Jet Printed Solder Paste and Cleaning Challenges

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Abstract

In case of broadband technology, component packages and other devices assembled on the PCBs are ever-shrinking, yet demands for quality, precision and reliability remain the same. Thus, how can manufacturers ensure they are sufficiently clean to meet the stringent quality and reliability demands?

It has been well documented that flux residues can lead to failure mechanisms such as leakage current, electrochemical migration and dendritic growth and these can negatively impact the reliability of the PCBs. This is especially true in the case of Class 3 assemblies wherein failure is not an option.

Recent evidence has shown that it is becoming extremely challenging to consistently deliver the correct amount of solder using the screen printing process. More and more manufacturers in today's production environment are overcoming this challenge by incorporating jet printing as an additional add-on step to add extra solder paste volume to solve such challenges. Solder paste jetting offers the flexibility to deposit the right amount of solder paste volume on the boards that have both miniature and large size components that need to be soldered adjacent to each other.

Typically, jet printing pastes use Type 5 and 6 solder powder compared to Type 3 and 4 usually seen in screen printing processes. This poses several cleaning challenges.First, the presence of oxide for a given solder volume increases exponentially as solder powder becomes finer. Second, jetting pastes typically have a higher flux percentage than printed paste for the same volume and finally, the flux volume decreases in proportion to the pad size and the work load of flux increases for finer pitch applications.

Recent findings have shown that solder pastes with reduced metal content and finer powder soldered via jet printing process (Type 5 and 6) results in cleaning challenges as compared to pastes soldered via stencil printing process (Type 3 and 4). Cleaning process settings that produced acceptable results for Type 3 and 4 pastes may produce insufficient results for Type 5 and 6 pastes.

Anecdotal evidence with current industry companies indicates that as solder powder becomes finer, the resulting flux residues become more difficult to remove. This paper is part of an initial study executed specifically on jet printing (Type 5) solder pastes using multiple cleaning agents in both spray-in-air inline and batch cleaning systems. The results are further validated by several industry case studies.

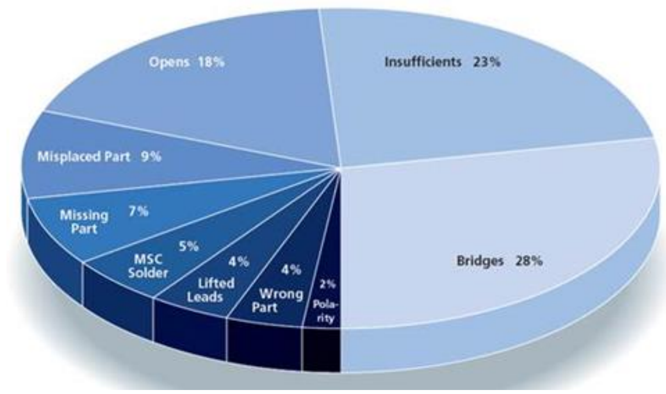
Keywords:

Screen Printing, Jet Printing, Jet Printed Solder Paste, Cleanliness Assessment

Introduction

Within an SMT production process, most industry professionals would agree that solder paste printing is the most critical step. Many of the defects in circuit board assembly, such as excess solder or insufficient solder volumes, are a direct result of the solder paste printing process. Today, the solder paste deposition process is accomplished by printing, dispensing or most recently by jetting.

Even though metal stencil solder paste printing is a mature process, it remains the part of the assembly process that has the biggest impact on the soldering result. In a well-adjusted process, stencil printing is often regarded as the source for approximately 70% of soldering defects. Reference Figure 1.



Solder defects found after reflow, of which insufficient solder, open joints and bridges most often depend on the result of the stencil printing process.[1]
Figure 1: Commonly Found Solder Defects

The solder paste stencil printing process is certainly the most widely used process particularly for high volume mass production assemblies in surface mount manufacturing process. However, the limitations or difficulties of the screen printing process is realized as PCB designs have become more challenging. This results from complex component geometries that have reduced conductor spacing, the use of non-planar or multilayered boards, and the placement of varying size components right next to each other.

Needle dispensing has proven useful in overcoming some of the challenges of screen printing. However, with needle dispensing, fluid remains attached to the needle tip and substrate surface, while the robot mechanics traverse in the X, Y, and Z axes. Gravity and surface tension of the substrate are used to pull fluid away from the needle. By contrast with jet printing, when fluid is ejected from the jet nozzle, it detaches from the nozzle tip before contacting the substrate. Solder paste is delivered in certain volumes on the substrate to form individual dots, or combined to form lines or patterns. When moving from one dispense location to the next, it is not necessary to move the Z-axis, which saves a considerable amount of time [2].

Thus, the concept of jet printing is gaining market acceptance. Main reasons for this interest are high throughput/productivity of jetting, contactless material deposition, high volume precision and freely designable deposition patterns. Additionally, the jet printing process eliminates the need for stencils and underside wiping materials.This includes the use of step stencils for applications requiring 3D cavity printing. For boards having closely spaced components of varying sizes, jet printing technology can deposit the right solder volume for each specific component as it deposits paste by single dots.

Thus, jet printing can be used as an add-on tool complimenting the screen printing process in a high throughput/productivity environment. An industry leading OEM has demonstrated that mixing current pastes with jet printed paste has fully passed all qualification tests [2].In this way, jet printing technology can meet the demand of greater flexibility in modern electronics production without loss of throughput speed.

However, one drawback to jet printing is that it requires jettable solder pastes. What does this imply? Understanding the makeup of solder paste is critical to understanding the requirements of jettable solder paste. Essentially, solder paste is a suspension of solder particles in a flux-containing vehicle (Figure 2), in which the shape and size of the particles and the flow properties or rheology of the flux vehicle are matched to the method of paste application most appropriate to the design of the SMT assembly [3]. For typical solder pastes, the typical metal content is between 88 to 91% by weight, and about 30 to 70% by volume [4].

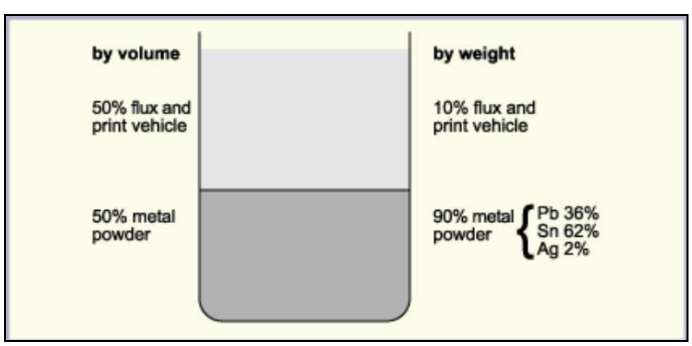


Figure 2: Constituents of a Typical Solder Paste

The metal solder particles are spherical as this helps to reduce surface oxidation and ensures good joint formation with the adjoining particles. Solder powder particle size is classified by IPC in accordance with J-STD 005 [5]. Reference Table 1.

Table 1:% of Sample by Weight: Nominal Size (in µm)

Type	Less than 0.5% larger than	10% max between	80% minimum between	10% maximum less than
1	160	150-160	75-150	75
2	80	75-80	45-75	45
3	60	45-60	25-45	25
4	50	38-50	20-38	20
5	40	25-40	15-25	15
6	25	15-25	5-15	5
7	15	11-15	2-11	2

For print applications, solder paste Types 3 and 4 are typically used. However, all jettable pastes are Type 5 and 6 with particles smaller than 30 µm. As identified in Table 1, Types 5 and 6 solder pastes are made with solder spheres that are smaller in diameter and thus the resulting solder powder is finer. With miniaturization advancing quickly for advanced packaging, solder powder used in paste materials also needs to get finer. As noted earlier, all solder pastes contain flux that facilitates flow behavior during the application process.

Printable pastes contain the lowest content of flux which is attributed to the robustness of the printing process. On the other hand, higher flux content seems to be needed to reach a constant flow through channels of different sizes during dispensing and jetting [5]. Thus, for jettable solder pastes the metal content can be reduced by about 10 wt.% meaning that flux content is increased by 10 wt.-%. As a result, a greater amount of flux residue may be present on the substrate surface or underneath components following heat cycle(s). Herein lies the challenge for the electronic assembly cleaning processes.

Aqueous-based cleaning agents are commonly used to remove post solder flux residues for all paste types whether it is no clean, rosin-based, synthetic or water soluble based. Anecdotal evidence suggests that an optimized aqueous based cleaning process for a given paste type may not produce the same results for the same process if the equivalent jettable solder paste is used. Given the higher flux content of the jettable solder paste, this is not surprising. Thus, a Design of Experiment (DoE) was developed to assess the cleaning requirements of five jettable solder pastes employing an aqueous-based cleaning system with a variety of engineered cleaning agents including pH neutral and alkaline inhibited and uninhibited cleaning agents.

Methodology

The main purpose of this study was to evaluate the cleaning efficiency of the industry standard aqueous-based defluxing agents on populated surface mount PCBs that are assembled with jet printable solder pastes. The visual inspection was carried out in accordance with current IPC standards, for cleanliness assessment. For this study, only surface and undercomponent inspection was evaluated. Other quantitative cleanliness assessment techniques were not included in this study since the study purpose was to strictly assess the efficacy of various cleaning agents on jettable solder pastes.

As undercomponent cleanliness assessment was the focus of the study, a test vehicle was selected and assembled with commonly used surface mount components using jet printable pastes at an equipment supplier having jet printing capability.The assembled boards were subsequently subjected to cleaning trials.

For the cleaning process, a spray-in-air conveyorized inline and batch cleaner were used with seven leading aqueous-based cleaning agent alternatives. Following cleaning, the boards were visually inspected for surface contamination. Additionally, all components were mechanically removed for visual inspection for undercomponent cleanliness.

Main Research

Five commonly used jettable solder pastes were selected. Reference Table 2.

Table 2: Solder Paste Selection

Solder Paste	Paste Type	Solder Type	Avg Size (µm)	Flux Content
1	Lead-Free No Clean	5	15~25	14%
2	Lead-Free No Clean	5	15~25	14%
3	Leaded No Clean	5	10~28	15±0.5%
4	Lead-Free No Clean	5	10~28	15
5	Leaded No Clean	5	15~25	13±0.5%

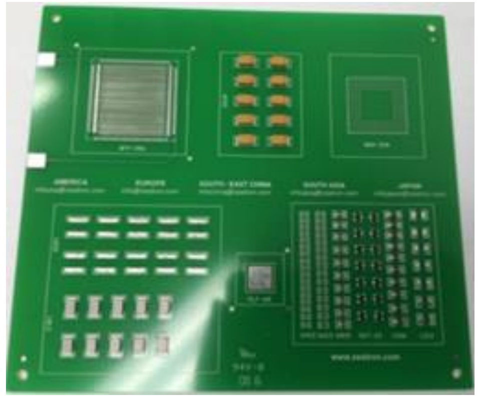


Figure 3: Test Vehicle

The test vehicle (Figure 3) used for all cleaning trials was populated with several commonly used low standoff surface mount components. In total,70 boards were populated (35 boards required for both batch and inline trials). Thus, two (2) boards were prepared for each paste type and each board was populated with a total of 86 componentsas per Table 3.

Table 3: Component Types

Component Type	No. of Components
6032	10
1812	10
0402	17
0603	15
0805	10
SOT-23	14
1206	10
Total Components	**86**

Leaded and lead-free reflow profiles were used as required as per Tables 4 and 5.

Table4: Leaded Profile, Belt Speed: 45 in./min.

Zone	1	2	3	4	5	6	7
Top(°C)	150	175	175	200	225	225	225
Bottom(°C)	150	175	175	200	225	225	225

Table 5:Lead-Free Profile: Belt Speed: 75 in./min.

Zone	1	2	3	4	5	6	7
Top (°C)	160	175	220	235	250	265	265
Bottom (°C)	160	175	220	235	250	265	265

Component standoff heights were measured to assess consistency of component placement. Reference Table 6.

Table 6: Component Standoff Heights

Component Type	Solder Paste Type	Overall Avg. (microns)	Overall Avg. (mils)
0402	1	25.81	1.03
	2		
	3		
	4		
	5		
0603	1	27.11	1.08
	2		
	3		
	4		
	5		
0805	1	30.32	1.21
	2		
	3		
	4		
	5		
1206	1	68.17	2.72
	2		
	3		
	4		
	5		
1812	1	85.39	3.41
	2		
	3		
	4		
	5		
6032	1	194.77	7.79
	2		
	3		
	4		
	5		
SOT-23	1	58.94	2.35
	2		
	3		
	4		
	5		

Figures 4 and 5 are representative pictures of the leaded and lead-free component standoff height.

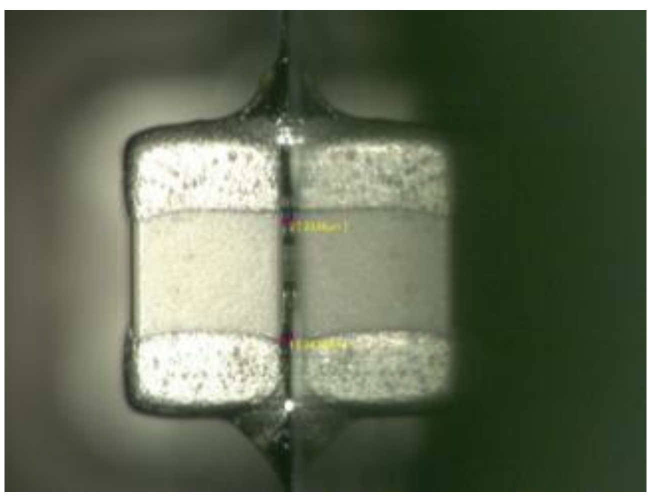


Figure 4:Paste A, Leaded (0402) Component Standoff Height

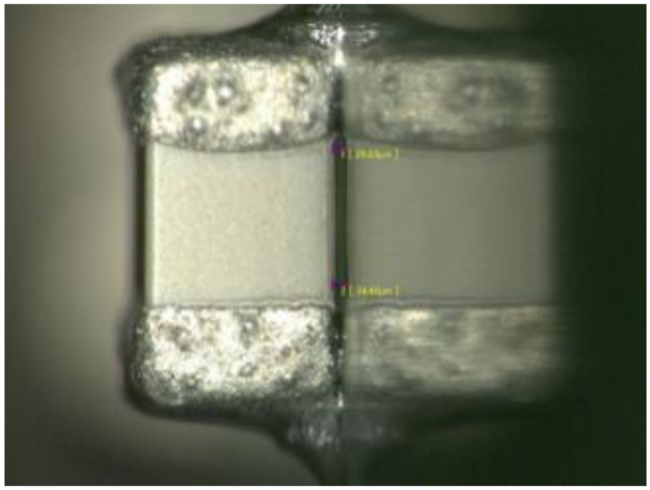


Figure 5:Paste B, Lead-Free(0402) Component Standoff Height

The inline cleaner was configured with a standard intermix spray bar configuration. For both the inline and batch cleaning trials, a 10% cleaning agent concentration was selected, with a wash time of 5.2 minutes (1 ft./min. inline conveyor belt speed) and 10 minutes for the inline and batch cleaner respectively. All cleaner operating parameters were maintained as constant for all trials as per Table 7 and 8. Test parameters established were designed to compare the cleaning results and not to achieve 100% cleanliness with each cleaning agent.

Table 7: Inline Cleaning Parameters

Wash Stage	
Cleaning Process	Spray-in-air conveyorized Inline Cleaner
Concentration	10% (by volume)
Conveyor Belt Speed	1 ft. /min.
Pre-Wash Pressure (Top/Bottom)	40 PSI / 40 PSI
Wash Pressure (Top/Bottom) [4 JIC + 4 V]	75 PSI / 60 PSI / 40 PSI / 40 PSI
Cleaning Temperature	150°F
Chem-Iso Pressure (Top/Bottom)	30 PSI / 30 PSI
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	75 PSI / 60 PSI / 40 PSI / 40 PSI
Rinsing Temperature	140°F
Final Rinse Pressure (Top/Bottom)	30 PSI / 30 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Dryer 1	160°F
Dryer 2	220°F
Dryer 3	220°F

Table 8:Batch Cleaning Parameters

Wash Stage	
Cleaning Process	Spray-in-air Batch Cleaner
Concentration	10% (by volume)
Wash Time	10 min
Cleaning Temperature	150°F
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Time	20 seconds
Rinse Cycles	6
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Time	15 min.
Drying Temperature	150°F

Seven aqueous-based engineered cleaning agents were selected as per Table 9.

Table9: Cleaning Agent Types

Cleaning Agent	Type
A	Non Surfactant Alkaline Inhibited
B	Non Surfactant Alkaline Uninhibited
C	Non Surfactant pH Neutral Inhibited
D	Non Surfactant pH Neutral Inhibited
E	Dynamic Surfactant Uninhibited
F	Dynamic Surfactant Inhibited
G	Dynamic Surfactant Inhibited

Cleanliness assessment by visual inspection was conducted on the board surface and under the component. Visual inspection was performed in accordance with IPC-A-610 utilizing a microscope at 40x viewed vertically at a slanted angle. A polarized filter was used to improve the contrast during inspection. Each board was inspected by three different application engineers, independent of each other,and the results were averaged for each board.

For the undercomponent cleanliness evaluation, all components were sheared from the boards and the visual inspection rating criteria was reported aseither fully cleaned or not cleaned. The evaluations from the three engineers were recordedand for each board were averaged and reported for each cleaning agent and solder paste type.

The percent undercomponent cleanliness per board calculation is shown in Figure 6.

$$\textbf{Avg. undercomponent cleanliness} = \frac{\textbf{No. of components fully cleaned}}{\textbf{Total No. of components}}$$

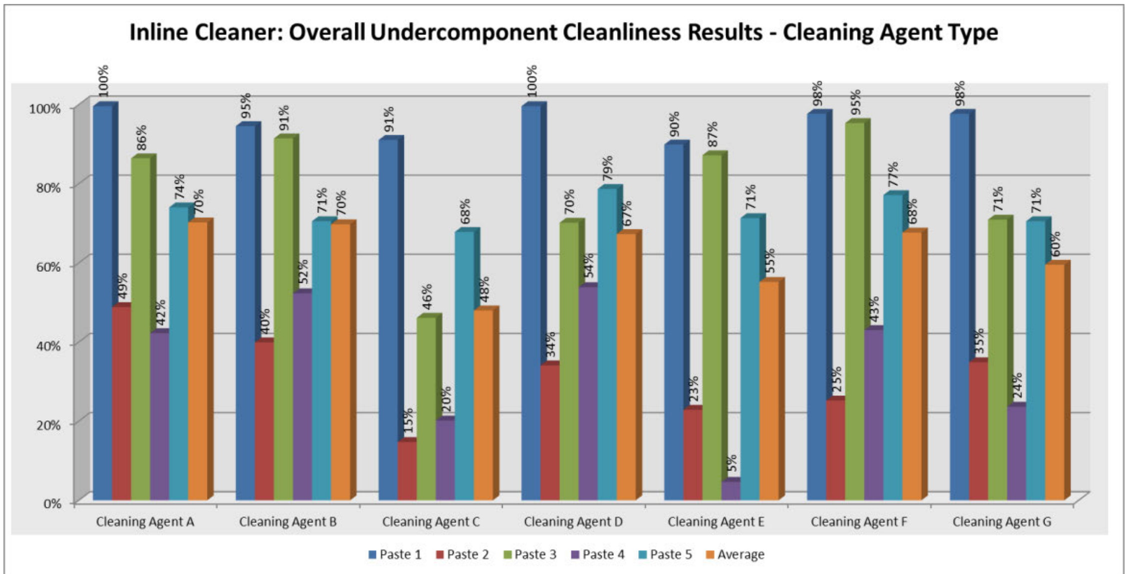
Figure 6: Percentage Under Component Cleanliness Calculation

Inline Cleaner Results

The results for undercomponent cleaning results with the inline cleaner are shown in Tables 10 and 11 and Figures 7 to 9.

Table 10: Inline Cleaner, Overall UnderComponent Cleanliness Results for All Cleaning Agents

	Cleaning Agent A	Cleaning Agent B	Cleaning Agent C	Cleaning Agent D	Cleaning Agent E	Cleaning Agent F	Cleaning Agent G	Average
Paste 1	100%	95%	91%	100%	90%	98%	98%	96%
Paste 2	49%	40%	15%	34%	23%	25%	35%	32%
Paste 3	86%	91%	46%	70%	87%	95%	71%	78%
Paste 4	42%	52%	20%	54%	5%	43%	24%	34%
Paste 5	74%	71%	68%	79%	71%	77%	71%	73%



Average	70%	70%	48%	67%	55%	68%	60%	63%

Figure 7: Inline Cleaner, Overall Cleanliness Undercomponent Results by Cleaning Agent Type

Table 11:Inline Cleaner,Overall Cleanliness UnderComponent Results by Component Type

		Cleaning Agent A	**Cleaning Agent B**	**Cleaning Agent C**	**Cleaning Agent D**	**Cleaning Agent E**	**Cleaning Agent F**	**Cleaning Agent G**
10% Inline	**6032**	100%	100%	84%	82%	83%	80%	98%
	1812	58%	59%	17%	45%	63%	60%	31%
	0402	100%	100%	67%	98%	56%	99%	92%
	0603	83%	77%	47%	96%	67%	68%	68%
	0805	22%	19%	23%	25%	28%	42%	23%
	SOT-23	64%	68%	59%	60%	62%	67%	60%
	1206	41%	42%	22%	32%	17%	37%	18%

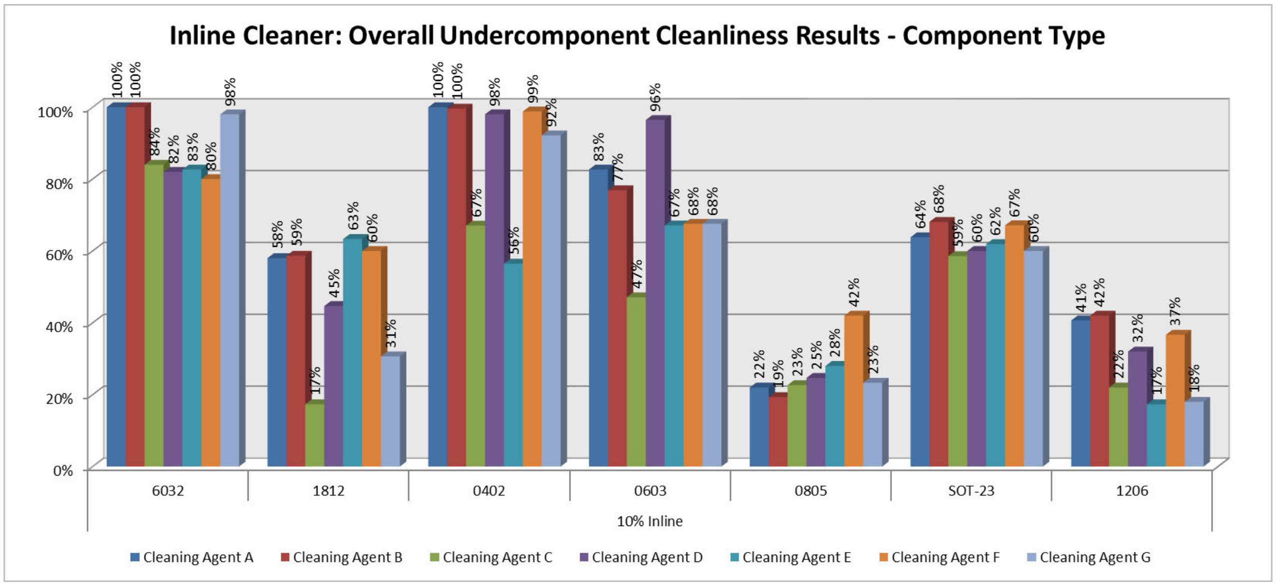


Figure 8: Inline Cleaner, Overall Under Component Cleanliness Results by Component Type

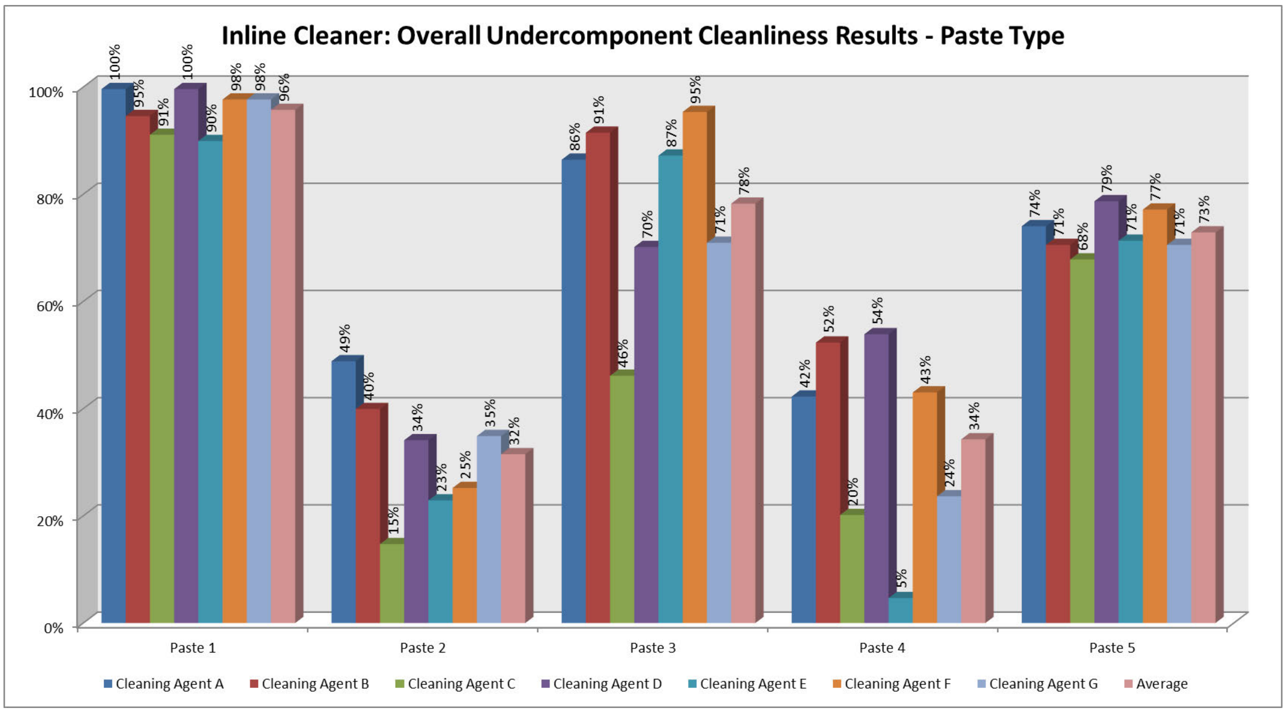


Figure 9:Inline Cleaner,Overall UnderComponent Cleanliness Results by Paste Type

Batch Cleaner Results

The undercomponent cleaning results with the batch cleaner are shown in Tables 12 and 13 and Figures 10 to 12.

Table 12: Batch Cleaner, Overall UnderComponent Cleanliness Results for All Cleaning Agents

	Cleaning Agent A	Cleaning Agent B	Cleaning Agent C	Cleaning Agent D	Cleaning Agent E	Cleaning Agent F	Cleaning Agent G	Average
Paste 1	99%	98%	97%	97%	97%	84%	99%	96%
Paste 2	35%	54%	36%	54%	48%	19%	63%	44%
Paste 3	89%	95%	82%	86%	95%	99%	91%	91%
Paste 4	80%	46%	87%	67%	50%	55%	63%	64%
Paste 5	82%	59%	90%	74%	74%	81%	73%	76%
Average	77%	71%	78%	76%	73%	67%	78%	74%

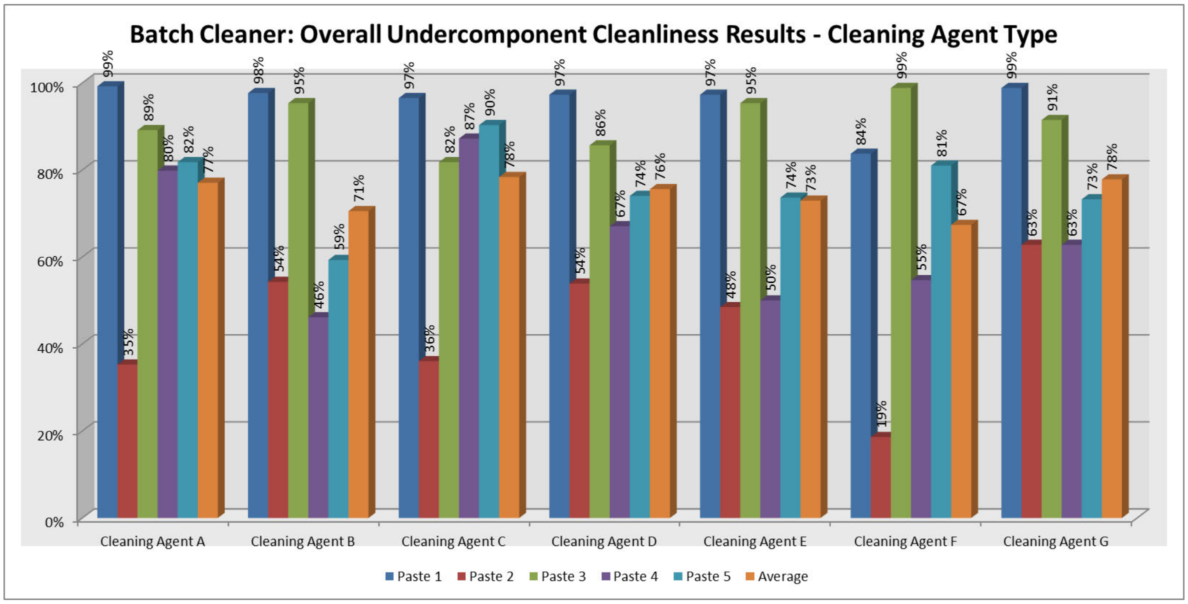


Figure 10: Batch Cleaner, Overall Under Component Cleanliness Results by Cleaning Agent Type

Table 13: Batch Cleaner, Overall Under Component Cleanliness Results by Component Type

		Cleaning Agent A	**Cleaning Agent B**	**Cleaning Agent C**	**Cleaning Agent D**	**Cleaning Agent E**	**Cleaning Agent F**	**Cleaning Agent G**
10% Batch	6032	79%	71%	79%	96%	85%	63%	99%
	1812	54%	60%	65%	59%	55%	41%	51%
	0402	100%	96%	100%	99%	100%	92%	100%
	0603	97%	82%	93%	94%	83%	85%	98%
	0805	68%	47%	79%	53%	41%	57%	55%
	SOT-23	79%	76%	79%	76%	77%	60%	76%
	1206	35%	36%	32%	25%	45%	49%	41%

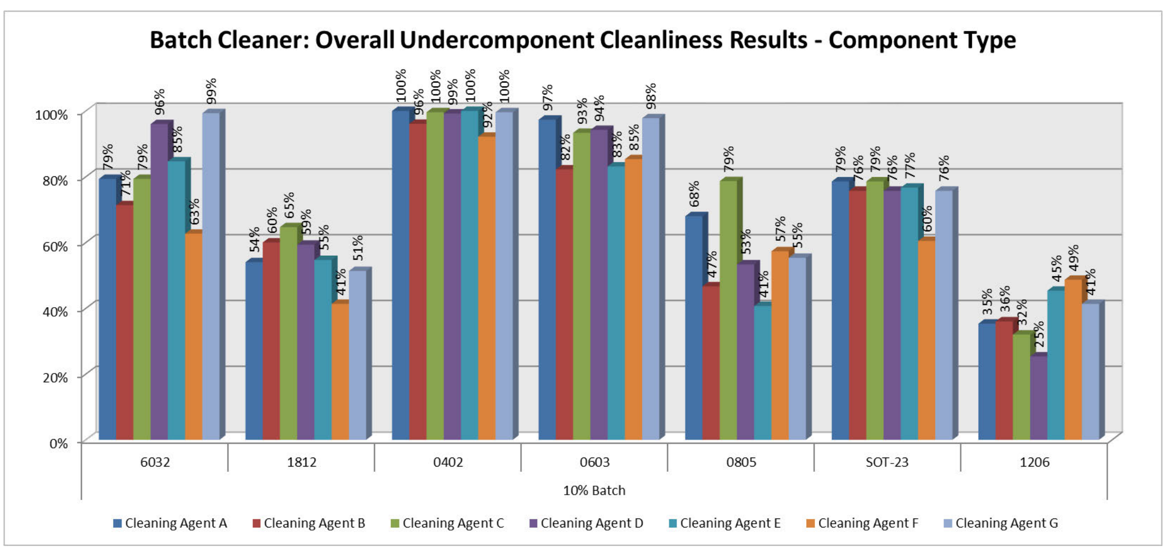


Figure 11: Batch Cleaner, Overall Under Component Cleanliness Results by Component Type

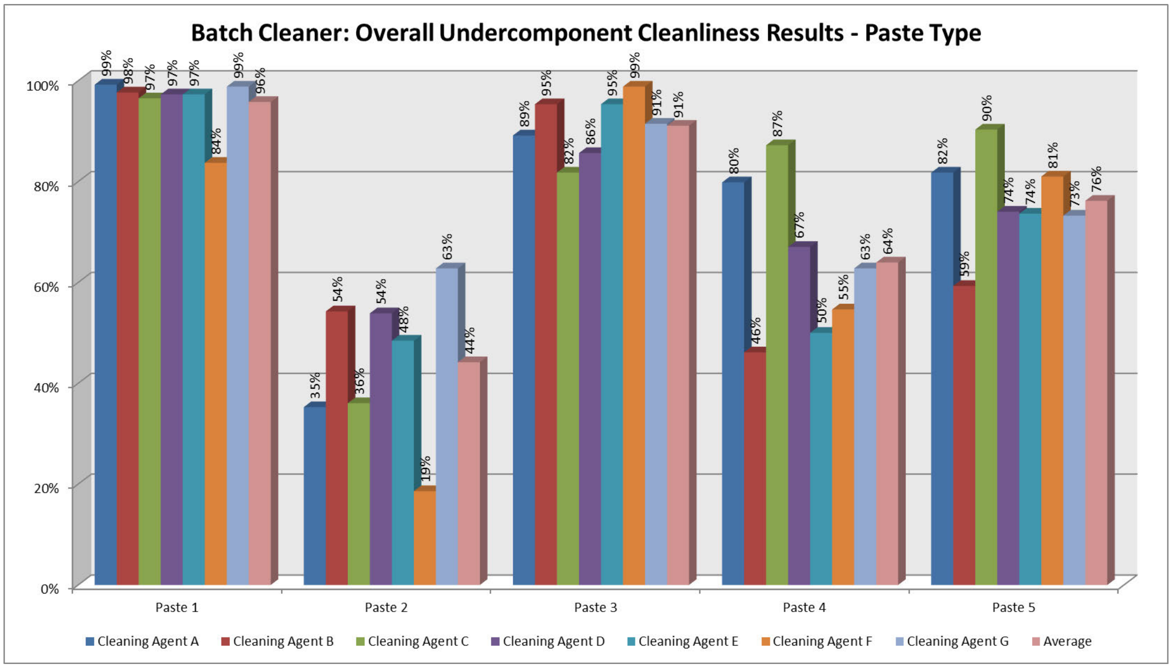


Figure 12: Batch Cleaner, Overall Under Component Cleanliness Results by Paste Type

Inline and Batch Process Discussion/ Conclusions

The inline cleaning process results regarding undercomponent cleanliness were varied. All cleaning agents produced excellent results with Paste 1 (96% overall). Paste 2 and 4 proved to be the most difficult to clean with overall results averaging 32% and 34% respectively (Table 10).

The batch cleaning process also produced varying results regarding undercomponent cleanliness. Pastes 1 and 3 averaged the highest cleanliness assessment result while Paste 2, 4 and 5 proved to be the most difficult to clean, averaging 44%, 64% and 76% cleanliness levels respectively (Table 12).

It should be noted that the cleaning process was not optimized for the paste type or cleaning agent used as this study was to assess the relative differences of cleaning each paste with various cleaning agent types under same process conditions. This study provided insight as to the type of cleaning agent that may be best suited for cleaning a particular jet printed solder pasteand to understand the challenges associated with cleaning post solder flux residue from jet printed solder paste and apply lessons learned to field applications which are discussed in the next section.

Case Study A

An aerospace OEM was experiencing cleaning challenges with boards assembled using Paste 3. In their case, they were using an aqueous-based cleaning agent in a batch cleaner with limited success ascleaning under low standoff components was problematic. Acceptable results were only achievable at 180°F wash temperature and one hour wash cycle time. However, at this temperature, cleaning agent evaporation loss and ink marking removal were the main concerns. The OEM was seeking an alternate solution enabling them to use the cleaning agent at lower temperatures to maximize cleaning process efficiency, prevent label ink marking removal and minimize process costs. Given the information obtained through the initial jet paste study, the authors chose cleaning agent F as the most suitable for the OEM cleaning process.

Given the sensitive nature of their products, the OEM was unable to provide actual substrates for the initial cleaning evaluation. Thus, the authors used an industry test vehicle for all cleaning trials.

Case StudyA Methodology

Eleven (11) test vehicles were prepared for this evaluation. In this case, the OEM fully populated the test vehicles at their facility and sent them out for cleaning trials. It is interesting to note that the standoff height on the boards populated by the OEM were substantially lower than those on the test vehicles used for the internal study. Reference Table 14.

Table 14: Test Vehicles Standoff Height (mils)

Component	Standoff Heights (mil)	
	Aerospace OEM Populated	Internal Study Boards
0402	0.56	1.05

0603	0.62	1.16
0805	0.62	1.33
SOT-23	1.58	2.31
1206	0.74	2.92
1210	0.85	n/a
1812	1.70	3.53
1825	1.61	2.45
6032	6.69, 3.39	8.00, 2.92
BGA	15.75	n/a

The eleven test vehicles were fully populated with 106 components on each board as per Table 15 and Figure 13.

Table 15: Component Types

Component Type	No. of Components
0402	17
0603	15
0805	10
SOT	14
1206	10
1210	7
1812	10
1825	10
6032	10
MLF	1
BGA	1
QFP	1
Total	**106**

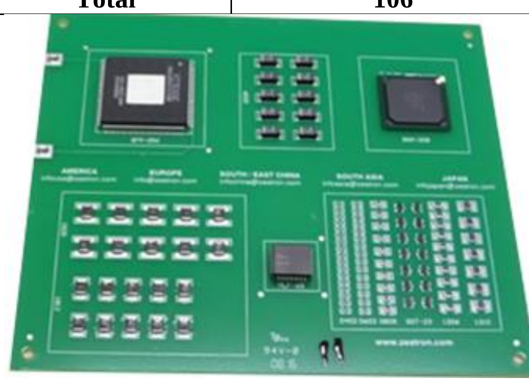


Figure 13:Aerospace OEM Populated Test Vehicle

Representative images of component standoff heights are detailed in Figures 14 (0402) and 15 (0603).

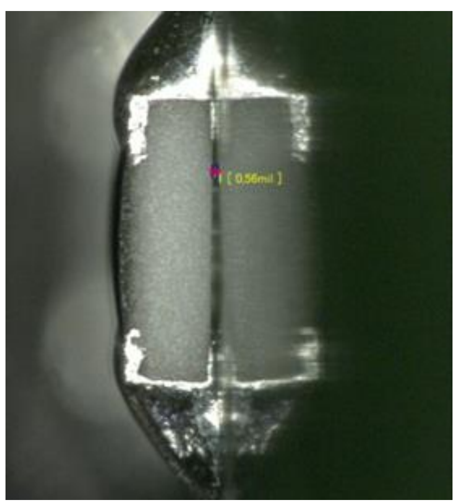


Figure 14:OEM populated, **0.56mils standoff height, 0402 Component**

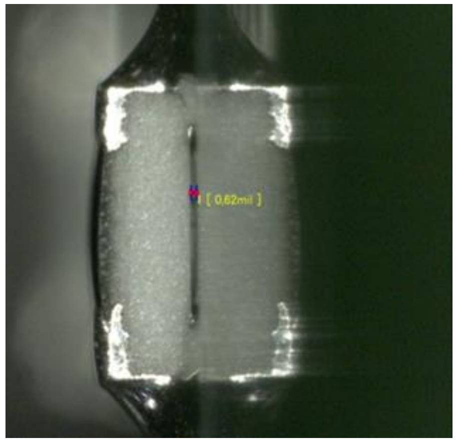


Figure 15:OEM populated,**0.62 mils standoff height, 0603 Component**

In collaboration with the aerospace OEM, it was decided that undercomponent visual inspection would be used for cleanliness assessmentfor this evaluation. Visual inspection was conducted in accordance with IPC-A-610F standard, vertically viewed.

For the batch cleaner, the operating parameters selected are detailed in Table 16. Two sets of trials were conducted employing cleaning agent concentrations of 15% and 20%. All other batch cleaner parameters were maintained constant.

Table 16: Cleaning Parameters

Wash Cycle	
Equipment	Batch Cleaner
Cleaning Agent F	Dynamic Surfactant based
Cleaning Agent Concentration	Refer to Table 17
Wash Temperature	
Chemical Isolation	30 seconds
Rinse Cycle	
Rinsing Agent	DI-water
Flood Rinse	30 seconds
Rinsing Temperature	Room Temperature
Max # of Rinse Steps	8
Rinse Conductivity Set point	2 µS/cm
Final Rinse Time	30 seconds
Final Rinse Temperature	85°F / 29.4°C
Drying Cycle	
Drying Time	900 seconds
Drying Temperature	200°F / 93°C
Cool Down	60 seconds

The cleaning process effectiveness was evaluated through undercomponent cleanliness assessment. For all trials conducted, the components were sheared from the test vehicle and the undercomponent surface was inspected and defined as either fully clean, or not clean. The number of clean components was expressed as a percent of the total number of components on the test vehicle with results shown in Table 17.

Table17: Case Study Results

Trial #	Conc (%)	Temp (°F)	Time (minutes)	Results (# of clean components)												Overall Cleanliness (%)
				0402	0603	0805	SOT	1206	1210	1812	1825	6032	MLF	BGA	QFP	
1	15%	150°F	46 min	17	15	7	3	3	0	0	1	9	1	1	1	54 72%
2	15%	160°F	46 min	17	15	10	14	5	2	2	3	10	1	1	1	76 42%
3	15%	160°F	46 min	17	15	10	14	10	1	5	3	10	1	1	1	83 02%
4	15%	170°F	46 min	17	15	10	14	10	4	10	6	10	1	1	1	93 40%
5	15%	180°F	46 min	17	15	10	14	10	7	10	10	10	1	1	1	100 00%

6	20%	170°F	46 min	17	15	10	14	10	3	10	10	10	1	1	1	96 23%
7	20%	170°F	46 min	17	15	10	14	10	5	9	10	10	1	1	1	97 17%
8	25%	170°F	46 min	17	15	10	14	10	4	9	10	10	1	1	1	96 23%
9	25%	170°F	46 min (m)	17	15	10	14	10	5	8	10	10	1	1	1	96 23%
10	20%	170°F	56 min	17	15	10	14	10	7	10	10	10	1	1	1	100 00%
11	20%	160°F	56 min	17	15	10	14	10	2	9	8	10	1	1	1	92 45%

Based on the results in Table 17, components 1210, 1812 and 1825 were found to be the most difficult to clean. Recognizing this, it was decided to combine the cleanliness results of these three component types from trials 3 to 6 and 10 and 11 in order to assess the effectiveness of the cleaning trials indicated in Table 18.

Table 18: Under Component Cleanliness Assessment

Concentration (%)	Wash time (minutes)	Wash Temp (°F)	Cleanliness % 1210, 1812&1825
15%	46 min	160°F	33%
		170°F	74%
		180°F	100%
20%	46 min	170°F	85%
20%	56 min	160°F	70%
		170°F	100%

Based on the above findings, wash temperature and wash time were found to be the main parameters affecting cleanliness results as shown in Figure 16. The wash temperature seems to have the most impact on the cleaning results, followed by wash time and concentration.

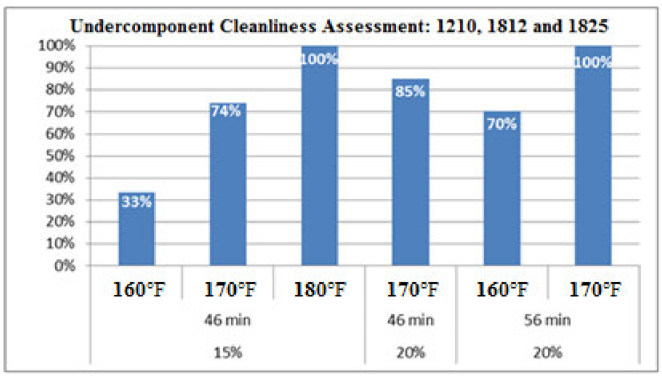


Figure 16:Cleanliness Under 1210, 1812 and 1825 components

Representative pictures of undercomponent cleaning are shown in Figure 17.

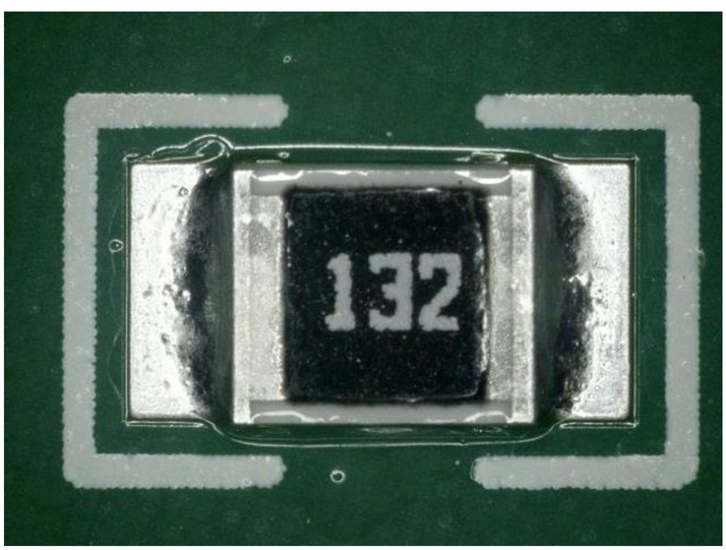


Figure 17A:Component 1210Before Cleaning

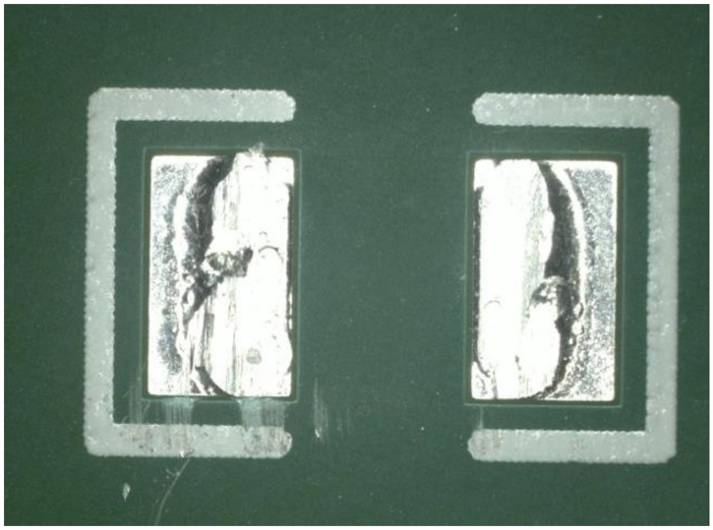


Figure 17B:Component 1210After Cleaning

Case Study A Conclusions

Excellent results were achieved in the cleaning trials conducted on the boards received from the aerospace OEM as cleaning agent F was able to fully clean the jet printed post solder paste residues on the surface as well as under the component.

It was observed that 100% cleaning results were obtained under Table 19 conditions:

Table 19: Optimal Cleaning Parameters

Concentration	15%
Wash Temperature	180°F
Wash Time	46 minutes

(or)

Concentration	20%
Wash Temperature	170°F
Wash Time	56 minutes

For this cleaning process, the wash temperature does have the most significant impact on cleaning results followed by wash time and then concentration of cleaning agent. It should also be noted that component standoff heights of various components on the industry test board soldered by the aerospace OEM were significantly lower as compared to the same test boards and components soldered for the internal study, thus increasing the cleaning challenges.

Case Study B

A leading CM (Contract Manufacturer) with design and assembly services decided to employ jet printing process using a lead-free No Clean solder paste (Paste 2). Given the production and reliability standards required, they specified using an aqueous-based inline cleaning process. They requested assistance forthe qualification process including cleaning agent recommendation and cleaning process operating parameters. Also, as their assemblies included sensitive materials, material compatibility with the cleaning process was critical. Additionally, the CM requested cleaning compatibility assessment with their selected labels used on their substrates.

Case Study B Methodology

A DoE was developed and a pH neutral cleaning agent was specified (cleaning agent C) as defined in the original study, and usedthe CM selected inline cleaner for all trials. The CM provided eight substrates, double-sided, for use in the cleaning trials. Side A was reflowed twice while side B was reflowed once. Due to confidentiality restrictions, pictures of the substrate cannot be included. However, pictures of the heat sinks as well as the test substrate used for label compatibility are included which are shown in Figures 18 to 20.

Figure 18: Side A of the Anodized Aluminum Heatsink

Figure 19: Side B of the Anodized Aluminum Heatsink

All substrates were reflowed at the CM siteand sent out for the cleaning trials. As the CM was interested in assessing the impact of staging time between reflow and cleaning, substrates were reflowed 24 and 72 hours prior to cleaning. Additionally, label compatibility was analyzed on substrates without reflow as well as substrates with lead-free reflow. Two cleaning agent concentrations and conveyor belt speeds were selected for the inline cleaning trials.

Figure 20 – Label Compatibility: Without Reflow

Per the CM request, cleanliness assessment methodologies included visual inspection (substrate surface only) in accordance with IPC-A-610F and ionic contamination analysis per IPC-TM 650 and J-STD-001F. The substrates used for the label compatibility analyses as well as the anodized aluminum heat sink were evaluated with the cleaning process separately.

All inline cleaner operating parameters are detailed in Table 20.

Table 20: Inline Cleaner Operating Parameters

Wash Stage	
Equipment	Spray-in-air Inline Cleaner
Cleaning Agent C Concentration	10% - 15%
Conveyor Belt Speed	1 ft./min.& 1.5 ft./min.

Wash Spray Configuration	8-spray bar enhanced intermix
Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI
Wash Pressure (Top/Bottom)	80 PSI / 70 PSI / 40 PSI / 30 PSI
Wash Temperature	150°F
Chemical Isolation Pressure (Top/Bottom)	30 PSI / 25 PSI
Rinse Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	80 PSI / 70 PSI / 40 PSI / 30 PSI
Rinse Temperature	140°F
Final Rinse Temperature (Top/Bottom)	25 PSI / 25 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Temperature (D1)	180°F
Drying Temperature (D2)	210°F
Drying Temperature (D3)	210°F

Case Study B Results

Figure 21A to 23B show the critical areas on the substrate before and after cleaning:

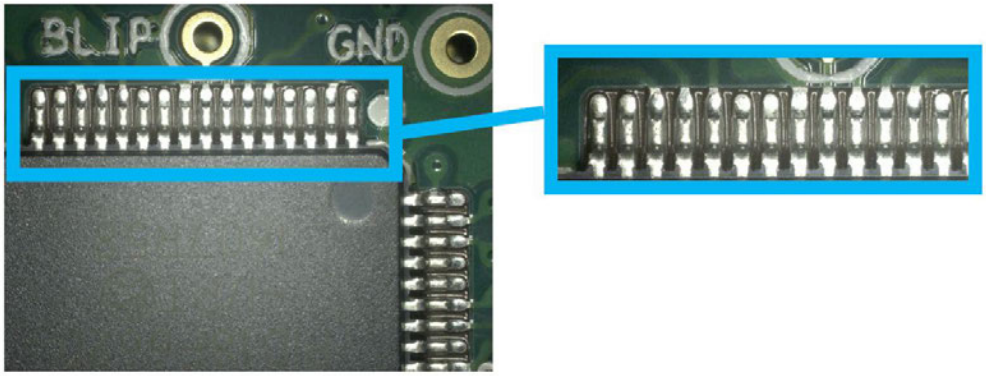


Figure 21A:Trial 1 Before Cleaning

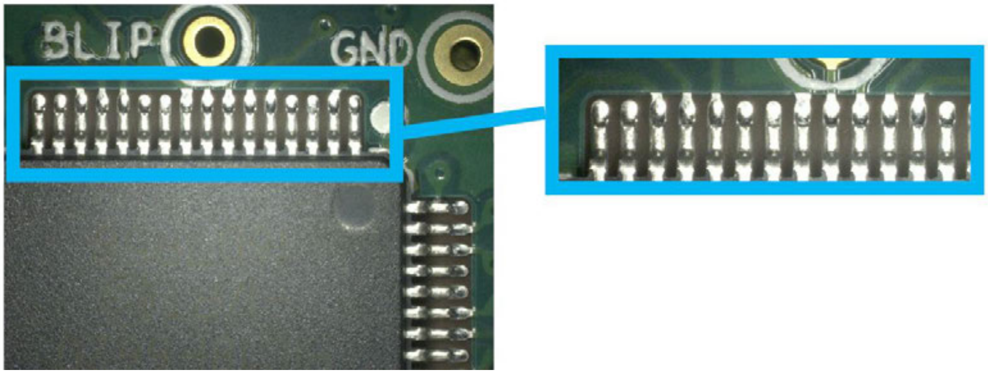


Figure 21B: Trial 1 After Cleaning

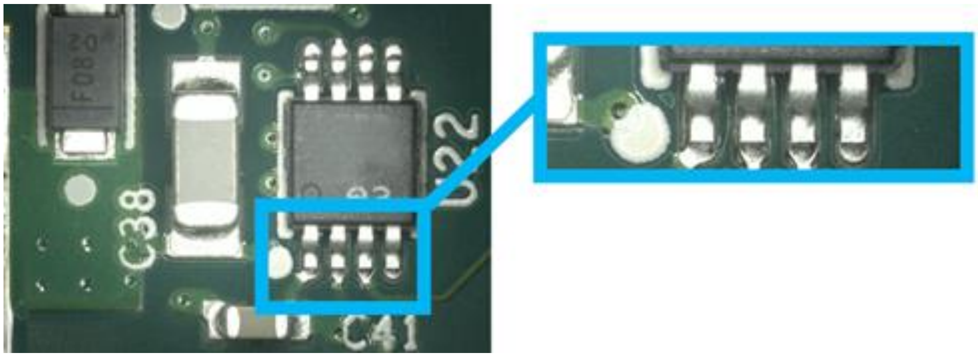


Figure 22A:Trial 2 Before Cleaning

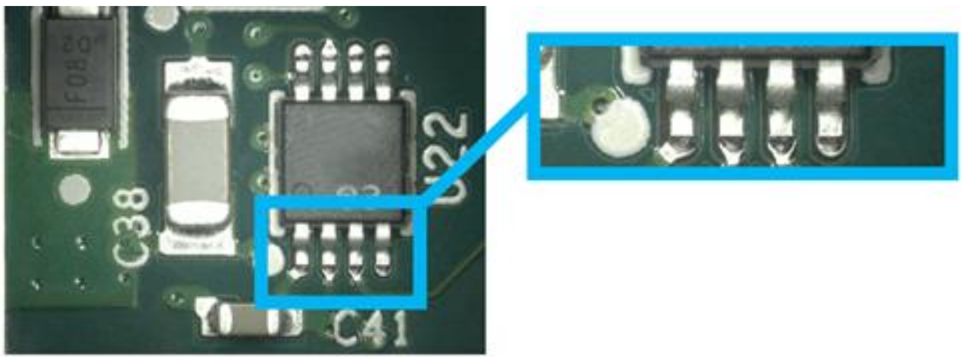


Figure 22B:Trial 2 After Cleaning

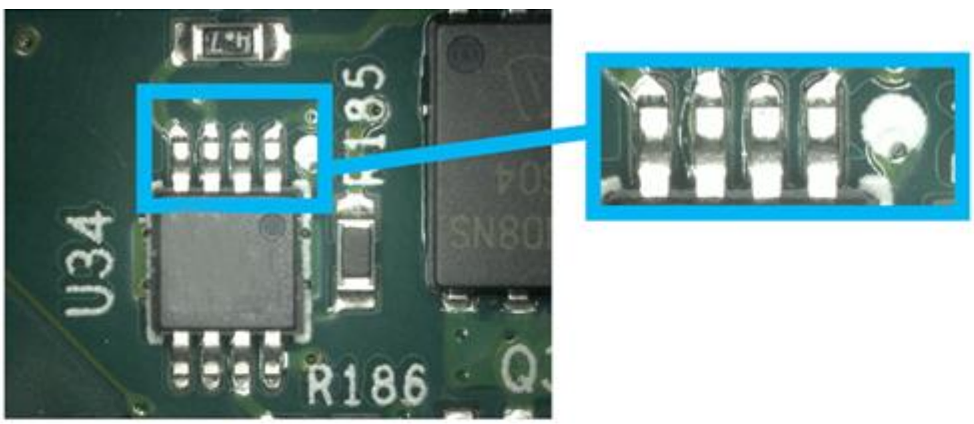


Figure 23A:Trial 10 Before Cleaning

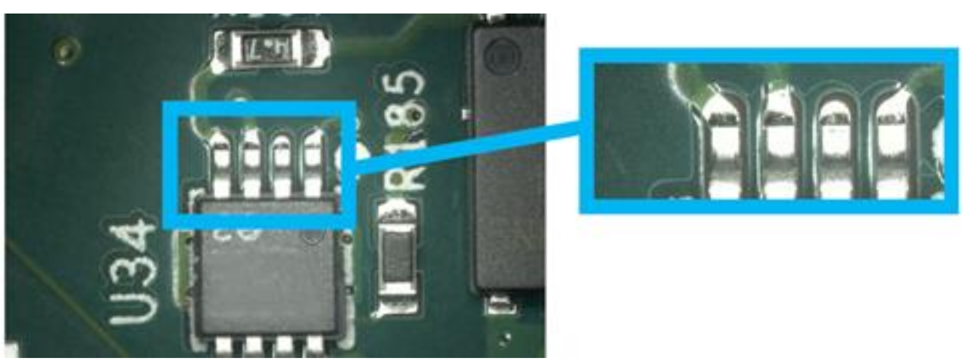


Figure 23B:Trial 10 After Cleaning

Visual Inspection Results
Visual inspection results are detailed in Tables 21 and 22.

Table 21: Visual Inspection - 24 Hour Time Interval

Trial #	Concentration	Belt Speed (ft./min.)	Visual Inspection
1	10%	1.5	Clean
2	10%	1	Clean
3	15%	1.5	Clean
4	15%	1	Clean

Table 22: Visual Inspection - 72 Hour Time Interval

Trial #	Concentration	Belt Speed (ft./min.)	Visual Inspection
5	10%	1.5	Minor flux residue observed in between chipcaps
6	10%	1	Clean
7	15%	1.5	Clean
8	15%	1	Clean

Ionic Contamination Results

The ionic contamination test was conducted according to IPC-TM-650. Standards were based on J-STD-001F. The pass/fail limits for this test is 10.06 µg/in^2. The substrate surface area is 49.5 in^2 with results shown in Tables 23 and 24.

Table 23: Ionic Contamination -24 Hour Time Interval

Trial #	Concentration	Belt Speed (ft./min.)	Ionic Contamination Value (Results)
1	10%	1.5	0.20 µg/in^2 (Pass)
2	10%	1	0.04 µg/in^2 (Pass)
3	15%	1.5	0.12 µg/in^2 (Pass)
4	15%	1	0.25 µg/in^2 (Pass)

Table 24: Ionic Contamination-72 Hour Time Interval

Trial #	Concentration	Belt Speed (ft./min.)	Ionic Contamination Value (Results)
5	10%	1.5	0.20 µg/in^2 (Pass)
6	10%	1	0.46 µg/in^2 (Pass)
7	15%	1.5	0.57 µg/in^2 (Pass)
8	15%	1	0.18 µg/in^2 (Pass)

Material Compatibility Results

The anodized aluminum heatsink was passed through the inline cleaner three times using the most aggressive wash settings to simulate worst case scenario. Parts were inspected after each pass and found to be fully compatible with the cleaning process.

Label Compatibility Test Results

The CM provided three types of printed labels for testing. These labels were applied on test boards provided by the CM. One set of boards were reflowed using the lead-free profile. The boards were passed through the cleaning process at 15% concentration, 150°F wash temperature and 1 ft./min. belt speed. The labels were found to be fully compatible with the cleaning process.

Case Study B Conclusions

The boards received from the CM were cleaned with excellent results as the flux residues were completely removed. The boards were visually inspected to check for surface cleanliness. All board surfaces were found to be clean except Trial 5 (cleaned at 10% concentration and 1.5 ft./min. belt speed, with time interval between reflow and wash of 72 hours). However, all the cleaned boards passed the ionic contamination test as the ion species was below the pass/fail limit. Anodized aluminum heatsinks and reflowed labels were found to be fully compatible with cleaning agent C and the wash processes.

Thus, it was confirmed that post reflow flux residues of jet dispensing lead free No Clean solder paste (Paste 2) can be fully removed using cleaning agent C in a spray-in-air inline cleaner.

Overall Conclusions

This study confirmed that matching the cleaning agent to the solder paste is critical. This preliminary data proved valuable in assisting the companies to provide an optimized cleaning process to both the OEM and the CM in the case studies discussed.

Future Work

The companyis currently expanding this study to evaluate the effect of a common No Clean flux chemistry with progressively finer SAC305 solder powders with a variety of cleaning chemistries and methods to attempt to quantify the implications of finer mesh powder on flux removal. Cleanliness levels will be measured using visual inspection under high magnification and industry recognized cleanliness test methods such as ion chromatography and SIR as per IPC TM-650 guidelines.

References

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[5] M.Koch, Steve Voges, M. Fliess, R. Aschenbrenner, K.D. Lang, Martin Schneider-Ramelow, Karl-Frierich Becker, Tina Thomas, Jörg Bauer, Tanja Brown, "Precision Jetting of Solder Paste – A Versatile Tool for Small Volume Production," IMAPS 2014.

Acknowledgement

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Jet Printed Solder Paste and Cleaning Challenges

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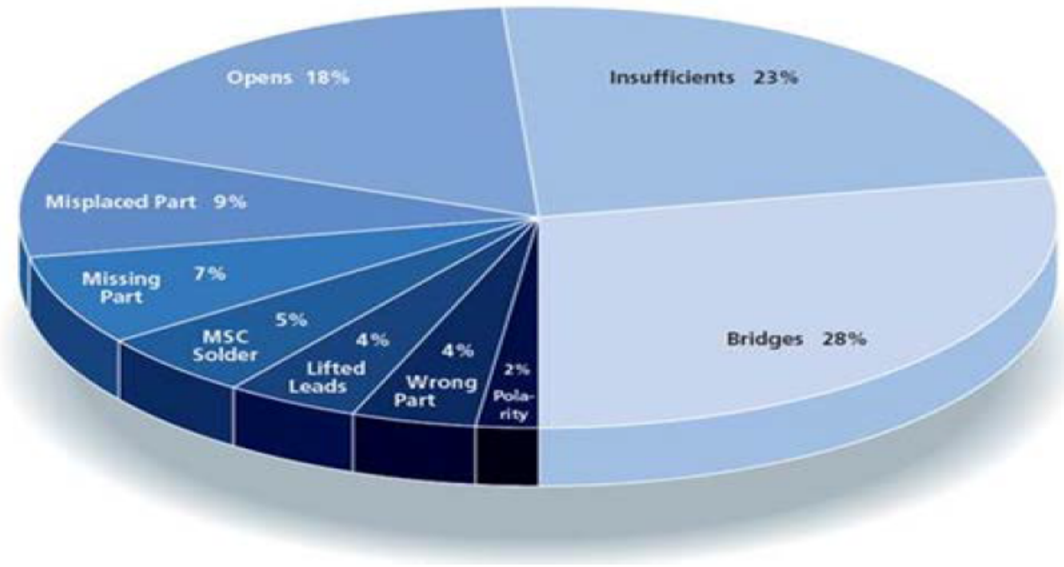
Agenda

- **Introduction**
- Main Research
- Results
- Conclusions
- Case Studies
- Summary
- Future Work

Introduction

- Within SMT manufacturing process, solder paste printing is one of the most critical step
- Metal stencil solder paste printing is a mature process
  - *Has the biggest impact on the soldering result*
- Stencil printing process = source of 70% soldering errors
  - *Bridges*
  - *Insufficients*
  - *Opens*



Introduction

- As PCB designs become more challenging, limitations/difficulties of screen printing process is realized
  - *Use of Complex component geometries*
    - Reduced conductor spacing
  - *Placement of varying size components right next to each other*
  - *Use of non-planar or multilayered boards*
  - *Need for stencils and underside wiping materials*
    - Step stencils, gasketing, etc.
    - Stencil handling

Introduction

- Jet printing technology is gaining market acceptance
  - *High throughput/precision of jetting*
  - *Contactless material deposition*
  - *Deposit right solder volume for each specific component*
  - *Eliminates need for stencils and underside wiping materials*
  - *CAD data (or production design data software) for particular PCB is compiled offline and sent to jet printer for printing*
  - *Add-on tool complimenting screen printing process*
- Jet printing requires jettable solder paste

Introduction

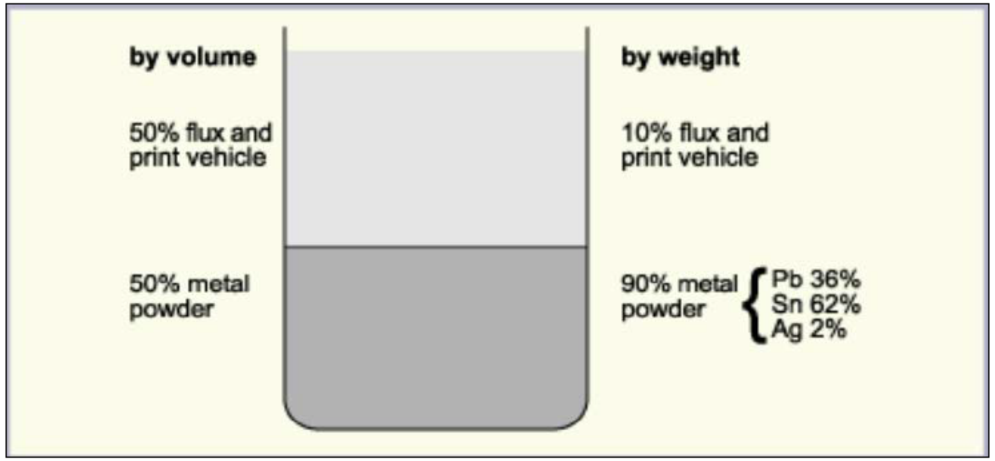
- Solder Powder Particle Size (in µm) classification as per J-STD-005

Type	Less than 0.5% larger than	10% max between	80% minimum between	10% maximum less than
1	160	150-160	75-150	75
2	80	75-80	45-75	45
3	60	45-60	25-45	25
4	50	38-50	20-38	20
5	40	25-40	15-25	15
6	25	15-25	5-15	5
7	15	11-15	2-11	2

- Metal solder particles are spherical in shape
  - *Reduces surface oxidation and*
  - *Ensures good joint formation with adjoining particles*

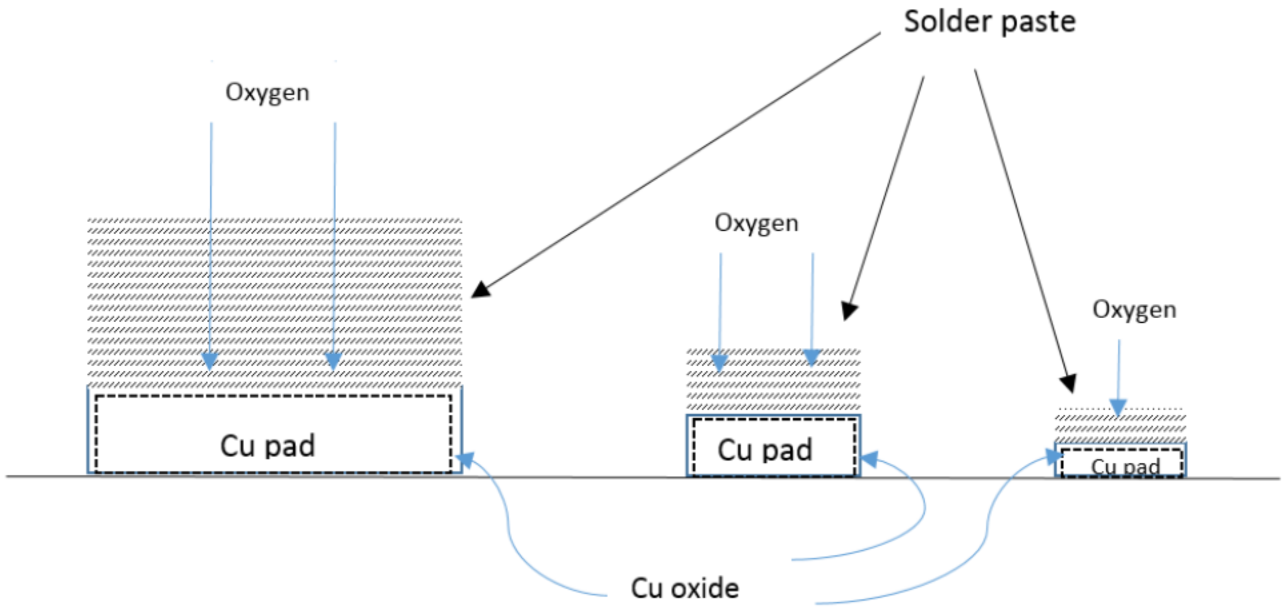
Introduction

- For typical solder pastes, the typical metal content is between 88 – 91% by weight, and about 30 – 70% by volume
- For stencil printing applications,
  - *Type 3 & 4 are typically used*
- For jet printing applications,
  - *Type 5 & 6 are typically used*
    - Finer solder powder
    - Metal content is reduced
    - Increased flux activity levels



Introduction

- As pad size reduces, the oxygen penetration path through flux or solder paste also decreases
  - *Results in more rapid oxidation of flux materials*
  - *Metal oxide thickness doesn't decrease with reduced pad size*
- Additional oxidation would demand more COOH in flux,
  - *Increasing the flux activity levels*



Introduction

- Anecdotal evidence suggests that an optimized cleaning process for a given paste type may not produce same results for same process if equivalent jettable solder paste is used
  - *Higher flux content*
- Design of Experiment (DOE) was developed to assess the cleaning requirements for five commonly used jettable solder pastes
  - *Aqueous-based cleaning system*
  - *Engineered cleaning agents*
    - pH neutral and pH alkaline inhibited and uninhibited cleaning agents

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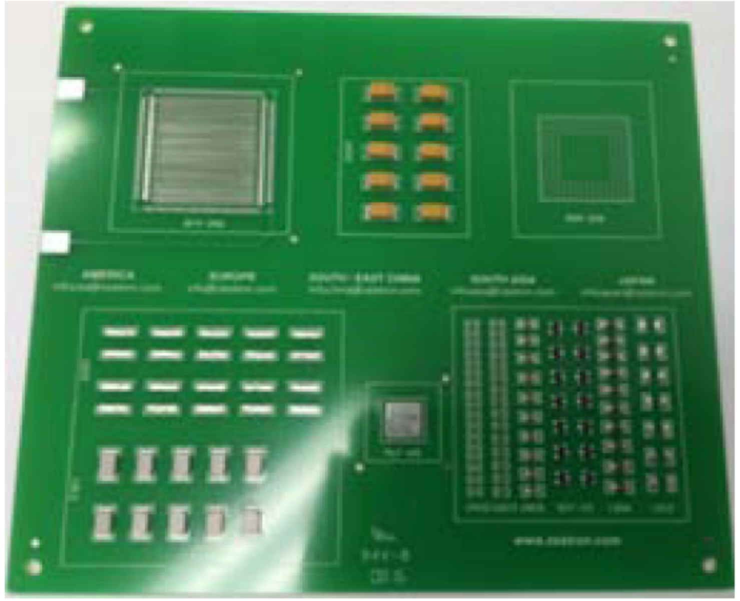
Main Research

- Evaluate cleaning efficacy of aqueous-based defluxing agents on populated PCBs assembled using jet printable solder pastes
  - *Populate several company test vehicle with various SMT components*
  - *Utilize reflow soldering equipment at OEM supplier having jet printing capability*
  - *Assembled boards were returned to chemical supplier for cleaning trials*
- Following the cleaning trials, the components were sheared from the test vehicles
- Visual inspection rating criteria in accordance with IPA-A-610 standard
  - *Fully Clean or Not Clean*

$$\textbf{Avg. undercomponent cleanliness} = \frac{\textbf{No. of components fully cleaned}}{\textbf{Total No. of components}}$$

Main Research

- 70 company test vehicles were populated with SMT components
  - *2 boards were prepared for each paste type, each with 86 components*
    - 35 for inline and batch cleaning processes



Component Type	No. of Components
6032	10
1812	10
0402	17
0603	15
0805	10
SOT-23	14
1206	10
Total Components	86

Main Research

- Five commonly used jettable solder pastes were selected

Solder Paste	Paste Type	Solder Type	Avg Size (μm)	Flux Content
1	Lead-free No Clean	5	15~25	14%
2	Lead-Free No Clean	5	15~25	14%
3	Leaded No Clean	5	10~28	15 ± 0.5%
4	Lead-free No Clean	5	10~28	15%
5	Leaded No Clean	5	15~25	13 ± 0.5%

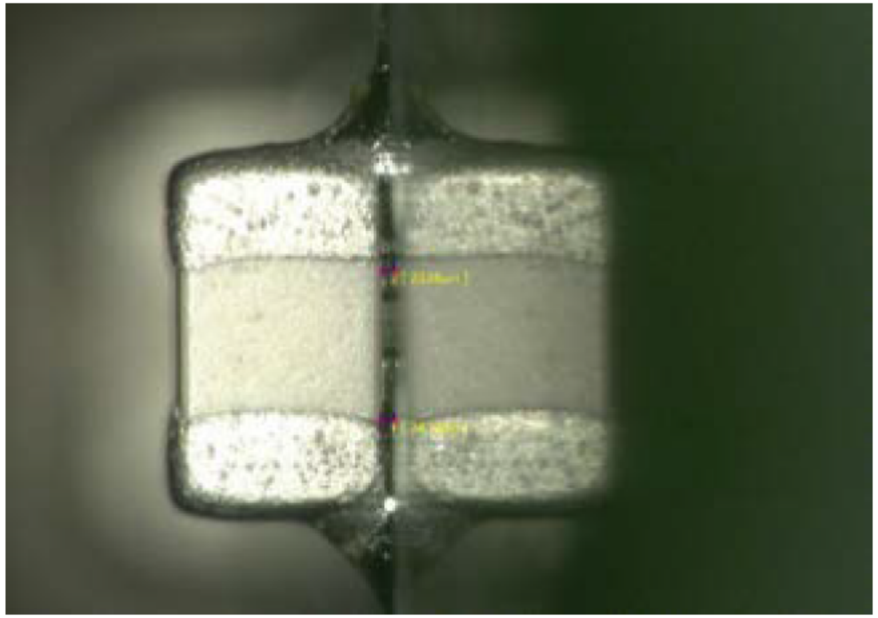
Main Research

- Leaded and lead-free reflow soldering profiles used at OEM Supplier

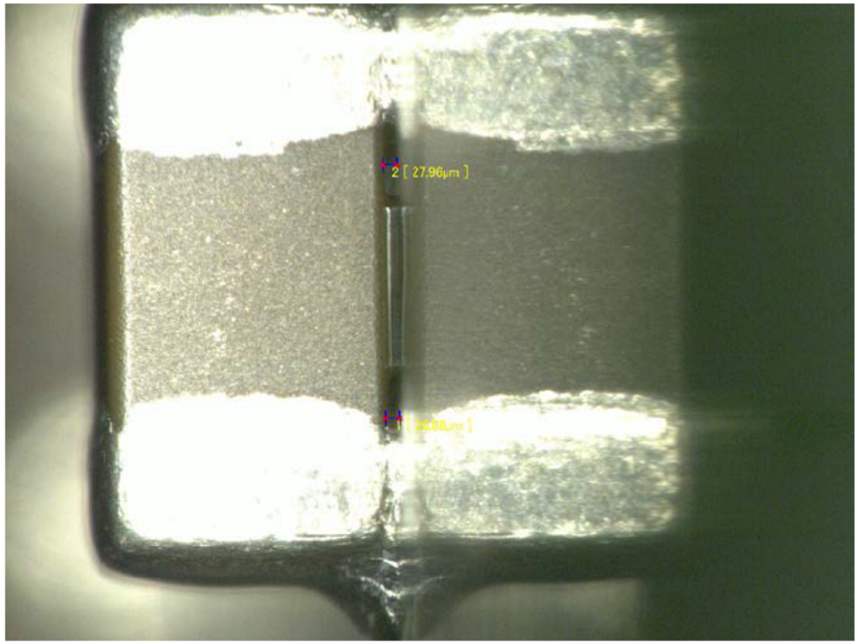
Leaded Profile – Belt Speed 45 in./min.							
Zone	1	2	3	4	5	6	7
Top (°C)	150	175	175	200	225	225	225
Bottom (°C)	150	175	175	200	225	225	225

Lead-free Profile – Belt Speed 75 in./min.							
Zone	1	2	3	4	5	6	7
Top (°C)	160	175	220	235	250	265	265
Bottom (°C)	160	175	220	235	250	265	265

Representative Pictures – Component Standoff



0402 – 1 mil standoff (avg.)



0603 – 1 mil standoff (avg.)

Inline & Batch Cleaning Process Parameters

Wash Stage	
Cleaning Process	Spray-in-air Conveyorized Inline Cleaner
Concentration	10% (by volume)
Conveyor Belt Speed	1 ft. /min.
Pre-Wash Pressure (Top/Bottom)	40 PSI / 40 PSI
Wash Pressure (Top/Bottom) [4 JIC + 4 V]	75 PSI / 60 PSI / 40 PSI / 40 PSI
Cleaning Temperature	150°F
Chem-Iso Pressure (Top/Bottom)	30 PSI / 30 PSI
Rinsing Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	75 PSI / 60 PSI / 40 PSI / 40 PSI
Rinsing Temperature	140°F
Final Rinse Pressure (Top/Bottom)	30 PSI / 30 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Dryer 1	160°F
Dryer 2	220°F
Dryer 3	220°F

Wash Stage	
Cleaning Process	Spray-in-air Batch Cleaner
Concentration	10% (by volume)
Wash Time	10 min
Cleaning Temperature	150°F
Rinsing Stage	
Rinsing Agent	DI-water
Rinse 1	20 seconds
Rinse Cycles	6
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Time	15 min.
Drying Temperature	150°F

Test parameters used for <u>assessing cleaning results</u> with each cleaning agent and not to achieve 100% cleanliness

Main Research

- Seven aqueous-based engineered cleaning agents were selected

Cleaning Agent	Type
A	Non Surfactant Alkaline Inhibited
B	Non Surfactant Alkaline Uninhibited
C	Non Surfactant pH Neutral Inhibited
D	Non Surfactant pH Neutral Inhibited
E	Dynamic Surfactant Uninhibited
F	Dynamic Surfactant Inhibited
G	Dynamic Surfactant Inhibited

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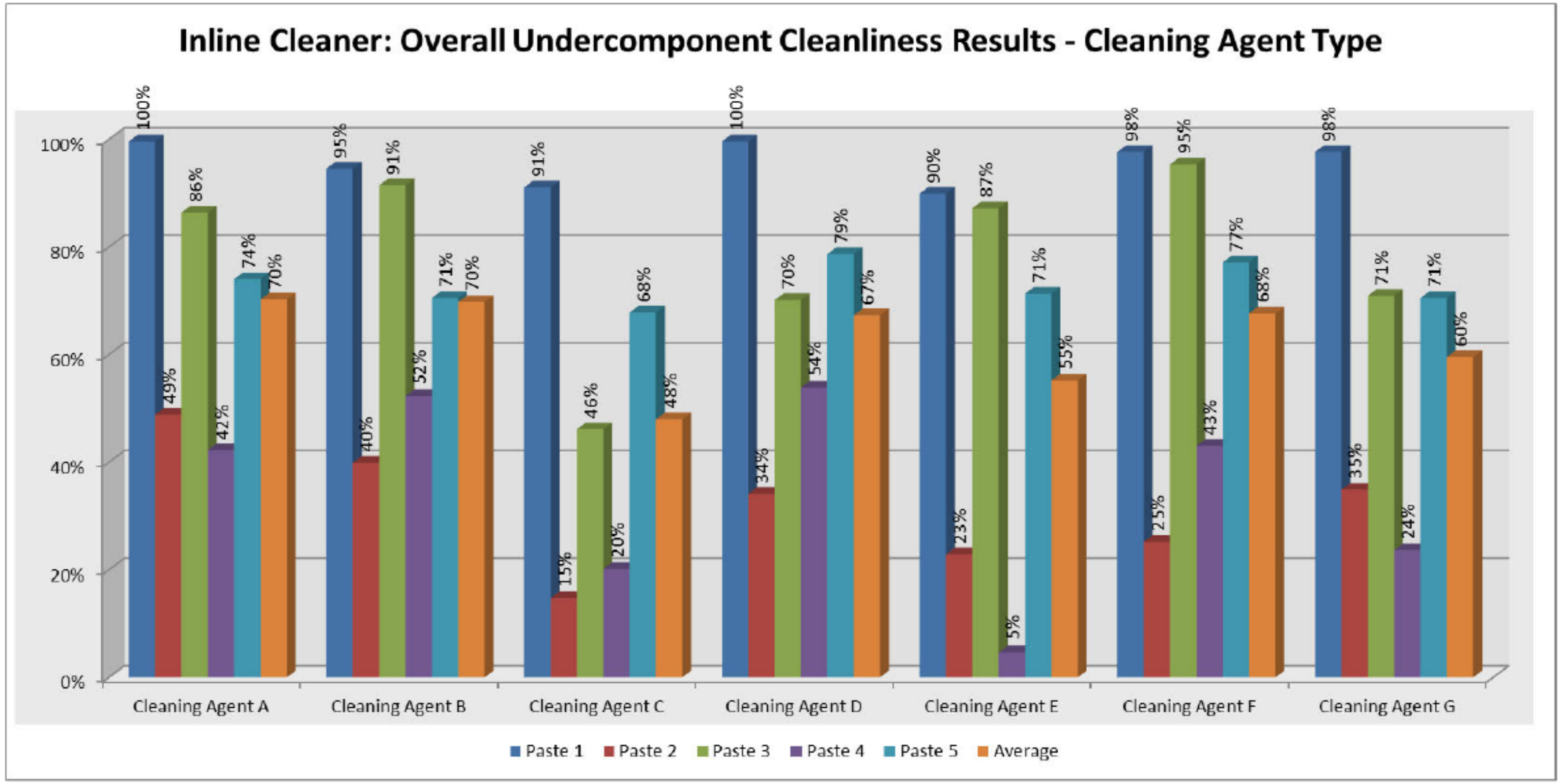
Results – Inline Cleaner (Cleaning Agent Type)

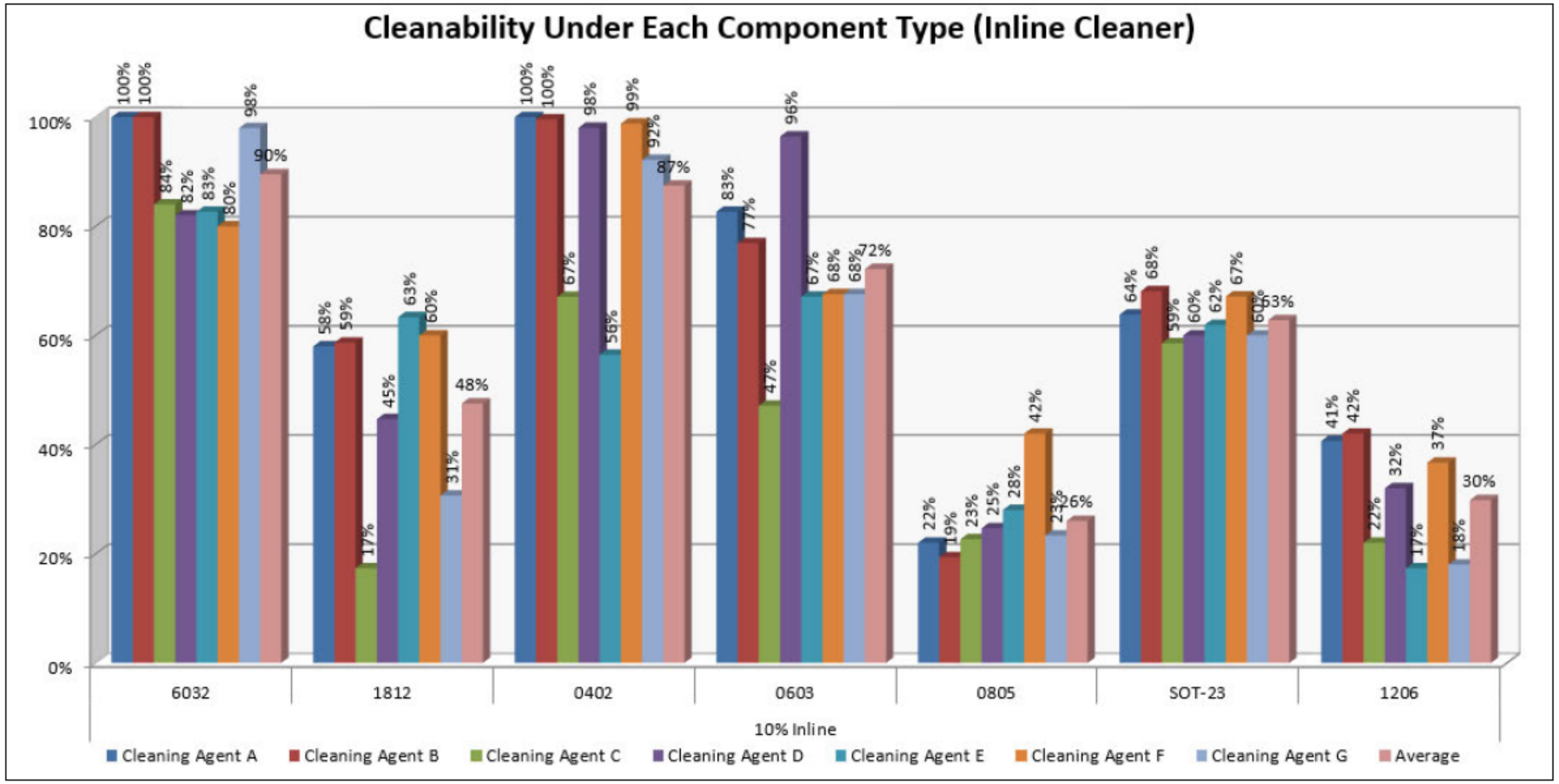
- Cleaning Agents A, B, D & F provided <u>above</u> average cleanliness levels

- Cleaning Agents C, E & G provided <u>below</u> average cleanliness levels



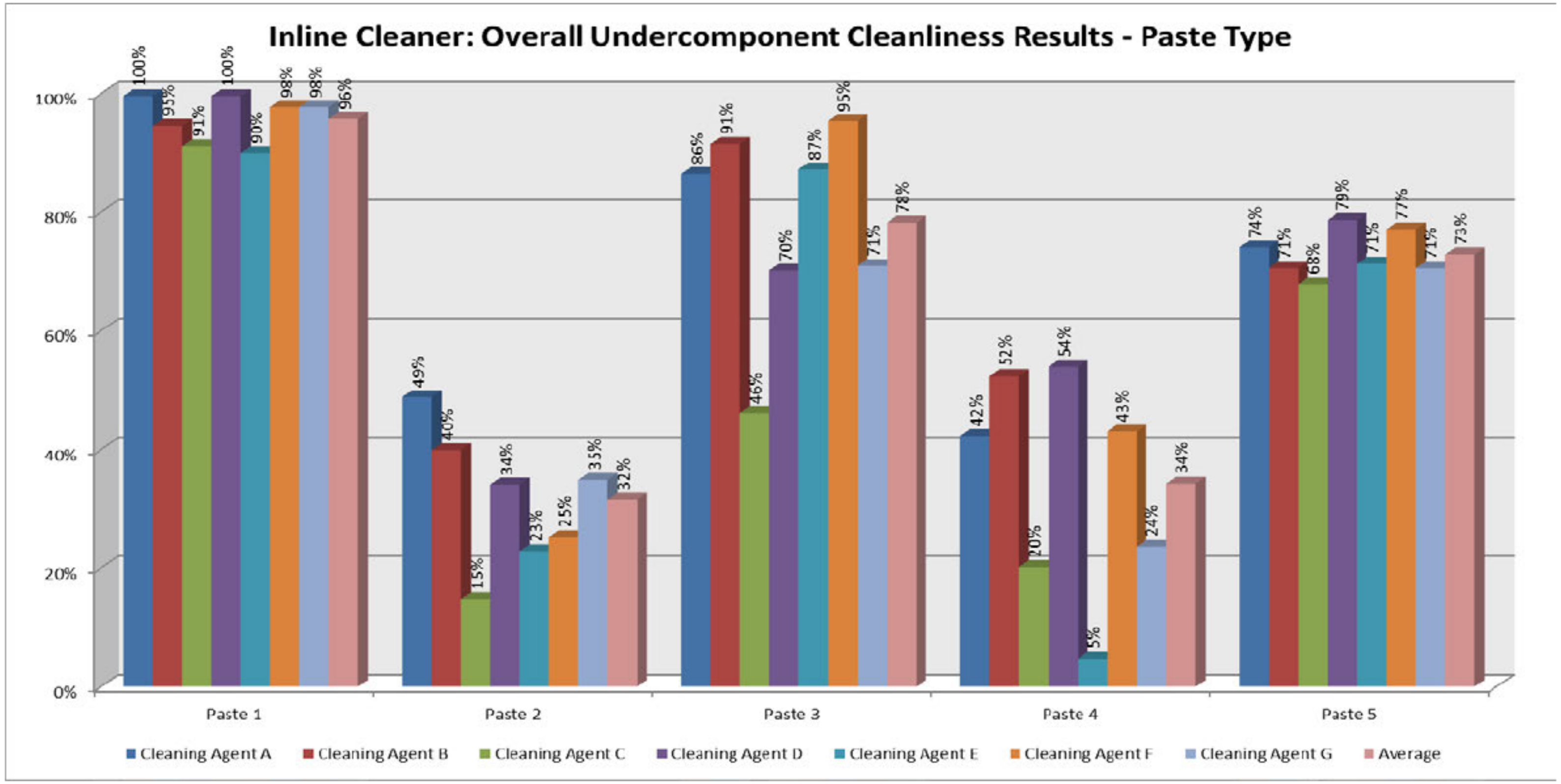
Results – Inline Cleaner (Component Type)

- 6032, 0402, 0603 & SOT-23 components provided <u>above</u> average cleanliness levels
- 1812, 0805 & 1206 components provided <u>below</u> average cleanliness levels



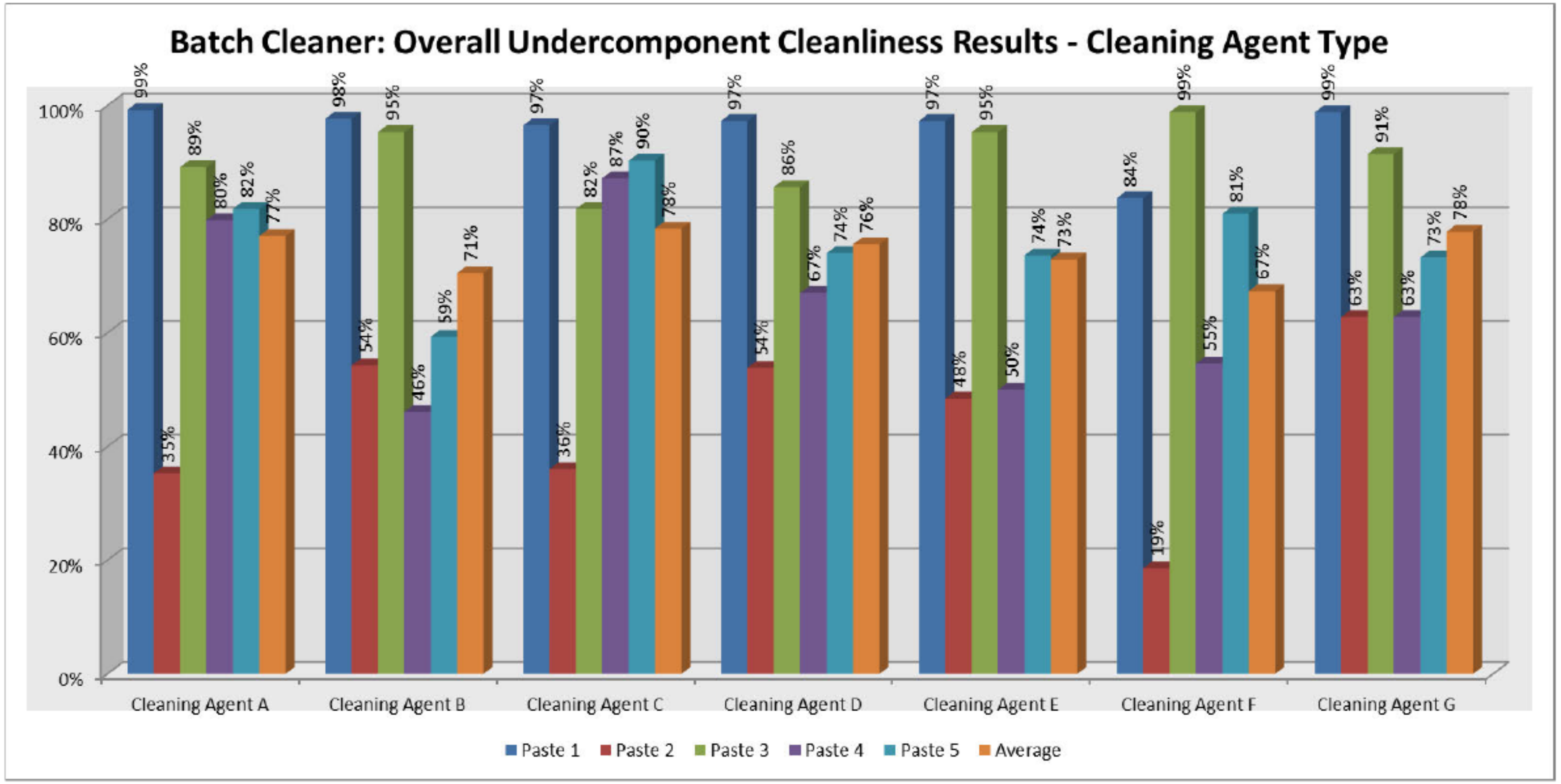
Results – Inline Cleaner (Solder Paste Type)

- Pastes 1, 3 & 5 provided above average cleanliness levels
- Pastes 2 & 4 provided below average cleanliness levels



Results – Batch Cleaner (Cleaning Agent Type)

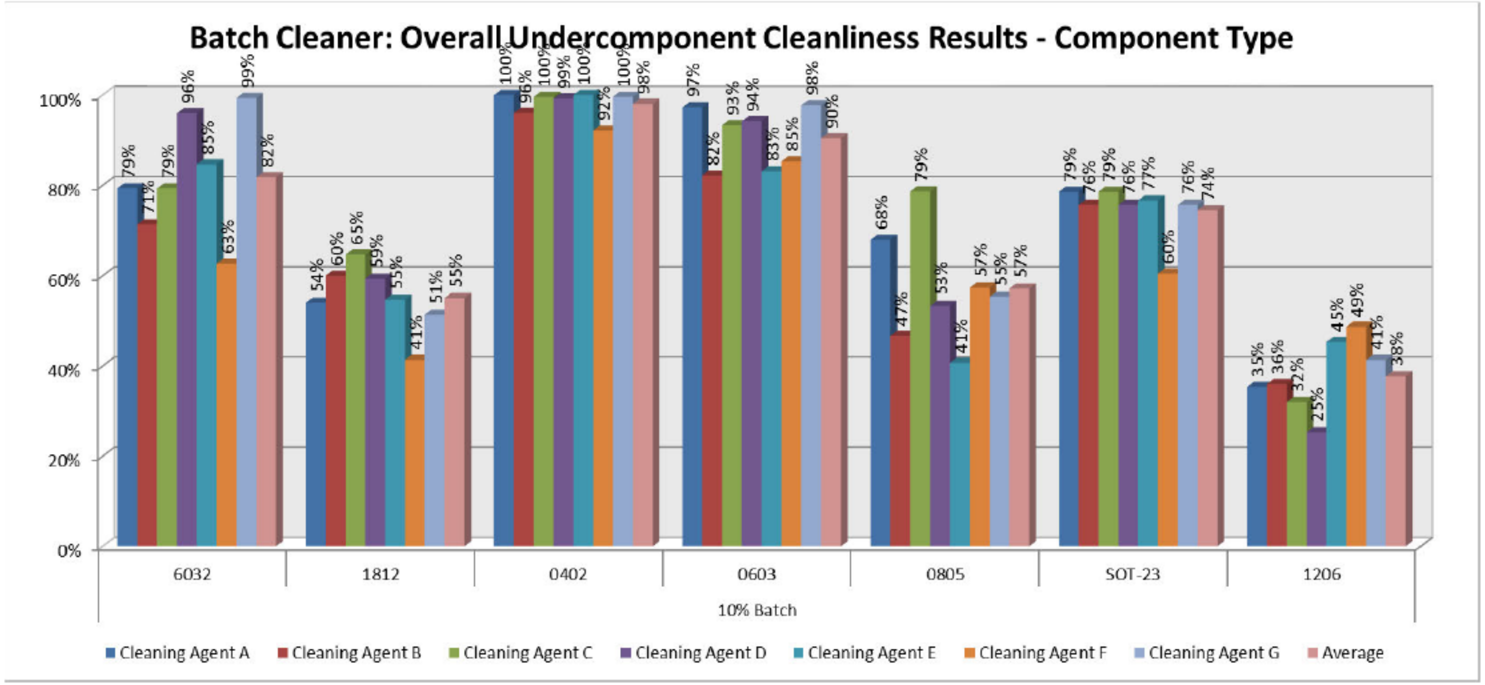
- Cleaning Agents A, C, D & G provided above average cleanliness levels
- Cleaning Agents B, E & F provided below average cleanliness levels



Results – Batch Cleaner (Component Type)

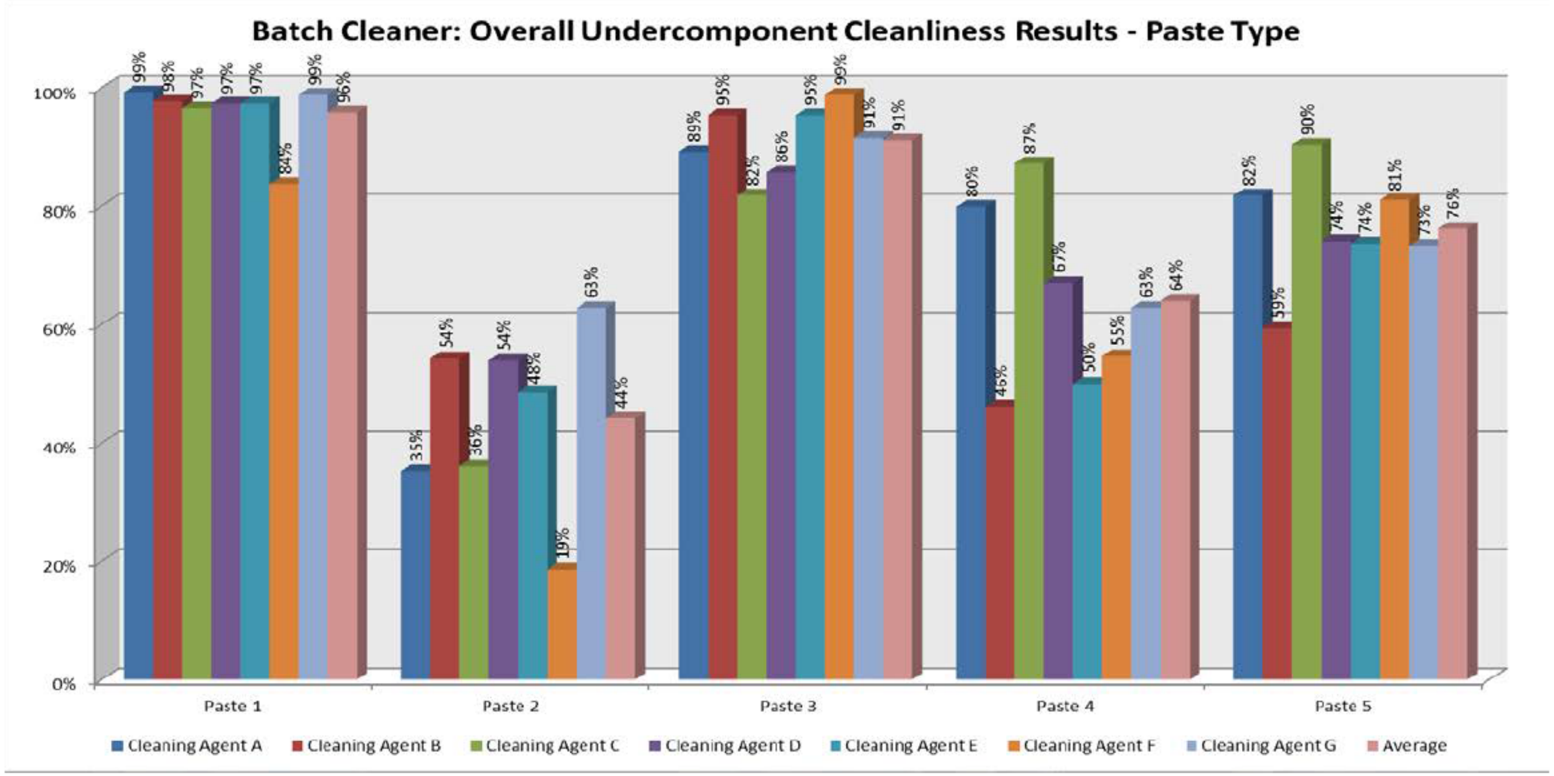
- 6032, 0402, 0603 & SOT-23 components provided above average cleanliness levels

- 1812, 0805 & 1206 components provided below average cleanliness levels



Results – Batch Cleaner (Solder Paste Type)

- Pastes 1, 3 & 5 provided above average cleanliness levels
- Pastes 2 & 4 provided below average cleanliness levels



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Conclusions

- Both inline and batch processes provided varying results for under component cleanliness
- All cleaning agents gave excellent results with Paste 1 (Lead-free, No Clean)
- In case of Inline cleaner,
    - *Paste 2 (Lead-free, No Clean) and Paste 4 (Lead-free, No Clean) were most challenging to clean*
- In case of Batch cleaner,
    - *Paste 2 (Lead-free, No Clean), Paste 4 (Lead-free, No Clean) and Paste 5 (Leaded, No Clean) were most challenging to clean*
- Cleaning process was not optimized for paste or cleaning agent
    - *Study was to assess the relative differences of cleaning each paste with various cleaning agent types under similar process conditions*

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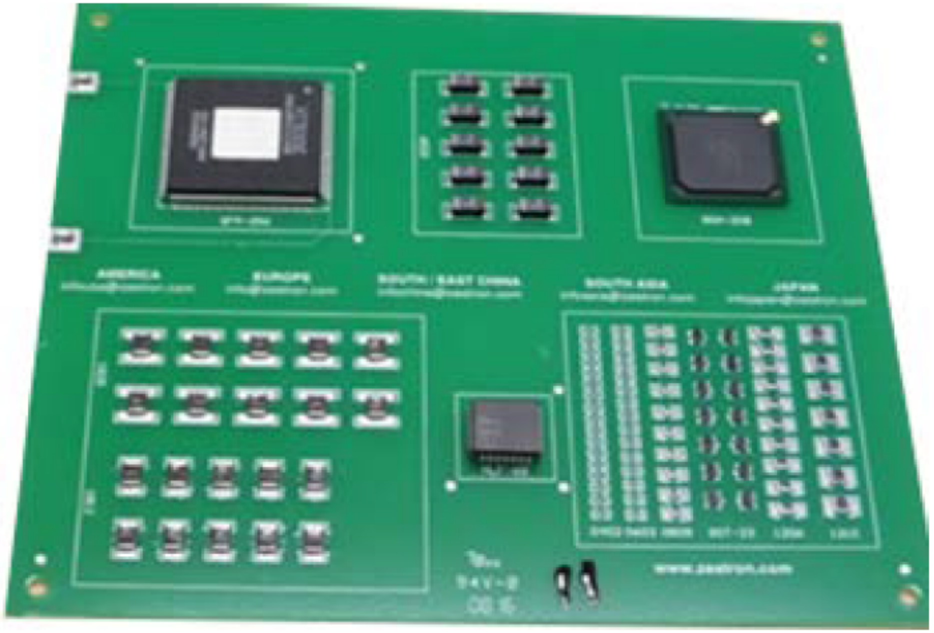
Case Study A

- Aerospace OEM manufacturer experiencing cleaning challenges
  - *Paste 3 (Leaded, No Clean)*
- Using batch cleaning process with aqueous-based chemistry
- Acceptable results only achievable at 180°F wash temperature & 1 hour wash cycle time
  - *Increased chemical usage*
  - *Label ink marking removed*
- Seeking cleaning process with lower temperature, label compatibility, and minimize process costs
- Selected Cleaning Agent F (Dynamic Surfactant Inhibited)

Case Study A

Methodology:

- Eleven (11) company test vehicles were prepared for this evaluation
  - *Total of 106 components on each vehicle*
- OEM assembled the test vehicles at their facility
- Cleaning trials conducted at chemical supplier site



Case Study A

Component Types	No. of Components
6032	10
1812	10
0402	17
0603	15
0805	10
SOT-23	14
1206	10
1210	7
1825	10
MLF	1
BGA	1
QFP	1
Total Components	**106**

Case Study A

Methodology:

- Cleanliness assessment
  - *Visual inspection – under component cleaning*
- The components were mechanically removed from the board
- Visual inspection rating was either “fully cleaned” or “not cleaned”

$$\text{Avg. undercomponent cleanliness} = \frac{\text{No. of components fully cleaned}}{\text{Total No. of components}}$$

Case Study A – Batch Cleaning Parameters

Wash Cycle	
Equipment	Spray-in-Air Batch Cleaner
Cleaning Agent F	Dynamic Surfactant based
Cleaning Agent Conc.	Refer to next slide
Wash Temperature	
Chemical Isolation	30 seconds

Rinse Cycle	
Rinsing Agent	DI-water
Flood Rinse	30 seconds
Rinsing Temperature	Room Temperature
Max # of Rinse Steps	8
Rinse Conductivity Setpoint	2 μS/cm
Final Rinse Time	30 seconds
Final Rinse Temperature	85°F / 29.4°C
Drying Cycle	
Drying Time	900 seconds
Drying Temperature	200°F / 93°C
Cool Down	60 seconds

Case Study A – Results

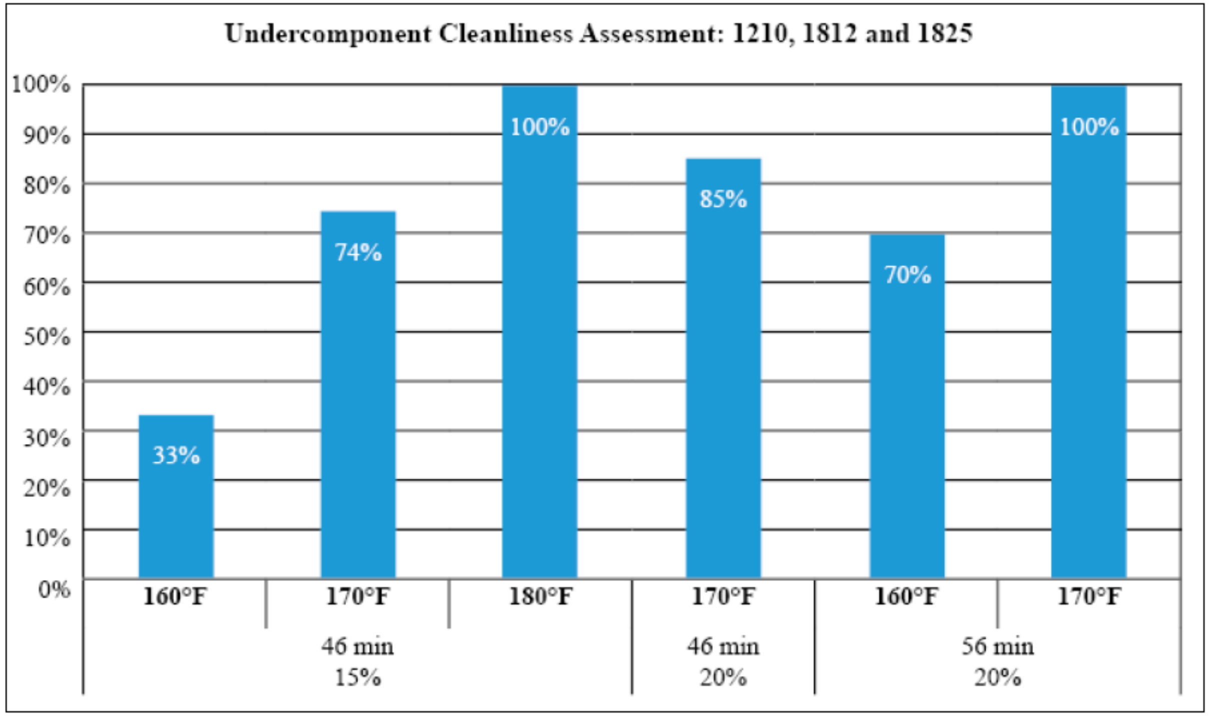
Trial #	Conc. (%)	Temp (°F)	Time (minutes)	Results (# of clean components)												Overall Cleanliness (%)
				0402	0603	0805	SOT-23	1206	1210	1812	1825	6032	MLF	BGA	QFP	
1	15%	150°F	46 min	17	15	7	3	3	0	0	1	9	1	1	1	54.72%
2	15%	160°F	46 min	17	15	10	14	5	2	2	3	10	1	1	1	76.42%
3	15%	160°F	46 min	17	15	10	14	10	1	5	3	10	1	1	1	83.02%
4	15%	170°F	46 min	17	15	10	14	10	4	10	6	10	1	1	1	93.40%
5	15%	180°F	46 min	17	15	10	14	10	7	10	10	10	1	1	1	100.00%
6	20%	170°F	46 min	17	15	10	14	10	3	10	10	10	1	1	1	96.23%
7	20%	170°F	46 min	17	15	10	14	10	5	9	10	10	1	1	1	97.17%
8	25%	170°F	46 min	17	15	10	14	10	4	9	10	10	1	1	1	96.23%
9	25%	170°F	46 min (m)	17	15	10	14	10	5	8	10	10	1	1	1	96.23%
10	20%	170°F	56 min	17	15	10	14	10	7	10	10	10	1	1	1	100.00%
11	20%	160°F	56 min	17	15	10	14	10	2	9	8	10	1	1	1	92.45%

- *Components 1210, 1812 and 1825 were found to be the most difficult to clean*

Case Study A – Results

- Trials 3-6 and 10-11 analyzed for component types 1210, 1825 and 1812
- Results for each trial averaged to identify optimum process settings

Concentration (%)	Wash time (minutes)	Wash Temp (°F)	Cleanliness % 1210, 1812, 1825
15%	46 min	160°F	33%
		170°F	74%
		180°F	100%
20%	46 min	170°F	85%
20%	56 min	160°F	70%
		170°F	100%



Case Study A – Conclusions

- Wash temperature and wash time had the most significant impact
- Followed by cleaning agent concentration
- 100% cleaning results were obtained

Process Parameters	
Concentration	15%
Wash Temperature	180 °F
Wash Time	46 minutes

Process Parameters	
Concentration	20%
Wash Temperature	170 °F
Wash Time	56 minutes

- Aerospace OEM manufacturer ran evaluation in batch cleaner subsequently
  - *Better cleaning results with reduced wash time*
  - *Label ink markings fully compatible*

Case Study B

- A leading CM decided to employ a jet printing process
  - *Lead-free No Clean solder paste (Paste 2)*
- Inline cleaning process with aqueous-based chemistry
  - *Required qualification process including cleaning agent recommendation and cleaning process parameter specifications*
  - *Material compatibility for components and labels was critical*

Case Study B

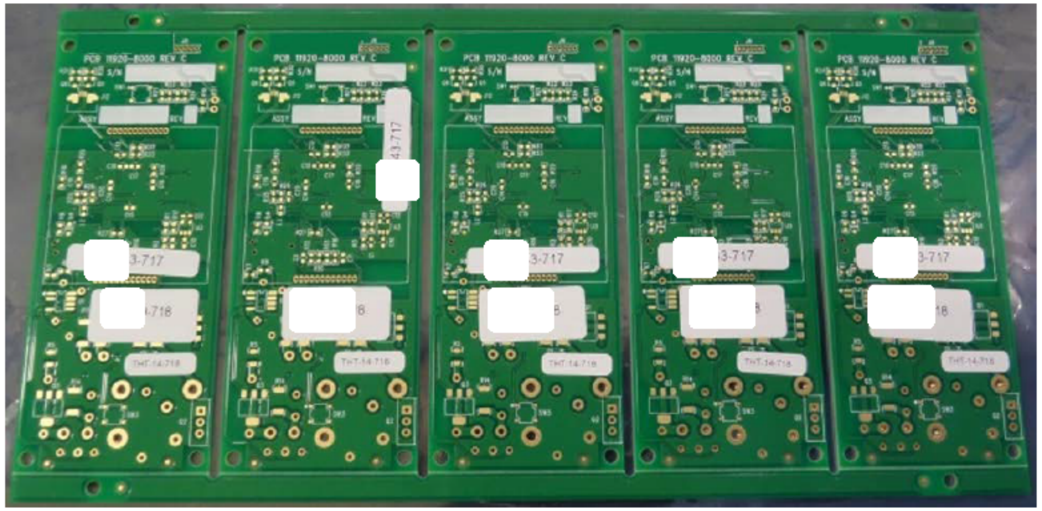
Methodology:

- Developed DOE
  - *Selected Cleaning Agent C – pH neutral cleaning agent*
  - *Employed CM selected inline cleaner for all trials*
  - *Eight substrates – double sided PCBs*
    - Side A – Reflowed twice
    - Side B – Reflowed once

Case Study B

- Heat sinks & Labels for compatibility testing

Anodized Aluminum Heatsink



PCB with labels (with & w/o reflow)

Case Study B

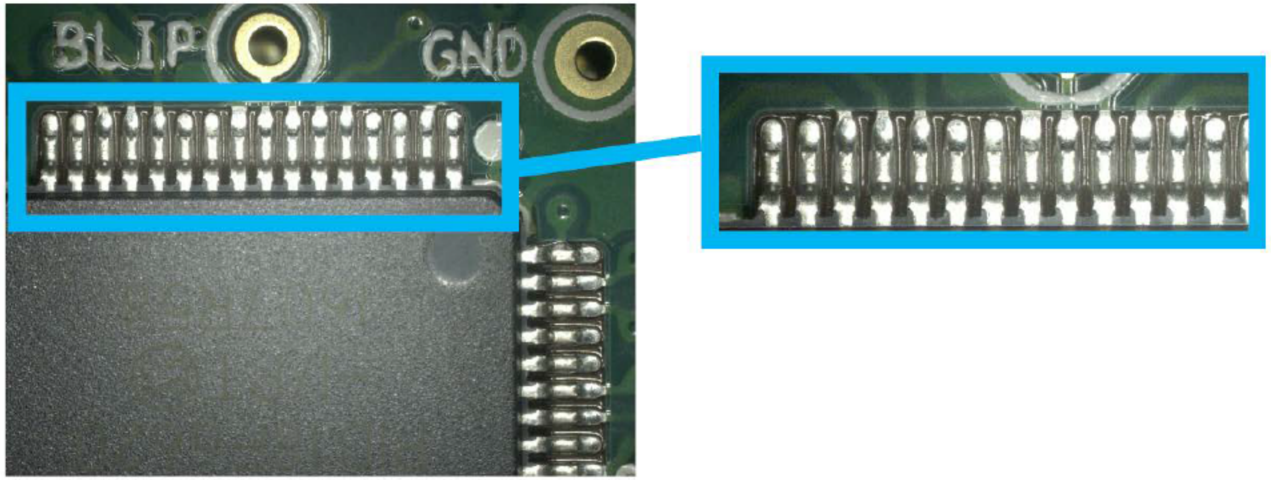
Methodology:

- PCBs reflowed at CM site and sent to chemical supplier for cleaning trials
  - *Flux staging time = 24 hours & 72 hours*
- Varying cleaning agent concentration levels & conveyor belt speeds
- Label compatibility analyzed on substrates
  - *No reflow*
  - *After lead-free reflow*
- Visual inspection in accordance with IPC-A-610F Rev E.
  - *Substrate surface only (24-72 hours post reflow)*
- ROSE Testing in accordance with IPC-TM-650 and J-Std-001F

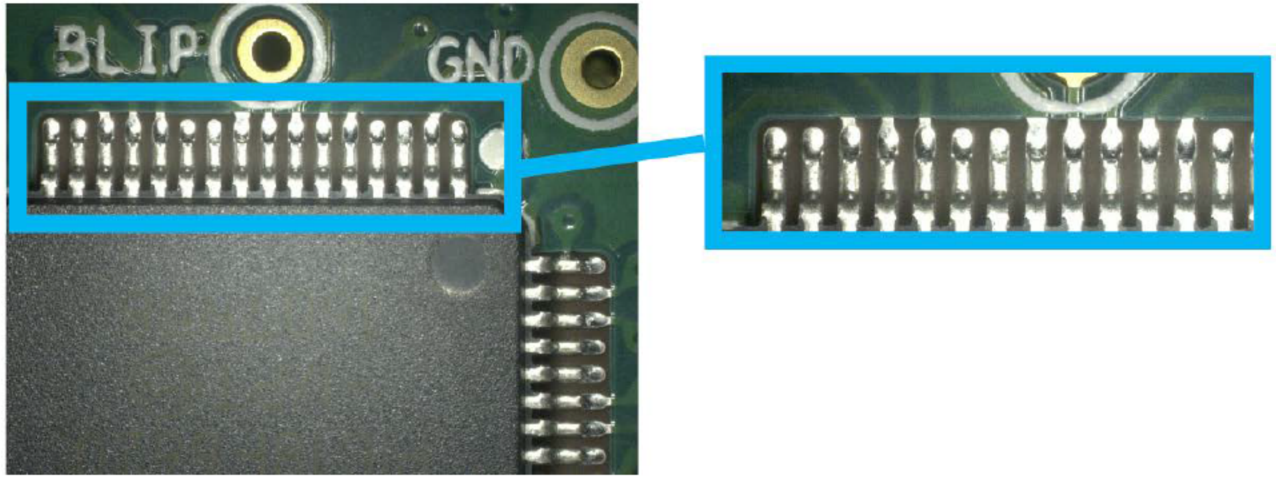
Case Study B - Inline Cleaning Parameters

Wash Stage	
Equipment	Spray-in-air Conveyorized Inline Cleaner
Cleaning Agent C Concentration	10% - 15% (by volume)
Conveyor Belt Speed	1 ft./min. & 1.5 ft./min.
Wash Spray Configuration	8-spray bar enhanced intermix
Pre-Wash Pressure (Top/Bottom)	50 PSI / 40 PSI
Wash Pressure (Top/Bottom) [4 JIC + 4V]	80 PSI / 70 PSI / 40 PSI / 30 PSI
Wash Temperature	150°F
Chemical Isolation Pressure (Top/Bottom)	30 PSI / 25 PSI
Rinse Stage	
Rinsing Agent	DI-water
Rinse Pressure (Top/Bottom)	80 PSI / 70 PSI / 40 PSI / 30 PSI
Rinse Temperature	140°F
Final Rinse Temperature (Top/Bottom)	25 PSI / 25 PSI
Final Rinse Temperature	Room Temperature
Drying Stage	
Drying Method	Hot Circulated Air
Drying Temperature (D1)	180°F
Drying Temperature (D2)	210°F
Drying Temperature (D3)	210°F

Case Study B – Representative pictures

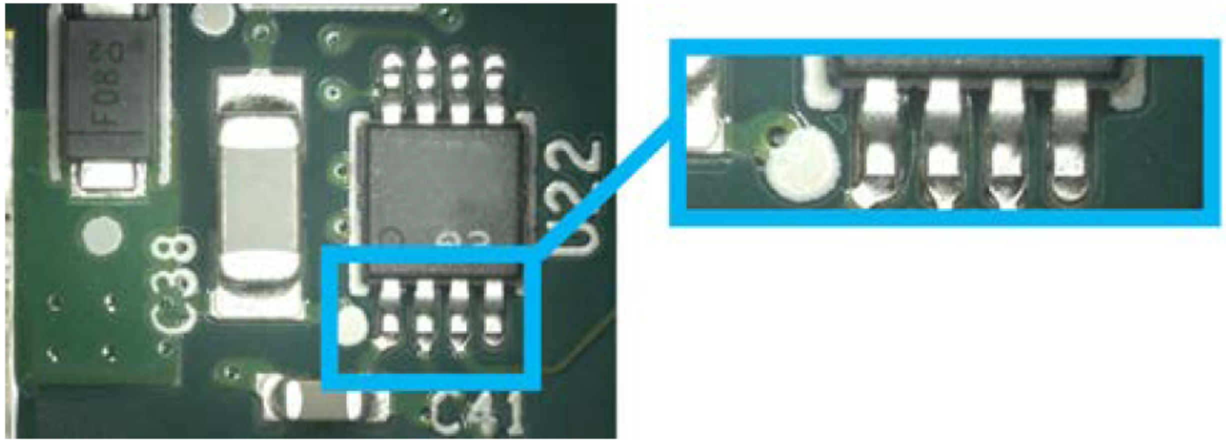


Before Cleaning

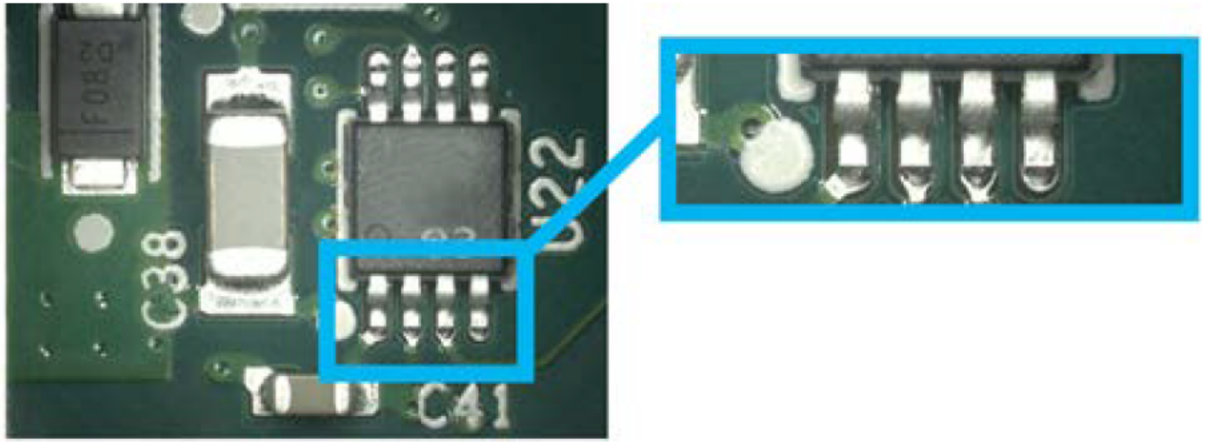


After Cleaning

Case Study B – Representative pictures



Before Cleaning



After Cleaning

Case Study B – Visual Inspection Results

	Trial #	Conc.	Belt Speed (fpm)	Visual Inspection
Flux Staging Time = 24 Hours	1	10%	1.5	Clean
	2	10%	1.0	Clean
	3	15%	1.5	Clean
	4	15%	1.0	Clean
Flux Staging Time = 72 Hours	5	10%	1.5	Minor amount of flux residue visible in between chip-caps
	6	10%	1.0	Clean
	7	15%	1.5	Clean
	8	15%	1.0	Clean

Case Study B – Ionic Contamination Results

	Trial #	Conc.	Belt Speed (fpm)	Ionic Contamination Value (Results)
Flux Staging Time = 24 Hours	1	10%	1.5	0.20 µg/in^2 (Pass)
	2	10%	1	0.04 µg/in^2 (Pass)
	3	15%	1.5	0.12 µg/in^2 (Pass)
	4	15%	1	0.25 µg/in^2 (Pass)
Flux Staging Time = 72 Hours	5	10%	1.5	0.20 µg/in^2 (Pass)
	6	10%	1	0.46 µg/in^2 (Pass)
	7	15%	1.5	0.57 µg/in^2 (Pass)
	8	15%	1	0.18 µg/in^2 (Pass)

Case Study B – Results

- Material Compatibility – Fully compatible
  - *Anodized aluminum heat sink passed through the inline cleaner 3X times with the most aggressive wash settings*

- Label Compatibility – Fully compatible
  - *Provided three different types of labels (with & w/o reflow)*
  - *15% concentration, 150°F wash temperature, 1 fpm belt speed*

Case Study B – Conclusion

- Boards were cleaned with excellent results – flux residues completely removed
- Visual inspection – surface cleanliness
  - *All were found to be clean except Trial 5*
    - Trial 5 – 10% concentration, 1.5 ft./min., 72 hours flux staging time
- Post-soldered flux residues of Solder Paste 2 (Lead-Free, No Clean) fully removed using pH neutral cleaning agent (Cleaner C) using spray-in-air inline cleaner

Agenda

- Introduction
- Main Research
- Results
- Conclusions
- Case Studies
- **Summary**
- Future Work

Summary

- Matching cleaning agent to jet printing paste is critical to ensure best cleaning results in both inline and batch cleaners
- Anecdotal evidence has shown that an optimized cleaning process for a given paste type may not produce same results for same process if equivalent jettable solder paste is used
  - *Higher flux content*
- Preliminary internal data proved extremely valuable in optimizing the cleaning processes at several customer sites
- Highly recommended to engage with the chemical suppliers to determine the ideal process conditions that would meet your cleaning requirements

Agenda

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Future Work

- Currently in progress comparing common No Clean flux chemistries with progressively finer SAC 305 solder powders with various cleaning agents

- Methods to attempt to quantify implications of finer mesh powder on flux removal
  - *Cleanliness effect to be measured using several industry recognized guidelines*

Acknowledgement

- Mycronic Inc.
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- Solder Paste Suppliers