IPC Electronics Midwest 2010

Integrating Cleaning Equipment and Cleaning Agent for Maximum Performance

Mike Bixenman, Ph.D.
Kyzen Corporation

Biography:
Mike Bixenman is the Chief Technology Officer of Kyzen Corporation. Mike owns four earned degrees including a Doctorate of Business Administration from the University of Phoenix.

Executive Summary
The growing complexity of electronic assemblies increases the cleaning challenge due to miniaturization, lower component gaps, and improved flux designs. The need to remove ionizable contaminants is critical to production yields and reliability. As user's source cleaning equipment and cleaning agents to meet these increased cleaning demands, a number of options must be considered such as batch versus inline, cleaning agent designs, impingement options, controlling the cleaning agent, rinsing, drying, and waste management. The purpose of the research paper is to provide operational data for integrating aqueous cleaning equipment and cleaning agent for maximum performance. The conference participates will gain knowledge of batch and inline aqueous cleaning equipment designs, cleaning agents, energy sources for penetrating low residue gaps, air management, controlling the cleaning agent, managing rinse water, and waste management.

Contact Information:
430 Harding Industrial Drive
Nashville, TN 37211 USA
615-831-0888
615-831-0889
mike_bix@kyzen.com

Electronics Midwest

Integrating Cleaning Agent and Cleaning Equipment for Maximum Performance

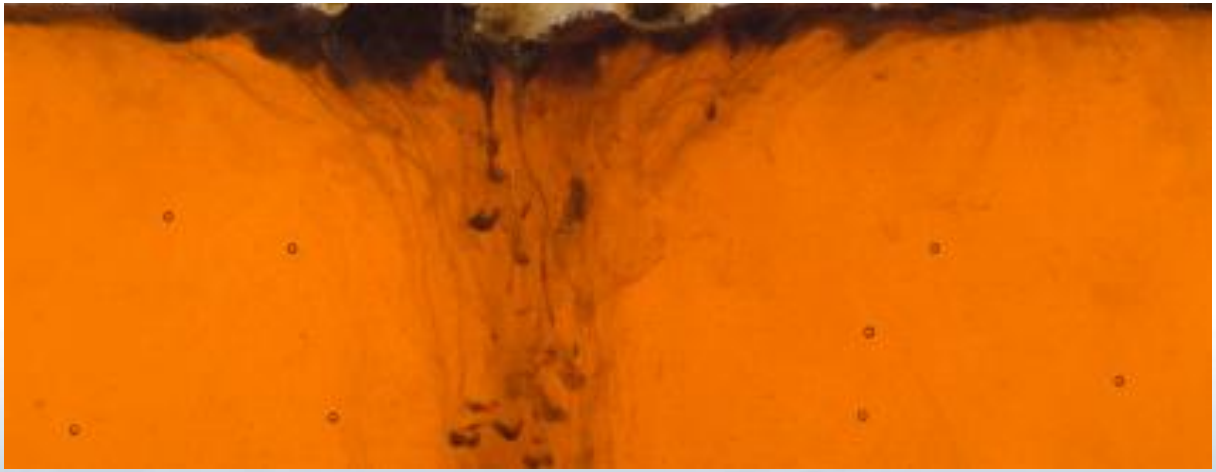
Dr. Mike Bixenman
Chief Technology Officer
Kyzen Corporation

Agenda

- Cleaning Laws
- Soil Changes
- Cleaning Agent / Equipment DOE
- Matching Cleaning Agent to Soil
- Repeatable & Reproducible Process

1st Law of Cleaning

Cleaning Agent – Mechanical Impingement = Internal Energy



2nd Law of Cleaning

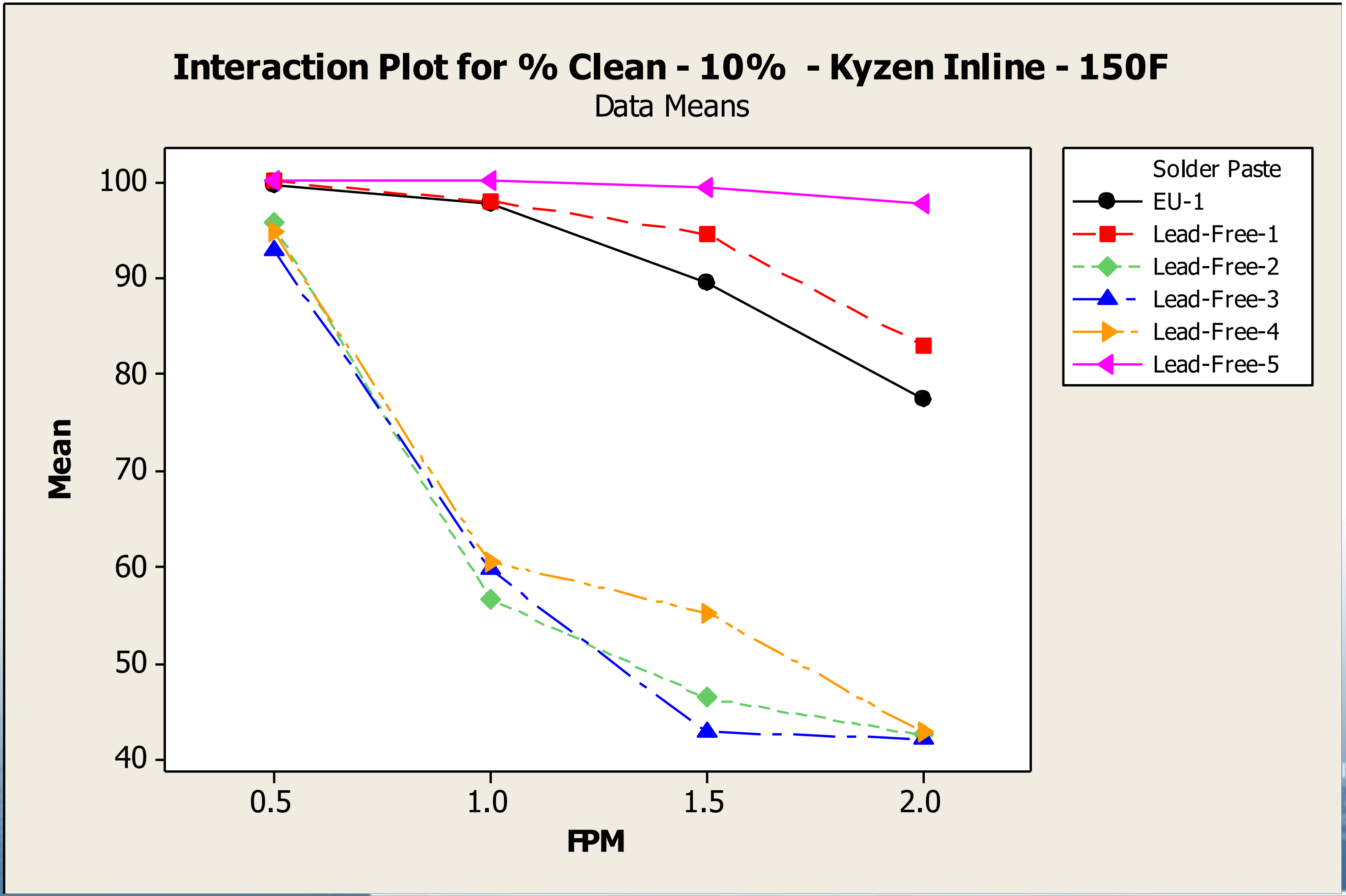
[Pressure + Flow + Directional Forces] + Cleaning Agent = Increased Performance

High Pressure Fan Nozzle

High Pressure Coherent Nozzle

3rd Law of Cleaning

Poorly Matched Cleaning Agent + Mechanical Energy = Poor Cleaning



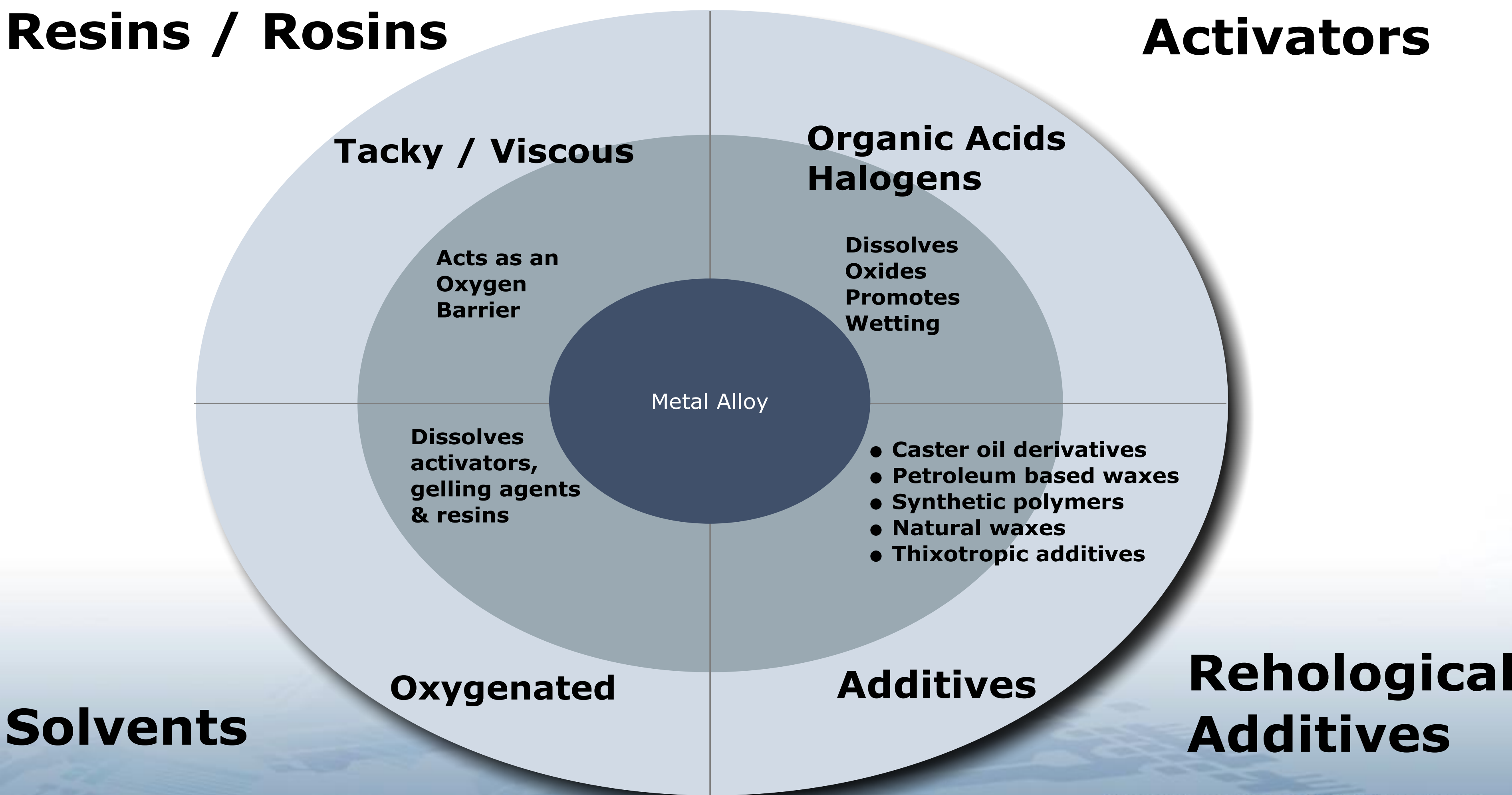
Soil Effects

Flux Types

- RMA ~ 5% Market Share
  - Rosin based with mild activation
  - Cleaned post soldering
- Water Soluble ~ 10% Market Share
  - Flux residue must be cleaned post soldering
  - DI water specified for cleaning
  - Additive may be needed to clean
- No Clean ~ 85% Market Share
  - Flux residue is benign
  - Many leave on PCB post soldering
  - Cleaned post soldering

Source: Jenson, 2010

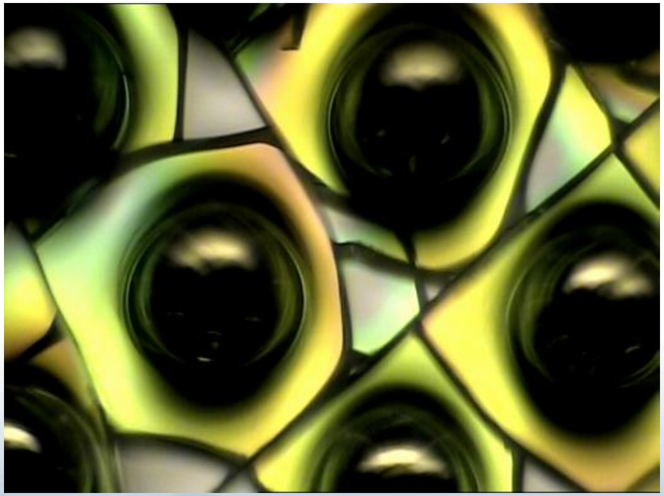
Flux Compositions



Lee, 2002

New Flux Designs

- Miniaturization and Lead-Free Drive Change
  - Flux Consistency
  - Oxide
  - Oxygen Penetration Path
  - Flux Burn Off
  - Wetting Speed
  - Spattering
  - Soldering Under Air



Source: Lee, 2010

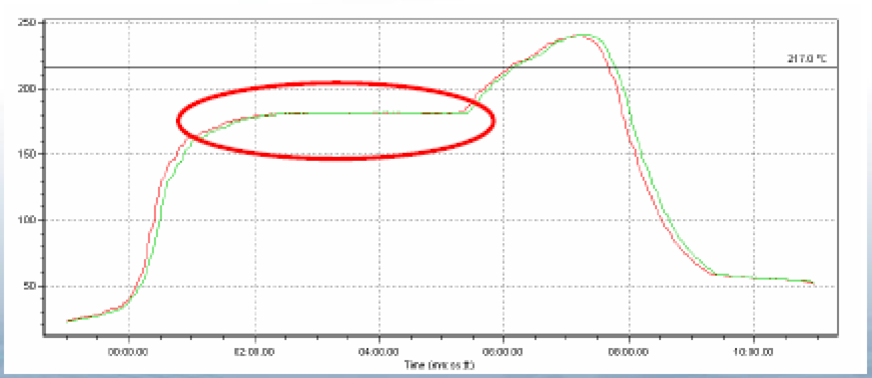
Issues of Concern for Cleaning

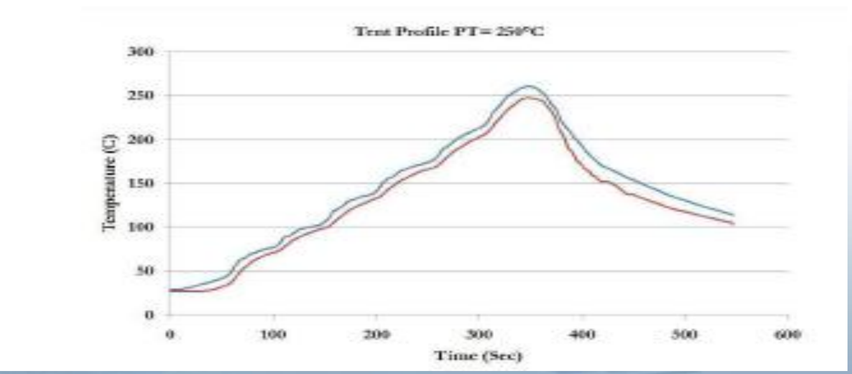
- Profile
  - Ramp rate and soak time
  - Peak Temperature
  - Environment (air vs. nitrogen)
- Flux exhaustion
  - Total heat input
  - Burn-off
  - Oxidation at the leading edge
- Flux composition
  - Rosin versus Resin
  - Halide versus Halide Free
  - Rheological Additives
    - Natural/Petrolatum waxes
    - Synthetic polymers
    - Caster oil derivatives
    - Thixotropic agents
- Low Gap Components
  - 2 mils and lower gaps
  - Flux dams underside

Source: Jenson, 2010

Profile

- Ramp - Soak - Spike
  - Oxidation occurs entire time in preheat and soak stages
  - Oxidation barrier critical
  - Harder to Clean
- Ramp – to – Spike
  - Flux vehicle maintained throughout preheat stage
  - HIP, transfer efficiency, & voiding concerns
  - Easier to clean

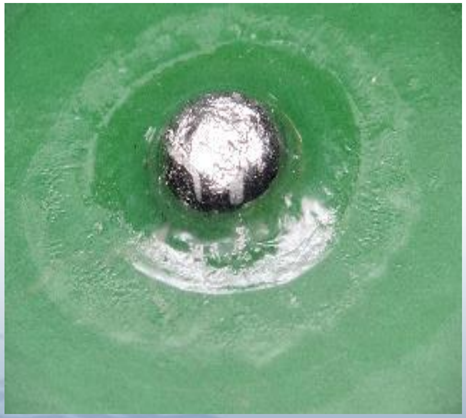




Source: Jenson, 2010

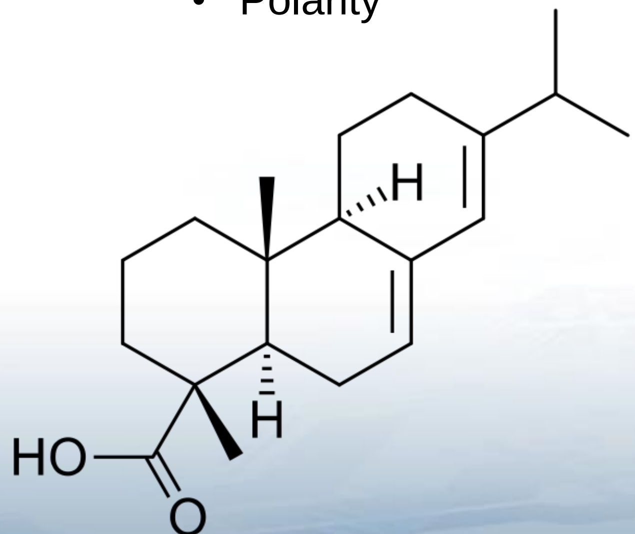
Flux Exhaustion

- Volatilization of flux components
  - Sensitive to high density / miniaturization
  - Increases with decreasing flux quantity deposited
- Solution: Flux employed for finer pitch needs to be
  - More non-volatile
  - High molecular weight materials needed
- Increases cleaning difficulty

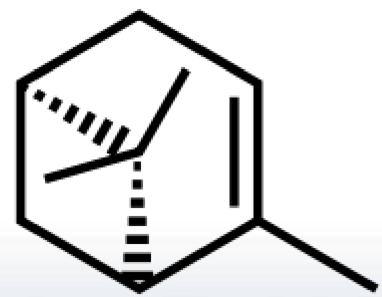


Flux Composition

- Rosin
  - Carboxylic acid structure
  - Easier to clean due to
    - Hydrogen bonding
    - Polarity



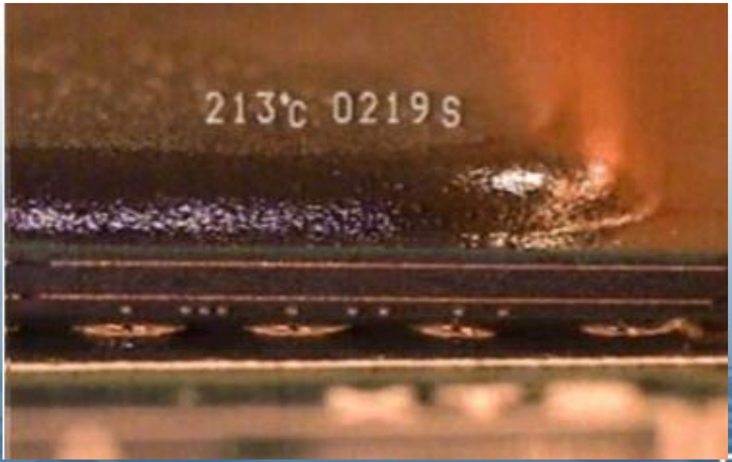
- Resin
  - Aromatic structures
  - Polar covalent
  - Harder to clean
    - Higher solvency needed



(+)-α-pinene

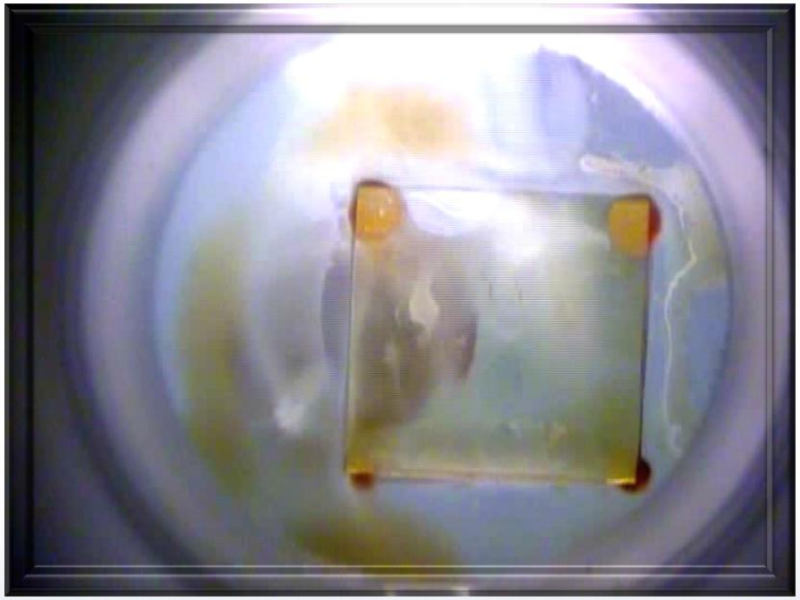
Low Gap Components

- Leadless chip carriers
- Flush mounted chip caps
- Area array components
- Capillary action and surface tension fill the underside of the components with flux residue
- Increase time needed to clean

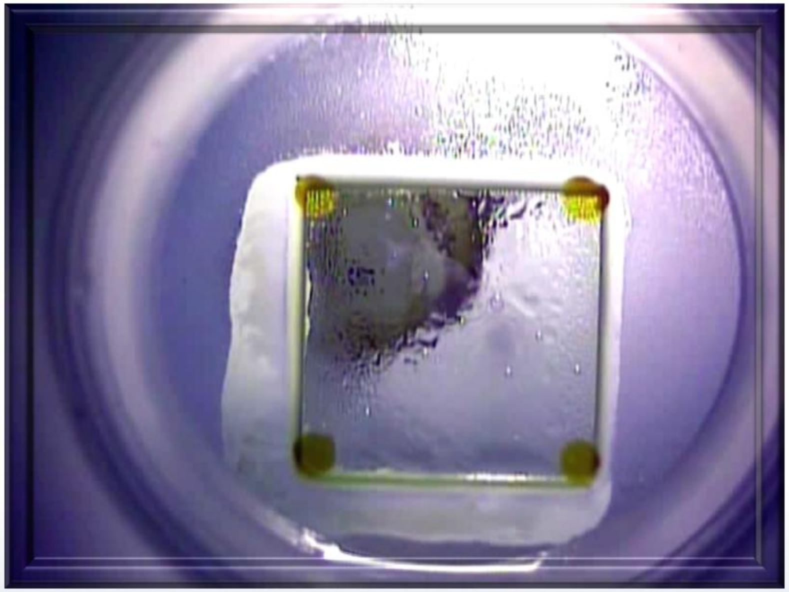


Hard versus Soft Residue

- Time is a critical factor when cleaning hard residue



Difficult to Clean Flux Residue



Soft Easily Cleaned Flux Residue

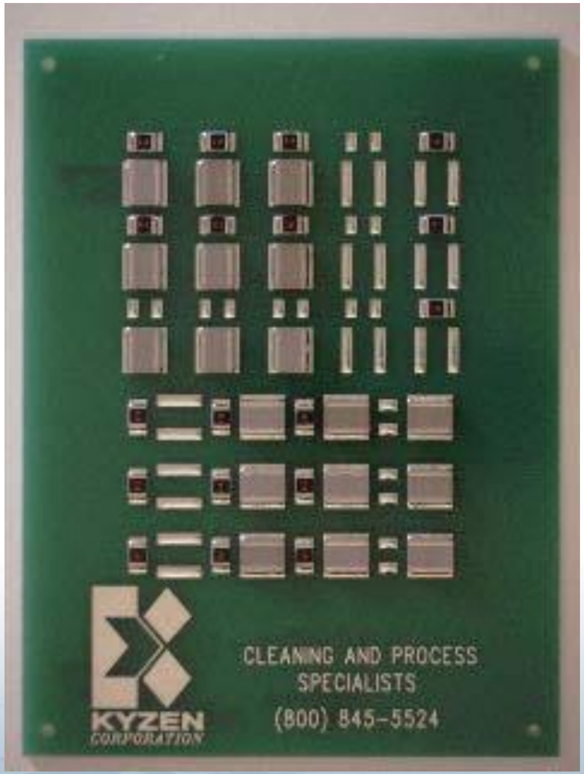
Cleaning Agent / Equipment DOE

DOE

- Cleaning Equipment
  - Ultrasonic 80 KHz
  - Spray under Immersion @ 50 PSI
  - Batch Spray in Air @ 45 PSI
  - Planar Spray in Air @ 70 PSI
- Solder Pastes
  - Water Soluble ~ 7 Lead-Free
  - Rosin ~ 3 Tin-lead
  - No Clean
    - 5 Tin-Lead
    - 8 Lead-Free
- Cleaning Agents
  - Ultrasonic
    - Aqueous @ 20%
    - 2 ~ Semi-Aqueous @ 100%
  - Spray under Immersion
    - Aqueous @ 20%
    - 2 ~ Semi-Aqueous @ 100%
  - Batch Spray in Air
    - 4 ~ Aqueous @ 10%
  - Planar Spray in Air
    - 1 ~ Aqueous @ 15%
    - 2 Spray Manifold Configurations

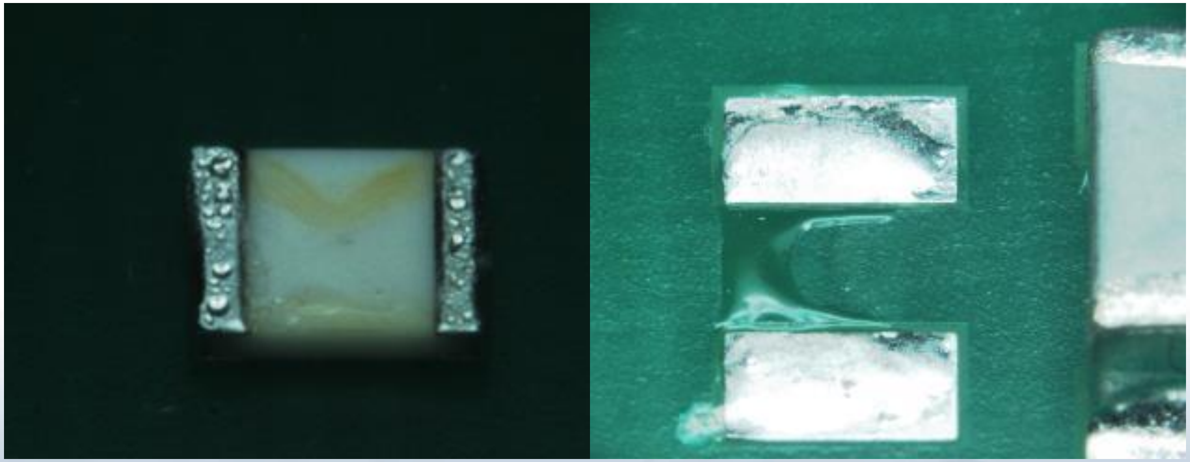
Test Card Design

- Size: 3.0” X 4.0” X .060”
- FR-4 with LPI Solder Mask
- IPC Specified Pad Geometry’s and Sizes
- Chip caps utilized:
- 1210SMR .5 mil stand-off
- 1825SMC 1.0 mil stand-off



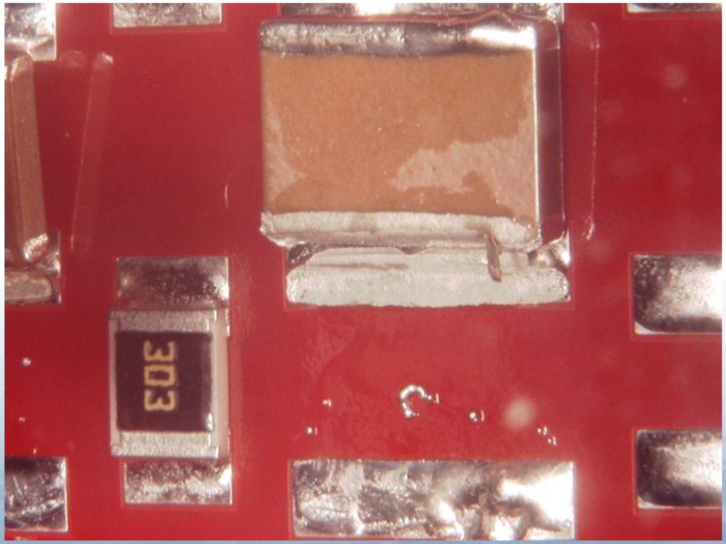
1210 Chip Caps

- Sealed on two sides
- Flux fills the components underside
- Must break dam to clean underside



1825 Chip Caps

- Sealed on two sides
- Flux fills the components underside
- Large surface area
  - Increases cleaning challenge



DOE Matrix

C - A	Energy	Power	Conc.	Temp	Time	1210 Sites	1825 Sites	Response % Clean
A-1	Ultrasonic	80 KHz	20%	140F	10 min.	18	18	
SA-1	Ultrasonic	80 KHz	100%	140F	10 min.	18	18	
SA-2	Ultrasonic	80 KHz	100%	140F	10 min.	18	18	

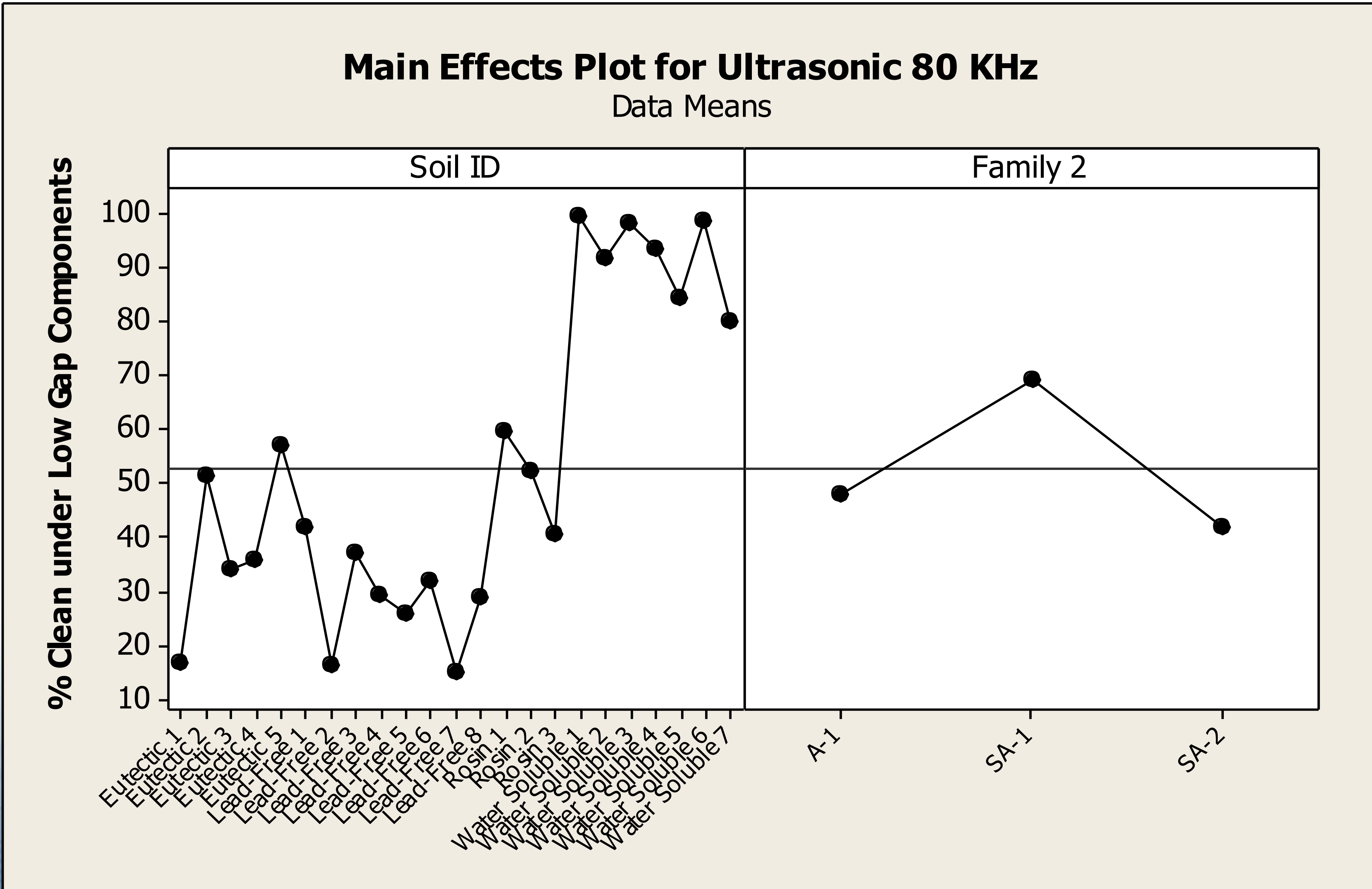
C - A	Energy	Power	Conc.	Temp	Time	1210 Sites	1825 Sites	Response % Clean
A-1	SUI	80 KHz	20%	140F	10 min.	18	18	
SA-1	SUI	80 KHz	100%	140F	10 min.	18	18	
SA-2	SUI	80 KHz	100%	140F	10 min.	18	18	

DOE Matrix

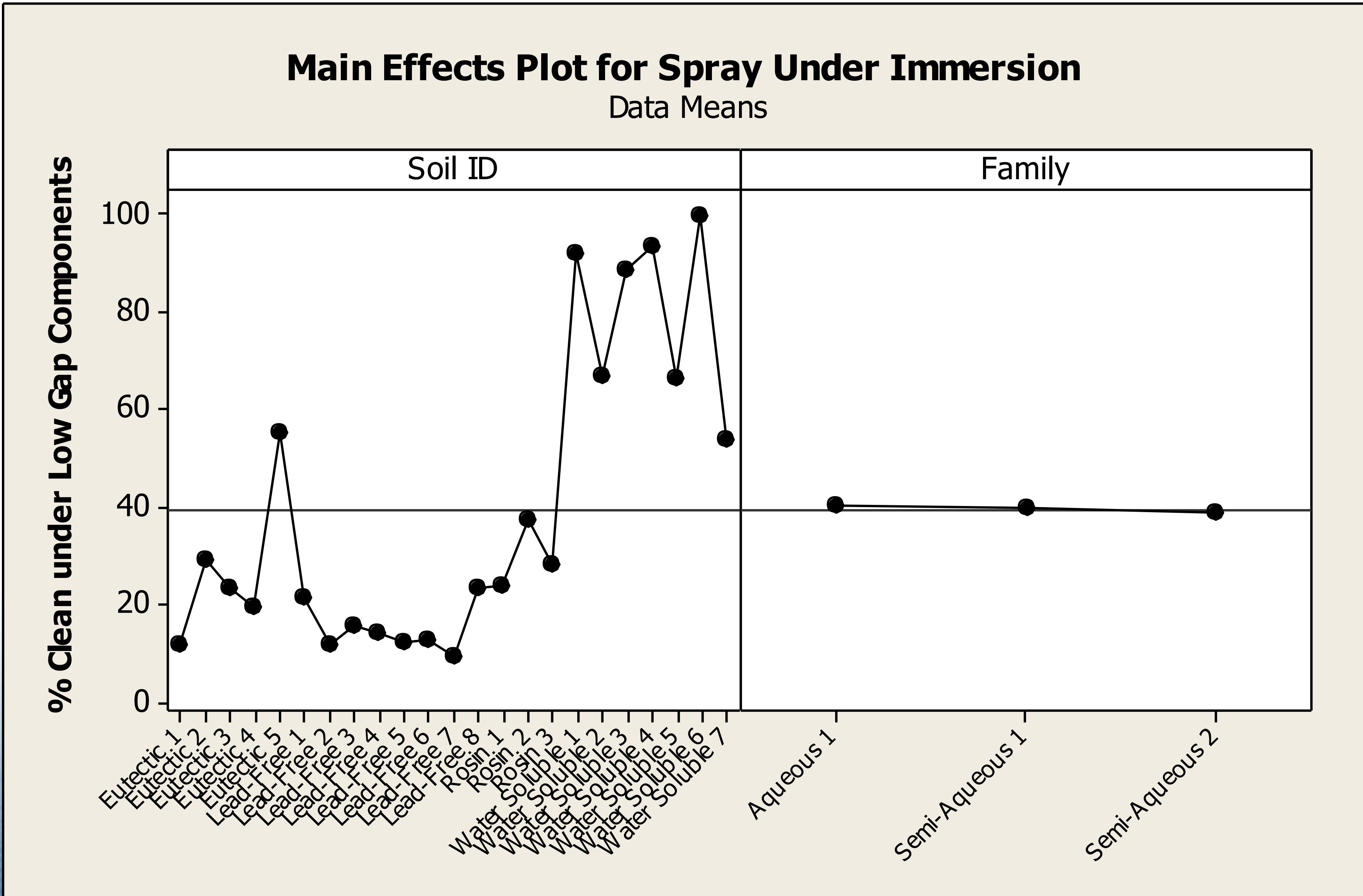
C - A	Energy	Power	Conc.	Temp	Time	1210 Sites	1825 Sites	Response % Clean
Neutral	Batch SIA	45 psi	10%	150F	10 min.	18	18	
MS-HA	Batch SIA	45 psi	10%	150F	10 min.	18	18	
MS-MA	Batch SIA	45 psi	10%	150F	10 min.	18	18	
HS-LA	Batch SIA	45 psi	10%	150F	10 min.	18	18	

DOE Matrix

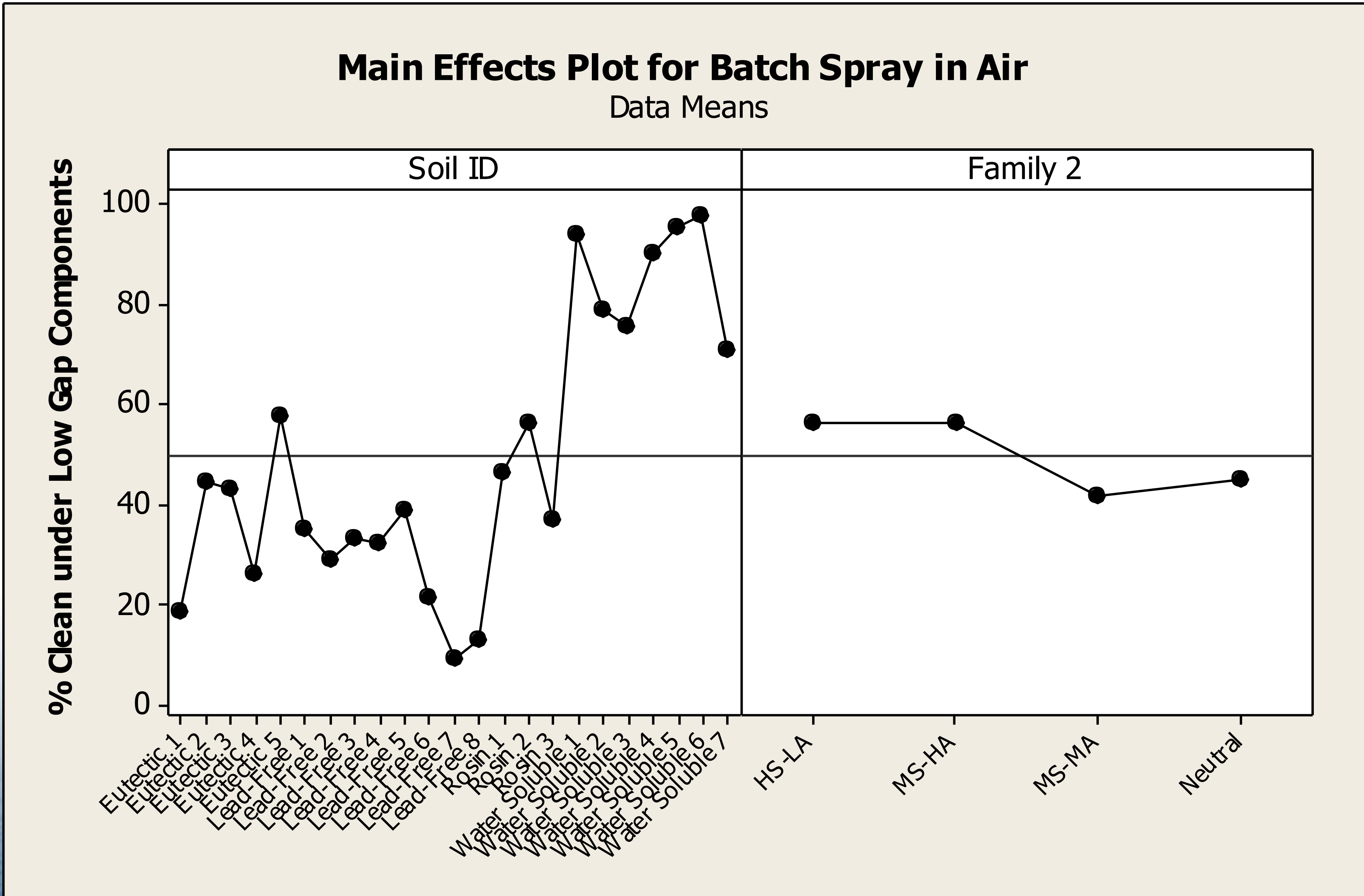
C - A	Energy	Power	Conc.	Temp	Time	1210 Sites	1825 Sites	Response % Clean
HS-LA	SIA-1	70 psi	15%	150F	0.5 FPM	18	18	
HS-LA	SIA-1	70 psi	15%	150F	1.0 FPM	18	18	
HS-LA	SIA-1	70 psi	15%	150F	1.5 FPM	18	18	
HS-LA	SIA-2	70 psi	15%	150F	0.5 FPM	18	18	
HS-LA	SIA-2	70 psi	15%	150F	1.0 FPM	18	18	
HS-LA	SIA-2	70 psi	15%	150F	1.5 FPM	18	18	



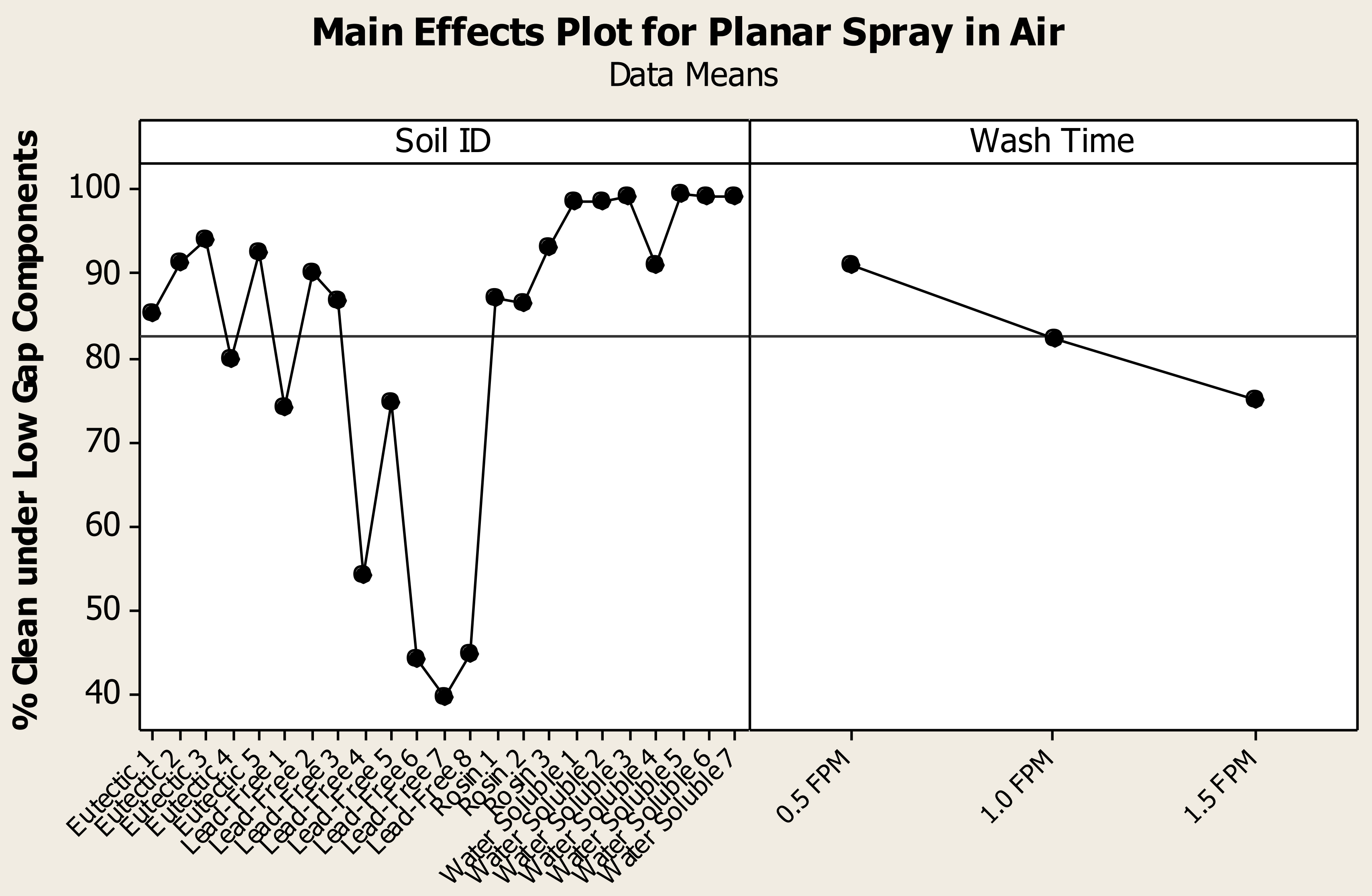
Main Effects Plot for Ultrasonic 80 KHz
Data Means
Soil ID
Family 2
% Clean under Low Gap Components
100
90
80
70
60
50
40
30
20
10
Eutectic 1
Eutectic 2
Eutectic 3
Eutectic 4
Eutectic 5
Lead-Free 1
Lead-Free 2
Lead-Free 3
Lead-Free 4
Lead-Free 5
Lead-Free 6
Lead-Free 7
Lead-Free 8
Rosin 1
Rosin 2
Rosin 3
Water Soluble 1
Water Soluble 2
Water Soluble 3
Water Soluble 4
Water Soluble 5
Water Soluble 6
Water Soluble 7
A-1
SA-1
SA-2



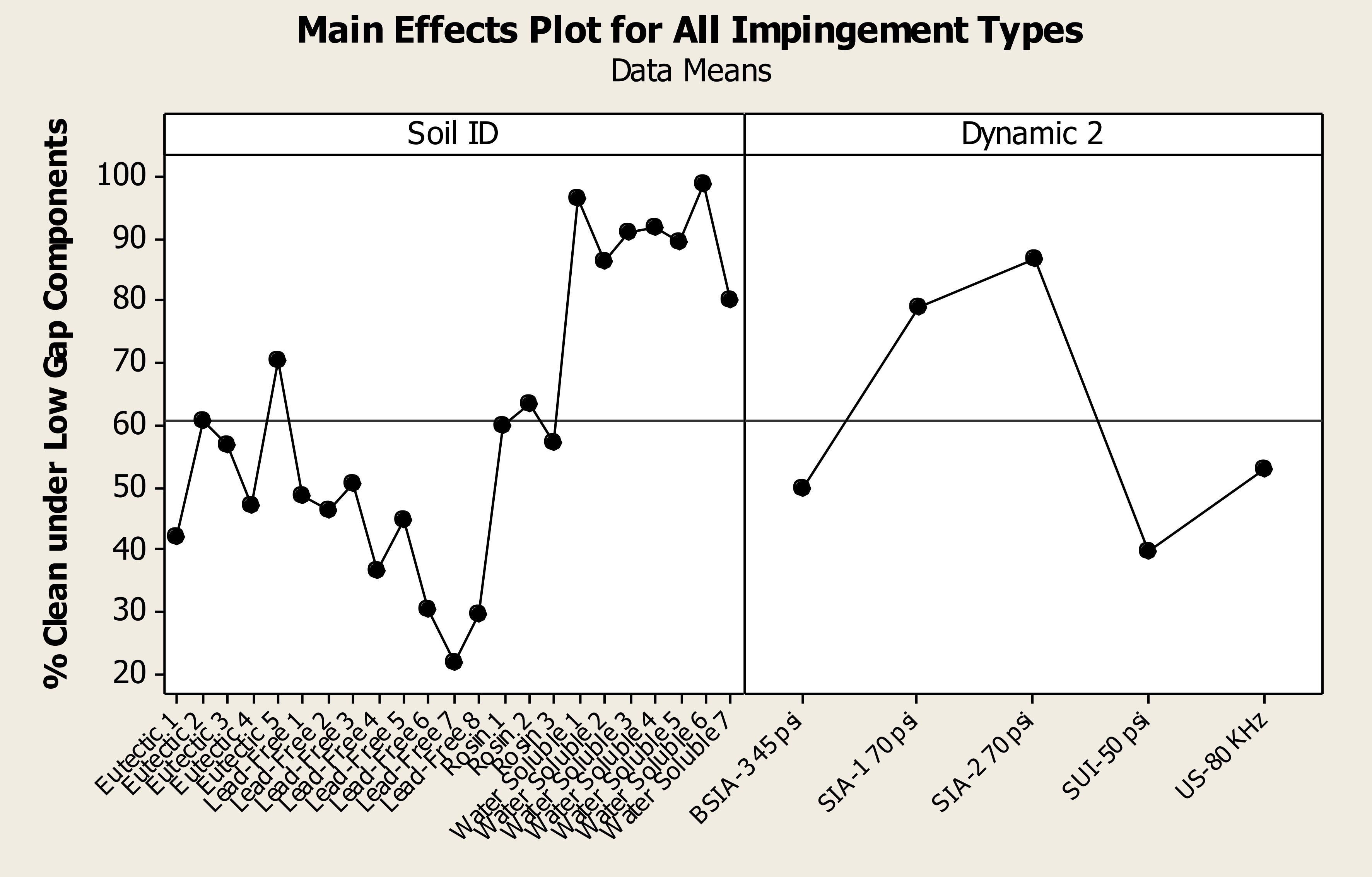
Main Effects Plot for Spray Under Immersion
Data Means
Soil ID
Family
% Clean under Low Gap Components
100
80
60
40
20
0
Eutectic 1
Eutectic 2
Eutectic 3
Eutectic 4
Eutectic 5
Lead-Free 1
Lead-Free 2
Lead-Free 3
Lead-Free 4
Lead-Free 5
Lead-Free 6
Lead-Free 7
Lead-Free 8
Rosin 1
Rosin 2
Rosin 3
Water Soluble 1
Water Soluble 2
Water Soluble 3
Water Soluble 4
Water Soluble 5
Water Soluble 6
Water Soluble 7
Aqueous 1
Semi-Aqueous 1
Semi-Aqueous 2


Main Effects Plot for Batch Spray in Air
Data Means
Soil ID
Family 2
% Clean under Low Gap Components
100
80
60
40
20
0
Eutectic 1
Eutectic 2
Eutectic 3
Eutectic 4
Eutectic 5
Lead-Free 1
Lead-Free 2
Lead-Free 3
Lead-Free 4
Lead-Free 5
Lead-Free 6
Lead-Free 7
Lead-Free 8
Rosin 1
Rosin 2
Rosin 3
Water Soluble 1
Water Soluble 2
Water Soluble 3
Water Soluble 4
Water Soluble 5
Water Soluble 6
Water Soluble 7
HS-LA
MS-HA
MS-MA
Neutral

Electronics IPC Midwest



Electronics Midwest



Inferences from Data

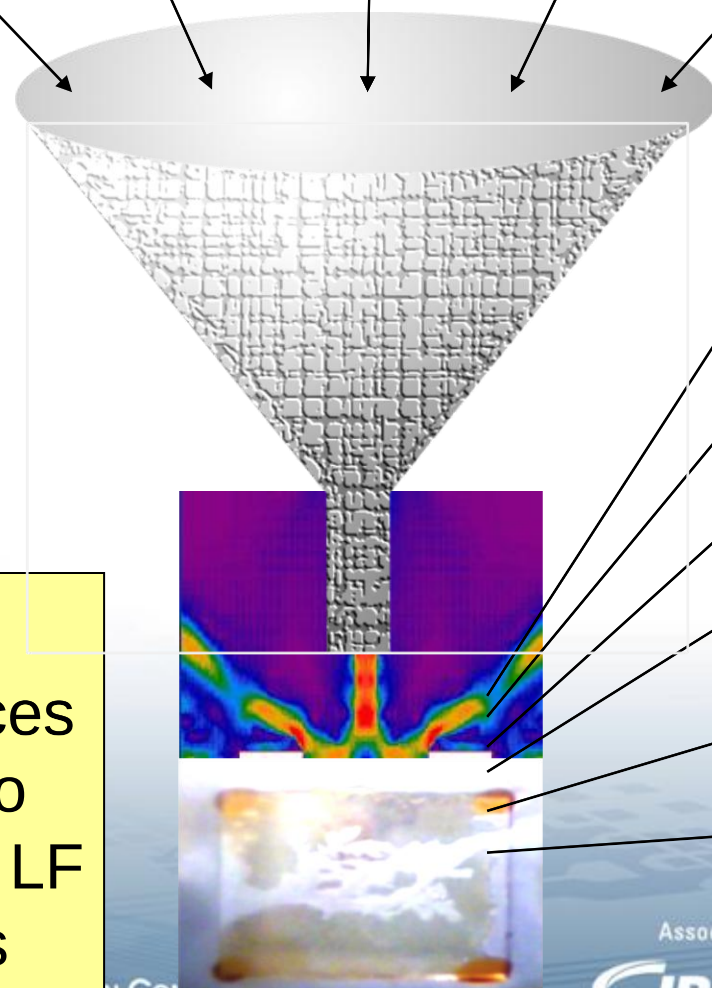
1. Flux residue compositions have changed
2. Lead-Free flux forms a hard residue
3. Hard residue requires increased wash time
4. Hard residue requires increased dispersion
5. Impingement energy is critical for removing residues under low gap components

Match Cleaning Agent to Soil

Cleaning Agent

- Critical differentiator
- The static rate
  - *“Cleaning agent dissolves residue in the absence of energy”*
  - Correlates to wash time
- Static rate needs improvement on Lead-Free no-clean flux residues

Two Phase Fluid Flow



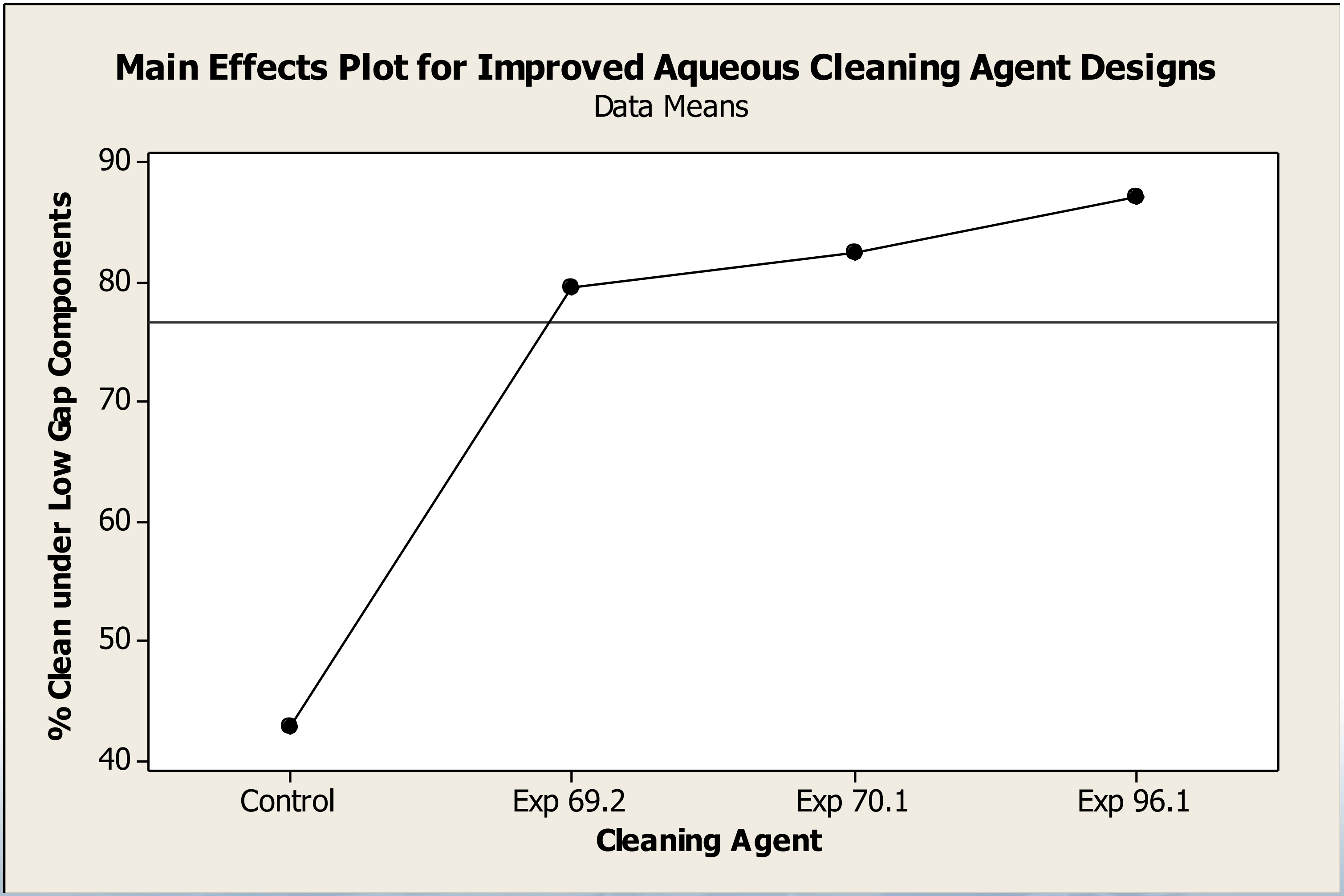
Inter/Intra Molecular Forces are needed to clean no-clean LF flux residues

Improved Static Rate

- Water is the universal solvent from which to build the ideal properties
  - High dielectric strength
  - Dissolves ionic salts
  - Solvates ions
  - Binds ions and delocalizes charge density
- Intermolecular forces
  - Ingredients that improve the electrostatic attraction of the cleaning agent for the polar constituents within the flux residue
  - Building blocks that hydrogen bond with polar residues and ions within the flux residue composition

Intramolecular Forces

- Ingredients with partial solubility in water improve cleaning on non-polar resin and rheological additives
- Materials that form an unusual behavior in water
  - A portion of the molecule likes water
  - A portion of the molecule likes flux resins
- Two phase fluid flow improves the static rate on no-clean lead-free flux residues


Main Effects Plot for Improved Aqueous Cleaning Agent Designs
Data Means
% Clean under Low Gap Components
90
80
70
60
50
40
Control
Exp 69.2
Exp 70.1
Exp 96.1
Cleaning Agent

Inferences from the Data

1. Flux residues are multi component mixtures
2. No-Clean Lead-Free flux compositions require higher dispersion forces to clean
3. Cleaning agents with properties that are attracted to the flux residue component mixtures improve the static cleaning rate
4. % Clean under Low Gap components increases with improved static cleaning rates

Gage R&R

Efficient Cleaning Processes

- Require a study of random effects from
  - Upstream factors
  - Downstream factors
- Once factors have been identified
  - Set up a series of DOEs to measure system variability induced by design factors and levels
- Process window is established from
  - Interactions of the data
- The cleaning system goal
  - Repeatability
  - Reproducibility over time

Upstream and Downstream Factors

- Capture sources of measurement variation
- Analyze the interactions between the
  - Cleaning agent
  - Cleaning machine
  - Electronic assembly
  - Specification requirements
  - Materials compatibility
  - Operator
  - Method
- Access the precision of the cleaning system

Concluding Remarks

- Cleaning PCBs requires both
  - Cleaning Agent
  - Cleaning Machine
- Cleaning machine studies find the following critical factors
  - Wash pressure needed to penetrate low gaps
  - Wash flow needed to move cleaning agent through low gaps
  - Wash time is needed to remove all residue under low gaps
- Cleaning agents matched to the residue
  - Increase the static cleaning rate
  - Open the process window
- Gage R&R
  - Identify and measure factors to define process window

Questions

- Dr. Mike Bixenman
  Chief Technology Officer
  Kyzen Corporation
  mikeb@kyzen.com

References

1. Jensen, T. (2010, July). Head-in-Pillow Defect. Flextronics Engineering Conference. Guadalajara, MX.

1. Lee, N.C. (2002). Reflow Soldering Processes and Troubleshooting SMT, BGA, CSP and Flip Chip Technologies. Butterworth-Heinemann.

1. Lee, N.C. (2009). Lead-Free Flux Technology and Influence on Cleaning, SMTAI, San Diego