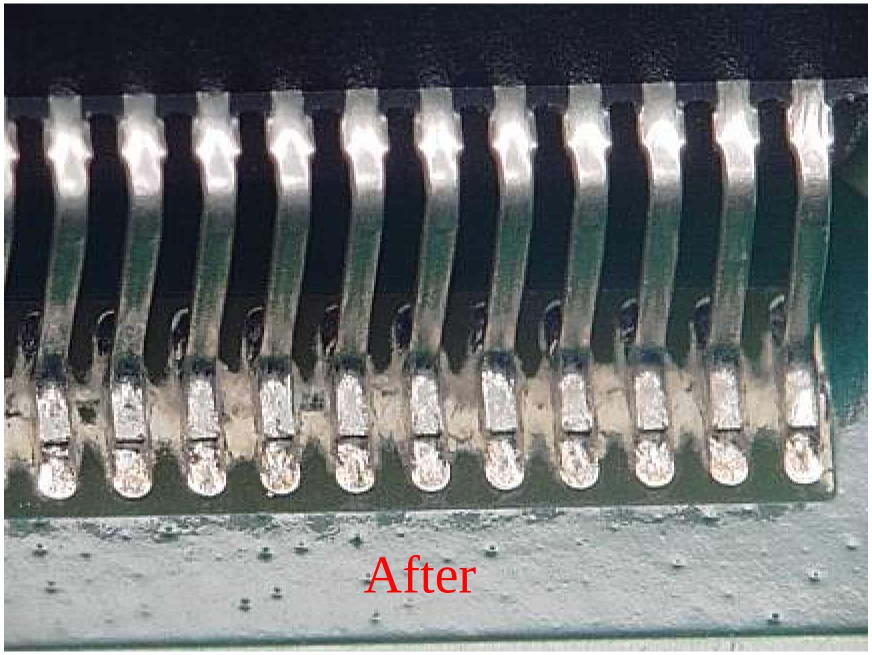

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Chemistry 1

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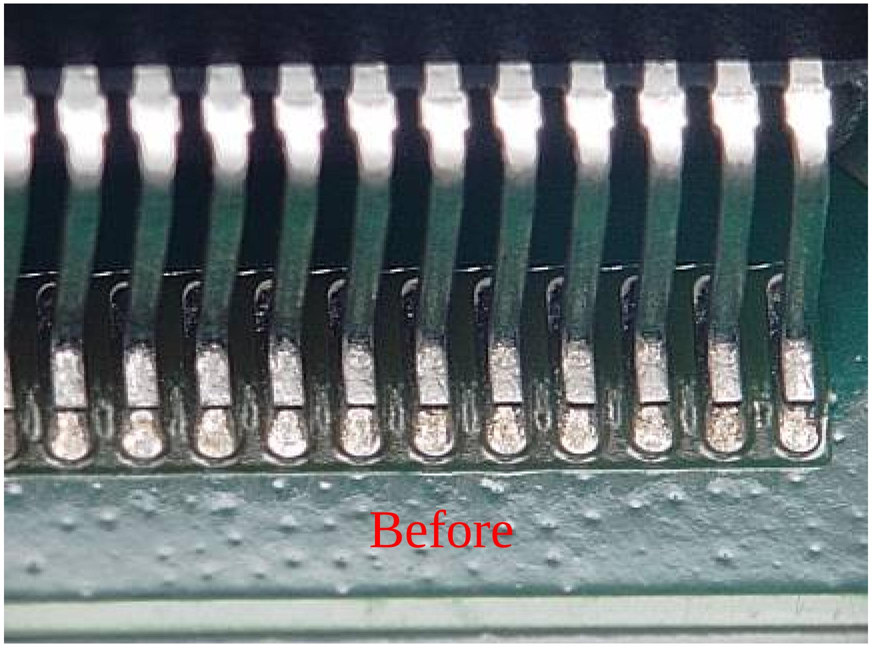

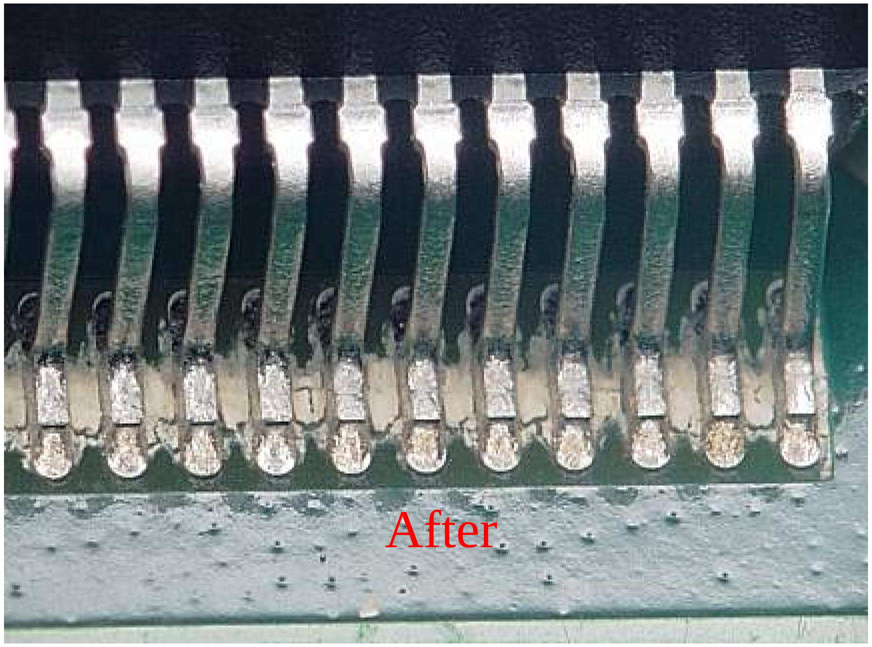

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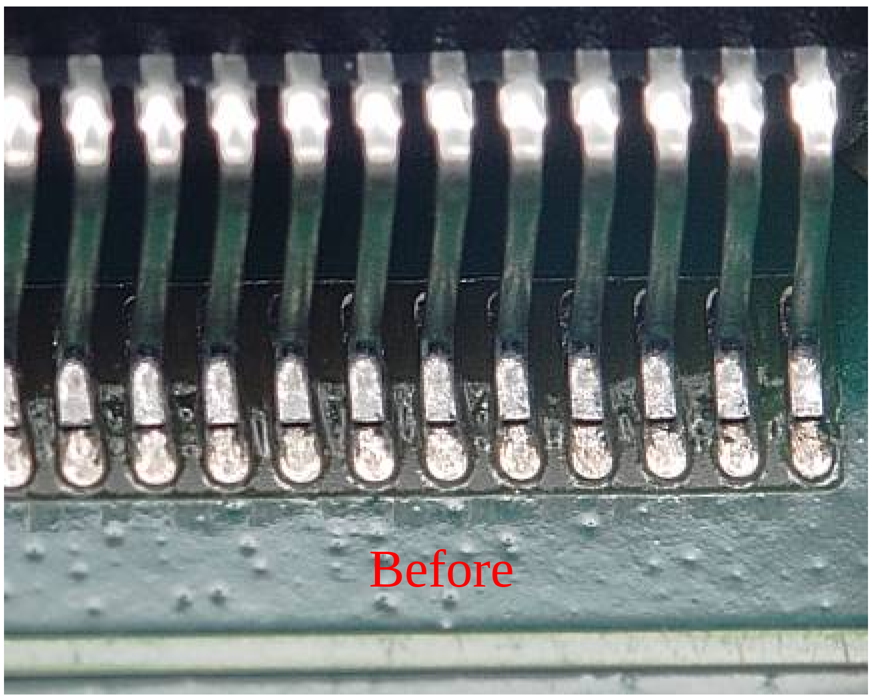

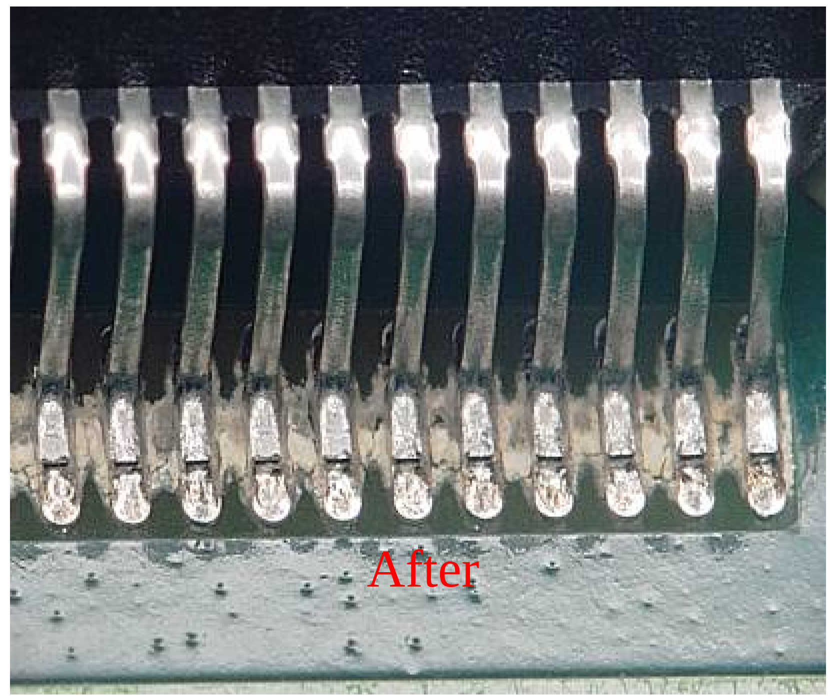

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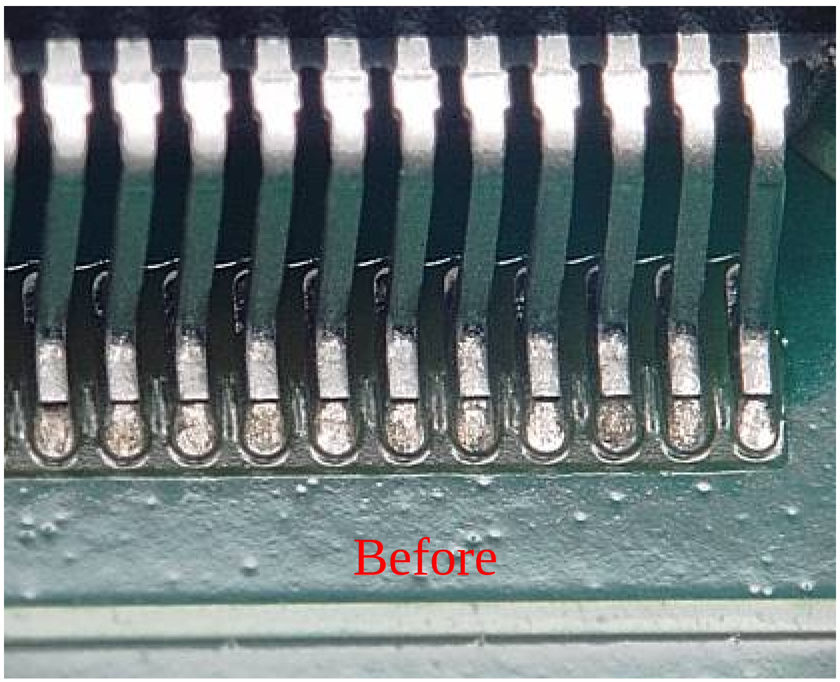

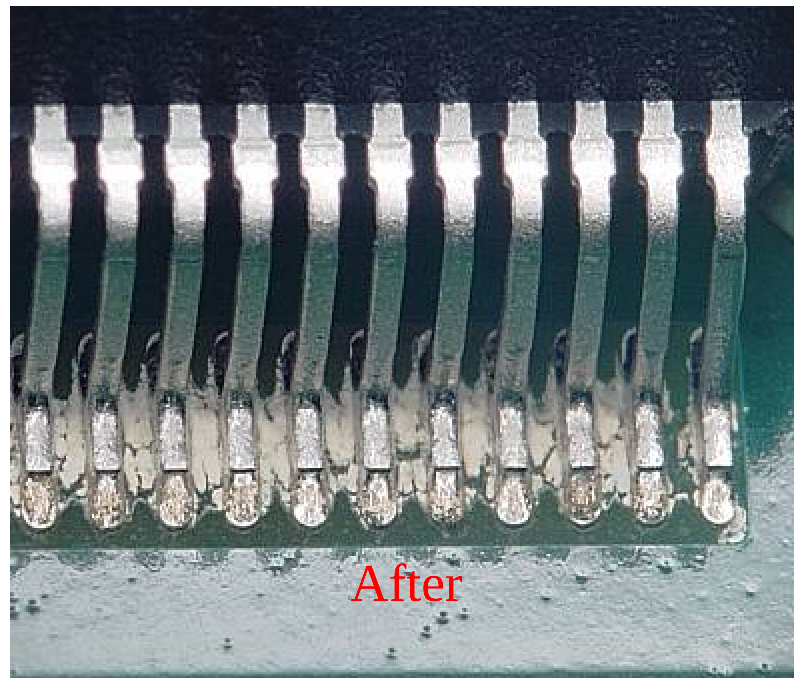

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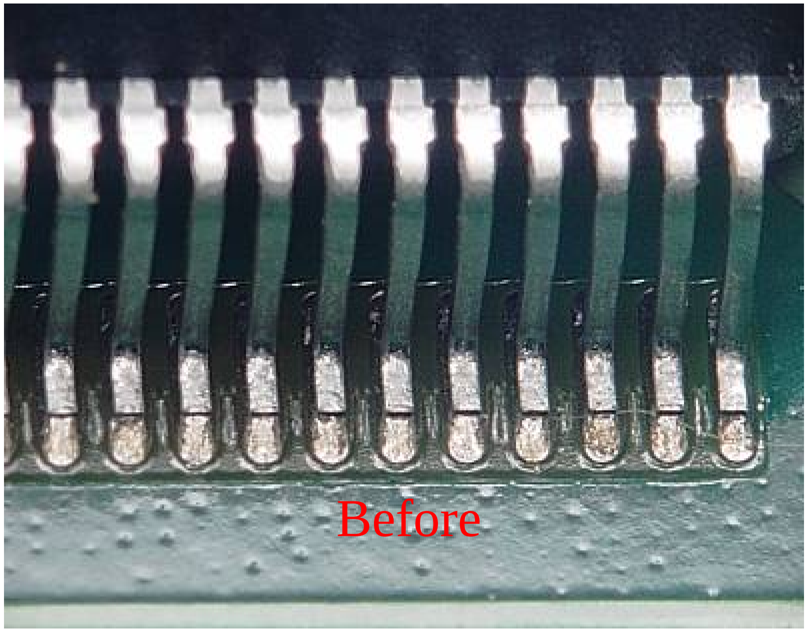

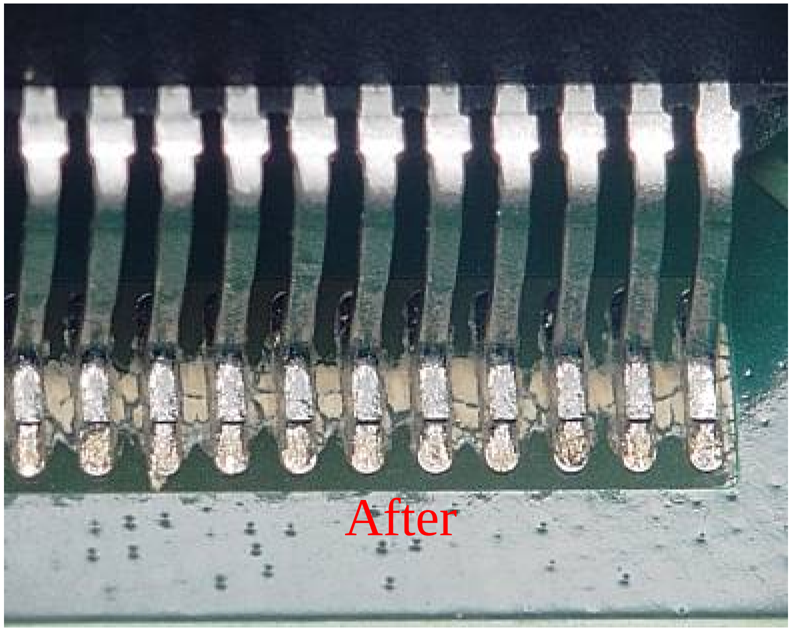

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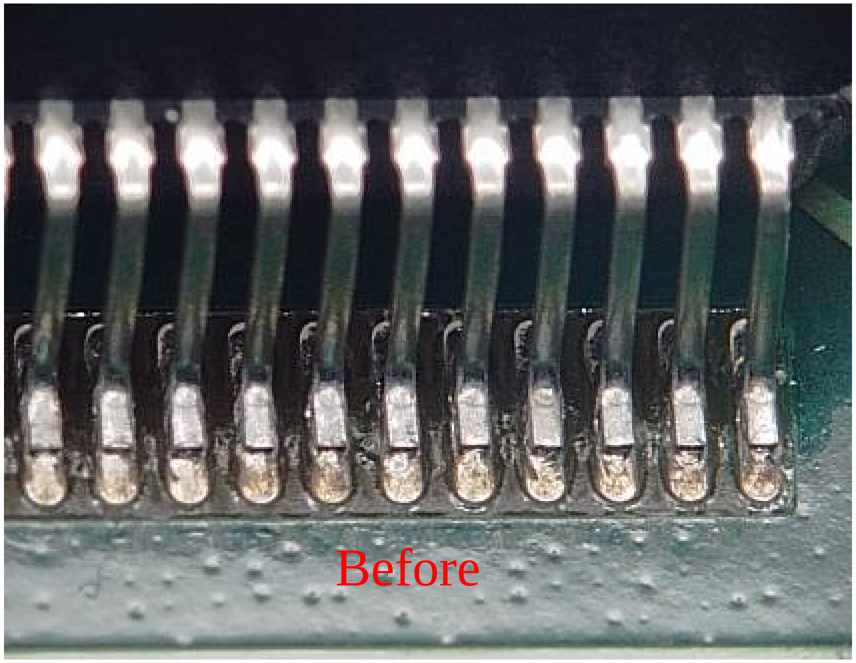

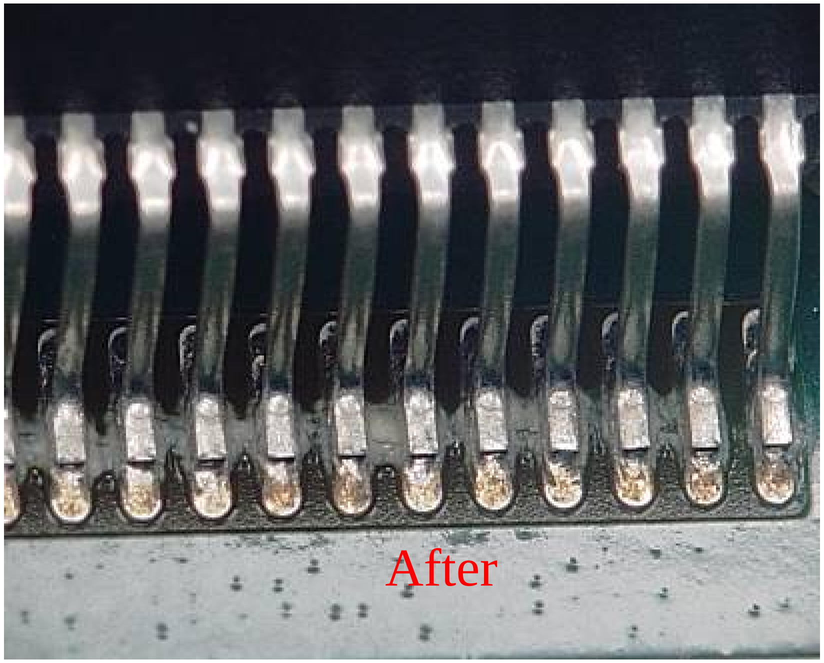

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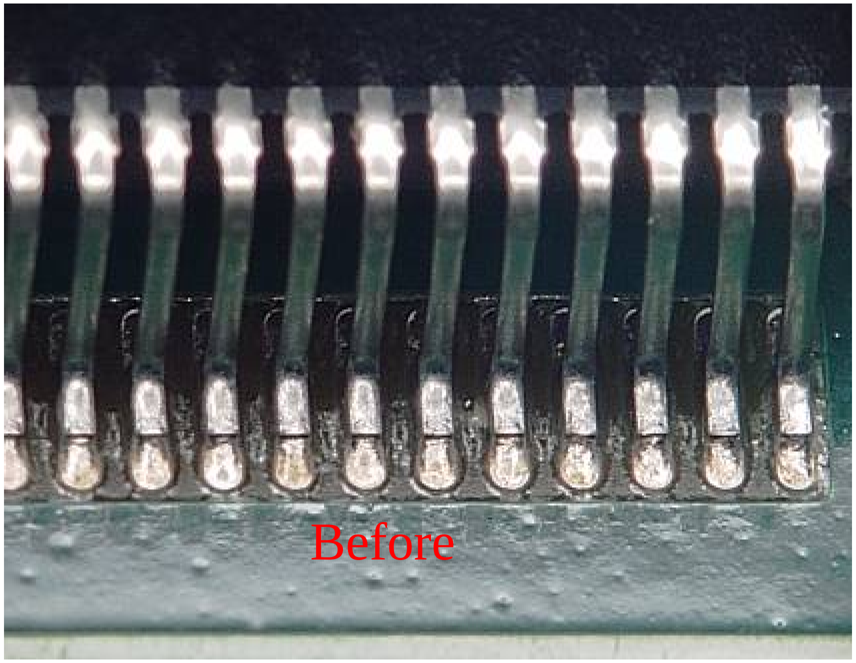

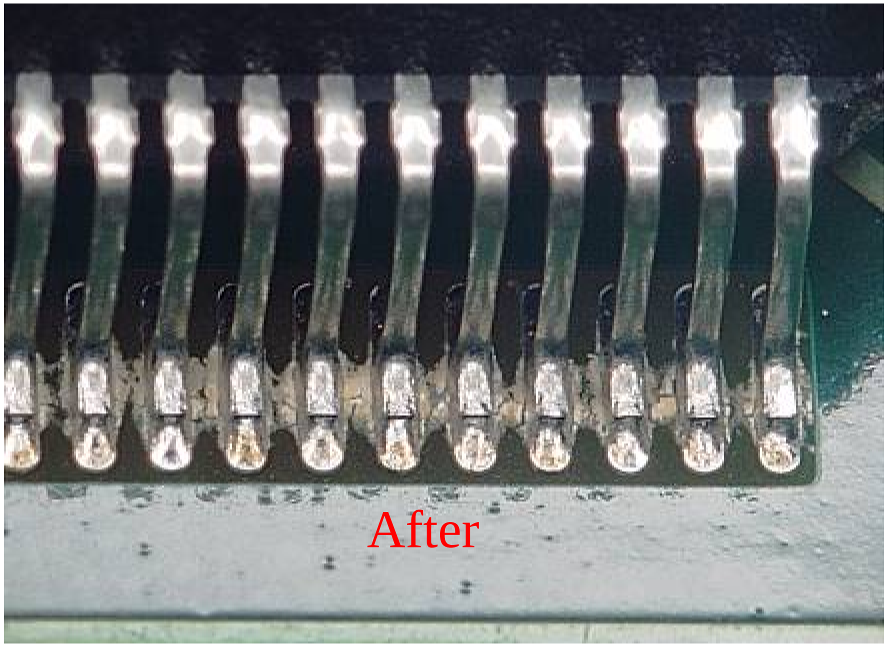

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Chemistry 2

- Low Reflow Profile (Peak 230°C)
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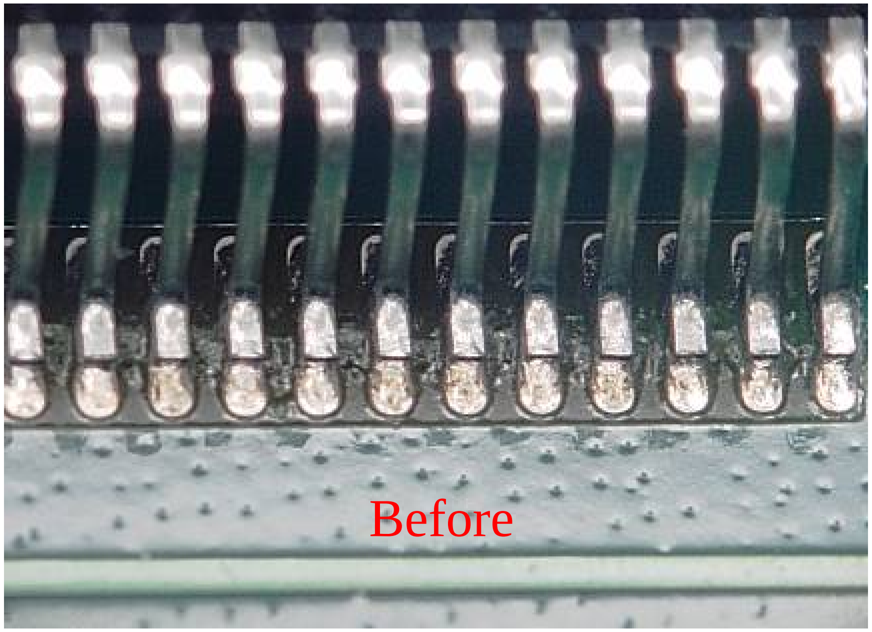
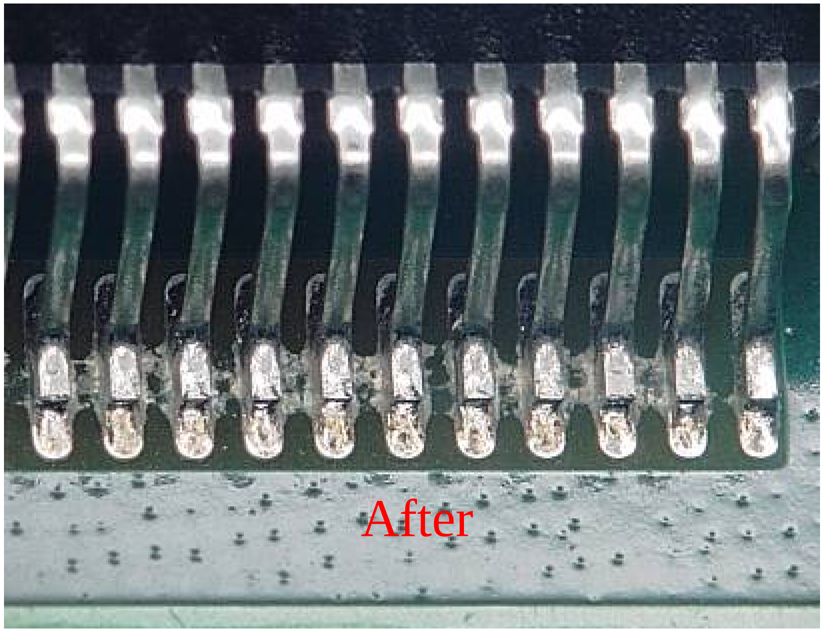
- 8 minute wash time, 150°F, 20%





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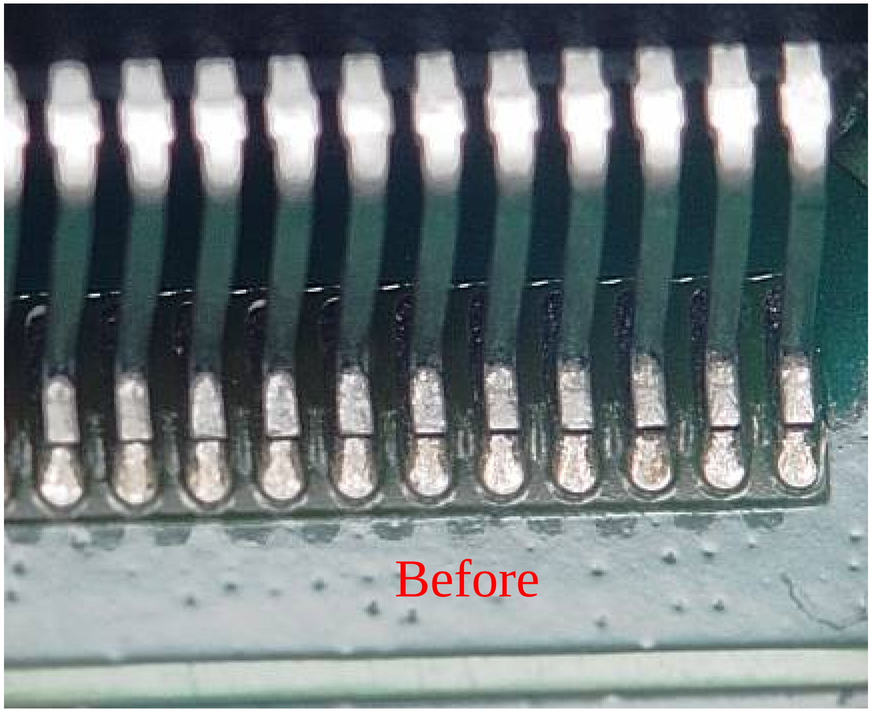

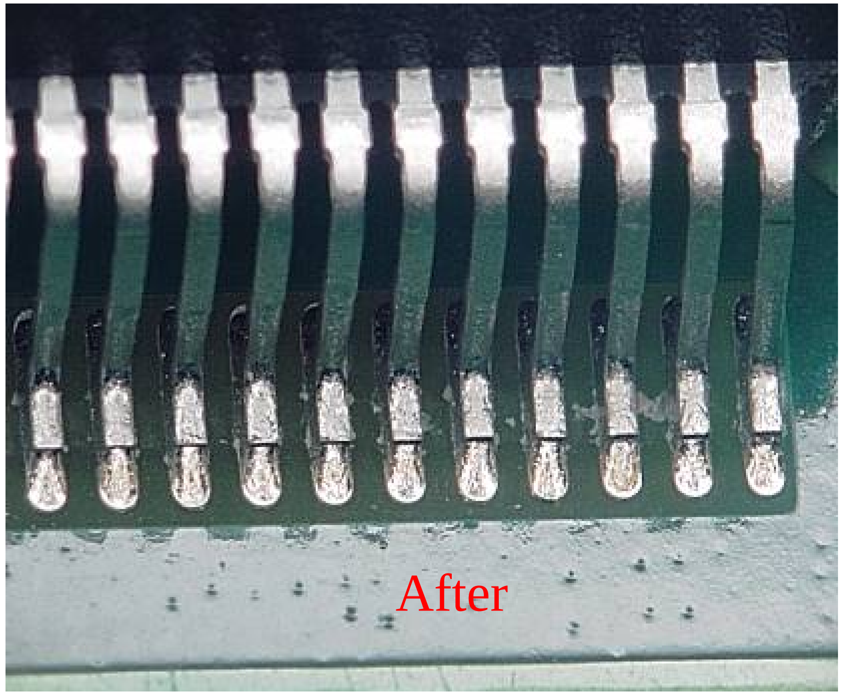

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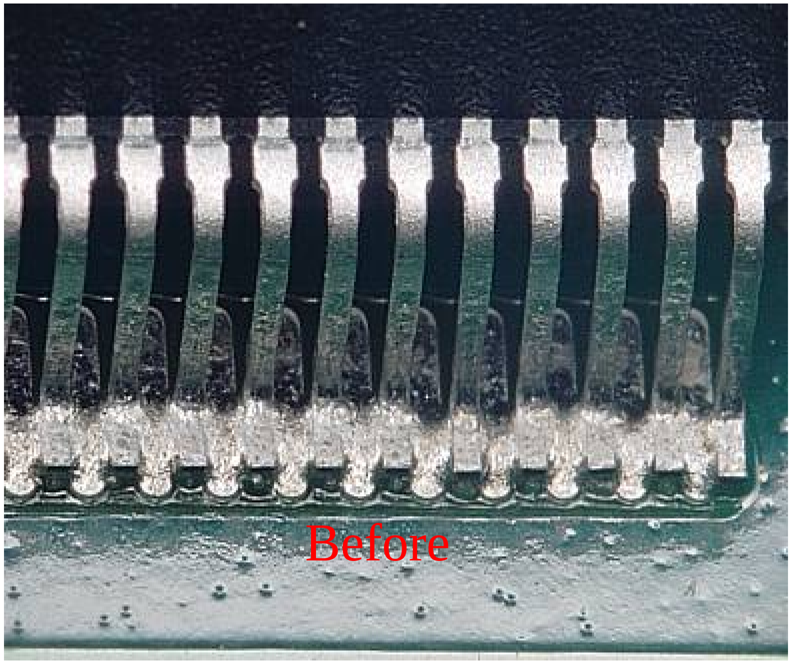

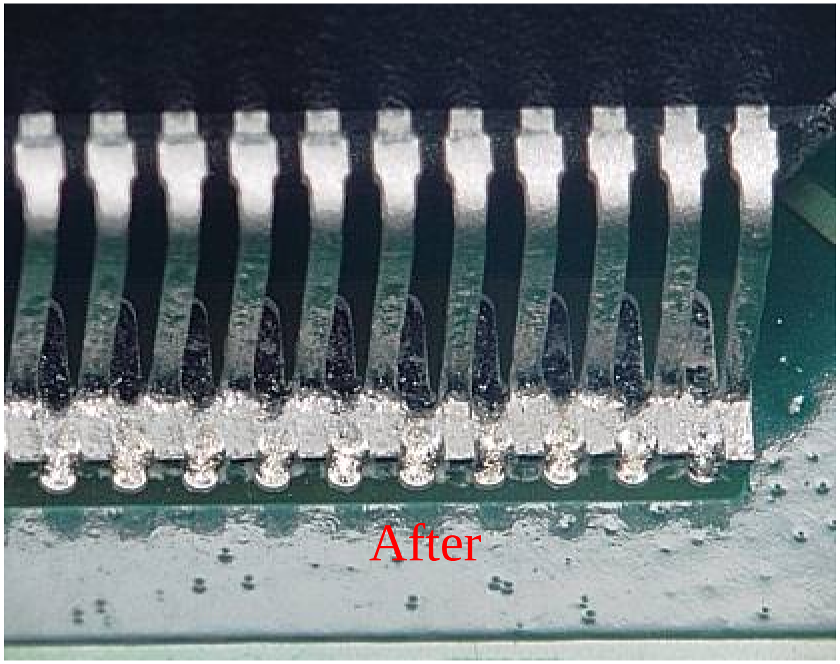

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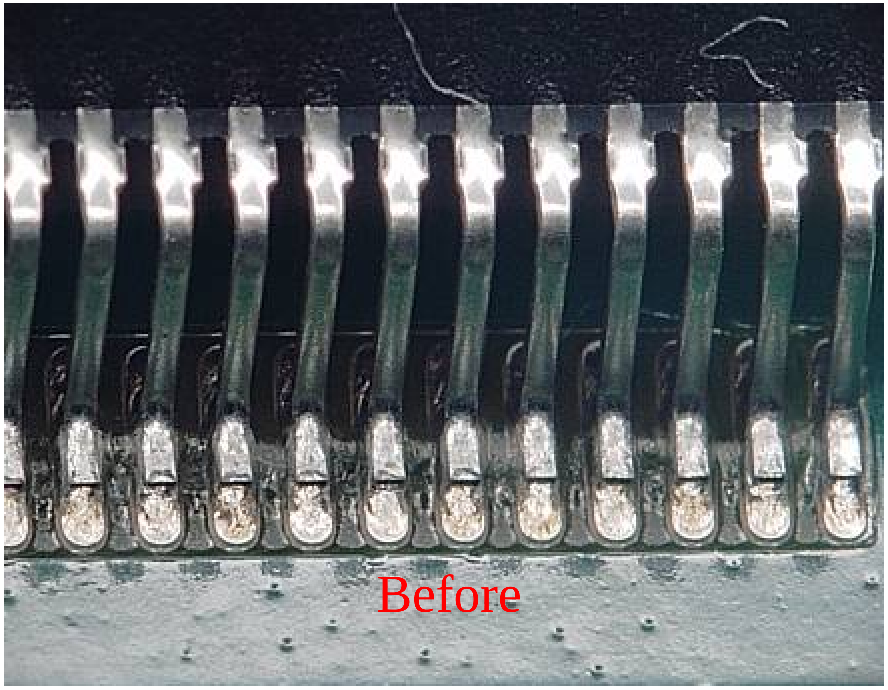

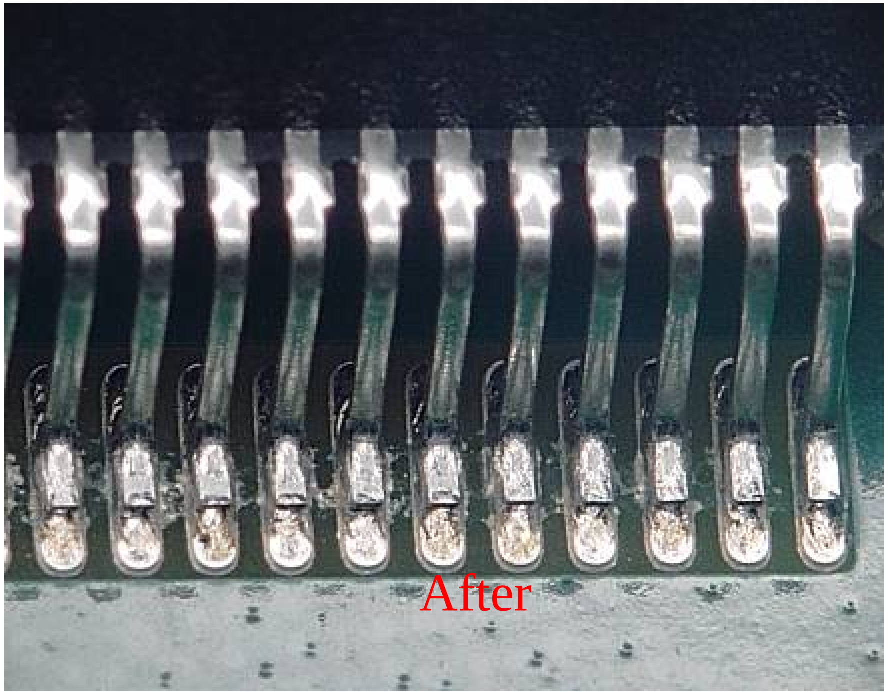

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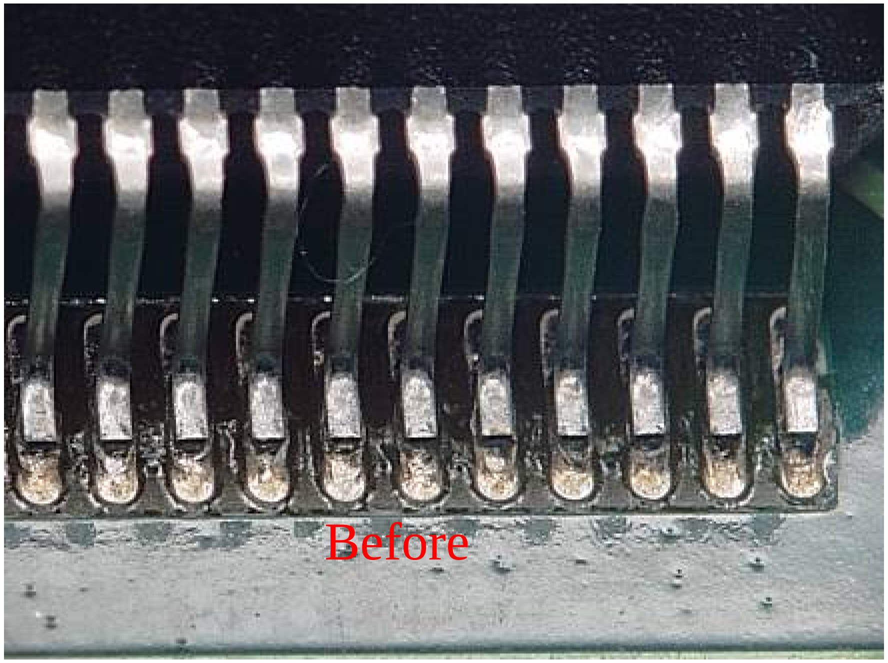

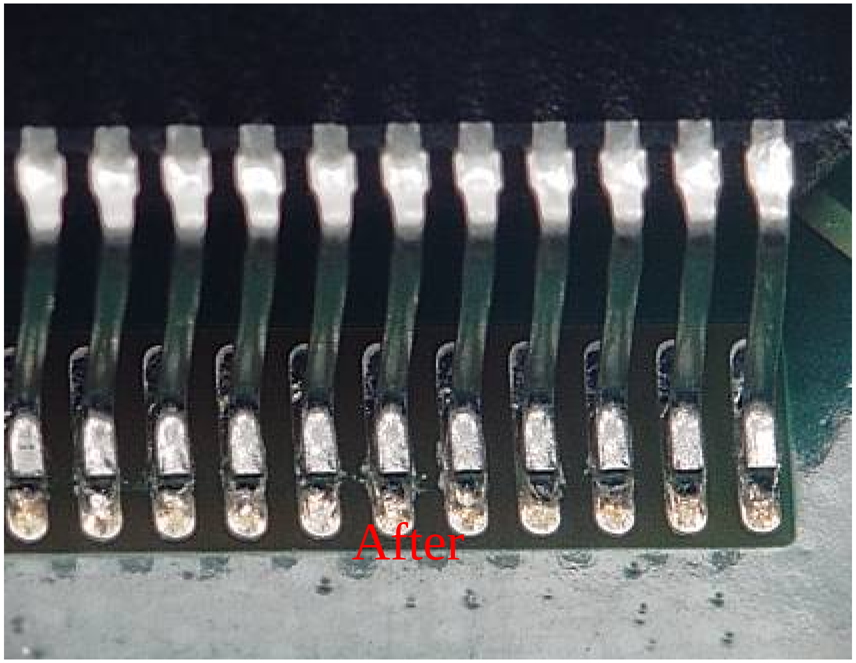

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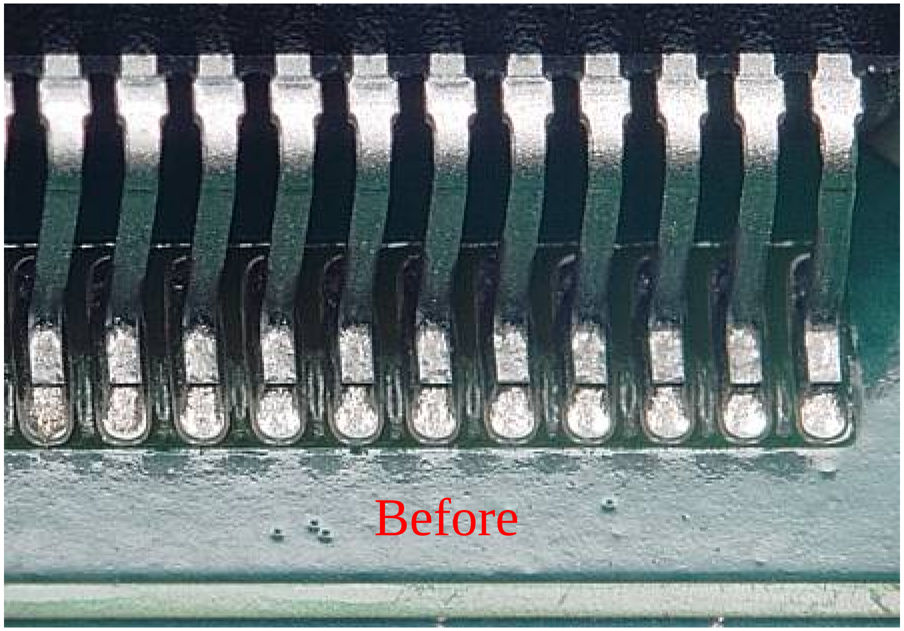

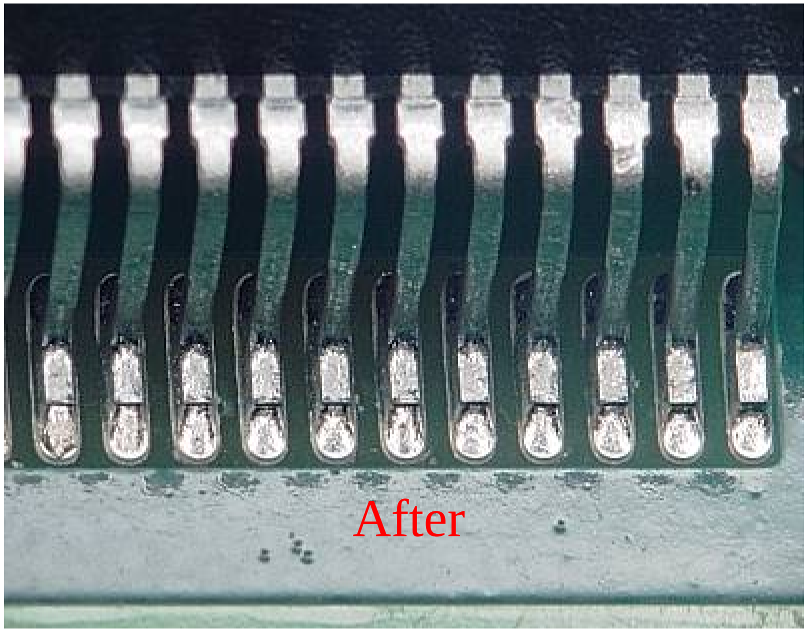

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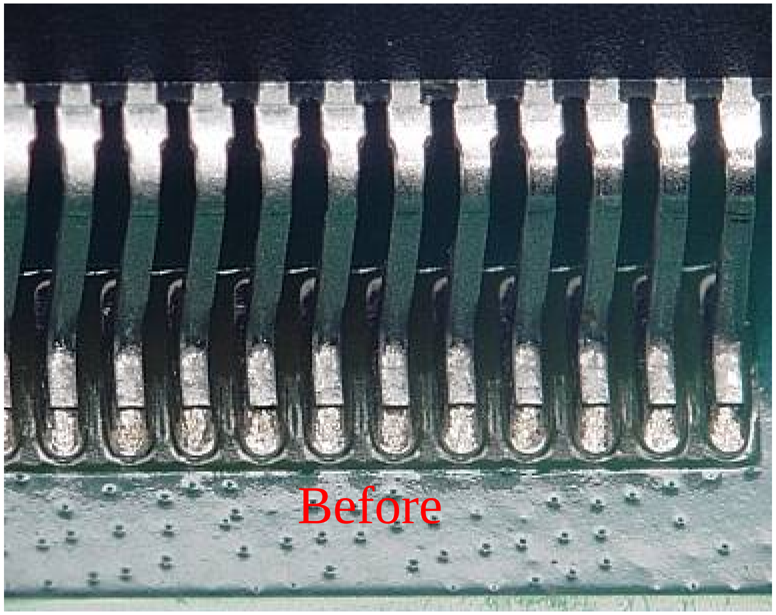

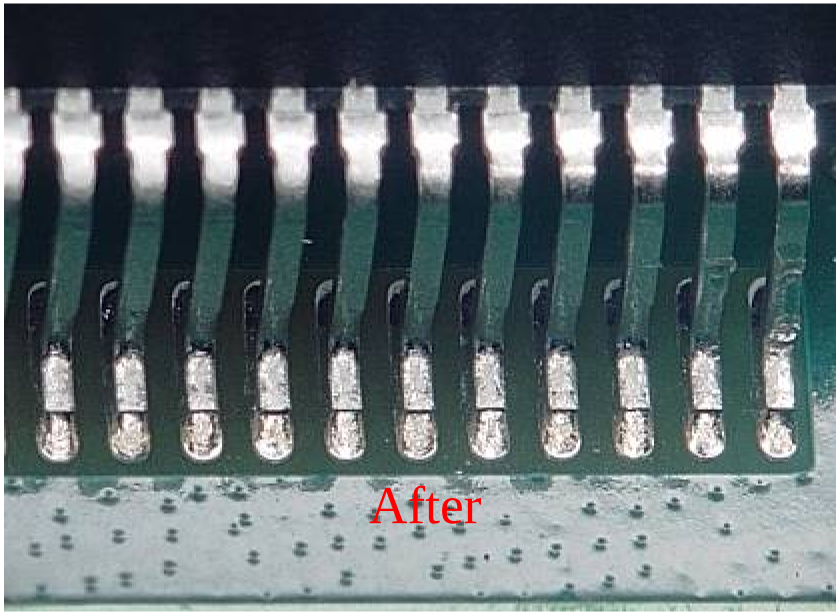

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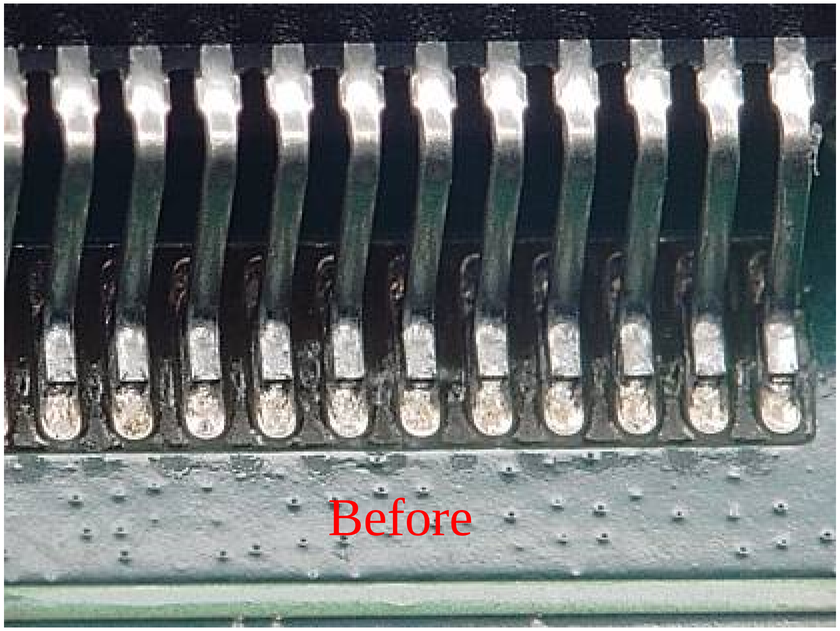
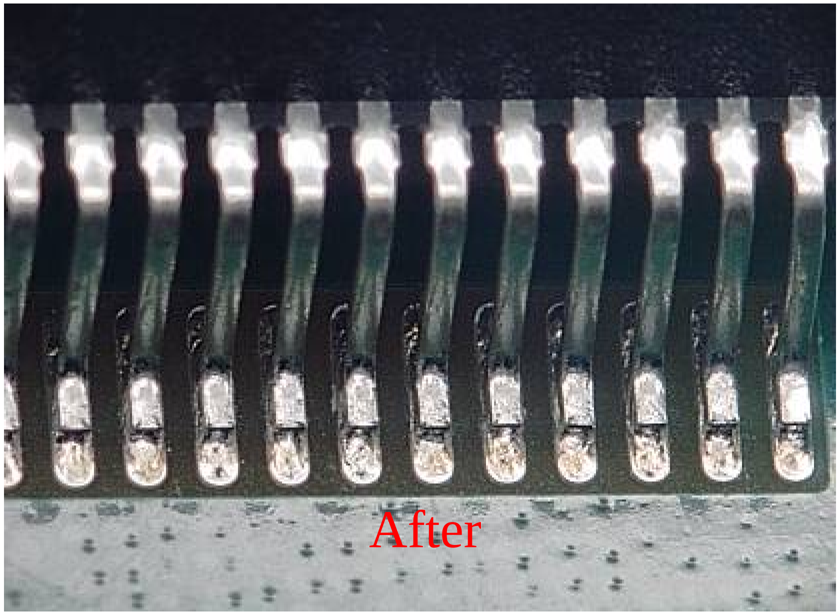
- 16 minute wash time, 150°F, 20%





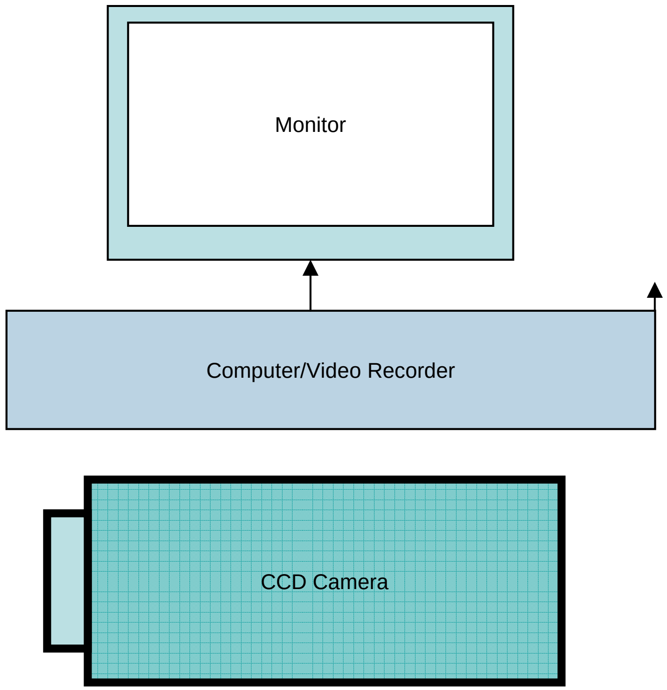
Outcome Table

Run	QFP Visual Exam (1-10)	QFP 90 Visual Exam (1-10)
1	1	1
2	1	1
3	2	1
4	2	1
5	2	1
6	3	1
7	2	3
8	2	2
9	7	5
10	9	8
11	9	8
12	7	7
13	10	9
14	10	10
15	10	10
16	10	10

Dynamic Cleaning Rate

Cleaning Analysis Recording Lab

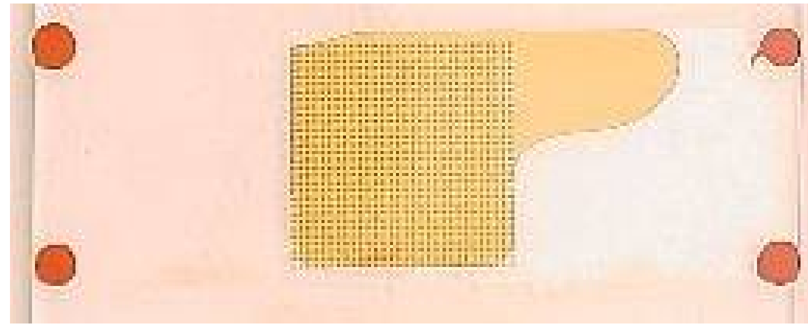
- Visual evidence of the influence of ….
  - Cleaning fluid
  - Wash temperature
  - Wash time
  - Nozzle types
  - Spray pressure
  - Movement variations

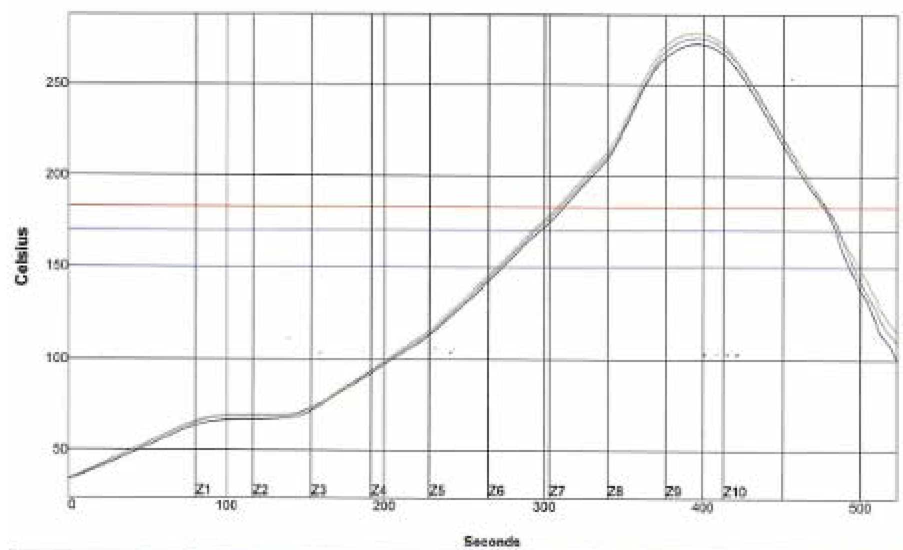


Data Capture

Test Vehicle

- Glass substrates prepared
  - Slides were bumped with epoxy
  - 75 mm pitch
  - 900 I/O
  - Die size 25mm x 25mm
  - Alpha 615-50
  - Reflowed with Pb-free profile
  - Peak reflow temp 278°C



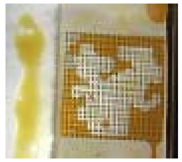
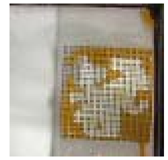
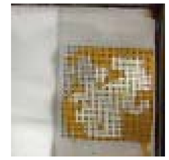
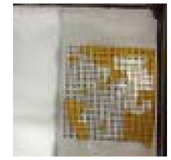
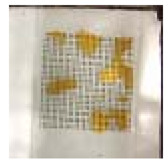
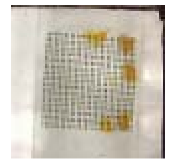
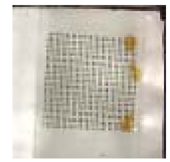


PWI= 606%	Max Rising Slope		Soak Time 150-170C		Reflow Time /183C		Peak Temp	
3	1.8	152%	22.1	-26%	168.5	362%	276.2	582%
4	1.8	161%	21.9	-27%	170.6	369%	278.6	606%
5	1.8	152%	23.1	-23%	164.9	350%	272.8	540%
Delta	0.0		1.1		5.7		5.8	

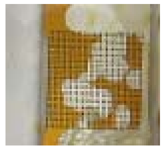
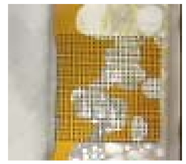
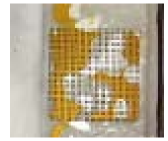
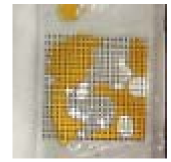
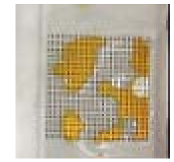
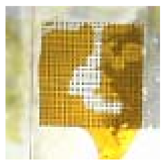
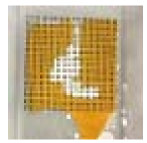
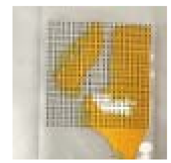
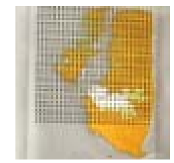
Factorial Design

Nozzle	Pressure	Wash Temperature	Visual Image Before Cleaning	Time in seconds	Time in seconds	Time in seconds	Time in seconds
1	1	150ºF	BC	15	30	45	60
1	2	150ºF	BC	15	30	45	60
2	1	150ºF	BC	15	30	45	60
2	2	150ºF	BC	15	30	45	60
3	1	150ºF	BC	15	30	45	60
3	2	150ºF	BC	15	30	45	60
4	1	150ºF	BC	15	30	45	60
4	2	150ºF	BC	15	30	45	60
5	1	150ºF	BC	15	30	45	60
5	2	150ºF	BC	15	30	45	60
6	1	150ºF	BC	15	30	45	60
6	2	150ºF	BC	15	30	45	60

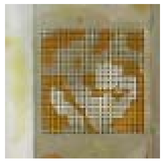
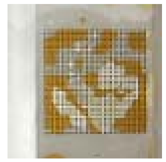
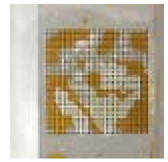
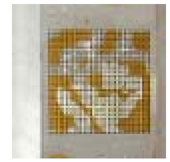
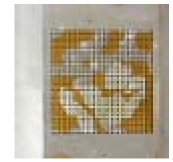
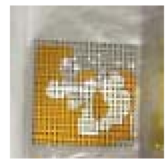
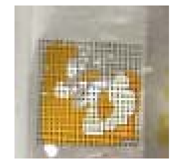
Nozzle 1

Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 Pressure 1					
Nozzle 1 Pressure 2					

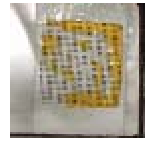
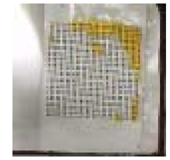
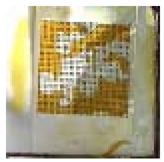
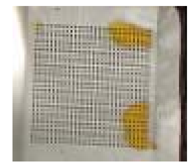
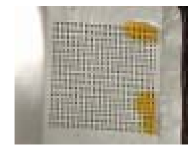
Nozzle 2

Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 Pressure 1					
Nozzle 1 Pressure 2					

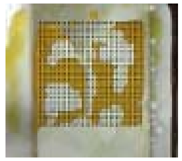
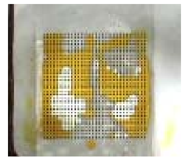
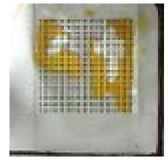
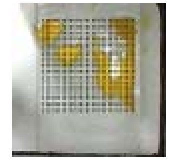
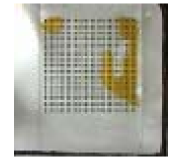
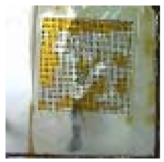
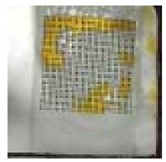
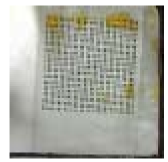
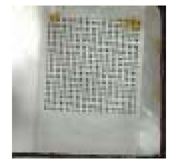
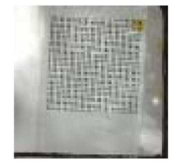
Nozzle 3

Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 Pressure 1					
Nozzle 1 Pressure 2					

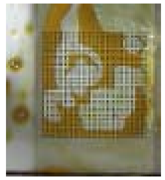
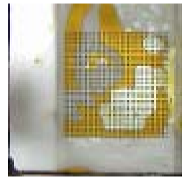
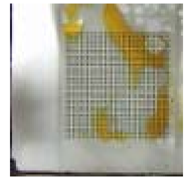
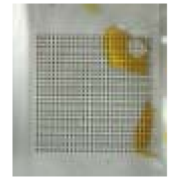
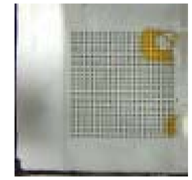
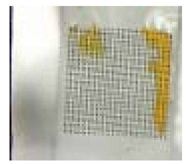
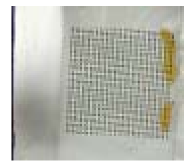
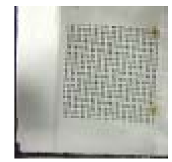
Nozzle 4

Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 **Pressure 1**					
Nozzle 1 **Pressure 2**					

Nozzle 5

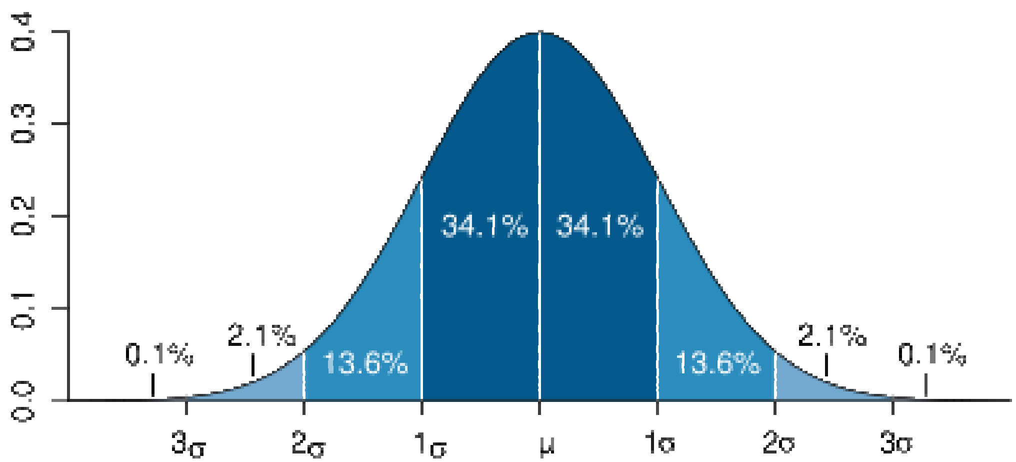
Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 Pressure 1					
Nozzle 1 Pressure 2					

Nozzle 6

Nozzle	Before Cleaning	15 seconds	30 seconds	45 seconds	1 minute
Nozzle 1 Pressure 1					
Nozzle 1 Pressure 2					

Impingement Data Findings

- Three variables influence the cleaning rate
  - Nozzle selection
  - Flow
  - Pressure
- Focal point at the center
  - Fastest cleaning rate
  - Distance from focal point cleaning drops off



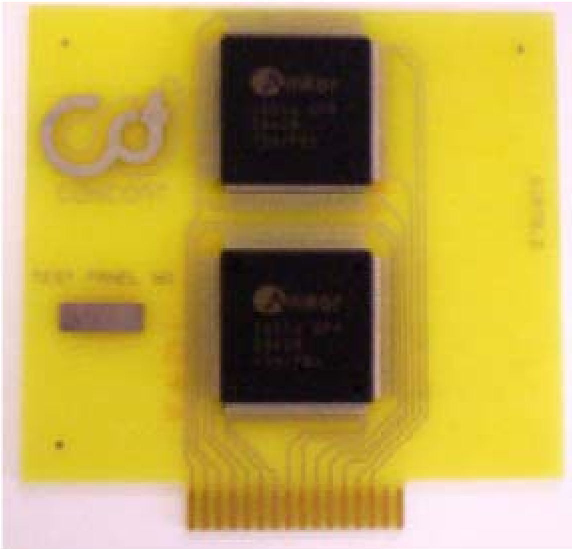
Optimization

- Step 1: Upstream process conditions
  – Substrate, contaminate, reflow
- Step 2: Static cleaning rate
  – Rate of solubility in the absence of strong impingement forces
- Step 3: Dynamic cleaning rate
  – Fluid flow, pressure, and directional forces
- Process cleaning rate = static rate + dynamic rate

Validation

Cleanliness & Electrical Performance

- Concoat Test Board
- Ion Chromatography: IPC-TM-650
  - 4 test boards
- Surface Insulation Resistance: IPC-TM-650



IPC MIDWEST CONFERENCE & EXHIBITION

IC Data Findings

Table #1: PAL Recommended Cleanliness Guidelines

PAL's Recommended Cleanliness Guidelines						
Condition	Cl	Br	NO3	PO4	SO4	Organic Acids
Bare Board (Cold plating)	< 1.0	< 12.0	< 3-5.0	PI	< 3-5.0	PI
Bare Board (HASL)	< 2.0	< 12.0	< 3-5.0	PI	< 3-5.0	PI
Assembly (No clean)	< 2.5	< 12.0	< 3-5.0	PI	< 3-5.0	20-50.0
Assembly (Water-soluble / RMA)	< 4-5.0	< 12.0	< 3-5.0	PI	< 3-5.0	20-50.0

Table #1: All values reported in $\mu g/in^2$. Cold plating refers to immersion Ag, immersion Sn, and ENIG. PI indicates that the component is treated as a process indicator as there are no industry guidelines currently available.

Ion Chromatography Data:

Table #2: Numerical Anion Chromatography Data

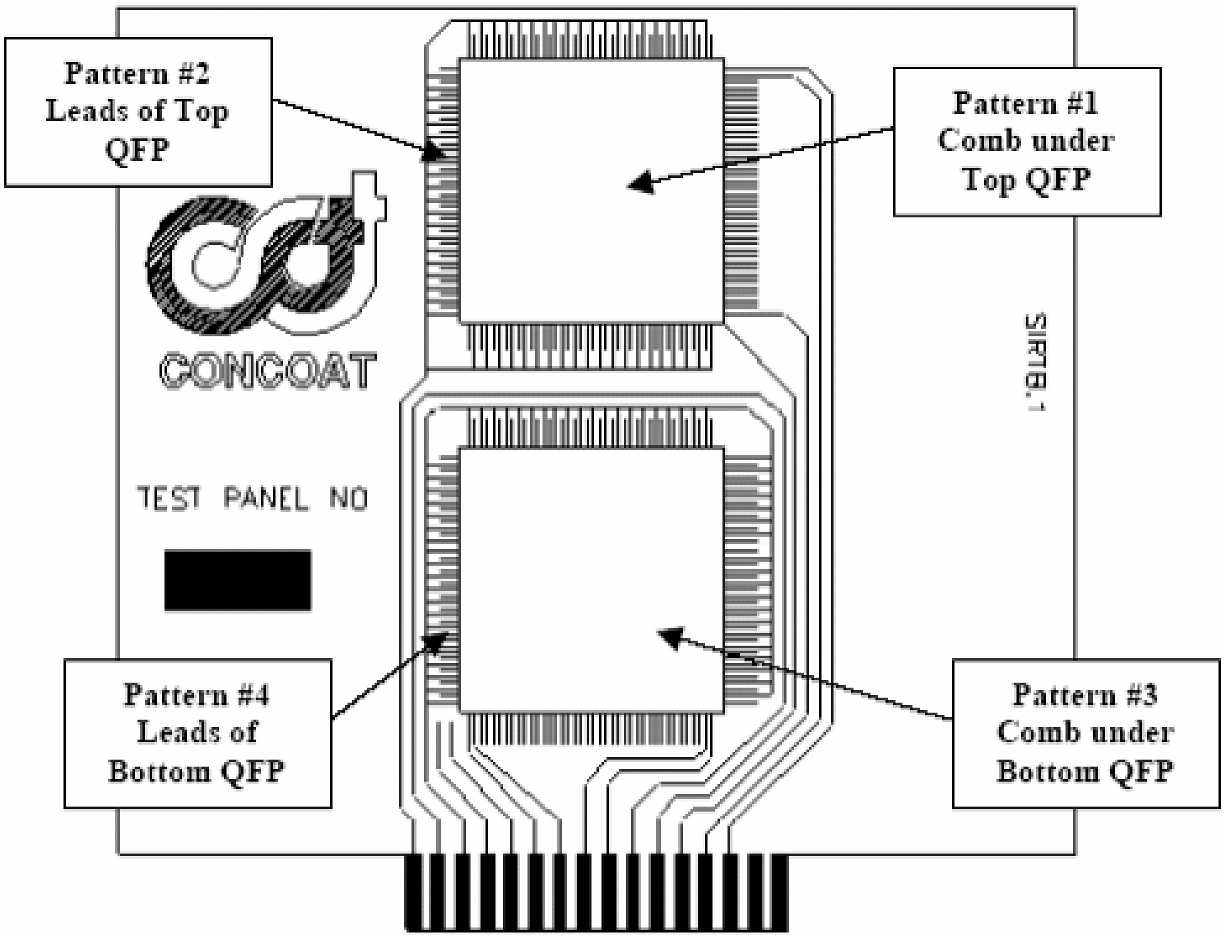
Sample Number	Sample Description	Extract Vol (mL)	Area (in^2)	Dilution Factor	Chloride Cl	Bromide Br	Nitrate NO3	Phosphate PO4	Sulfate SO4	Organic Acid
Blank	Kapak 502	10.00	72.00	0.14	ND	ND	ND	ND	0.06	ND
3106-009-01	Control	20.00	31.31	0.64	2.31	1.32	0.15	ND	ND	1.85
3106-009-02	Brd #1	20.00	31.31	0.64	1.37	1.04	0.14	ND	ND	1.03
3106-009-03	Brd #2	20.00	31.31	0.64	1.19	0.92	0.14	ND	ND	1.28
3106-009-04	Brd #3	20.00	31.31	0.64	1.26	1.00	0.13	ND	ND	1.06

Table #2: All ion values reported in the table are in $\mu g/in^2$. ND = None Detected. All bag blank contaminants have been subtracted from the sample amounts.

IC Data Conclusion

- All boards showed very low levels of ionic contamination
- The cleaned samples showed consistently lower amounts
  - Chloride
  - Bromide
- Nitrate levels were unremarkable and not of any concern
- Organic acid showed slight improvements compared to control board

SIR Patterns



SIR Data Findings

Sample ID	Resistance Readings (Ohms)					
	Pattern	Initials 5/22/2007	24 Hours 5/23/2007	96 Hours 5/26/2007	168 Hours 5/29/2007	Finals 5/29/2007
Control	1	4.13E+10	1.78E+07	1.39E+08	1.49E+08	1.18E+09
	2	1.73E+12	2.44E+08	4.76E+08	4.00E+08	1.03E+12
	3	1.56E+09	6.71E+07	5.62E+07	3.73E+07	8.62E+10
	4	1.24E+12	1.54E+08	2.56E+08	2.78E+08	4.44E+12
Cleaned Brd #1	1	9.99E+11	5.00E+08	6.28E+08	6.16E+08	1.60E+12
	2	4.16E+12	3.89E+09	1.81E+09	1.27E+09	2.22E+12
	3	3.53E+10	5.00E+08	6.16E+08	6.69E+08	1.09E+11
	4	3.02E+12	3.44E+09	1.52E+09	1.30E+09	1.76E+12
Cleaned Brd #2	1	1.74E+12	3.33E+08	5.26E+08	5.96E+08	4.35E+11
	2	1.17E+13	3.02E+09	1.67E+09	1.35E+09	1.62E+12
	3	4.67E+10	2.56E+08	4.76E+08	5.26E+08	1.61E+11
	4	4.94E+12	2.90E+09	1.41E+09	1.14E+09	1.18E+12
Cleaned Brd #3	1	6.47E+12	4.17E+08	6.15E+08	6.44E+08	1.32E+12
	2	1.08E+13	2.91E+09	1.64E+09	1.26E+09	3.66E+12
	3	3.65E+10	3.57E+08	6.08E+08	6.45E+08	1.64E+11
	4	9.77E+12	2.60E+09	1.43E+09	1.22E+09	2.50E+12
Cleaned Brd #4	1	2.45E+12	3.57E+08	6.28E+08	7.11E+08	2.05E+12
	2	4.98E+12	3.76E+09	2.07E+09	1.52E+09	2.10E+12
	3	3.48E+10	3.13E+08	5.26E+08	6.64E+08	1.54E+11
	4	2.26E+12	2.60E+09	1.76E+09	1.43E+09	1.80E+12
Cleaned Brd #5	1	1.64E+12	2.86E+08	4.35E+08	4.55E+08	4.76E+11
	2	2.61E+12	2.33E+09	1.35E+09	1.09E+09	1.99E+12
	3	3.70E+10	3.33E+08	5.26E+08	5.56E+08	1.75E+11
	4	3.08E+12	2.27E+09	1.27E+09	1.08E+09	2.02E+12

SIR Data Conclusion

- Initial measures verify test boards are returning good readings
- 24 hour results are expected to drop as boards acclimate to environmental conditions
- 96 hour cleaned boards showed slight improvement and were above the pass limit
- 168 hour cleaned boards maintained and were passing
- All cleaned boards returned high readings and passed.

Conclusion

- Cleaning process optimization requires an understanding of
  - Upstream processing conditions
  - Static cleaning rate
  - Dynamic cleaning rate
- Improved cleaning fluids
  - Higher static cleaning rate
  - Lower surface tension
  - Clean Pb-free flux soils
- Improved cleaning equipment
  - Optimize flow, pressure, and directional forces
- Result
  - Broader processing window to addressing challenging cleaning needs

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