BIG CLEANING JOB VS. SMALL CLEANERS THE ADVANTAGES AND PITFALLS OF GOING SMALL

Eric Camden
Foresite, Inc.
Kokomo, IN, USA

ABSTRACT
Manufacturers face many challenges cleaning today's smaller components with tighter pitch and lower standoff. With every manufacturing dollar needing to go further than ever there is a movement to save money in the cleaning operations. There are many reasons a company would move to a batch type washer over the traditional in-line washing systems. The vast amount of floor space these units consume as well as the utilities and operators needed to maintain the cleaning operation can add up to a real burden on resources of all types. It is this type of thinking that is driving companies to move to shorter in-line and batch type cleaners. Of course the capacity of this type of machine will greatly impact the amount of product that can be completed in a timely manner. The limitation of throughput on the smaller equipment will eliminate this option for almost all major contract manufacturers so we are going to focus on the high mix/low volume sector. This group includes Military, Aerospace, and Medical markets as well as others. This paper will compare traditional large in-line cleaning systems to batch (dishwasher) style as well as other batch systems. Each has unique advantages and drawbacks that must be considered when choosing a cleaning system to effectively remove flux residues from your assembly.

Key words: Batch Cleaning, Flux Removal, PCBA Cleaning Challenge

INTRODUCTION
Why clean no-clean? When using a no-clean paste the residues left behind can inhibit conformal coating, underfill material, probe testing, and possibly absorb moisture from ambient conditions causing a litany of other problems. When agreeing to build a company's product utilizing a wash process to remove no-clean flux the decision of what style of equipment is right for the particular job is not an easy one but the parameters are even more important. If the product being built is sparse in the number and complexity of components this can be a very easy choice. In the best of situations a small system can be used with acceptable results. The problem is that this situation is usually the exception and not the norm. Common component packages like the QFN's, BGA's, and micro-BGA's present cleaning issues that must be addressed on high density applications. An average stand-off height of the QFN is 2-3 mils. Most, if not all, QFN component manufacturers highly recommend using low-solids no-clean type paste flux because of the known challenges with penetrating the low stand-off parts. With BGA's the issue is not only the standoff of the component since that will vary largely based on ball count and paste type used (leaded or lead-free due to ball collapse) and ball height. Ball-to-ball pitch can be a larger issue as it can be as low as 0.5 mm up to 1.25mm. Penetration of cleaning solution is critical to achieve the total removal of detrimental flux residues. Surface tension of the cleaning solutions is paramount to getting under the low stand-off as well as the fine pitch leads. Of course these are not the only types of components that have issues with cleaning; any type can have issues if they are in a shadowed area, shielded by larger components placed nearby. Figure 1 shows an example of shielding on a full assembly

Figure 1. BGA's Shielded on Full Assembly

In figure 1 you see a row of large components above and below the BGA's to be tested that will re-direct the solution spray rather than allow it to flow uninhibited if it is racked in the normal vertical manner in a batch style cleaner. Even with units that have multiple spray bars spraying from top, bottom, and both sides large components can shield smaller parts that are placed in close proximity. When gravity does its job and the solution is not allowed to spend as much time working at board level and under the components vs. standard in-line cleaning, all of the process parameters become even more critical. The spray pattern /flow dynamic will be disrupted and the surface mount components will be suspect after cleaning, especially if no-clean flux is being removed. So what is the answer to properly cleaning no-clean flux from low stand-off/shielded parts with a batch cleaner? That is the issue we will address in this paper and prove out the answers using both visual and ion chromatography data.

BACKGROUND

The study of how to effectively clean circuit boards with a batch cleaner has been done many, many times before. The difference between all of those studies and this one is the test board. All other studies found during research used a test coupon that was supposed to represent a standard build process, this study uses actual product. The test boards used in this study are from a customer project that had agreed to scrap out the boards after testing. These were used because of the dense population of components and the many shadow opportunities on the assembly.

TEST PARAMETERS

On these test subjects there are 2 BGA's that are near 100% shadowed by a large SMT connector on one side and by a row of relays on the other. There are 2 more identical BGA's (1 on either side) that are less shielded than the primary 2 of concern. All 4 BGA's were doped with a widely used no-clean wave flux with equal amounts and were then partially heat activated, see thermal profile figure 2.

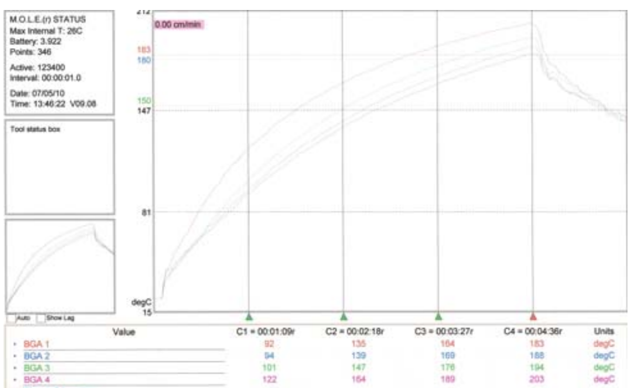


Figure 2. Thermal Profile

The control board was cleaned with a standard inline cleaner with remaining samples processed in a batch cleaner with various parameters, as described with each sample. After cleaning the samples with various parameters the BGA's were mechanically removed and visual observations under 10x magnification was performed. After the visual examination local extractions under each removed BGA (component side) was performed and the solution was processed through ion chromatography. The two key ions in question are succinic acid and ammonium, the activators in this flux. Since we are not a production facility and the point of the paper is to discuss cleaning variability, a full build process was not possible or needed. The main idea was to start with equal levels of contamination across all samples. Baseline data was taken on BGA's after conditioning and not cleaned at all and those results are compared to various cleaning parameters. The BGA's tested have a 196 I/O with 40 mil pitch and 10 mil standoff. This isn't normally considered an extremely tough component to clean, even better to prove the potential issues with shielding and batch cleaning.

TEST RESULTS

The first samples tested were of an uncleaned control sample. The BGA's were mechanically removed and tested to give baseline data on the starting cleanliness levels. The photos in figure 3 show the heavy flux residues from the application of pure wave flux.

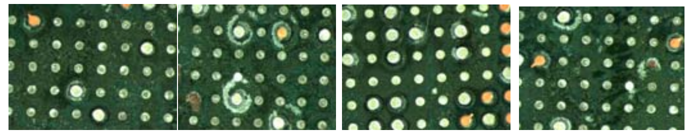


Figure 3.BGA's 1-4

The ion chromatography results in table 1 show the very high levels of succinic and ammonium on the uncleaned samples and give us a baseline to compare the different cleaning processes against

Table 1. Unclean Samples

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	1216.70	71.53
BGA 2	1189.35	73.50
BGA 3	1213.14	71.44
BGA 4	1301.20	72.87

In-Line Sample

The control sample was processed through an in-line cleaner with 10% MEA based saponifier at 2.0 FPM, 66^{o}C wash and 60^{o}C rinse. Top side pressures of 60 PSI, bottom side pressure of 50 PSI with 2 air knives and IR heat set at 60^{o}C. The board was horizontal on the belt so the saponifier had ample time to soften and remove most of the flux residues as evident in the figure 4.

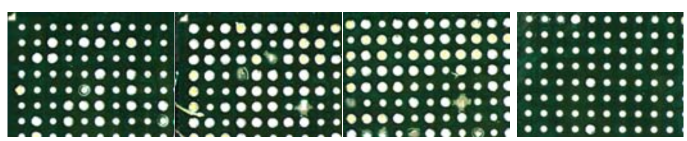


Figure 4. BGA's 1-4

The ion chromatography results in Table 2 show that with enough time and energy a standard in-line process with saponifier can overcome the problems that shielding from large components can pose, mainly due to the horizontal position of the assembly on the belt.

Table 2. In-Line Cleaned Sample

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	5.96	0.18
BGA 2	5.05	0.26
BGA 3	5.16	0.21
BGA 4	5.66	0.29

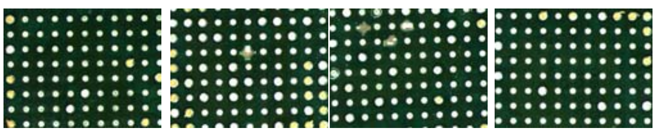
Batch Cleaner Samples

The batch cleaner used was a standard in the industry with the following parameters, wash at 60^{o}C for 6 minutes, rinsed 6 times until >1MΩ is met, and dried for 12 minutes at 46^{o}C. 0-5 bare panels of comparable size were placed with the samples in the basket to present a variety of cleaning conditions. We recommend levels of Succinic acid less than 25 ug/in2 and ammonium residues less than 3.0 ug/in2 for good electrical performance.

Batch Sample 1

One single assembly was placed in the rack with the SMT connector facing up (see figure 5) and ran through the batch wash process. This is what we would consider the best case scenario with only the connector to shield the BGA's. The theory is that components 2 and 3 are the most difficult to clean as 1 and 4 are more exposed. We see these as marginal levels. The photos in figure 5 show very similar levels of cleanliness.

Figure 5



The ion chromatography results in table 3 also show similar levels of cleanliness across all 4 components.

Table 3. Batch Sample 1

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	21.56	2.24
BGA 2	24.85	3.78
BGA 3	25.47	3.62
BGA 4	21.95	2.31

Batch Sample 2

One bare panel was placed on either side of this assembly and again racked with the connector facing up. The photos of the removed BGA's, figure 6, show some remaining flux residues due to the boards that were added to the basket blocking some of the solution from hitting the assembly surface as it did in batch sample 1.

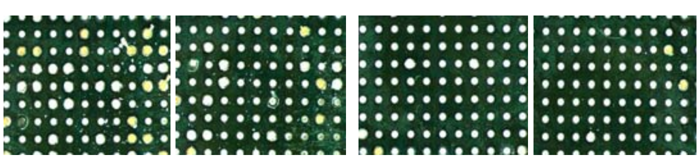


Figure 6. BGA's 1-4

The ion chromatography data in table 4 also shows the effect of the shielding from the bare panels as BGA's 1 and 4 show lower levels of ionics than numbers 2 and 3, but still high levels of ionics.

Table 4. Batch Sample 2

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	44.28	5.87
BGA 2	46.99	6.56
BGA 3	47.59	7.02
BGA 4	43.08	5.51

Batch Sample 3

5 bare panels were placed on either side of the assembly for this trial to determine if it matters if there are two or more boards surrounding the sample. The photos of the removed BGA's in figure 7 show similar results to batch sample 2.

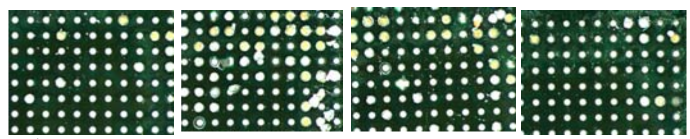


Figure 7 BGA's 1-4

The ion chromatography results in table 5 are also similar to those for batch sample 2. This data tell us that it does not matter if there is one or five boards on either side of the test subject. The shielding can leave high flux levels.

Table 5. Batch Sample 3

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	45.02	5.59
BGA 2	46.85	6.26
BGA 3	46.99	6.94
BGA 4	44.24	5.92

Batch Sample 4

The test subject was turned 90^{o} so the BGA's were closest to the top spray bar with one bare panel on either side to better simulate a production run. This time the visual results in figure 8 show similar levels of cleanliness but the ion chromatography data in table 6 shows that the BGA's are progressively dirtier as they get farther from the top spray bar. This proves that even small standoff components can cause their own shielding problems.

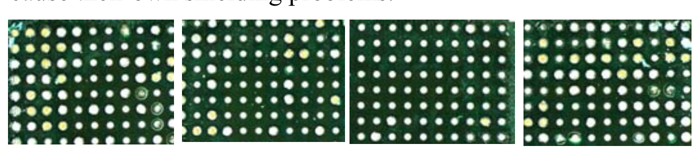


Figure 8. BGA's 1-4

Table 6. Batch Sample 4

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	17.01	1.54
BGA 2	25.54	2.66
BGA 3	22.98	2.58
BGA 4	13.87	1.97

Batch Sample 5

The last sample in the group was laid flat on the wash basket in the same manner as the in-line sample. Not surprisingly the visual, figure 9, and ion chromatography, table 7, results were very similar to the in-line results. This supports the philosophy of cleaning is chemistry + time = flux removal when given enough time and thermal energy to soften the flux residues on the surface that will give you the best chance to remove the flux residues.

Figure 9. BGA's 1-4

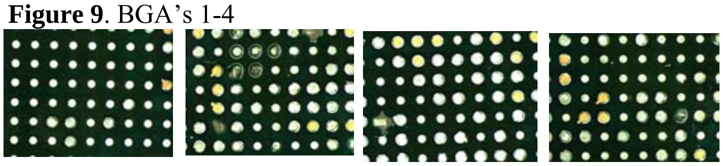


Table 7. Batch Sample 5

all values are in ug/in2	Ion Chromatography	
Sample Description	**Succinic**	**Ammonium**
BGA 1	9.85	0.78
BGA 2	10.26	1.01
BGA 3	10.02	0.93
BGA 4	9.75	0.84

CONCLUSIONS

Orientation of the assemblies is of critical concern when using a batch washer to remove any type of residues if large standoff components are involved and especially when removing a no-clean flux. Not only is spacing important to keep in mind but also the degree of canting the board is subject to in the basket as they do not sit straight up in the racks. This can play a vital role if you are cleaning a double sided, densely populated assembly. The results of the horizontal orientation with the in-line cleaned sample and also with batch sample 5 show that if the saponifier is given time and thermal energy this is the best way to remove residues.