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pH neutral Cleaning Agents – Market Expectation & Field Performance

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Abstract
With regard to precision cleaning applications within electronics manufacturing, pH neutral product development was a major breakthrough in recent years. The impetus for this development resulted from changes with regard to solder paste formulations and resulting assembly processes.

The greater use of lead-free solder paste and the required higher reflow profiles have resulted in even more difficult to remove burnt-in flux residues. Coupled with increases in component density, larger component packages, higher lead counts, finer lead spacing, and lower standoff distances, effective cleaning is greatly challenged. The aqueous alkaline based cleaning agents can effectively remove these flux residues, however, the process often requires an increase in wash temperature and exposure time, chemical concentration, and mechanical energy. Although an efficient and effective cleaning process can be developed, oftentimes, the required operating parameters present a new set of challenges with regard to material compatibility.

Since their introduction, the newly developed pH neutral formulations have proven to be capable not only of removing these difficult post reflow residues from complex board geometries, but do so without affecting material compatibility of sensitive components. Additionally, they perform at low concentration levels. This study reviews the performance of pH neutral cleaning agents as compared to alkaline cleaning agent alternatives and includes field data demonstrating their effectiveness with regard to material compatibility and cleaning performance.

Introduction
As engineered aqueous based cleaning agents are developed, they tend to be alkaline with pH values ranging from 8 to 14 for this is required in order to solubilize the burnt-in flux residues found on board surfaces. However, components are being developed with an increasing amount of sensitive materials and these can be adversely affected by alkaline cleaning agents. One way to address the material compatibility issues with alkaline cleaning agents is to add inhibitor packages, commonly referred to as corrosion inhibitors, to the cleaning agent formulation. Although these can minimize if not eliminate the detrimental impact to sensitive materials, inhibitor type and quantity is critical and must be properly balanced with the cleaner operating parameters in order to achieve effective results. An alternative solution is the use of pH neutral cleaning agents. These have the advantage of requiring small amounts of inhibitors in order to maintain the integrity of the sensitive material surfaces while retaining the cleaning effectiveness of the alkaline cleaning agents.

pH neutral cleaning agents were introduced to the market in early 2010 with the promise of offering excellent material compatibility and cleaning effectiveness. They also offered environmental advantages such as the possibility of eliminating waste water neutralization processes as well as the option for a closed loop rinse water cycle. Since their introduction, this has proven to be the case.

At SMTA International 2010, a study titled “Benchmark Study: pH neutral vs. Alkaline Cleaning Agents” was presented [1]. This study compared and documented the material compatibility and cleaning effectiveness of an alkaline cleaning agent with that of a pH neutral cleaning agent. An excerpt of this study is included as background information with regard to the key differences between pH neutral and alkaline cleaning agents. The complete study details a comparative analysis of the results of short and long term effects of pH neutral and alkaline cleaning agents on sensitive materials such as anodized, alodine and iridite coatings, electroless nickel plating as well as aluminum and copper. It also compares the cleaning effectiveness of each on the substrate surface and undercomponent utilizing spray-in-air inline cleaning equipment. Based on the results of this study, pH neutral cleaning agents held the promise of offering superior material compatibility, comparable if not improved cleaning performance and lower concentrations as compared to alkaline alternatives for cleaning No Clean, RMA and OA flux residues. This paper presents three customer case studies whereby the specific customer explored the option of employing a pH neutral cleaning agent due to issues with alkaline cleaning agents and/or DI-water with their cleaning processes.

Background
(**Excerpt from "Benchmark Study: ph Neutral vs. Alkaline Cleaning Agents" [1])**

With the emergence of pH neutral defluxing technologies in early 2010, pH neutral formulations promised to set a new standard for material compatibility, while proving valuable to those who worked toward environmentally sound processes. As a result, potential users are very interested in assessing the differences between alkaline cleaning agents and the newer pH neutral products, with regard to both, cleaning performance and material compatibility. One area of particular interest is the cleaning agent impact on sensitive metals.

Material compatibility issues between sensitive metals and cleaning solution arise when corrosion, i.e. the electrochemical deterioration of a metal due to the reaction with its environment, takes place. To prevent corrosion caused by the very cleaning solution that is meant to safeguard the assembly from corroding in-field and potentially fail, inhibitors come into play. In general, corrosion inhibitors are chemicals that form coordinative chemical bonds with metallic surfaces (adsorption), thereby developing a thin protective layer. They are normally distributed through a solution or by dispersion. Inhibitors slow corrosion processes by either increasing the anodic or cathodic polarization behavior, by reducing the movement or diffusion of ions to the metallic surface or by increasing the electrical resistance of the metal's surface. Corrosion inhibitors can be classified as either inorganic or organic, with the latter being more prevalent due to solubility advantages, performance, and fewer environmental concerns. Examples of typical corrosion inhibitors are silicates, borates, alkanolamines, naphthalenesulfonic acid, triazoles, carboxylic acids, molybdates, polyols, and phosphate [2].

If the respective cleaning media does not work as intended, several types of corrosion can commonly occur on electronic assemblies, such as gas phase, uniform, pitting, electrolytic metal migration, and galvanic [3]. Fortunately, this has been an area of much research and electronics manufacturers today have a variety of cleaning choices to prevent such issues with the newer and more effective aqueous alkaline chemistries strongly preferred over solvents or traditional surfactants. Recently, however, the choices of aqueous products available for defluxing have expanded significantly with the introduction of pH neutral formulations.

For aqueous solutions to do a superior job without affecting sensitive metal substrates, i.e. corrosion control, manufacturers have to add inhibitors. Studies have shown that choosing the correct type and amount of inhibition chemistry is critically important. Otherwise, the inhibitors themselves can present several problems in the SMT production process.

First, the solubility of certain inhibitors in chemistry concentrate is sometimes low and only a small percentage of the inhibitor can be added to the cleaning product formulation. Therefore, to achieve proper protection of sensitive metals using such problematic inhibitors, a higher recommended operating concentration is often required in the wash tank, which leads to unnecessary chemistry consumption. On the other hand, lowering the concentration leads to a lower amount of inhibitor available to protect sensitive metals. Second, these organic additives can have detrimental effects on the cleaning process as they also interact with any residue as well as the environment and inhibit the dissolution of such residue into the cleaning fluid. Finally and most importantly, certain inappropriate inhibitors are tightly bound to the metal surface and are more difficult or impossible to rinse from the substrate's surface and under components, where they linger insidiously, causing a host of problems over time. This contamination can adversely increase the electrical resistance of the contaminated areas, leading to conformal coating issues and causing unpredictable failures, thereby threatening the long-term reliability of the assembly.

The type and amount of inhibitors selected is also a function of the pH conditions in the process. Some inhibitors that work well at a certain pH will not function as well or at all if the pH is outside of this range. Therefore, pH neutral cleaning agents offer distinct advantages and require very small amounts of inhibitors. At this pH range (7 +/- 0.5), a unique and customized set of corrosion inhibitors is very effective, thereby solving the problems mentioned above. Due to their lower surface tension (less than 30 mN/m vs. 72 mN/m for water), pH neutral solutions can penetrate the tiny spaces in and around components, do their job of removing contamination even at low concentrations and can be easily rinsed and dried [4]. Furthermore, pH neutral cleaners are more environmentally friendly and eliminate waste water neutralization processes. Most importantly, however, using pH neutral agents has been shown to eliminate material compatibility concerns in cases where alkaline agents have failed, thereby offering users a solution that previously did not exist.

Case Study Review – Customer A:

Company A is a global OEM designing and producing electronic assemblies for numerous applications within the military, aerospace, automotive, industrial, and medical industries. A new customer was acquired and the plant in question was tasked with manufacturing the newly designed PCBs.

Within their current SMT process, this plant used an aqueous based inline spray-in-air cleaning process and an alkaline cleaning agent. Although this process produced satisfactory results, material compatibility issues arose with one particular substrate that was manufactured with lead-free solder paste and liquid flux.

This PCB was double-sided and populated with capacitors, microprocessors and various size resistors and connectors. Additionally, the substrate included pluggable press fit cages or shields with a nickel silver coating. Reference Figures 1 and 2.

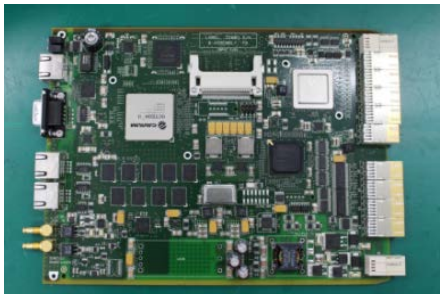

Figure 1 - PCB Side 1

Figure 2 – PCB Side 2

It should be noted that it was critical to maintain the integrity of the shield material throughout the manufacturing process. As doubled-sided substrates, they were passed through reflow and wave consecutively, and then cleaned employing the current cleaning process. As this system had been satisfactorily used for many years, plant personnel planned to use this system to meet the cleaning challenges of the new substrate.

Utilizing the alkaline cleaning agent at 15% concentration and a belt speed of 0.5 ft/min, two passes through the cleaner were required due to the resulting burnt-in fluxes from multiple heat cycles. However, even as they were able to clean the substrates, the surface of the shields became degraded. Thus, a new cleaning process was required. Furthermore, as the initial cleaning trials progressed, a second material compatibility issue developed as a result of an additional assembly step. A third party sourced subassembly with a polyurethane conformal coating had to be added to the main substrate, prior to the cleaning process. As the customer attempted multiple wash cycles to achieve the desired cleanliness level, the added wash time also affected the conformal coating causing peeling.

The customer partnered with the company and developed a two part Design of Experiment (DOE) to resolve both material compatibility issues.

- Part 1: Utilizing their current cleaning system, identify an alternate aqueous based cleaning agent and utilizing the customers current cleaner, develop the process parameters to achieve the desired cleaning results without degrading shield coating.
- Part 2: Utilizing the cleaning process parameters developed in Part 1, assess the compatibility of the selected cleaning agent with conformal coating materials recommending an optimum solution.

Part 1: Design of Experiment
The DOE was based on utilizing the current inline cleaning system. Based on the material compatibility issues identified, a pH neutral cleaning agent was selected for the initial trials.

Preliminary cleaning trials were conducted in the customer plant utilizing the pH neutral cleaning agent. Optimum parameters were developed as detailed in Table 1.

Table 1 – Preliminary Cleaning Trial Parameters

Wash Stage	
Equipment	Inline spray-in-air cleaner
Cleaning Agent:	pH neutral micro phase
Concentration:	20%
Conveyor Belt Speed	0.5 ft/min
Wash Pressure (Top/Bottom)	65 PSI / 65 PSI
Wash Temperature	145°F / 62.78°C
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Temperature	101°F / 38.33°C
Drying Stage	
Drying Method	Hot Circulated Air, 102°F-111°F / 38.89°C-43.89°C

Utilizing these conditions, three production boards were cleaned and sent to the company technical center in Manassas, VA, for a cleanliness assessment. The boards were analyzed through visual inspection and ion chromatography. The inspected boards were returned to the customer for functional tests.

Part 1: Visual Inspection Results

Visual inspection was conducted following IPC-A-610E. All of the boards were found to be fully cleaned. Reference Figures 3 – 6.

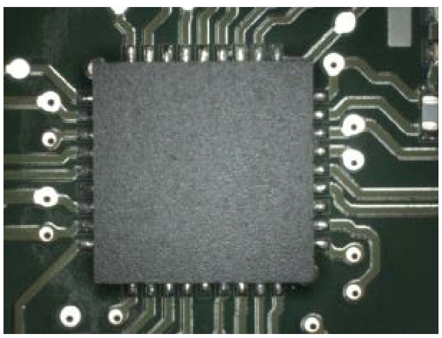

Figure 3 – Bottom

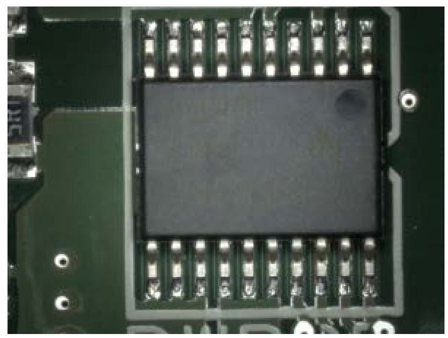

Figure 4 – Bottom

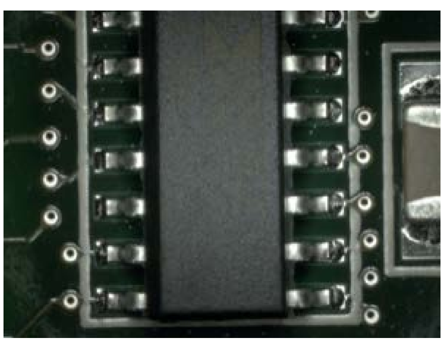

Figure 5 – Top

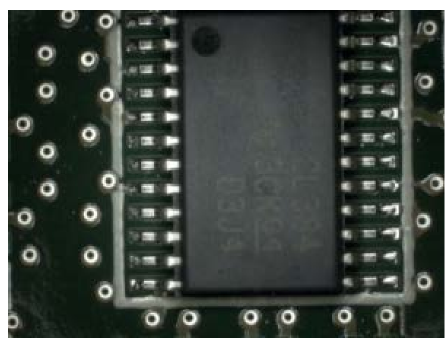

Figure 6 – Top

Shield surface was unaffected. Reference Figures 7 and 8.


Figure 7 – Top


Figure 8 – Top

As indicated through visual inspection, the substrate top and bottom surfaces were fully cleaned and the surfaces of the shields were left unaffected, therefore found to be fully compatible with the pH neutral cleaning agent.

Part 1: Ion Chromatography Results

Ion chromatography was conducted on all three boards per IPC-TM-650, Method 2.3.28.2. Results are detailed in Table 2.

Table 2

Anion Species Always Tested For (µg/in^2)				
Ionic Species	Maximum Contamination Limits	Board 1	Board 2	Board 3
Fluoride (F^-)	3	0.0148	0.0178	0.0153
Acetate ($C_2H_3O_2^-$)	3	0.3749	ND	ND
Formate (CHO_2^-)	3	ND	ND	0.0357
Chloride (Cl^-)	4	0.5925	0.2348	0.1932
Nitrite (NO_2^-)	3	0.1598	0.1082	0.1413
Bromide (Br^-)	10	0.6862	0.4264	0.6217
Nitrate (NO_3^-)	3	0.0098	0.0558	0.0226
Phosphate (PO_4^{2-})	3	0.0095	0.0083	0.0003
Sulfate (SO_4^{2-})	3	0.0003	0.0034	0.0021
WOA (Weak Organic Acid)	25	8.0331	7.1004	5.8772
Cation Species Always Tested For (µg/in^2)				
Lithium (Li^+)	3	ND	ND	ND
Sodium (Na^+)	3	0.8571	0.6789	0.7387
Ammonium (NH_4^+)	3	0.2105	0.2624	0.2338
Potassium (K^+)	3	0.2446	0.1061	0.1706
Magnesium (Mg^{2+})	1	ND	ND	ND
Calcium (Ca^{2+})	1	ND	ND	ND

ND – Not Detected 0 – Blank value is higher than sample value

All boards passed further validating that the cleanliness level desired was achieved with the pH neutral cleaning process. The boards were returned to the customer and found to be fully functional.

Part 2: Design of Experiment

Following Part 1 trials and cleanliness assessments, the customer was satisfied that the pH neutral cleaning process could result in achieving the desired cleanliness levels for the new substrates and is fully compatible with all materials used. Within Part 2 of the DOE, they assessed the compatibility of the optimized cleaning process with conformal coating materials.

Three coating types were compared for the initial compatibility analysis. These were parylene, acrylic and polyurethane. Based on internal tests conducted at the company R&D Center, parylene coating was found to be most compatible with the pH neutral cleaning agent. Thus, the next step was to coat substrates with the parylene and evaluate compatibility within the customers cleaning process utilizing the operating conditions identified in Part 1.

In this case, the substrate used was an unpopulated company test vehicle. Reference Figure 9.

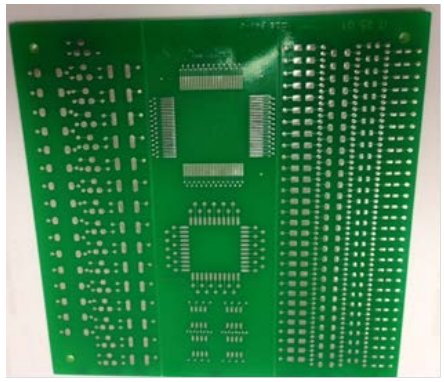

Figure 9

Three test boards were sent to the coating supplier for the parylene application. Each board was coated with a 33 µm layer of parylene-based conformal coating material. The boards were returned to the company technical center where they were subjected to a cleaning process utilizing an inline cleaner, similar to the one used by the customer, and operated with the same parameters as defined in Part 1. However, in this case, the boards were passed through the cleaner twice. Following the cleaning process, they were visually inspected under high magnification following the IPC-A-610E.

Part 2: Parylene Coating Visual Inspection Results

Based on the visual inspection results of the coated test vehicle following the first and second pass through the inline cleaner, the coating was found to be intact. Reference Figures 10 – 13.

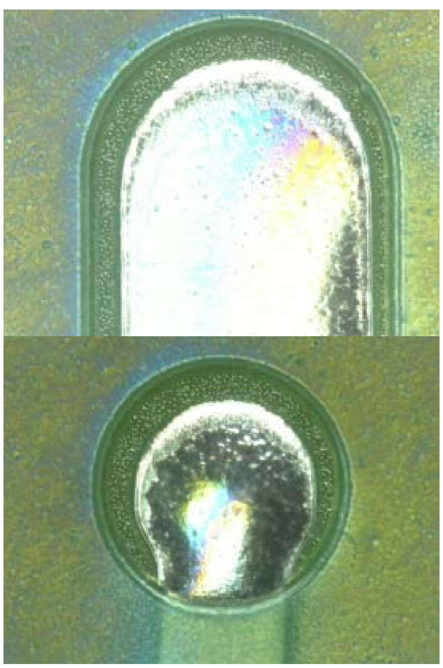

Figure 10 - Before

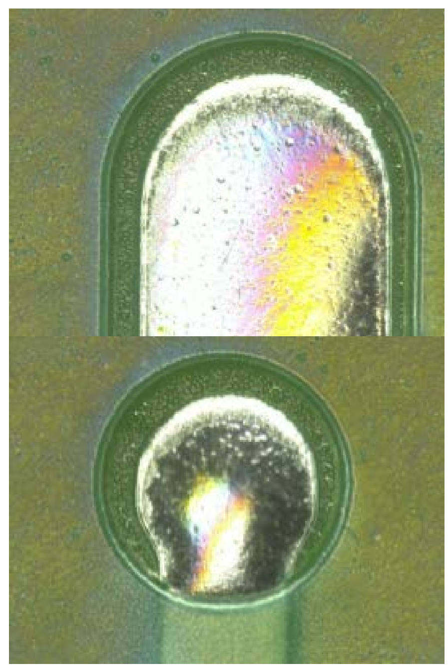

Figure 11 - After (1 pass)

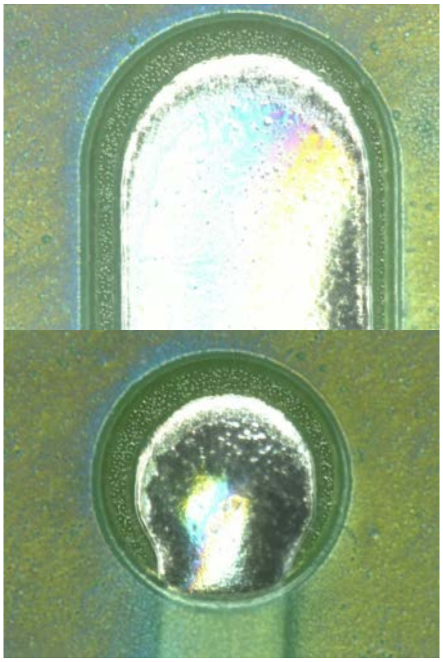

Figure 12 - Before

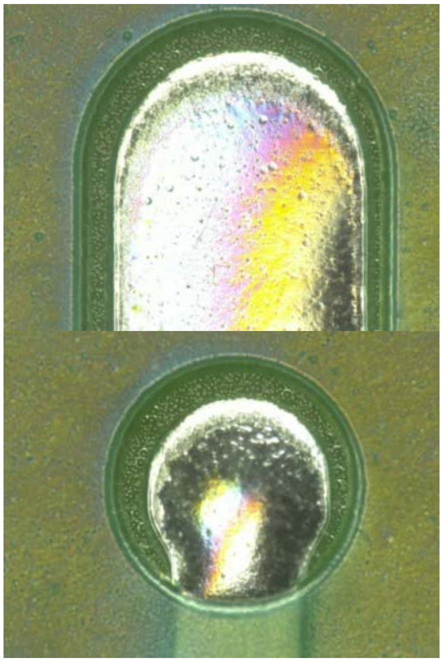

Figure 13 - After (2 pass)

Conclusions

The pH neutral cleaning process identified through the Part 1 cleaning trials resulted in:

- Fully cleaned the double-sided substrates assembled with lead-free solder paste and flux utilizing the customer's current spray-in-air inline cleaner, and optimized for the pH neutral cleaning agent
- Exhibited excellent material compatibility with the nickel silver shield coating
- Exhibited excellent material compatibility with the parylene conformal coating

Case Study Review – Customer B

Customer B is a value-added electronic manufacturing service provider to some of the world's leading OEMs. They specialize in PCBA and full product assembly, plastic molding, precision metal stamping, fabrication and finishing, and engineering services with products ranging from simple consumer devices to complex, high end commercial and industrial electro-mechanical products.

They had an opportunity to qualify a new manufacturing process for a high reliability electronic assembly for a medical application. The SMT process utilized No Clean solder paste and flux that required cleaning for which the customer planned to utilize an aqueous based inline cleaning process. In addition to sensitive materials on the substrate surface, the new process included the use of anodized aluminum carriers to hold the substrates as they are conveyed through the cleaner. Thus, a cleaning agent with excellent material compatibility was required.

The customer collaborated with the company to develop the cleaning process for their qualification. Based on the process and material compatibility requirements, a pH neutral aqueous based cleaning agent was selected.

Design of Experiment

The customer substrate was designed as a panel and each panel included 18 boards. Uncleaned substrates, double-sided and populated, and pallets were provided to the company for the initial cleaning trials. In total, six (6) panels and twelve (12) boards were provided for the evaluation. Reference Table 3. A spray-in-air inline cleaner was selected for the cleaning process.

Table 3

Substrate Type	Quantity
Main Board	5 Panels
Speculum Board	1 Panel
Scrap Boards	12 Boards

The Main and Speculum boards are part of the same assembly and the name is used for reference only. Cleanliness was assessed as follows:

- Visual inspection per IPC-610E Standard: before and after cleaning
- Ionic contamination analysis per IPC-TM-650
- Ion chromatography analysis per IPC-TM-650; Method 2.3.28

The boards and panels were utilized as detailed in Table 4.

Table 4

Test #	Parts Cleaned	Quantity	Pallet Used	Post Cleaning Analysis
1	Scrap boards	6	Yes	- Visual inspection (2) - Ionic contamination (4)
2	Scrap boards	6	No	Visual inspection
3	Main Board Panel	1	No	Ion chromatography
	Speculum Board Panel	1	No	Ionic contamination
	Main Board Panel	1	Yes	Customer B will conduct analysis
4	Main Board Panel	3	Yes	Customer B will conduct analysis

All panels were passed through the inline cleaner utilizing the anodized aluminum carriers. The carriers were inspected for surface integrity following the cleaning process.

With regard to the cleaning process, initial screening trials confirmed that the pH neutral cleaning agent used at 10% concentration and 145°F wash temperature would be sufficient to clean the substrates. The optimized inline cleaner operating parameters are detailed in Table 5.

Table 5

Wash Stage	
Equipment	Inline cleaner
Cleaning Agent Type	pH neutral micro phase
Cleaning Agent Concentration	10%
Conveyor Belt Speed	1.5 ft/min
Wash Temperature	145°F / 62.7°C
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Temperature	145°F / 62.7°C
Drying Stage	
Drying Method	Hot circulated air, 160°F (D1), 230°F (D2), 240°F (D3)

Results: Visual Inspection

Utilizing the inline cleaner with the operating parameters as detailed in Table 5, all boards and panels were cleaned in one pass. Reference Figures 14 – 25 for before and after cleaning comparisons.

Figure 14 – Before Cleaning

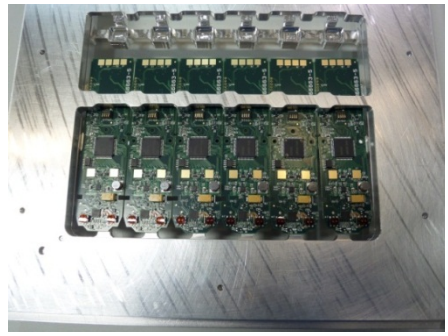

Figure 15 – After Cleaning

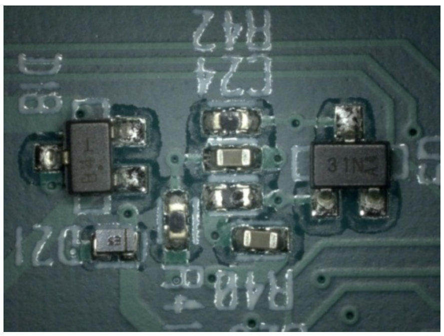

Figure 16 – Before Cleaning

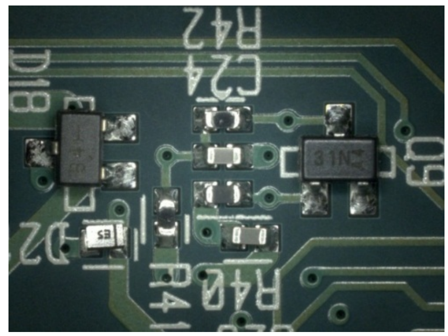

Figure 17 – After Cleaning

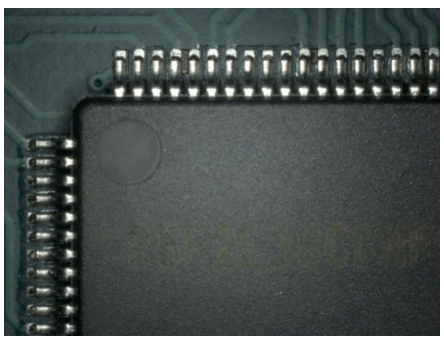

Figure 18 – Before Cleaning

Figure 19 – After Cleaning

Figure 20 – Before Cleaning

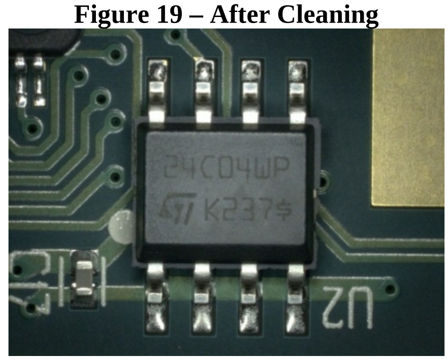

Figure 21 – After Cleaning

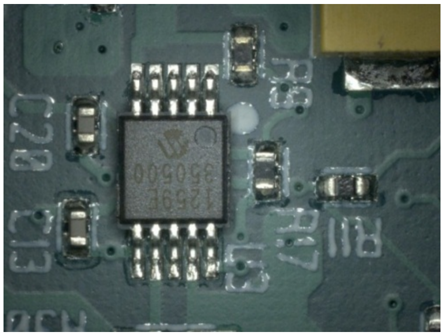

Figure 22 – Before Cleaning

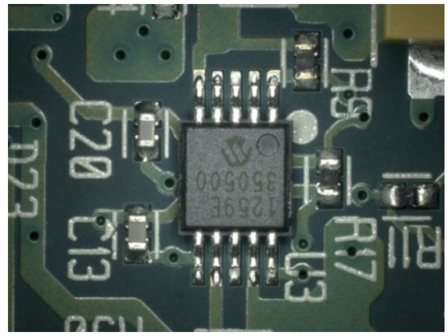

Figure 23 – After Cleaning

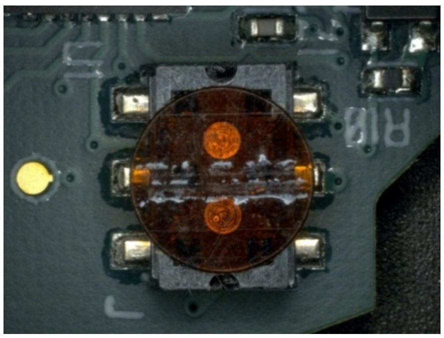

Figure 24 – Before Cleaning

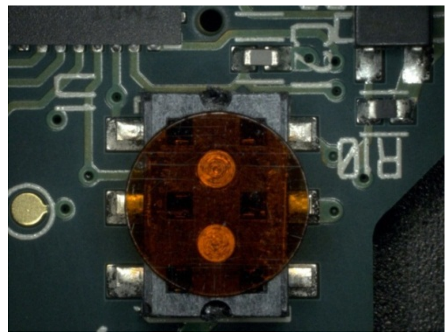

Figure 25 – After Cleaning

Ionic Contamination Test Results

For the ionic contamination test procedure, four (4) of the scrap boards were used. These were tested before and after the cleaning process. As expected, there is a significant difference in the results following the cleaning process. The Speculum board was also tested but only following the cleaning process. This board passed as well. Reference Table 6.

Table 6

Test #	Part Type	Quantity	Pass/Fail Limit	Ionic Contamination Value
1	Scrap Boards (before cleaning)	4	10.06 µg/in^2	2.21 µg/in^2
2	Scrap Boards (after cleaning)	4	10.06 µg/in^2	0.46 µg/in^2
3	Speculum Board Panel (after cleaning)	1	10.06 µg/in^2	0.03 µg/in^2

Ion Chromatography Results

One (1) panel was cleaned and used for ion chromatography analysis. The results are detailed in Table 7.

Table 7

Anion Species Always Tested For (µg/in^2)		
Ionic Species	**Maximum Contamination Levels**	**Panel**
Fluoride (F^-)	3	0.0056
Acetate ($C_2H_3O^-_2$)	3	ND
Formate (CHO^-_2)	3	ND
Chloride (Cl^-)	3	0.0245
Nitrite (NO_2^-)	3	1.0808
Bromide (Br^-)	10	0.4468
Nitrate (NO_3^-)	3	0.1549
Phosphate (PO_4^{2-})	3	ND

Sulfate (SO_4^{2-})	3	1.9182
WOA (Weak Organic Acid)	25	ND
Cation Species Always Tested For (µg/in^2)		
Lithium (Li^+)	3	ND
Sodium (Na^+)	3	0.9469
Ammonium (NH_4^+)	3	0.0969
Potassium (K^+)	3	0.8826
Magnesium (Mg^{2+})	1	0.6719
Calcium (Ca^{2+})	1	0.5885

ND – Not Detected 0 – Blank value is higher than sample value

As detailed in Table 7, the board passed the ion chromatography test as the ion species were below the maximum recommended contamination level.

Conclusion

The pH neutral cleaning agent:

- Successfully cleaned all substrates
- Exhibited excellent material compatibility with all substrate components as well as the anodized aluminum carriers
- Required 10% concentration 1.5 ft/min belt speed and 145°F wash temperature minimizing operating costs

Case Study Review – Customer C

Customer C is an OEM designing and manufacturing high-reliability electronic control systems for the aerospace and energy industry.

For one of their applications, substrates were manufactured with water soluble solder paste and flux and cleaned using a DI-water inline cleaner. Through visual inspection analysis, they confirmed that residues were left untouched underneath the low standoff components potentially leading to reliability issues. They wanted to explore the option of utilizing a water based engineered cleaning agent in order to increase the cleanliness level for the given substrates and preferred to use a batch cleaner due to plant space constraints.

However, if an aqueous based cleaning agent is used, it must be compatible with their component materials including anodized aluminum and olive drab cadmium. Also, given their geographic location, a closed loop rinse cycle is mandatory as rinse water cannot go directly to drain.

In collaboration with the company, a DOE was developed to explore the option of a chemically assisted cleaning process. Due to their requirements for material compatibility and a closed loop rinse cycle, a pH neutral cleaning agent was selected.

Design of Experiment

The DOE was divided into two parts with the following objectives:

- Part 1: Utilizing populated company test vehicles, the pH neutral cleaning agent and a batch cleaner, assess and optimize the process operating parameters to achieve the desired cleanliness level on the surface as well as underneath the components as measured by visual and ion chromatography analyses. Compare these results to those achieved with the customer's DI-water cleaning system.

- Part 2: Utilizing the equipment and optimized process parameters from Part 1, and the customer's test boards, assess cleanliness level achieved as measured by visual and ion chromatography analyses. Additionally, assess the effect of the cleaning agent on the sensitive materials.

Part 1: Methodology

Since the customer requirement included cleaning under low standoff components, the company test vehicle was used. Eight (8) boards were populated with chip capacitors (0402, 0603, 0805, SOT-23, 1206, 1210, 1812, and 1825) at the customer facility using the selected water soluble paste and flux. Reference Figure 26.

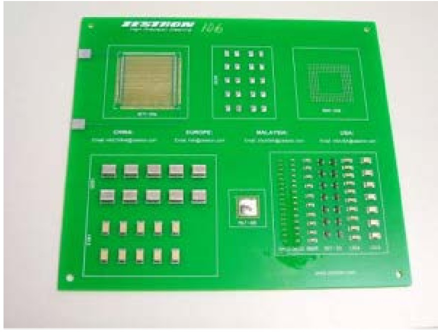

Figure 26

Two (2) of these boards were cleaned at the customer site using their current DI-water cleaning process. These boards were returned to the company technical center for cleanliness assessment, one each for undercomponent and ion chromatography assessment. The remaining six (6) boards were also returned for cleaning trials using the pH neutral cleaning process and cleanliness assessment.

Based on screening trials utilizing four (4) of the test boards, optimized operating parameters were defined and are detailed in Table 8. Two (2) additional boards were cleaned using these parameters and both were assessed for surface cleanliness. The components were removed from one (1) board to enable undercomponent cleanliness assessment and the other used for ion chromatography analysis.

The optimized process parameters are detailed in Table 8.

Table 8

Cleaning Process	**Cleaner**
Equipment	Batch cleaner
Cleaning Agent Type	pH neutral micro phase
Cleaning Agent Concentration	10%
Cleaning Time	15 min.
Cleaning Temperature	140°F / 60°C
Rinse	
Rinsing Agent	DI-water
Rinse Temperature	Room Temperature
Number Rinses Required	5 each with a dwell time of 20 seconds
Drying	
Drying Method	Hot Circulated Air
Drying Time / Temperature	15 min. / 150°F / 65.5°C

Table 9 – Visual Inspection Results

	DI-water Cleaned	**pH neutral Cleaned**
Surface Inspection	White residues remained	Fully cleaned
Undercomponent Inspection	Residues remained	Fully cleaned

Reference Figures 27 – 34 for undercomponent cleanliness comparison:

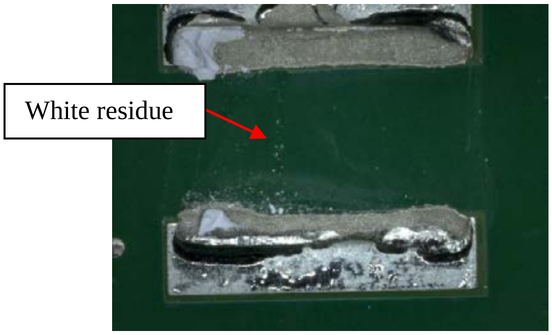

Figure 27 - Underneath 1825 Component After Cleaning using DI-water

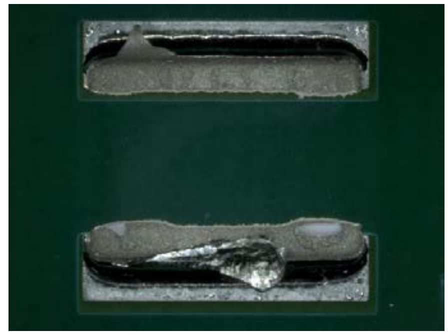

Figure 28 - Underneath 1825 Component After Cleaning using pH neutral

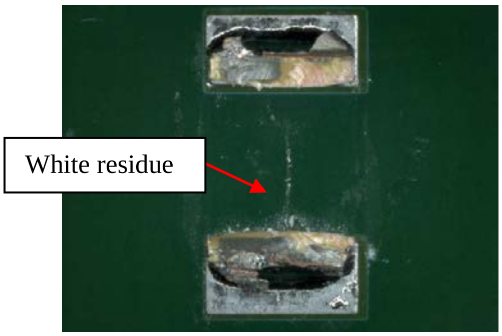

Figure 29 - Underneath 1812 Component After Cleaning using DI-water

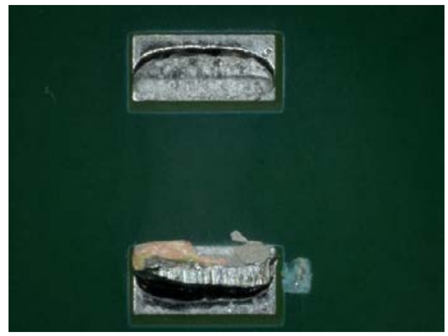

Figure 30 - Underneath 1812 Component After Cleaning using pH neutral

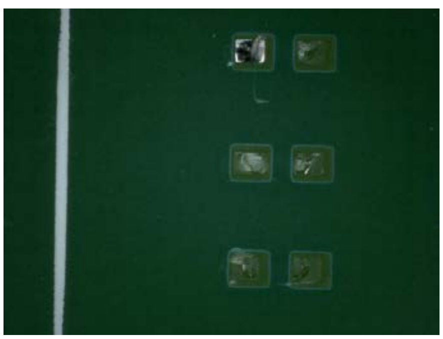

Figure 31 - Underneath 0402 Component After Cleaning using DI-water

Figure 32 - Underneath 0402 Component After Cleaning using pH neutral

Figure 33 - Underneath 0603 Component After Cleaning using DI-water

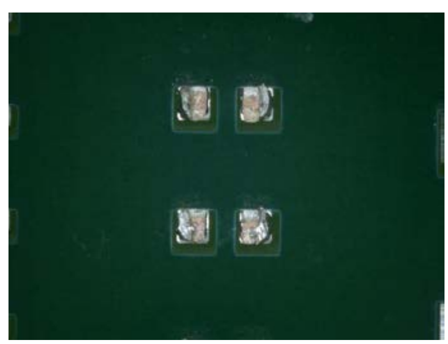

Figure 34 - Underneath 0603 Component After Cleaning using pH neutral

Part 1: Ion Chromatography Results

Two (2) boards were used for ion chromatography analysis, one cleaned with DI-water and another with the pH neutral cleaning agent. Results are detailed in Table 10.

Table 10

Anion Species Always Tested For (µg/in^2)			
Ionic Species	**Maximum Contamination Limits**	**DI-water Cleaned**	**pH neutral Cleaned**
Fluoride (F^-)	3	0.11	0.03
Acetate ($C_2H_3O_2^-$)	3	1.94	1.13
Formate (CHO_2^-)	3	ND	ND
Chloride (Cl^-)	4	0.92	0.68
Nitrite (NO_2^-)	3	ND	ND
Bromide (Br^-)	10	0.25	0.22
Nitrate (NO_3^-)	3	0.04	0.13
Phosphate (PO_4^{2-})	3	0.35	0
Sulfate (SO_4^{2-})	3	0	0
WOA (Weak Organic Acid)	25	ND	ND
Cation Species Always Tested For (µg/in^2)			
Lithium (Li^+)	3	0	0
Sodium (Na^+)	3	0	0
Ammonium (NH_4^+)	3	0.14	0.05
Potassium (K^+)	3	0.01	0.01
Magnesium (Mg^{2+})	1	0	0
Calcium (Ca^{2+})	1	0	0

ND – Not Detected 0 – Blank value is higher than sample value

Both boards passed the ion chromatography test for the ion species were below allowable maximum contamination levels. However, the total ionic contamination present on board cleaned with the pH neutral cleaning agent was less than what was present on the DI-water cleaned board. Additionally, the undercomponent assessment of the DI-water cleaned board confirmed that untouched flux residue remained under several components providing the opportunity for field reliability issues under use. Reference Figures 27 and 29.

Part 2: Methodology

Having confirmed that low standoff components can be fully cleaned on the surface as well as underneath the components, the customer provided with five (5) test boards for process assessment. Reference Figure 35.

Figure 35

Utilizing the same batch equipment and optimized parameters as used in Part 1, the boards were cleaned and assessed for cleanliness using visual and ion chromatography assessment.

The customer boards are double-sided thereby increasing the cleaning challenge. Thus, it was determined to increase the wash temperature to 150°F, as compared to 140°F as used in the Part 1 trials. All other batch cleaner operating parameters remained the same.

Part 2: Visual Inspection Results

All five (5) boards were cleaned using the optimized cleaning process. Surfaces were fully cleaned on all boards. Of the five (5) boards, one was used for ion chromatography analysis. Of the four (4) remaining boards, components were removed enabling undercomponent cleanliness assessment. Of the one hundred (100) components inspected, only four (4) components from two (2) boards had slight residue remaining while all others were fully cleaned underneath.

Table 11

Cleaning Results Underneath	Board # 101	Board # 102	Board # 103	Board # 104
C30	+	-	+	+
C41	+	+	+	+
C44	+	+	+	+
C48	+	+	+	+
C57	+	+	+	+
C58	+	+	+	+
C59	+	+	+	+
C82	-	+	+	+
R50	+	+	+	+
C122	+	+	+	+
C108	+	+	+	+
C101	+	+	+	+
C109	+	+	+	+
C96	+	+	+	+
C45	+	+	+	+
C42	+	+	+	+
C249	+	+	+	+
C280	+	+	+	+
C227	+	+	+	+
R205	+	+	+	+
C200	+	+	+	+
C152	+	+	+	+
C151	+	-	+	+
C165	+	-	+	+
C162	+	+	+	+

+ : Clean   - : Uncleaned

Reference Figures 36 to 43 for undercomponent post cleaning pictures.

Part 2

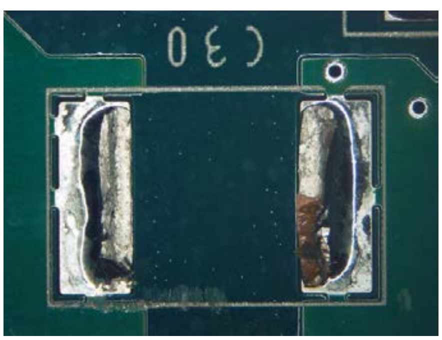

Figure 36 - Underneath C30

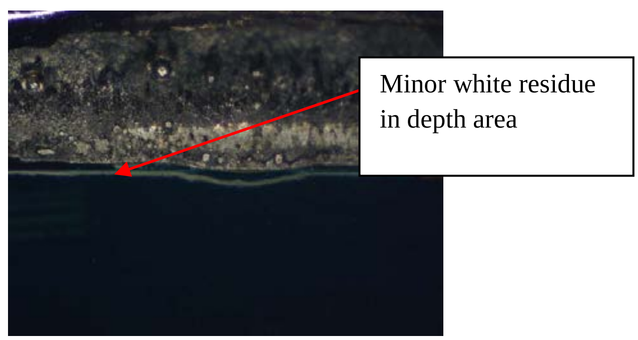

Figure 37 - Underneath C82

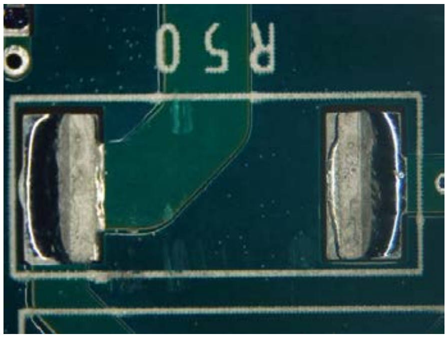

Figure 38 - Underneath R50

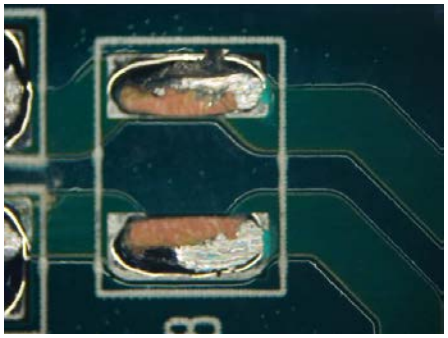

Figure 39 - Underneath C108

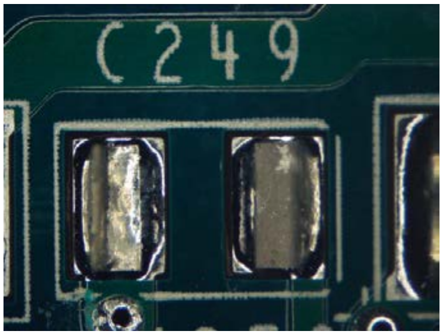

Figure 40 - Underneath C249

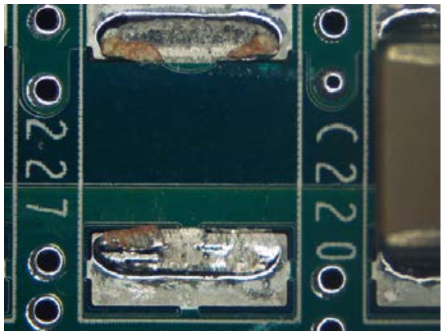

Figure 41 - Underneath C227

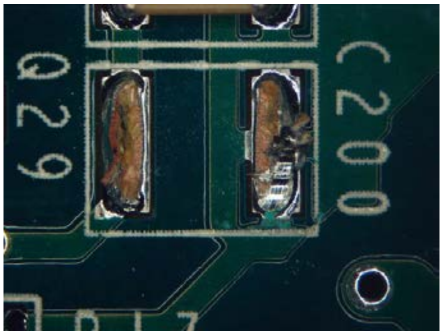

Figure 42 - Underneath C200

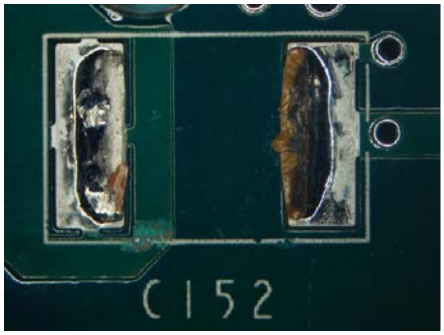

Figure 43 - Underneath C152

Part 2: Ion Chromatography Results

Table 12

Anion Species Always Tested For (µg/in^2)		
Ionic Species	**Maximum Contamination Limits**	**Board # 105**
Fluoride (F^-)	3	0.32
Acetate ($C_2H_3O_2^-$)	3	ND
Formate (CHO_2^-)	3	ND
Chloride (Cl^-)	4	0.48
Nitrite (NO_2^-)	3	ND
Bromide (Br^-)	10	0.97
Nitrate (NO_3^-)	3	0.41
Phosphate (PO_4^{2-})	3	ND
Sulfate (SO_4^{2-})	3	ND
WOA (Weak Organic Acid)	25	ND
Cation Species Always Tested For (µg/in^2)		
Lithium (Li^+)	3	ND
Sodium (Na^+)	3	0
Ammonium (NH_4^+)	3	0
Potassium (K^+)	3	0
Magnesium (Mg^{2+})	1	ND
Calcium (Ca^{2+})	1	ND

ND – Not Detected 0 – Blank value is higher than sample value

The sample board passed the ion chromatography test. The ion species were below allowable maximum contamination levels.

Conclusions

The pH neutral cleaning agent:

- Provided excellent cleaning results on the surface and underneath the components with an optimized batch cleaning system
- Exhibited excellent material compatibility with anodized aluminum and olive drab cadmium material
- Required 10% concentration 1.5 ft/min belt speed and 150°F wash temperature minimizing operating costs

Overall Conclusions

As reviewed in the background and introduction of this study, pH neutral cleaning agents held the promise of offering superior material compatibility and excellent cleaning results as compared to the inhibited alkaline cleaning agents currently available for various paste and flux residues. In this study, three case studies were presented, each with a different paste/flux vehicle and material compatibility constraints whereby a pH neutral process cleaning solution was identified as follows:

Customer A:

- Situation:
  - Lead-free solder paste and flux system producing double-sided substrates
  - Currently using an alkaline cleaning agent in spray-in-air process
  - Material compatibility issues with nickel/silver plating and conformal coating
- Resolution:
  - pH neutral cleaning agent optimized within their current cleaning process at 20% concentration and 145°F wash temperature
  - Desired cleanliness level achieved; fully compatible with nickel/silver plating and conformal coating

Customer B:

- Situation:
  - No Clean solder paste and flux system producing double-sided substrates
  - Required to qualify a cleaning process for the new substrate without degrading the anodized aluminum carriers
- Resolution:
  - pH neutral cleaning agent optimized for an inline cleaning process at 10% concentration and 145°F wash temperature
  - Qualified the new cleaning process
  - Desired cleanliness level achieved; fully compatible with substrate components and anodized aluminum carriers

Customer C:

- Situation:

- Water soluble paste and flux system
- Utilizing a DI-water inline cleaning process; residues remain under components
- Substrate components included anodized aluminum and olive drab cadmium
- Required alternate cleaning system with improved performance without degrading component surface materials; preferred batch cleaning process

- Resolution:
  - pH neutral cleaning agent optimized for a batch cleaning process at 10% concentration and 150°F wash temperature
  - Desired cleanliness level achieved; able to meet their environmental requirement for closed loop rinse cycle.

In summary, pH neutral cleaning agents can in fact meet the stringent cleaning requirements expected, even with burnt-in flux residues from multiple heat cycles, while exhibiting excellent material compatibility and with lower wash concentrations as compared to alkaline alternatives. Additionally, it is environmentally friendly eliminating the need for waste water neutralization.

References

[1] Dr. Harald Wack, "Benchmark Study: pH-Neutral vs. Alkaline Cleaning Agents," Proceedings of SMTA International, October 2010

[2] Michael and Irene Ash, "Handbook of Corrosion Inhibitors," Synapse Information Resources, Inc., 2001.

[3] "Cleanliness and Corrosion Mitigation," ACI Technologies, Inc., *Circuits Assembly*, April 2010.

[4] Dr. Harald Wack, Umut Tosun, Dr. Joachim Becht, Dr. Helmut Schweigart, "Why Switch from Pure DI-Water to Chemistry?" SMTA International 2009.