Fluid Flow Mechanics: Key to Low Standoff Cleaning

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Fluid Flow Mechanics:
Key to Low Standoff Cleaning

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1. Introduction

- Increased requirements for electronic packages
- This demands even cleaner electronic assemblies
- Current designs have fewer ICs and more discrete components
- Space under components is shrinking

1. Introduction

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

  Completely filling flux under tightly spaced components

Flux around surface mount

Flux under cap

Fluid Flow Mechanics: Key to Low Standoff Cleaning

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2. Fluid Flow Theory – Empty Gaps

- Depending on: 1 Surface tension
  2 Density of the cleaning agent
  3 Higher pressure and Higher Temperature
- Tighter gaps or tight spaces with solvent-phobic surfaces require differential pressure ≥10 psi
- Pump manifold pressures of 40 to 100 psi were used, depending on the type of nozzle

2. Fluid Flow Theory – Empty Gaps

- Interfacial pressure differential - **planar**

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

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

2. Fluid Flow Theory – Empty Gaps

- Interfacial pressure differential - **cylinder**

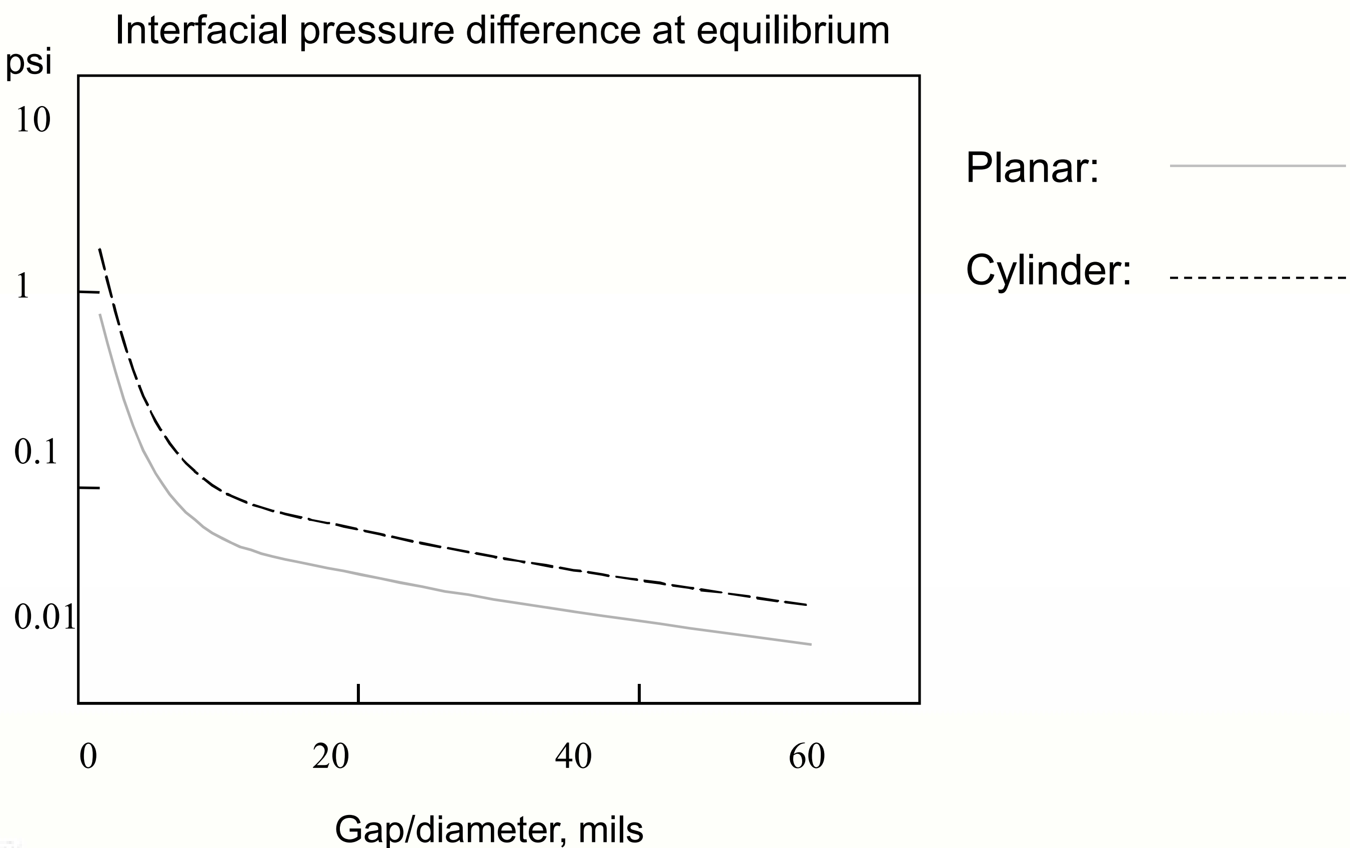
$$\Delta p = \gamma \cos\theta \;/\; R$$

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



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 Solvent depleted zone

  2 Liquid jet with sufficient energy forms flow channels

  3 Bulk residue is eroded

Fluid Flow Mechanics:
Key to Low Standoff Cleaning

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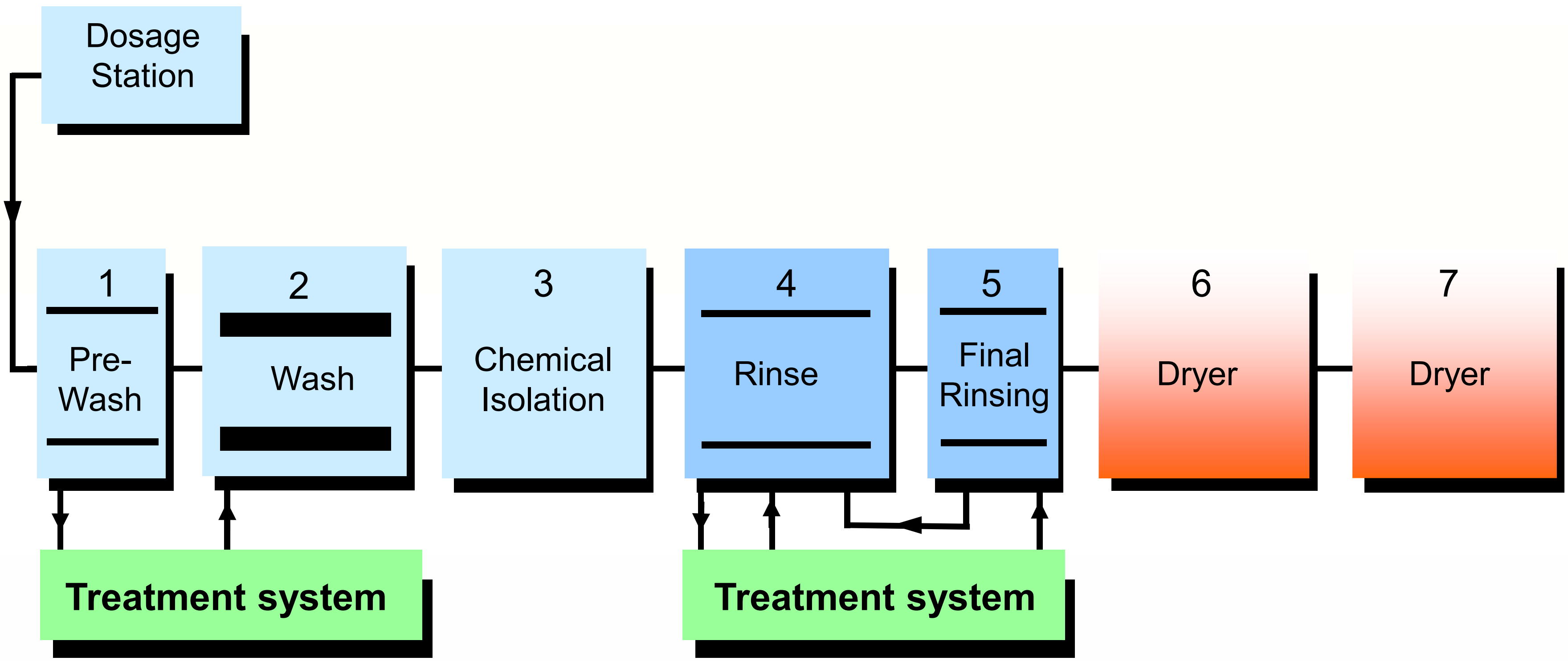
4. Testing Protocol
5. Overall Conclusion

3. Inline Progressive Energy Dynamics Approach

- Inline Cleaning Process Schematic



3. Inline Progressive Energy Dynamics Approach

- New approach to design in-line cleaner
- Requires innovative cleaning fluid technology
- Involves a manifold design
- Use of bigger pumps and more manifolds

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:

1 The availability of the appropriate amount of energy

2 Avoids wasting energy by directing less energy

Fluid Flow Mechanics:
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4. Testing Protocol

Overall Experimental Variables

- Equipment:
  - ✓ Pressure (psi)
  - ✓ Spray manifolds
  - ✓ Belt speed (ft/min)
- Cleaning agent:
  - ✓ Cleaning agent technology
  - ✓ Concentration (%)
  - ✓ Temperature (° F)
- Parts to be cleaned:
  - ✓ Component density
  - ✓ Solder paste

4. Testing Protocol

- Boards with 0603 chip capacitors
- Average standoff height of 1 mil.

- Maximum component density: 30 / board
- 3 different test phases

- Leaded and lead-free solder pastes – based on highest level of difficulty to clean
- Soldering performed in a 10-stage reflow oven under air-atmosphere

4. Testing 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			✓

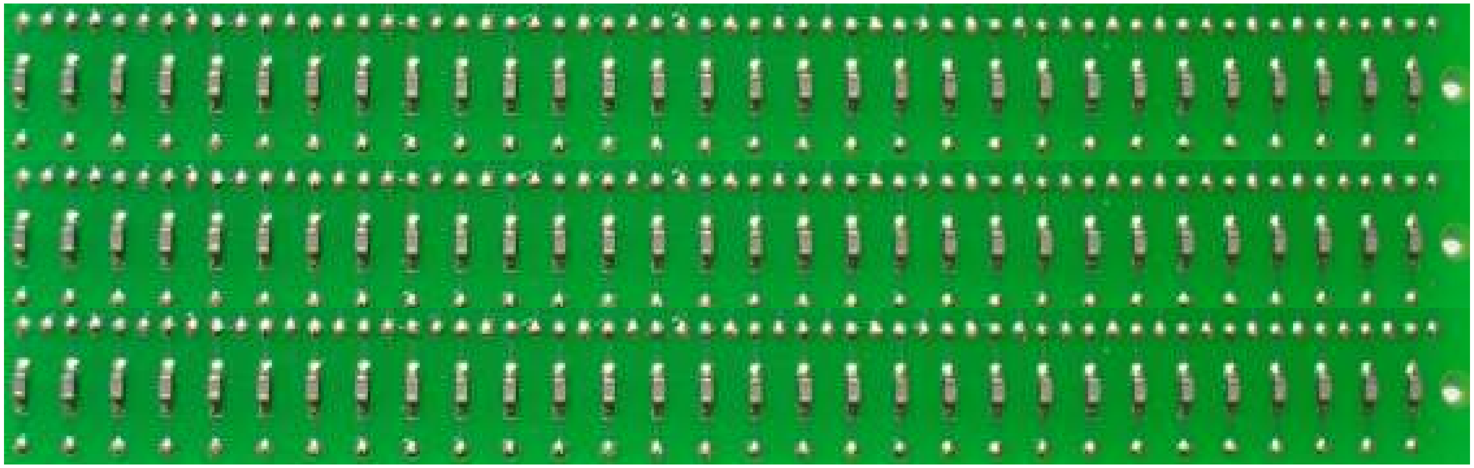
4. Testing Protocol

- Overall experimental overview:

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

4. Testing Protocol

- Board specification:



Test board area with 30 set series of 0603 components

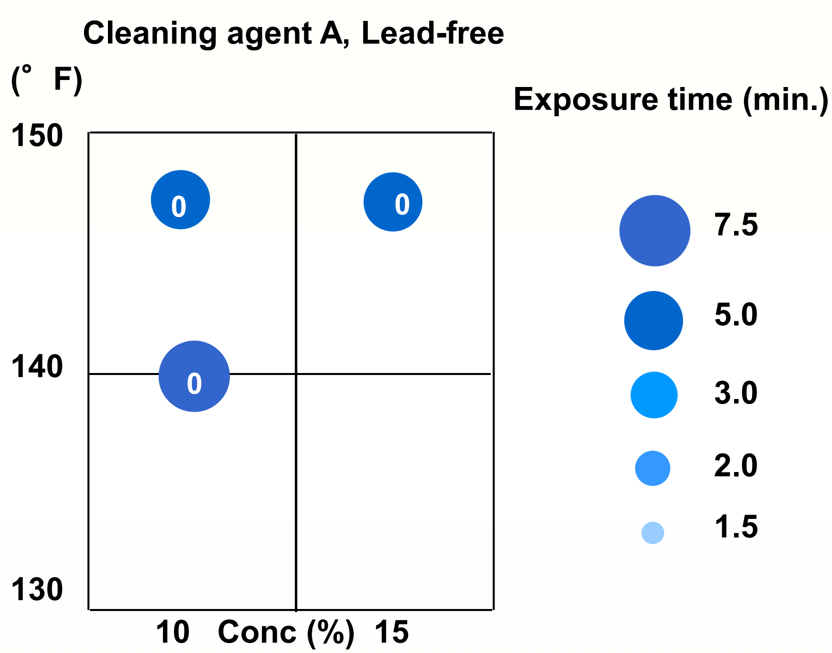
4. Testing Protocol

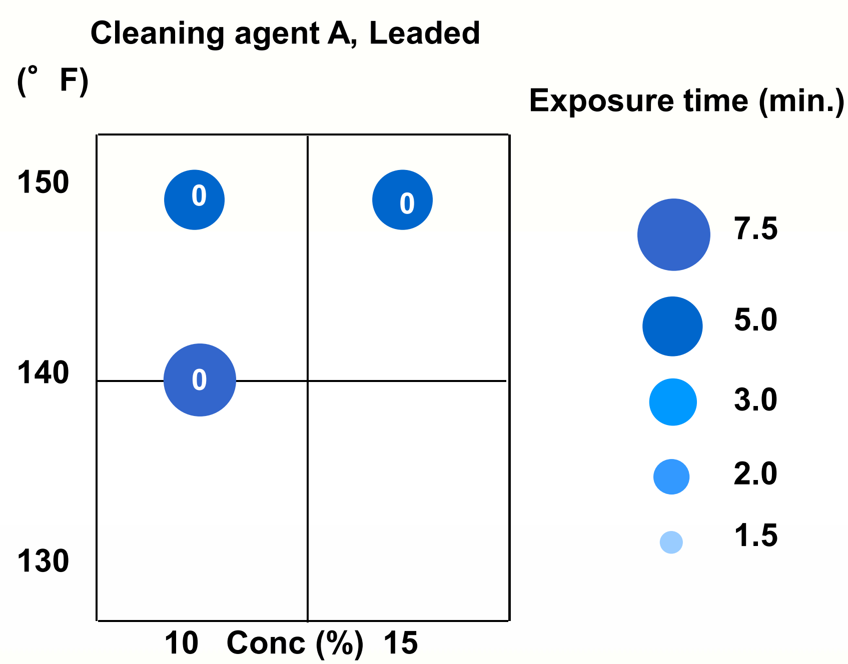
Findings Phase 1:

- Standard, non-progressive cleaning manifold tested
- For both leaded and lead-free formulations
- Consistent with results in other inline machines

4. Testing Protocol

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





4. Testing 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 clean the components
- For both – leaded and lead-free formulations

4. Testing Protocol

- Phase 1 – Experimental parameters and results

Variable Parameters						
	Cleaning Agent	#	%	(˚F)	(ft./min) / (min)	Cleaning Result
Lead-free	A	1	10	140	0.4 / 7.5	0
		3	10	150	0.6 / 5.0	0
		5	15	150	0.6 / 5.0	0
Leaded	A	2	10	140	0.4 / 7.5	0
		4	10	150	0.6 / 5.0	0
		3	15	150	0.6 / 5.0	0

+: Clean 0: Partially cleaned -: Not clean

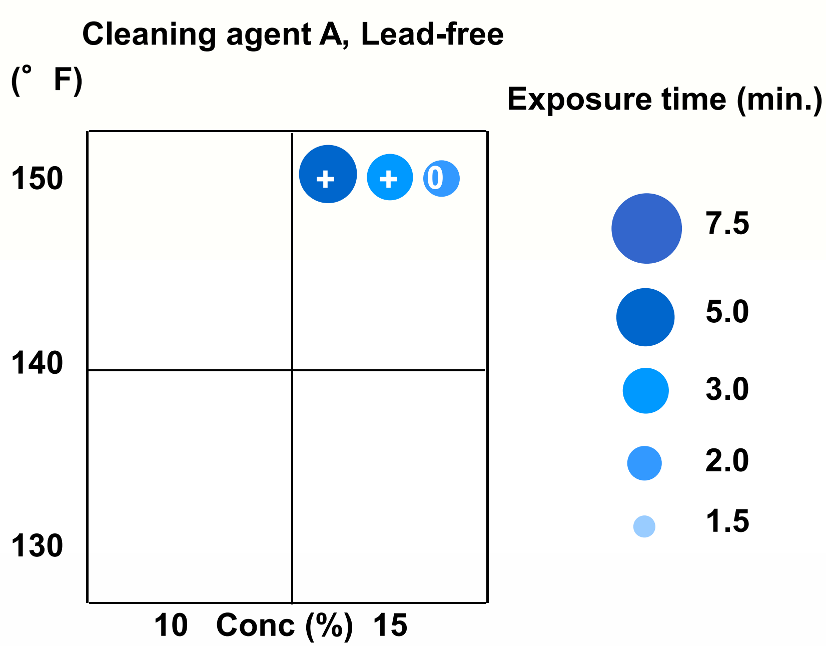
4. Testing Protocol

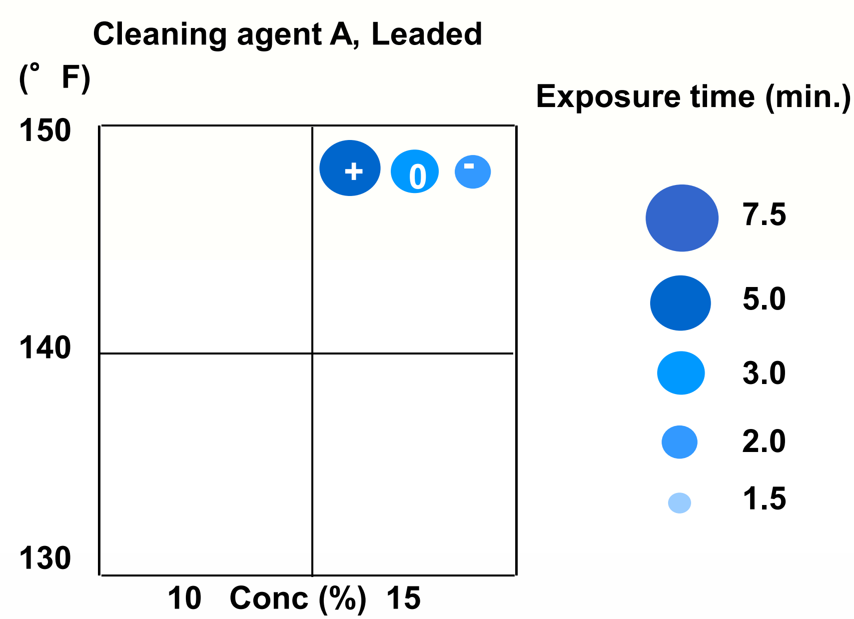
Findings Phase 2:

- Same machine but modified
- New manifolds were build in to increase flow
- Results significantly better than in previous study

4. Testing Protocol

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





4. Testing 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. Testing Protocol

- Phase 2 – Experimental parameters and results

Variable Parameters						
	Cleaning Agent	#	%	(˚ F)	(ft./min) / (min)	Cleaning Result
Lead-free	A	7	15	150	0.6 / 5.0	+
		9	15	150	1.0 / 3.0	0
		11	15	150	1.5 / 2.0	-
		13	15	150	1.5 / 2.0	-
Leaded	A	8	15	150	0.6 / 5.0	+
		10	15	150	1.0 / 3.0	+
		12	15	150	1.5 / 2.0	0
		14	15	150	1.5 / 2.0	0

+: Clean 0: Partially cleaned -: Not clean

4. Testing Protocol

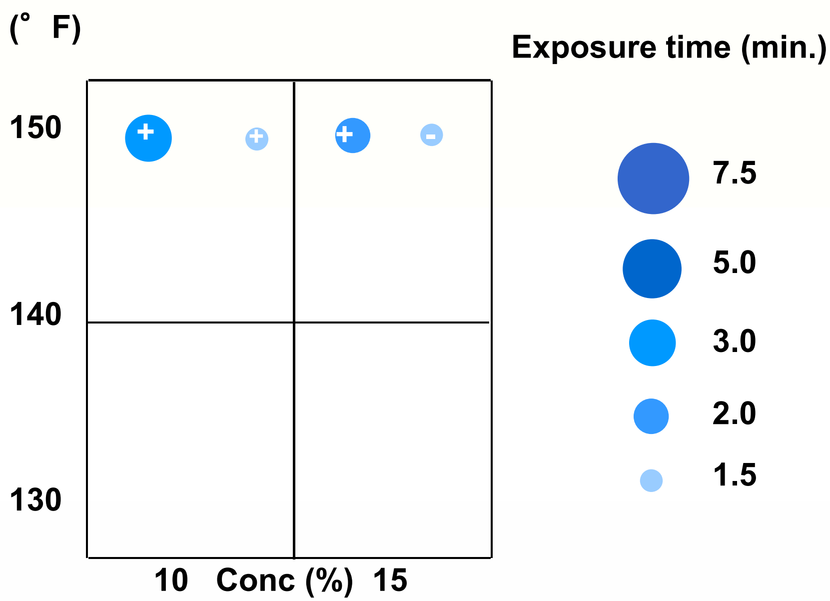
Findings Phase 3:

- New machine was built for Phase 3 testing
- Incorporating the progressive energy dynamics concept
- One additional feature
- Expanded wash tank about 6“

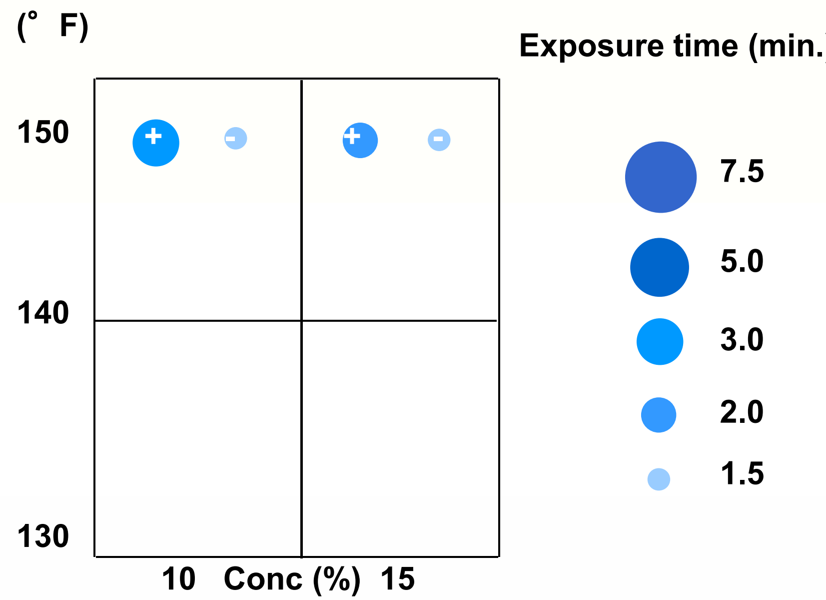
4. Testing Protocol

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

Cleaning agent A, Lead-free



Cleaning agent A, Leaded



4. Testing 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
- Effective at belt speeds of 1.7 fpm
- 2.1-minute exposure time
- Two-pump machine

4. Testing Protocol

- Phase 3 – Experimental parameters and results

Variable Parameters						
	Cleaning Agent	#	%	(˚ F)	(ft./min) / (min)	Cleaning Result
Lead-free	A	21	10	150	1.2 / 2.9	+
		22	10	150	1.7 / 2.1	+
		23	10	150	2.2 / 1.6	-
		24	15	150	1.2 / 2.9	+
		25	15	150	1.7 / 2.1	+
		26	15	150	2.2 / 1.6	-
Leaded	A	27	10	150	1.2 / 2.9	+
		28	10	150	1.7 / 2.1	-
		29	10	150	2.2 / 1.6	-
		30	15	150	1.2 / 2.9	+
		31	15	150	1.7 / 2.1	+
		32	15	150	2.2 / 1.6	-

+: Clean 0: Partially cleaned -: Not clean

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5. Overall Conclusion

- Component size will further decrease, in contrast board density will increase
- It will be more difficult to clean the assemblies
- Bigger pumps, longer machines, surfactant based cleaning agents are not the most effective and efficient cleaning methods
- Progressive energy manifold design to optimize pressure and flow

5. Overall Conclusion

- **Main Accomplishments**

- Fastest belt speed currently known in the industry
- Optimal Process Definition through adjustment of latest chemical and mechanical technologies