Fluid Flow Mechanics -Key to Low Standoff Cleaning

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EXECUTIVE SUMMARY

Over 3 years ago, Zestron initially addressed cleaning underneath 4 MIL standoff components. With the emergence of lead-free and even smaller components new challenges have now arisen to include components with less than 1MIL gaps.

This study set out to specifically investigate the impact of mechanical vs. chemical contributions during the removal of contamination under 1-2 MIL standoff components, respectively. To validate the results obtained, extensive studies were conducted, including actual user case-studies, specifically prepared test-assemblies, iterative experimentation, as well as new mechanical innovations that might help customers in future. The latter include but are not limited to various flow patterns as well as industry leading cleaning agents. As a result the authors will also include experimental data to address fluid flow mechanics, temperature and concentration related effects.

Initial results obtained indicate that clean-ability of residues under low standoff components has become *a non-trivial issue*. Not only are residues becoming harder to remove, but at the same token the penetration of the cleaning agent seems to be in direct relationship with the geometry and height of the components used. We will also illustrate surprising and unexpected results. For example, under specific conditions cleaning results under 1-2 MIL standoffs provided better cleanliness than under 4-5MIL standoffs!

Fluid Flow Mechanics: Key to Low Standoff Cleaning

ZESTRON
High Precision Cleaning

AUSTIN AMERICAN TECHNOLOGY CORPORATION

Speaker:

Jigar Patel
ZESTRON America

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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. Experimental Protocol
5. 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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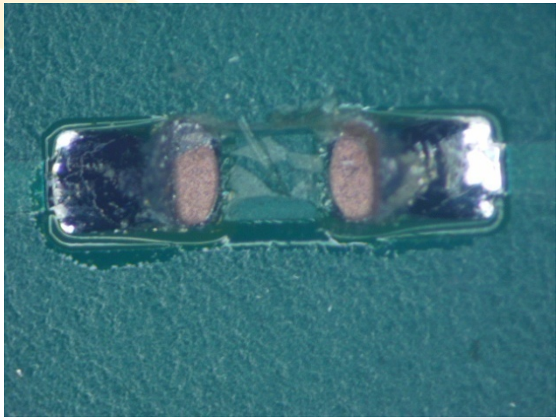
2. Fluid Flow Theory

- 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)
  2 Higher energy delivery
  (flow and pressure)

- Kinetic Energy = m x V^2

- Tighter gaps or tight spaces with solvent-phobic surfaces require differential pressure 1-10 psi

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2. Fluid Flow Theory – Empty Gaps Surface Tension Effects

- Interfacial pressure differential calculation

planar

$$\boxed{\Delta p = 2\gamma \cos\theta \; / \; R}$$

cylinder

$$\boxed{\Delta p = \gamma \cos\theta \; / \; R}$$

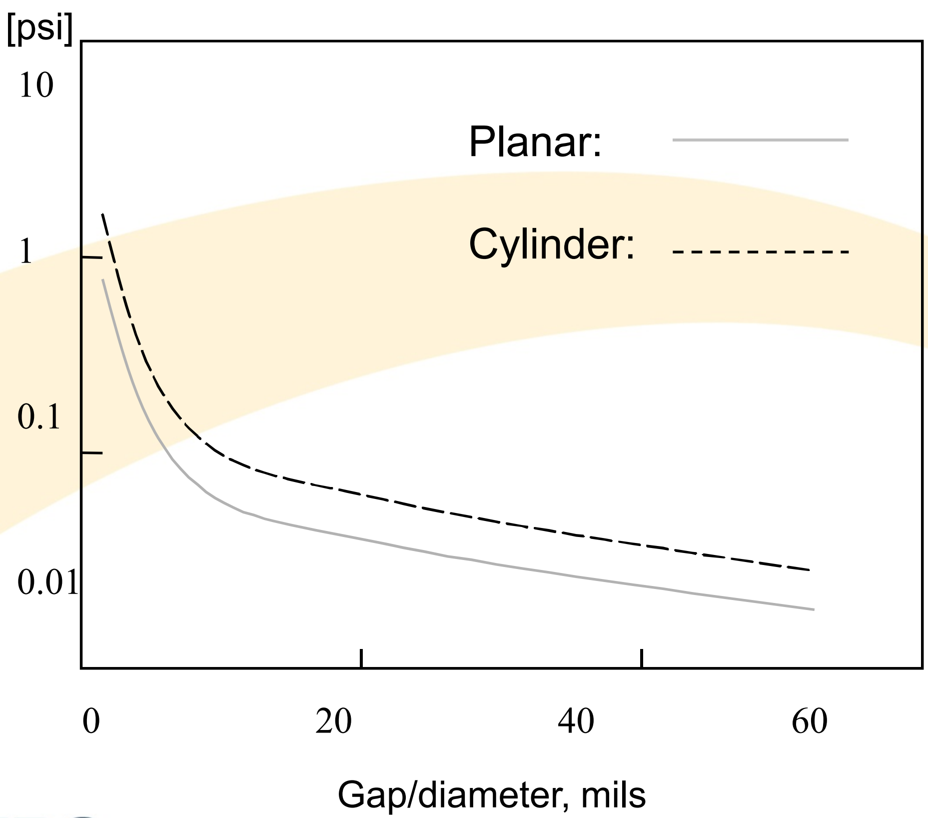
NOTE: if θ is greater than 90°, as with water on waxy surface, the force becomes negative or repulsive

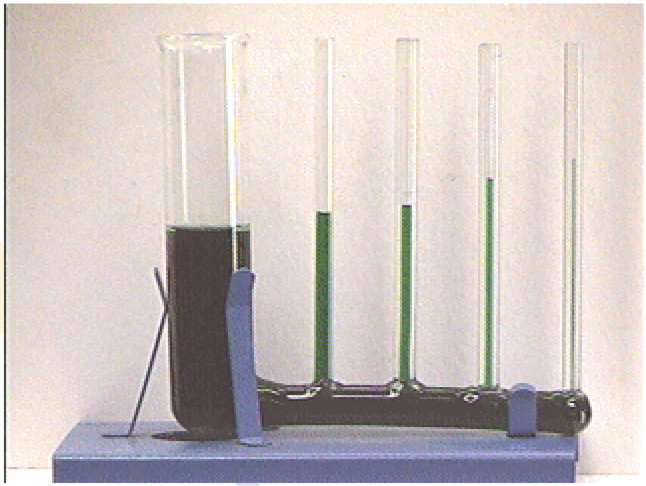
γ = surface tension
Θ = contact angle of liquid at surface
R = radius meniscus

2. Fluid Flow Theory – Empty Gaps

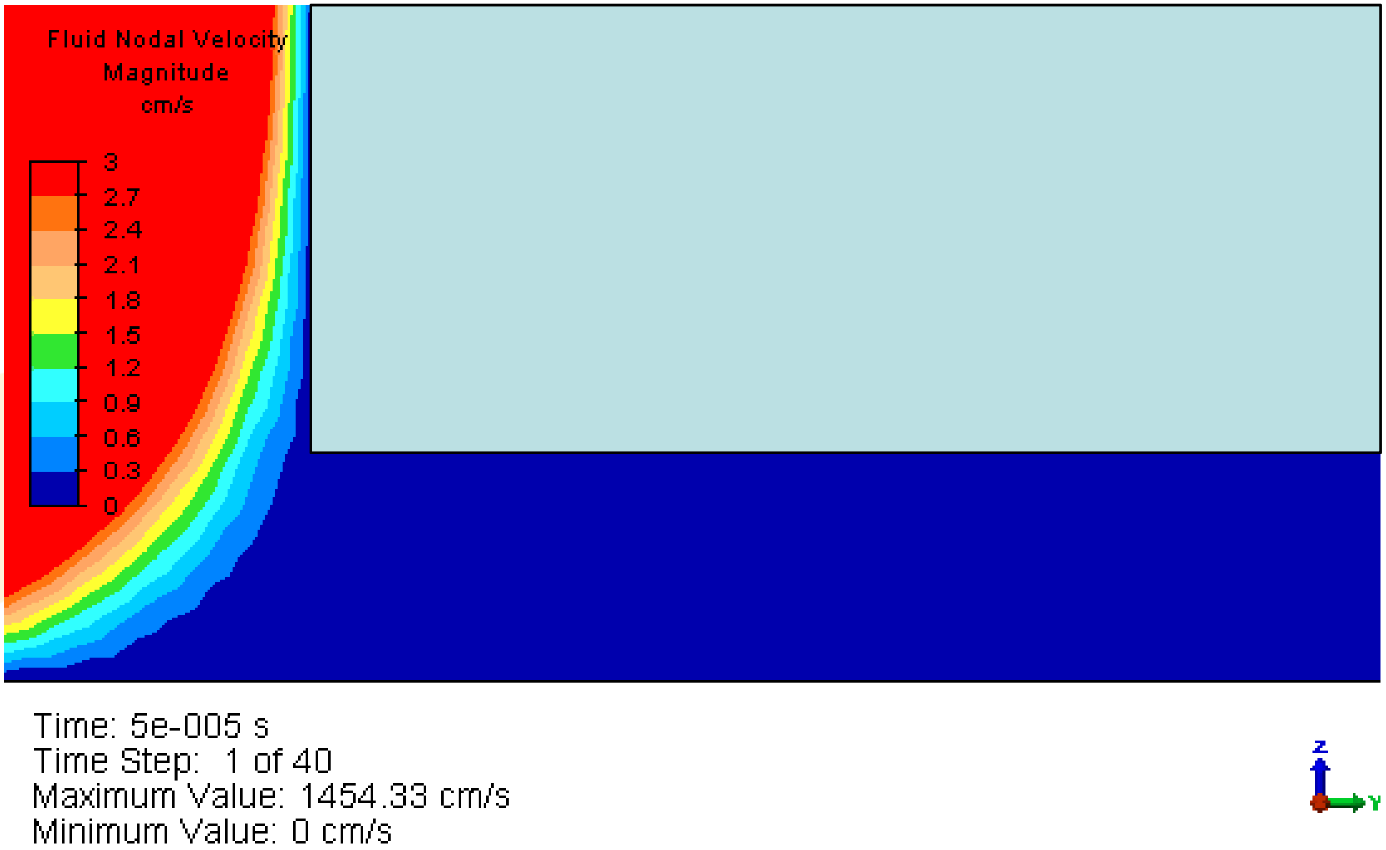
- Relationship between gap size and capillary force for water on glass

Interfacial pressure difference at equilibrium



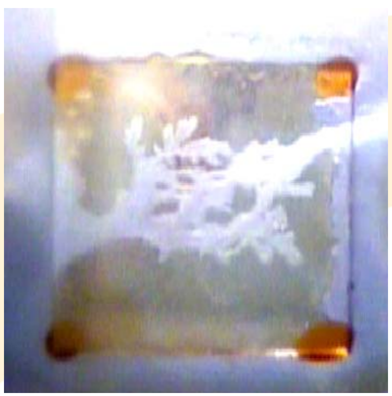


2. Fluid flow model – 1 mil unfilled gap



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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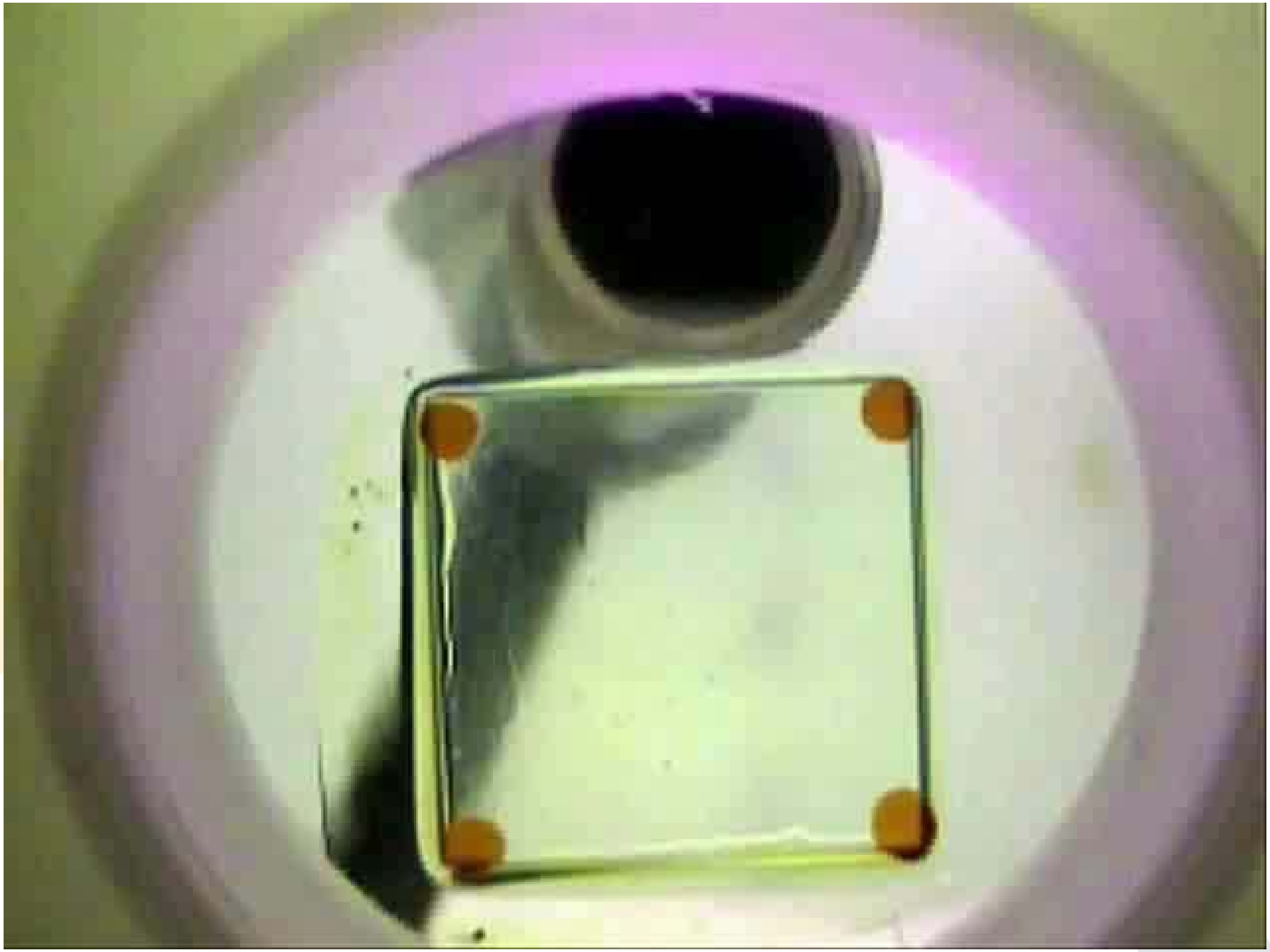
3. Inline Progressive Energy Dynamics Approach



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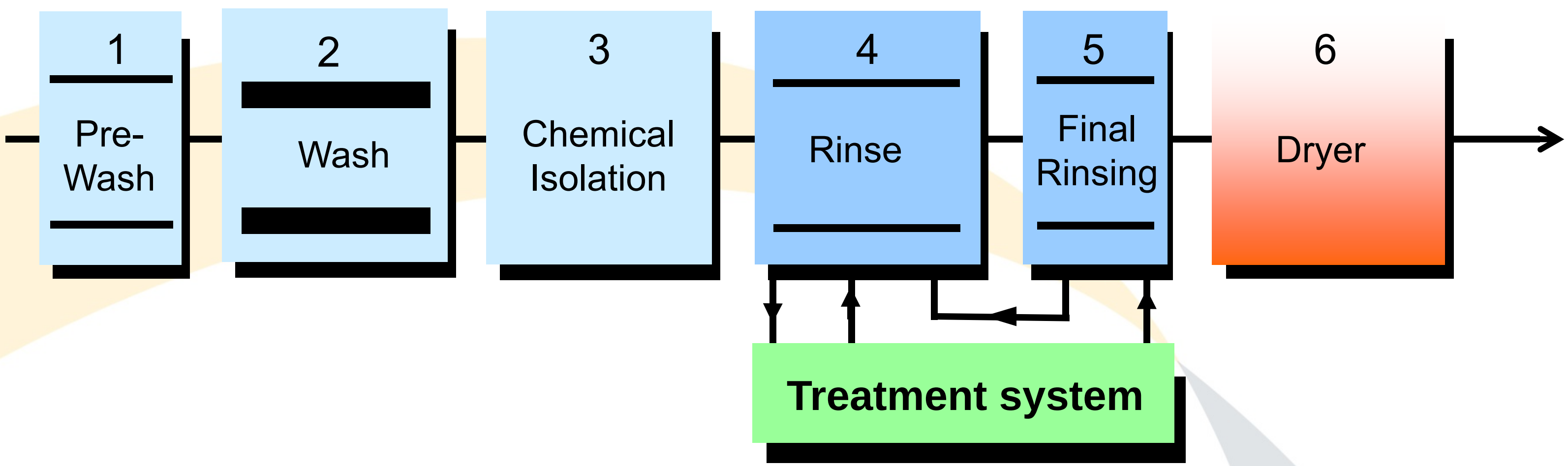
3. Inline Progressive Energy Dynamics Approach

- Inline Cleaning Process Schematic



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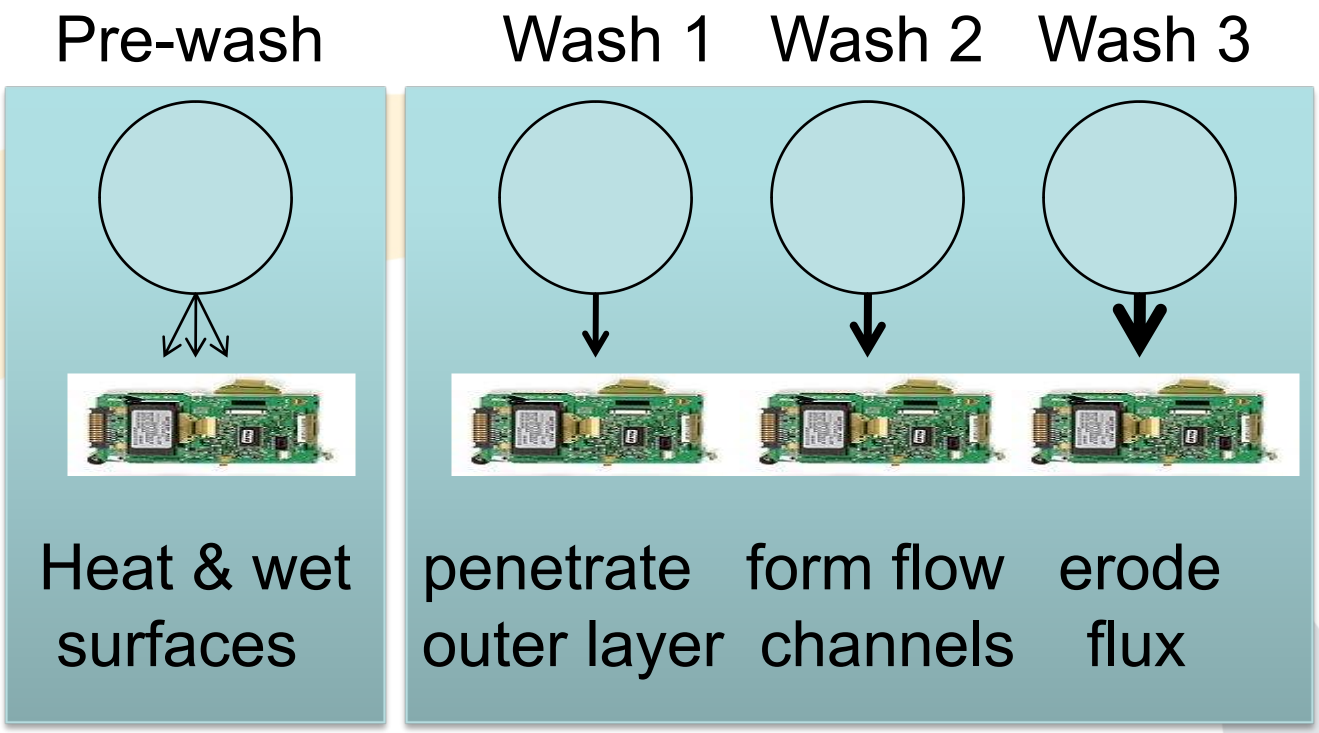
3. Inline Progressive Energy Dynamics Approach

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



3. Inline Progressive Energy Dynamics Approach

- Wash section equipped with progressive energy dynamics

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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:

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4. Experimental Protocol

Overall Experimental Variables

- Equipment:
  - ✓ Pressure [psi]
  - ✓ Spray manifold & design
  - ✓ Belt speed [fpm]
- Cleaning agent:
  - ✓ Micro Phase Cleaning Technology
  - ✓ Concentration [%]
  - ✓ Temperature [ºF]
- Parts to be cleaned:
  - ✓ Component density
  - ✓ Solder paste

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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			✓

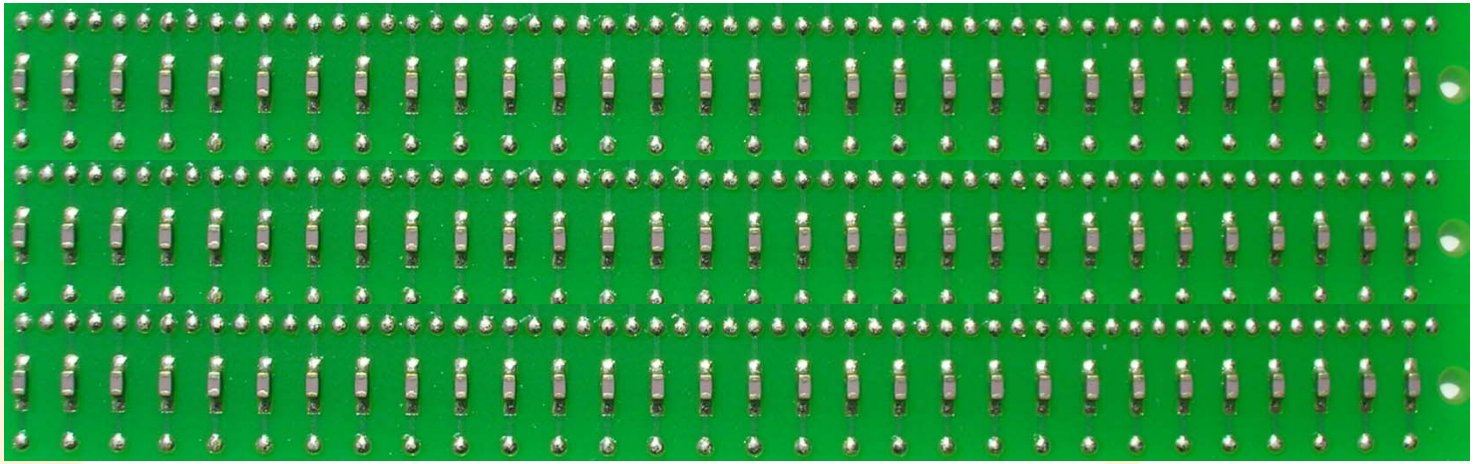
4. Experimental Protocol

- 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] / *Total wash section: 3ft.*	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:

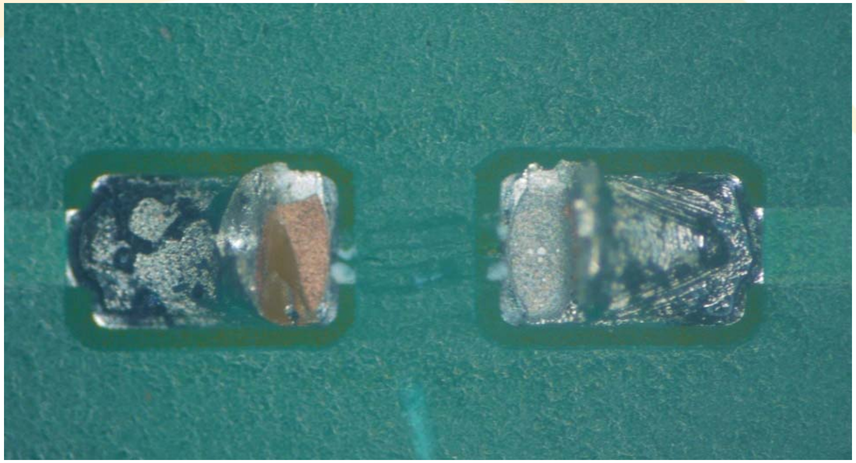


Test board area with 30 set series of 0603 components

4. Experimental Protocol

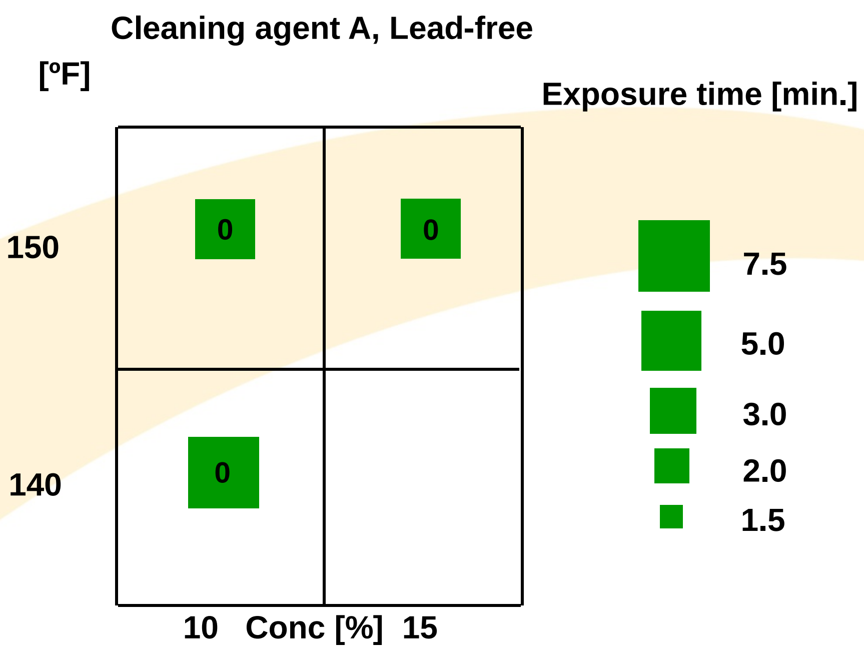
Findings Phase 1:

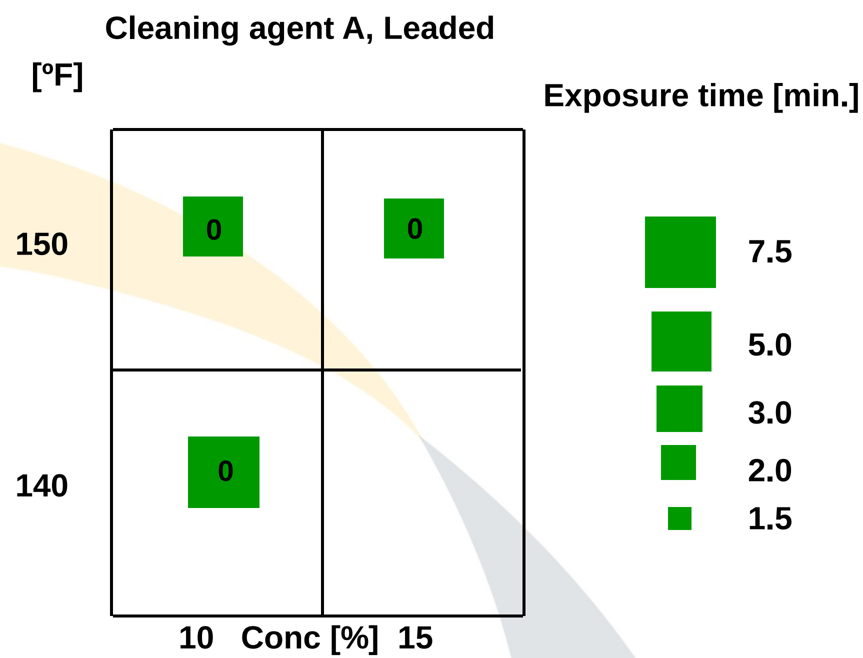
- Standard non-progressive cleaning manifold design
- Tested with leaded and lead-free formulations
- Minor residues underneath the components



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

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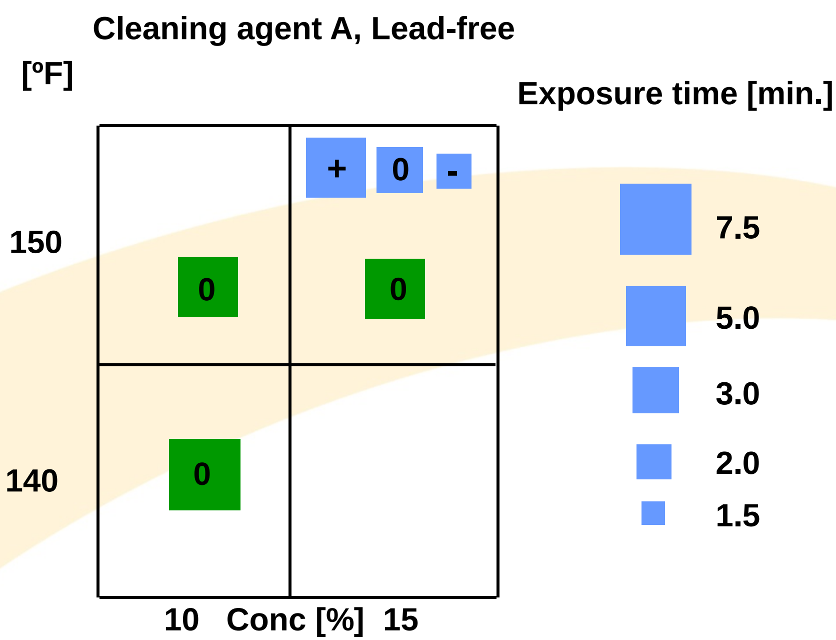
4. Experimental Protocol

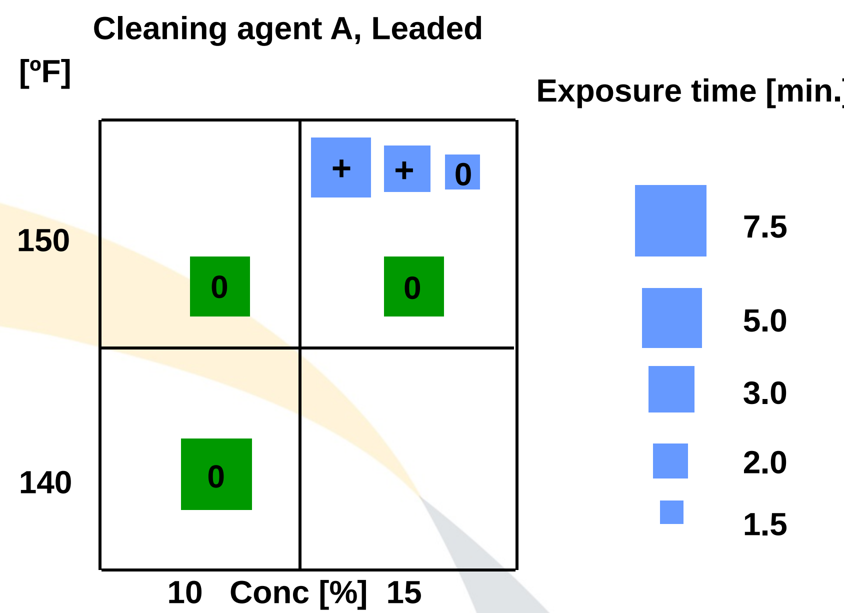
Findings Phase 2:

- 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

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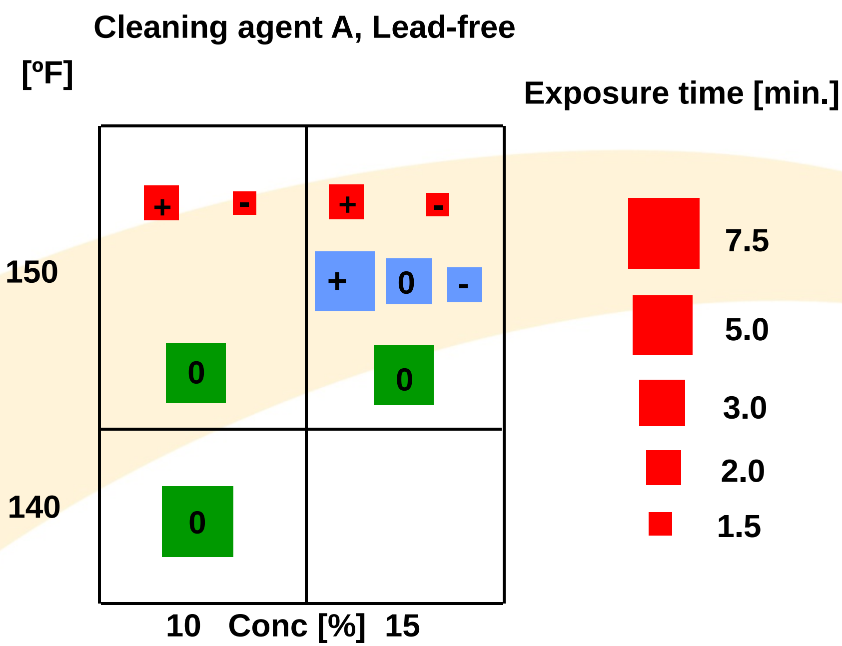
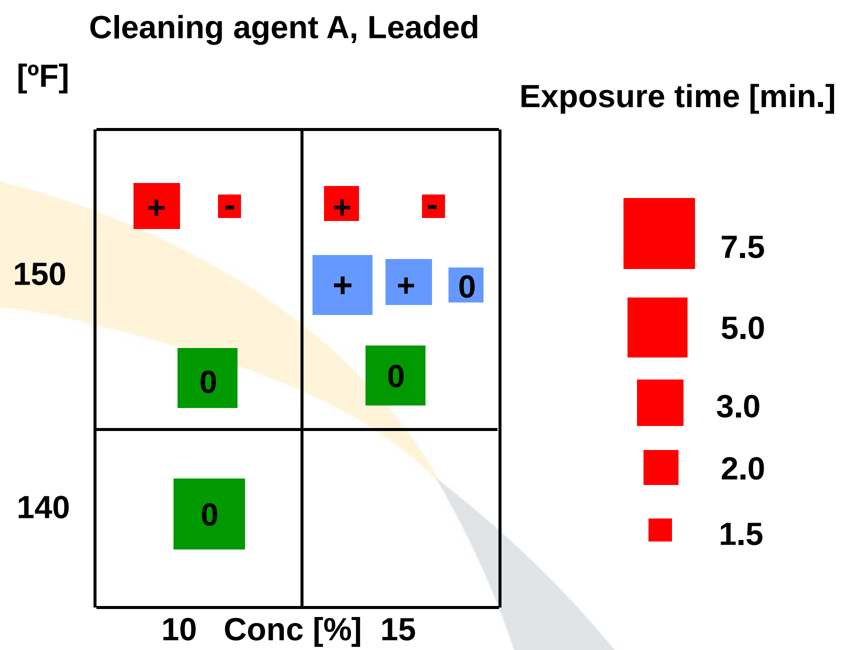
4. Experimental Protocol

- 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