



Fluid Flow Mechanics: Key to Low Standoff Cleaning

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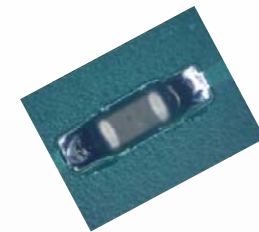
Fluid Flow Mechanics: Key to Low Standoff Cleaning

Outline:

1. Introduction – "The Problem"
2. Fluid Flow Theory for Best Cleaning Performance
3. Inline Progressive Energy Dynamics Approach
4. Testing Protocol
5. Test results
6. Overall Conclusions

1. The Problem is -

- Space under components is shrinking
- Interconnect densities are increasing
- Performance requirements are increasing
- Lead-free & no-clean fluxes are harder
- Fluxes are fully filling small gaps



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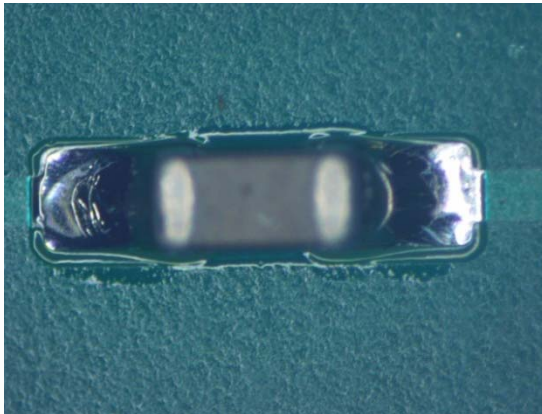
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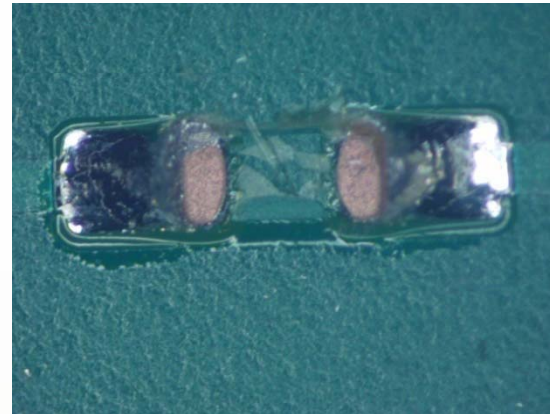
Fully Filled Gaps

- Transition from: Flux around the component
- To: Flux under the component

Completely filling flux under tightly spaced components



Flux around 0603 Cap



Flux under cap

2. Fluid Flow Theory – Empty Gaps

- Depending on: **1 Physical properties of the cleaning agent**
(surface tension, density and viscosity)
3 Higher energy delivery
(flow and pressure)
- Kinetic Energy = $m \times V^2$
- Tighter gaps or tight spaces with solvent-phobic surfaces require differential pressure 1-10 psi

2. Fluid Flow Theory – Empty Gaps Surface Tension Effects

- Interfacial pressure differential calculation

planar

$$\Delta p = 2\gamma \cos\theta / R$$

cylinder

$$\Delta p = \gamma \cos\theta / R$$

γ = surface tension

Θ = contact angle of
liquid at surface

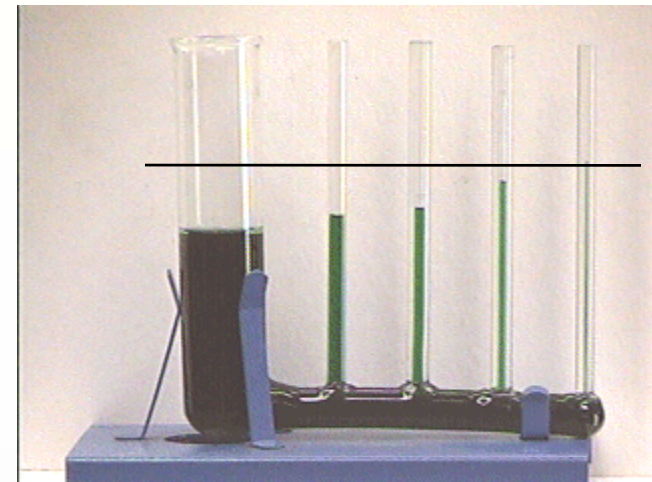
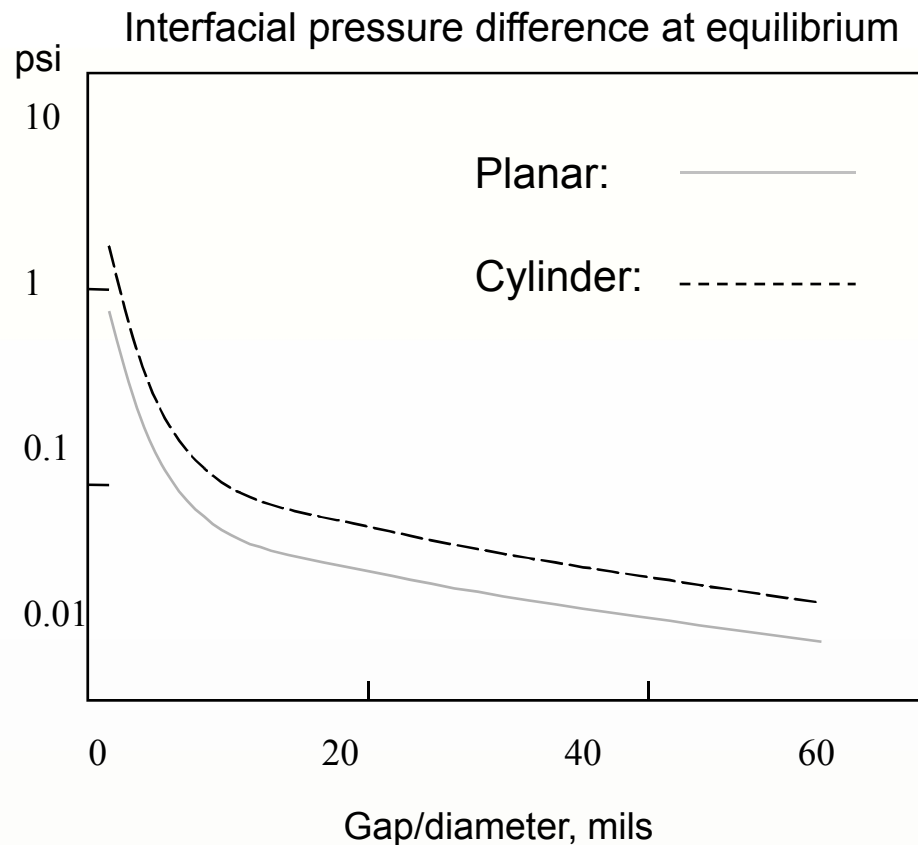
R = radius meniscus

NOTE: if θ is greater than 90° , as with water on waxy surface, the force becomes negative or repulsive



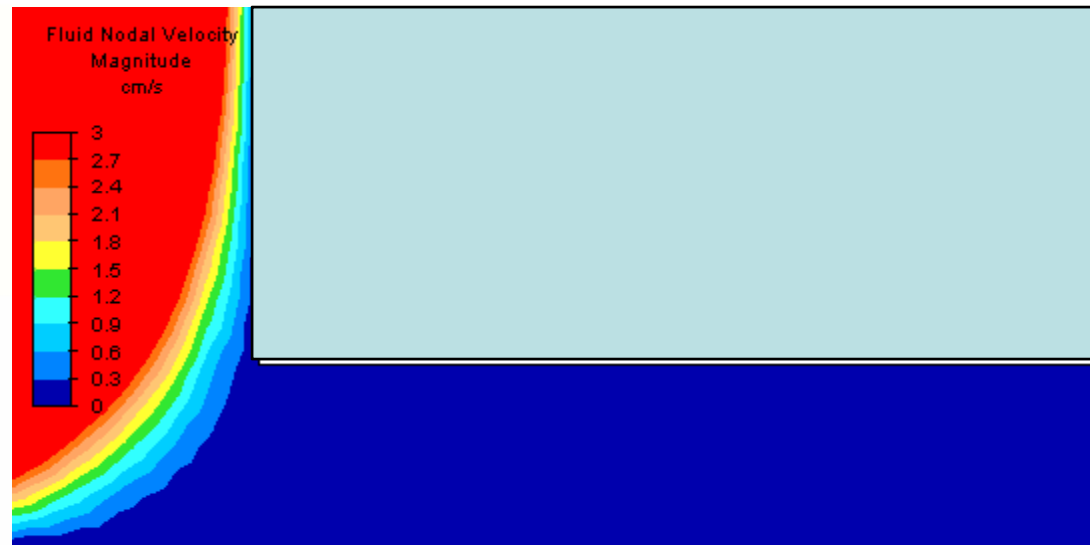
2. Fluid Flow Theory – Empty Gaps

- Relationship between gap size and capillary force for water on glass



Fluid flow model 1 mil unfilled gap

Movie 1



Time: 5e-005 s
Time Step: 1 of 40
Maximum Value: 1454.33 cm/s
Minimum Value: 0 cm/s



2. Fluid Flow Theory – Filled Gaps

- The residue must be softened if fluid path blocked
- Mechanical steps required to remove a fully blocked gap:



- 1 Outer solvent depleted zone softened
- 2 Liquid jet with sufficient energy forms flow channels
- 3 Bulk residue is eroded & dissolved by fluid flow

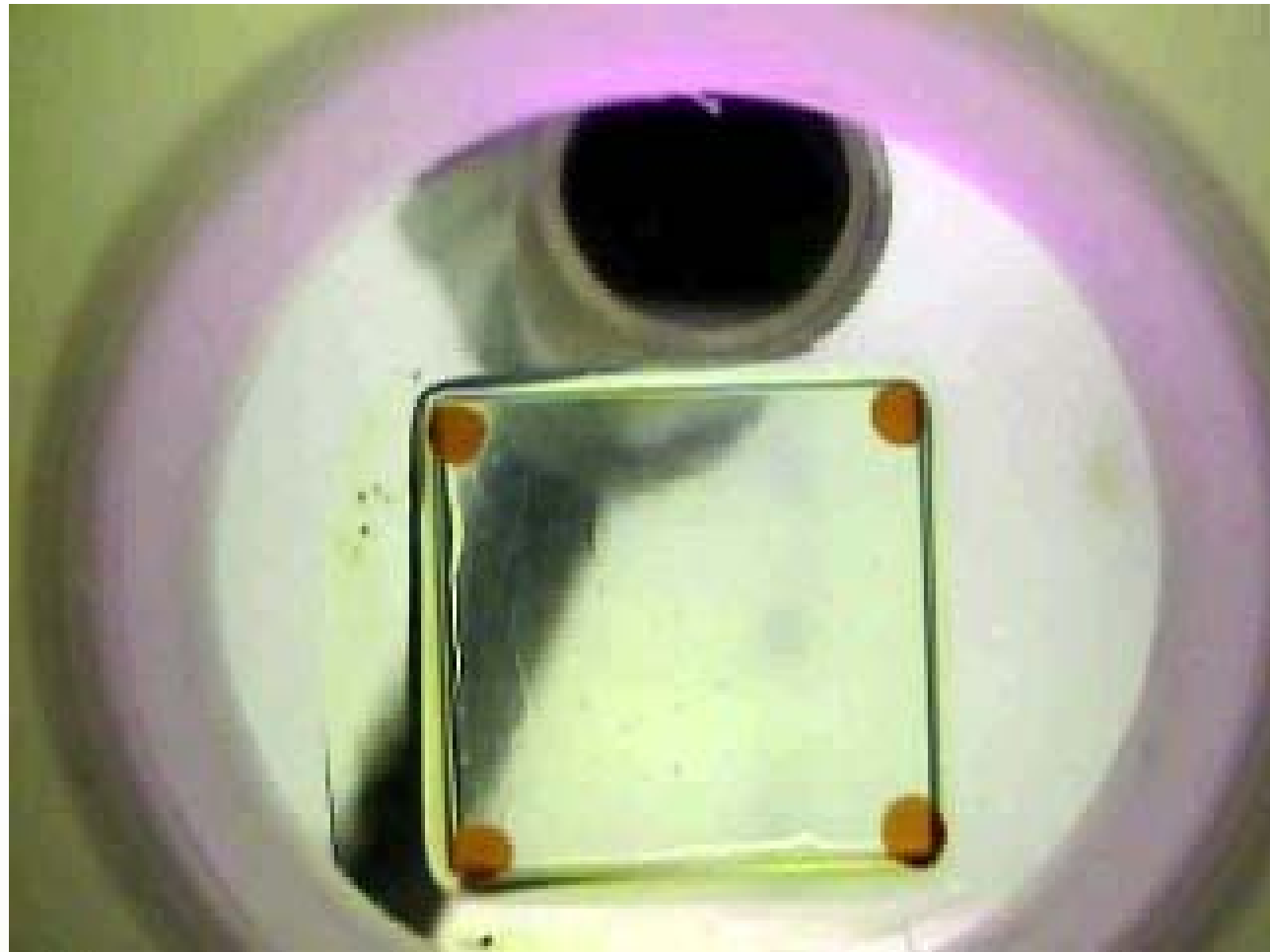
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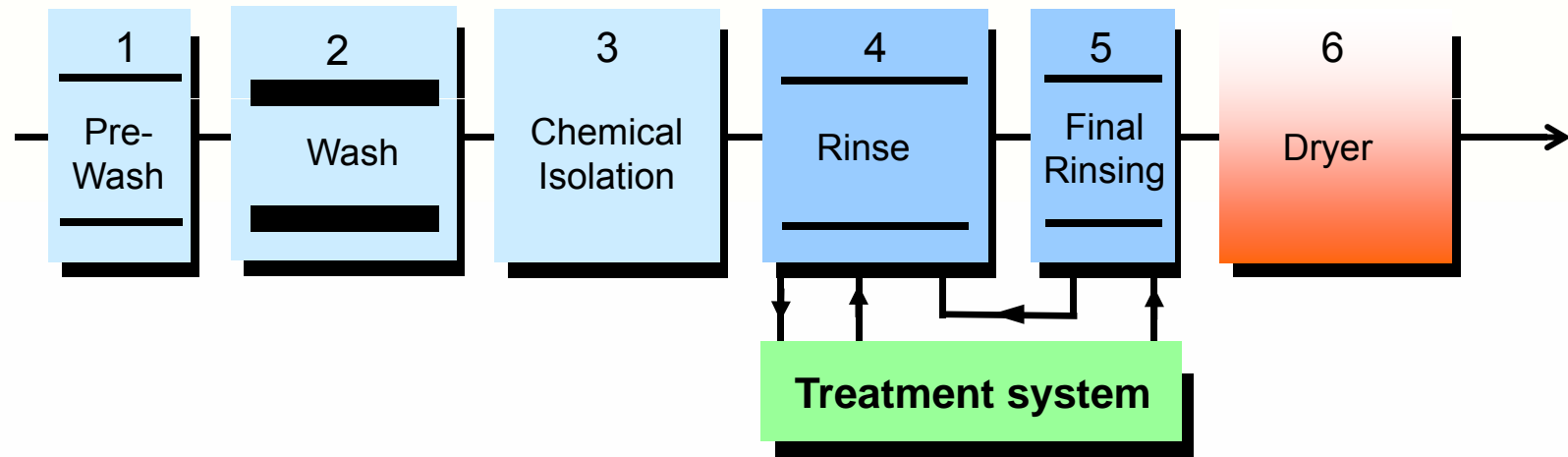
Glass Slide Testing

Movie 2



3. Inline Progressive Energy Dynamics Approach

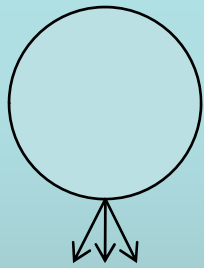
- Inline Cleaning Process Schematic



3. Inline Progressive Energy Dynamics Approach

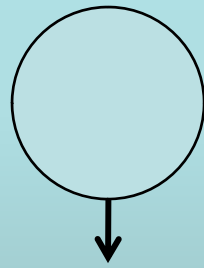
- New approach to design in-line cleaner
- Involves a manifold design with increasing energy at each manifold

Pre-wash



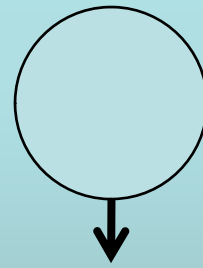
Heat & wet
surfaces

Wash 1



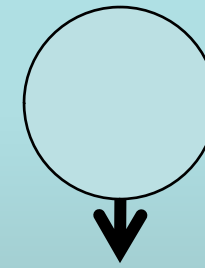
penetrate
outer layer

Wash 2



form flow
channels

Wash 3



erode
flux

3. Inline Progressive Energy Dynamics Approach

- Wash section equipped with progressive energy dynamics



3. Inline Progressive Energy Dynamics Approach

A Progressive Energy Design is:

- A fluid delivery system
- Recognizes the 3-step process required to clean flux-filled spaces
- Delivers only what is needed at each step:

Movie 3



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4. Experimental Protocol

Overall Experimental Variables

- Equipment:
 - ✓ Pressure (psi)
 - ✓ Spray manifold & design
 - ✓ Belt speed (ft/min)

- Cleaning agent:
 - ✓ Micro Phase Cleaning Technology
 - ✓ Concentration (%)
 - ✓ Temperature (° F)

- Parts to be cleaned:
 - ✓ Component density
 - ✓ Solder paste

4. Experimental Protocol

- TEST VEHICLE - Boards with 0603 chip capacitors (30 / Board)
- CLEANING GAP - Average 1 mil
- TEST PHASES -
 - Standard Non-Progressive Energy
 - Progressive Energy / Flow Differential
 - Improved Progressive Energy / Flow Differential
- CONTAMINATION - Leaded and Lead-free Solder Pastes
- REFLOW - 10-stage reflow oven, air-atmosphere

4. Experimental Protocol

- Overall experimental overview:

			Phase I	Phase II	Phase III
Fixed Parameters	Spray Configuration Design	1	✓		
		2		✓	
		3			✓
	0603 component density per board	30	✓	✓	✓
	Cleaning agent	A	✓	✓	✓
	Spray pressure (psi)	55	✓		
		49		✓	
		50 / 50			✓

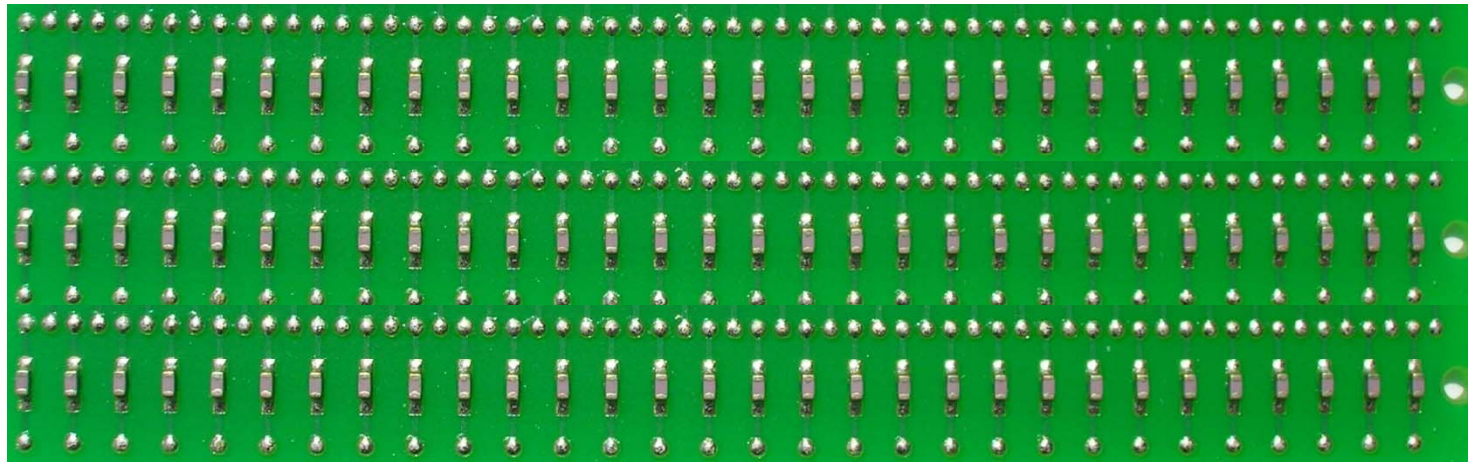
4. Experimental Protocol

- Overall experimental overview:

		Phase I	Phase II	Phase III	
Variable parameters	Pastes	Lead-free	✓	✓	✓
		Leaded	✓	✓	✓
	Concentration (%)	10	✓	✓	✓
		15	✓	✓	✓
	Temperature (° F)	140	✓	✓	✓
		150	✓	✓	✓
	Conveyor belt speed (ft/min) / Exposure time (min) / <i>Total wash section: 3ft.</i>	0.4 / 7.5	✓	✓	✓
		0.6 / 5.0	✓	✓	✓
		1.0 / 3.0	✓	✓	✓
		1.5 / 2.0	✓	✓	✓
		2.0 / 1.5	✓	✓	✓

4. Experimental Protocol

- Board specification:

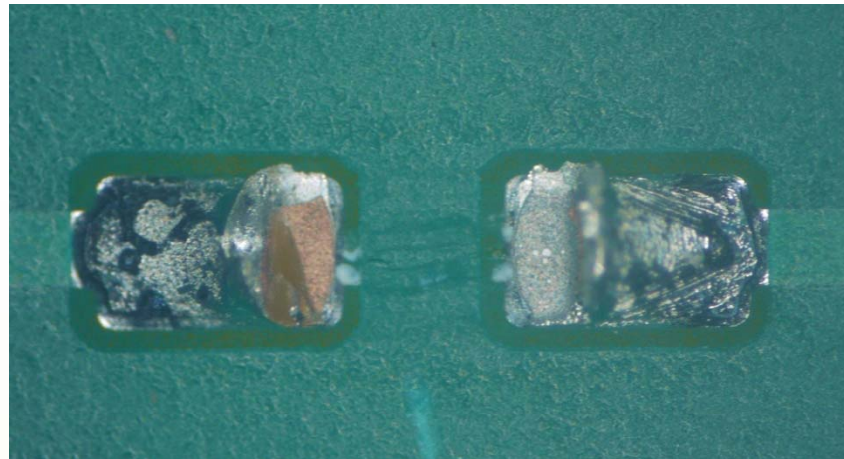


Test board area with 30 set series of 0603 components

4. Experimental Protocol

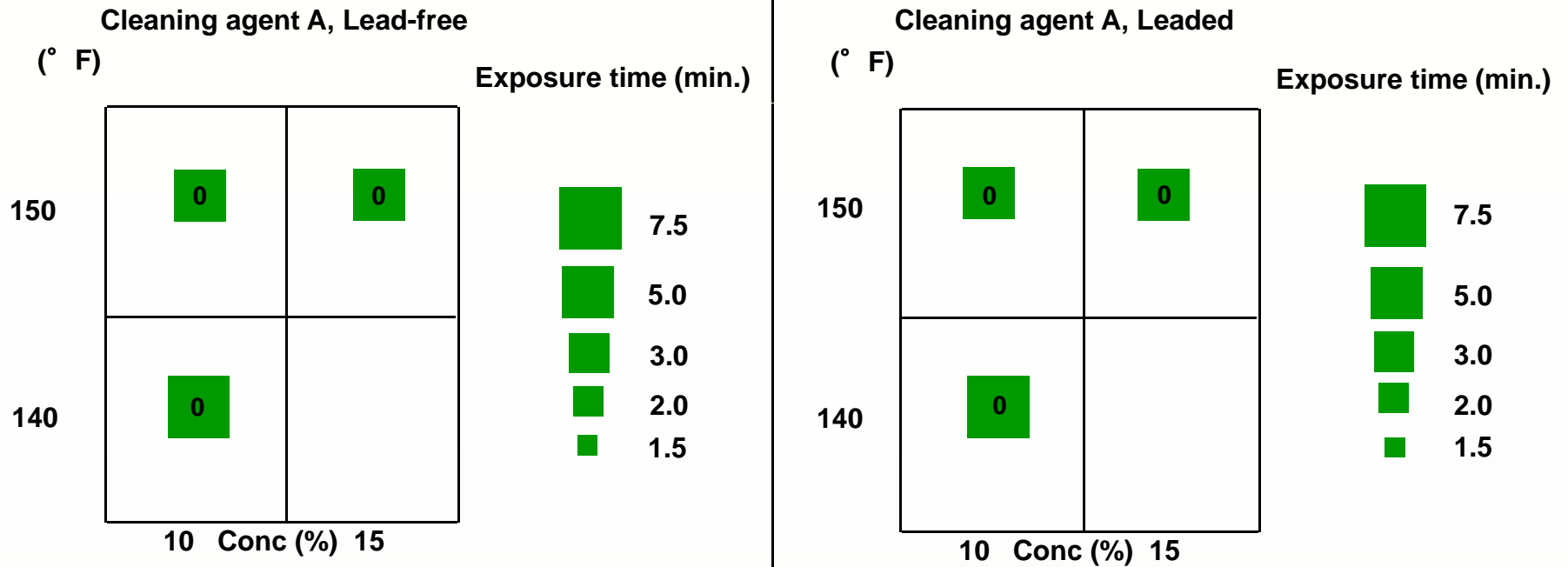
Findings Phase 1:

- Standard non-progressive cleaning manifold design
- Tested with leaded and lead-free formulations
- Minor residues underneath the components



4. Experimental Protocol

- Phase 1: Cleaning agent A – Removes lead-free and leaded



+: Clean 0: Partially cleaned -: Not clean

4. Experimental Protocol

- Phase 1 – Experimental parameters and results

Fixed Parameters		
Equipment Specification	Spray Pressure (psi)	55
	Spray bars (top)	5
Board Specification (0603 components)	Component density	30

- Even speeds as low as 0.4 fpm could not completely clean under the components
- For both leaded and lead-free formulations

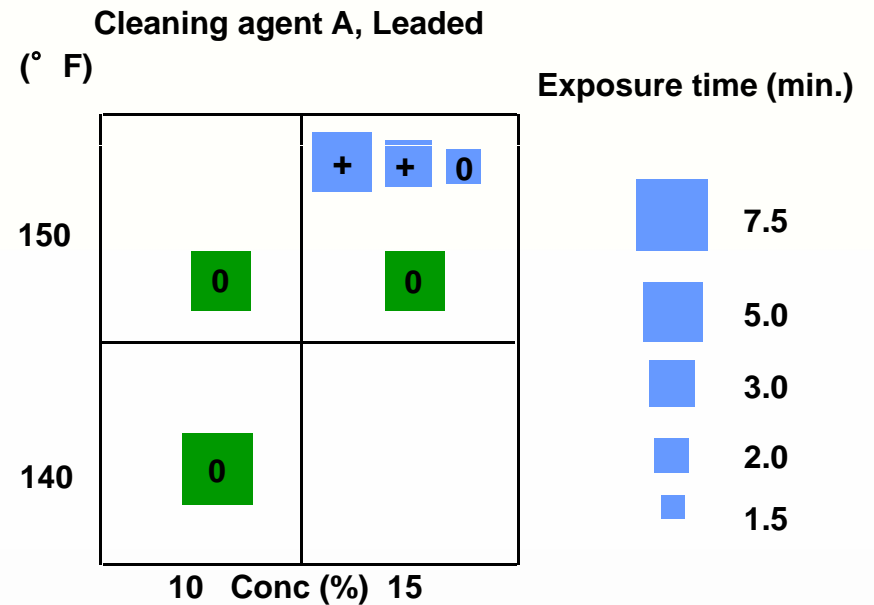
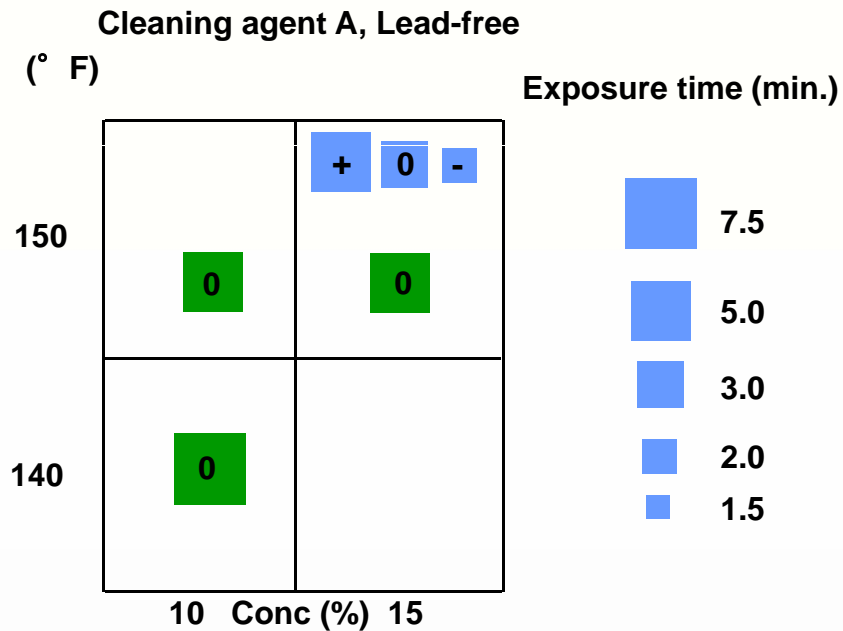
4. Experimental Protocol

Findings Phase 2:

- Same machine base is modified
- New progressive jets and nozzles were introduced
- Goal is to provide increasing flow from manifold to manifold
- Results significantly better than in previous study

4. Experimental Protocol

- Phase 2: Cleaning agent A – Removes lead-free and leaded



+: Clean 0: Partially cleaned -: Not clean

4. Experimental Protocol

- Phase 2 – Experimental parameters and results

Fixed Parameters		
Equipment Specification	Spray Pressure (psi)	49
	Spray bars (top)	5
Board Specification (0603 components)	Component density	30

- Effective cleaning under the low standoff components
- Belt speeds of 1 fpm employing a 3 ft. long wash section
- 3-minute exposure time

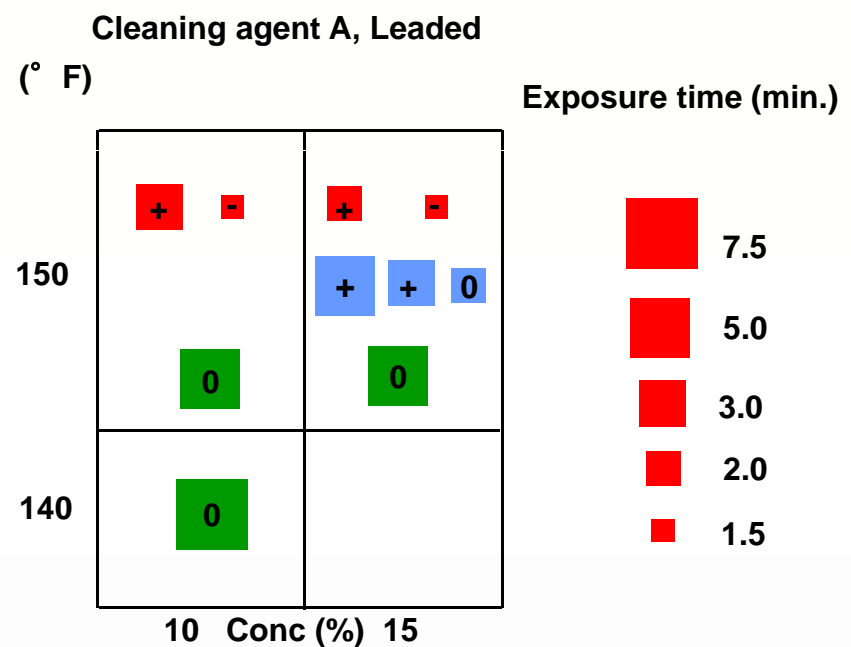
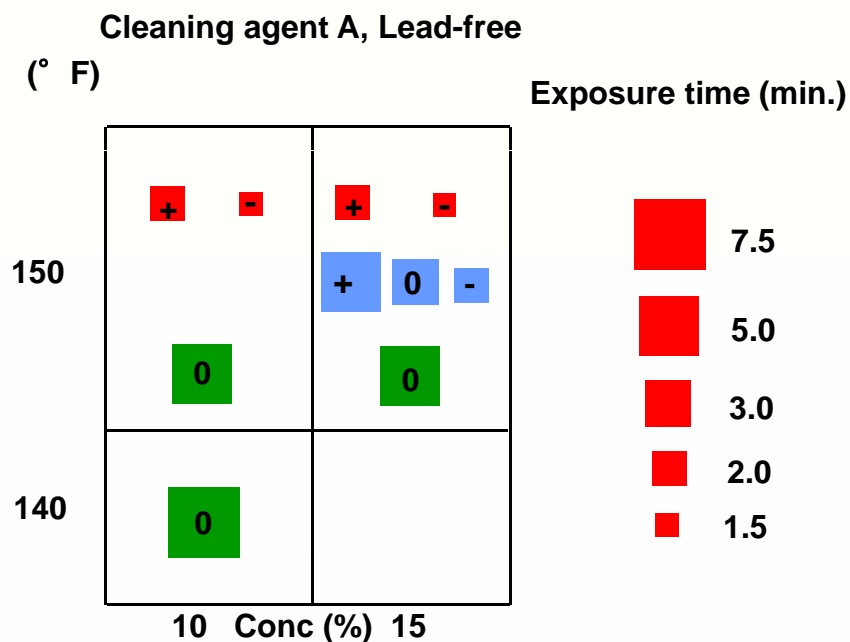
4. Experimental Protocol

Findings Phase 3:

- New equipment set up with 2 additional spray manifolds built for Phase 3
- 6 inches extended wash section
- Second higher-flow pump
- No residues left underneath components

4. Experimental Protocol

- Phase 3: Cleaning agent A – Removes lead-free and leaded



+: Clean 0: Partially cleaned -: Not clean

4. Experimental Protocol

- Phase 3 – Experimental parameters and results

Fixed Parameters		
Equipment Specification	Spray Pressure (psi)	50/50
	Spray bars (top)	7
Board Specification (0603 components)	Component density	30

- Additional improvement in cleaning performance achieved by adding a second higher-flow pump and changing the spray configuration
- Effectively at belt speeds of 1.7 fpm
- 2.1-minute exposure time

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5. Conclusion

- Industry trends will continue. Component sizes will further decrease in contrast to increased board density.
- It will be more difficult to clean the assemblies
- Use of higher capacity pumps, longer machines and surfactant based cleaning agents are not the most effective and efficient approach to PCB defluxing.

5. Conclusion

- Main Accomplishments

Combination of Progressive Energy with Micro Phase Cleaning (MPC) Technology provides the fastest belt speed with 100% surface cleanliness known in the PCB defluxing industry