

## CLEANING FOR RELIABILITY POST QFN REWORK

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### ABSTRACT

The need for cleanliness under individual components increases as the spacing between connector leads decreases and power increases. The low standoff height of QFNs traps flux between the ground pad and component leads. Entrapped flux under the QFN is a reliability concern. The purpose of this paper is to make an argument for removing flux residue under the QFN post rework and present cleaning process options for meeting this cleaning challenge.

### INTRODUCTION

An important issue when reworking electronic assemblies is the assurance that the product works for its designed life expectancy. Flux residue under Quad Flat Pack No Lead (QFN) components can impact performance when conductive ions migrate within the electrical field.<sup>1</sup> Moisture in the form of humidity creates an electrolyte where flux residue remaining under the QFN is propagated as conductive ions. The total current density entering and leaving the electrolyte causes metal ions to split and form dendrites. This spatial coupling depends on the distance between the conductors, with closer solder connections coupled more strongly. As the difference in potential across the conductors rises, the risk of failure increases.

QFNs are placed flush onto the printed circuit assembly. These components are difficult to clean due to size, spacing, and low standoff height.<sup>2</sup> The standoff clearance under QFNs is defined by the solder paste print and is typically less than 4 mils in height. Compounding the problem are the uses of smaller components and organic solder protected circuit boards that use solder mask defined on bare copper, which further reduces the spacing under the QFN to less than 2 mils.

The purpose of this research is to develop process knowledge for cleaning all flux residues from under the QFN device. The authors representing cleaning material and equipment organizations investigated process variables such as solder paste, cleaning agents, cleaning equipment, and wash process factors.

### REWORKING QFN COMPONENTS

Reworking QFN components is typically a low volume operation with limited options for cleaning flux residues post soldering. The common cleaning equipment used for rework operations is the dishwasher style aqueous spray-in-air machine. Engineered cleaning materials are needed to dissolve flux residues commonly used in the rework operation. To successfully clean all flux residues under the QFN, process factors must be understood.

The conceptual framework for this research provides insight into the problem of cleaning flux residues post QFN rework. The quantitative paradigm inquires into the problem of cleaning all flux residues under the QFN component based on hypothesis testing composed of variables, measured visually, and analyzed to determine best cleaning practice. This research study quantifies the relationship between flux type, cleaning time, and QFN standoff heights. The goal of the research is to provide the rework technician with process menu that is predictive, repeatable, and confirms cleaning efficacy.

This paper discusses best practices for designing the QFN cleaning process using the batch dishwasher style cleaning machine. The discussion will include an overview of the science of aqueous engineered cleaning fluids used to remove a broad range of flux residue types used to rework QFNs. The designed experiment will illustrate the relationship between research hypotheses and the variables tested. A Practical Components rework test card will be used to confirm the research findings. Best practice recommendations will draw the research paper to a close.

### BACKGROUND TO THE PROBLEM

Highly dense and smaller component features increase rework complexity as termination pads and standoff heights decrease. Miniaturization imposes a great challenge on the chemistry of fluxes creating higher levels of flux oxides.<sup>3</sup> Additionally, as QFNs decrease in size, the component and conductor spacing generate more heat during soldering, which increases the cleaning challenge.<sup>4</sup>

Notwithstanding flux changes, the QFN standoff height is considered to be the critical cleaning differentiator. To address this problem, technicians use shims, which can be placed onto the ground pad to elevate the QFN to a standoff height of 4-6 mils.<sup>2</sup> Increasing standoff height dramatically improves cleaning. The problem with this method is the solder joint has to form a bridge between the distance of the QFN and the pad. Another method is to plate the QFN pads up another 4 or 5 mils to increase the standoff height, but this is not practical for rework operations.

The electronic assembly industry is facing numerous changes such as RoHS and miniaturization that create new soldering demands. The chemical changes in flux materials and soldering temperatures can create cleaning difficulties. During QFN rework operations, the selection of a flux that provides thermal stability and forms a soft residue that readily dissolves into the cleaning agent is critically important.

### **BEST IN CLASS CLEANING AGENT**

The evolution of electronic assemblies demands technology innovations to satisfy evolving customer needs. The challenge to PCB manufacturers continues to be density and miniaturization. Electronic assembly cleaning agents must continue to improve solubility for a wide range of flux compositions; wetting properties for penetrating low standoff gaps; and improved materials compatibility to prevent damage to assembly board laminates, components, packages, and connectors.

Aqueous engineered cleaning material innovations continue to maintain pace with the electronic assembly roadmap. Best in class aqueous cleaning agents are derived from the laws of thermodynamics. Engineered cleaning agent building blocks use a combination of dispersive, polarity, and hydrogen bonding energies. The first design criterion is to engineer solvating blend combinations that show a high affinity for varied flux residue soils. A unique mix of polar materials with permanent dipole moments is needed to rapidly interact and soften rosin/resin structures. The unique combination of ingredients must form an electron exchange with water in an effort bond molecules and ions into a cohesive and stable composition.

The combination of thermodynamic (chemical) and kinetic (energy) forces are needed to clean residues under the QFN component. The aqueous cleaning agent is designed to be diluted with water and operate at an optimal concentration range from 12-15%. Kinetic energy in the form of heat, fluid flow, motion (spray impingement), and directional forces are needed to deliver the cleaning agent to electronic assembly. The thermodynamic energies requires the right combination of ingredients working in unison to wet, dissolve, and bond flux residues. Optimizing the thermodynamic and kinetic energies requires specific cleaning agents designed to operate in specific cleaning equipment.

Materials compatibility is a critical factor that must not be overlooked. Electronic assemblies expose the cleaning agent to wide range of metal alloys, board laminates, plastics, polymers, and coatings (inks). As electronic assemblies drive toward high density and miniaturization, many cleaning agents increase reactive ingredients in an effort to improve cleaning efficacy. Highly reactive cleaning agents oxidize and reduce metal alloys; attack some board laminates; and attack plastics, polymers and coating. These highly interactive reactive cleaning agent properties can improve cleaning performance but not without material compatibility issues. Best in class cleaning agents are engineered with high Van der Waals dispersive and low reactive forces. When formulating with low reactive forces, minor ingredients are highly effective and work to protect the assembly from materials compatibility concerns. An added benefit to this approach is the ability to increase kinetic forces in the form of time and energy without damaging the assembly.

### **BEST IN CLASS REWORK CLEANING MACHINE**

In past decades, vapor degreasers running CFC-based solvents such as Freon TMS or 111 Trichloroethene represented the conventional wisdom of that era. The workload between solvent and machine was unevenly divided. The solvent fulfilled dual roles both as a solubilizing agent and as a delivery device. This was due to the fact that vapor degreasers utilized an immersion process. The equipment was only responsible for containment, solvent distillation, and heat, the latter being the most critical of the equipment's process steps.

While solvent-based immersion defluxing systems still exist, they lack popularity due to several factors paramount of which are cleanliness capabilities and environmental concerns. Today's Best in Class processes utilize aqueous based chemistries in aqueous defluxing equipment.

The technological differences between the vapor degreasers of yesterday and conventional aqueous defluxing systems are vast indeed. While yesterday's equipment relied on the chemistry to do most of the work, the pendulum has swung towards the direction of the equipment. The best modern cleaning chemistries will produce vastly different cleanliness results when used in differing equipment designs. A successful defluxing process requires a proper marriage between chemical and equipment selection. No longer is sheer contact between the defluxing chemistry and the target the sole requirement of a successful defluxing process.

While modern defluxing chemistries require contact between the chemical and the target, there is much more to the process than that. There are fourteen fundamental elements across four specific design criteria to a Best in Class defluxing machine. They are:

#### *Wash Cycle Heat*

- Contact
- Spray Design
- Segregation of Wash Solution

- Chemical Dosing

#### *Rinse Cycle*

- Contact
- Spray Design
- Ionic Contamination Detection

#### *Dry*

- CFM
- Convection Heater Power
- Radiant Heater Power

#### *General Equipment Guidelines*

- Chemical Compatibility
- Operator Safety
- Environmental Safety
- Process Control

#### *Wash Cycle (Heat)*

All Best in Class aqueous chemistries require heat. If operated unheated, disastrous results including poor cleanliness and extreme foaming can occur. Most cleaning chemicals produce optimum results when operated at temperatures between 50° - 70° C. The defluxing machine must be capable of heating and maintaining the wash solution to these temperatures.

#### *Wash Cycle (Contact)*

No defluxing chemistry can ever remove flux if it cannot come into contact with the assembly. Modern surface mount assemblies feature complex geometries. Both large and small components may be mounted in close proximity to each other, allowing one component to shadow another.

In the industry's most popular format (batch), shadowing is of particular concern as assemblies are stacked much like dishes in a dishwasher. While batch defluxing machines utilize upper and lower rotating spray bars that produce thousands of possible angles of attack, there remains a potential for shadowing. This remaining potential may be mitigated with the implementation of an oscillating device that moves the assemblies in a forward / rearward motion simultaneous to the spray-arm rotation. The rack oscillating device increases contact by reducing the possibility of shadowing.

#### *Wash Cycle (Spray Design)*

There are two competing theories when it comes to fluid diffusion. All cleaning begins with contact; contact between the cleaning fluid and the cleaning target. Even though a defluxing machine may be equipped with rotating spray arms and even a rack oscillating device, at the core is the fluid delivery device. Some equipment designs utilize spray nozzles while others do not. The purpose of a spray nozzle is to "bend" the fluid to a shape that best fits the target, much like placing your thumb over the end of a hose to increase the fluid's diffusion pattern. This action forces fluid through a smaller hole, increasing its velocity and

therefore its impact pressure while reducing the water drop size and associated surface tension.

While some defluxing equipment utilizes nozzle-based fluid distribution, others do not. These nozzle-less machines simply utilize a hole with a specified diameter to produce a coherent stream of fluid with no diffusion. The advantage of a coherent spray is that the flow can travel further before losing velocity. This is due to the fact coherent fluid flows produce larger fluid drop sizes and are therefore capable of greater travel before losing velocity.

The debate between nozzle-based and coherent-based fluid delivery designs is based on indisputable factors. The more water is "bent", the faster it loses its impact pressure. On the other hand, nozzles produce smaller droplet sizes, aiding in under component penetration. As we will discuss later, under component penetration (impingement) is among the most critical elements in a successful defluxing process. Nozzles, by widening the fluid's trajectory, ensure full (and even overlapping) contact with the target assemblies.

Coherent fluid distribution maintains fluid velocity for a longer distance but produces the largest fluid droplet size, impeding its ability to penetrate under low standoff components. In addition, coherent spray patterns do not overlap. Thorough assembly coverage is only possible if the fluid hitting the assembly ricocheted in a manner to allow thorough coverage. It should be noted that when the fluid changes direction (like with ricochets), it loses the majority of its velocity, and rapidly becomes ineffective.

#### *Wash Cycle (Segregation of Wash Solution)*

Most modern defluxing chemicals are prepared and shipped as a concentrated. They are mixed with water (normally deionized water) to form wash solution. Common in-use percentages are 10 % - 20% concentrated defluxing chemistry and 90% - 80% DI water. Most modern defluxing chemistries provide a relatively wide process window. Commonly, +/- 5% concentration or dilution still produces acceptable cleanliness results. Due to many corporation's increased environmental sensitivities and budgets, many defluxing equipment manufacturers have incorporated wash solution recyclers in their equipment. With a wash solution recycler, the same chemical / water mixture may be used dozens of times, over the course of days or even weeks. Because of this, it is vital that the defluxing machine have incorporated within its basic design safeguards to prevent the dilution of wash solution with rinse water.

Design elements such as segregated spray and drain / transfer pumps reduce the chance of chemical dilution. Anti-dragout features such as programmable rest (drainage) times, and self-purging wash pumps also contribute to the reduction of chemical dilution. A highly effective drying system will also prevent chemical dilution by eliminating

any residual rinse water from mixing with the upcoming cycle's wash solution.

#### *Wash Cycle (Chemical Dosing)*

As previously stated, most chemical manufacturers, to reduce the cost to their customers, provide their defluxing chemical in concentrated forms. Most of the failures in a defluxing process witnessed by this author have been caused by inaccurate chemical mixing, mostly by equipment operators. A well designed automatic chemical dosing technology combined with periodic monitoring (via titration or refractometer) will provide consistent and accurate chemical concentrations without the need for operator intervention. This reduces operator errors and ensures that the process stays within the required guidelines.

#### *Rinse Cycle (Contact)*

Like the wash cycle, contact between water (the rinsing agent) and the assemblies is required. Because most batch defluxing systems utilize the same chamber for all cycles (wash, rinse, and dry), the spray technology used in the wash cycle will be used in the rinse cycle. All required design attributes associated with the wash section (contact and spray design) are identical.

#### *Rinse Cycle (Spray Design)*

While both contact and spray designs are identical between wash and rinse cycles, it is vitally important to make the following statement. The most critical aspect of a successful defluxing process is the rinse cycle.

While most attention is bestowed upon the wash cycle, cleanliness results would be catastrophically worse if the rinse cycle were not performed properly. While conventional aqueous defluxing chemicals perform substantially better than their obsolete solvent counterparts, they cannot be allowed to remain on an assembly. Most modern defluxing chemistries maintain a pH level in excess of eleven. While anti-corrosion (brightening) agents prevent dulling of the solder joints during the wash cycle, the defluxing chemical must be thoroughly removed.

After the wash cycle, the assemblies are covered in wash solution, both above and below the components. A thorough rinsing process must be initiated to remove all traces of wash solution from the assembly. Because the wash chemical contains surface tension reducing components that can reduce the surface tension of the wash solution from 72 dynes (water) to 25 dynes, under component penetration is much more easily achieved in the wash cycle than in the rinse cycle. This is when the small water droplet attributes of spray nozzles come into play. The only way to effectively chase out 25 dyne fluid with 72 dyne fluid is to manipulate the water droplet size mechanically, with the use of precision cut spray nozzles and a very large pump (to provide significant pressure and velocity).

#### *Rinse Cycle (Ionic Detection)*

A successful defluxing process relies on the successful removal of flux into the wash solution during the wash cycle and the successful removal of the wash solution during the rinse cycle. Fortunately, all aqueous defluxing chemistries have one thing in common. They contain highly ionic properties. The incorporation of an ionic residue detection device (resistivity sensor) into the rinse plumbing is highly effective at detecting ionic contamination in the normally non-ionic deionized rinse water. A defluxing machine equipped with this technology can automatically add or subtract rinse cycles until the rinse effluent's ionic properties reach a limit preset by the user. Use of this technology ensures the complete removal of wash solution (and the flux it contains) consistently batch after batch.

#### *Dry Cycle (CFM)*

Dry assemblies are essential to a successful defluxing process. Most batch format defluxing systems utilize a mechanical blower to provide air exchange within the process chamber. The larger the blower (CFM), the greater frequency of complete air exchange within the process chamber. For rapid and thorough drying, the objective is to exchange the moisture saturated air with hot and dry moisture receptive air. Depending on the specific location of the defluxing equipment, a particle filter may be required to remove unwanted particles from the rapidly moving air.

#### *Dry Cycle (Convection Heat Power)*

As mentioned above, hot, moisture saturated air needs to be replaced with hot dry air. This requires the incorporation of convection heaters to heat the incoming air before it enters the process chamber. The degree of power (wattage) should be proportionate to the CFM of the blower.

#### *Dry Cycle (Radiant Heat Power)*

While the convection heater is working to produce hot incoming heat, a radiant heater will allow the assemblies to absorb heat and themselves become mini-heaters. As the assemblies absorb heat, water trapped below components (and between layers) begins to evaporate. A successful drying process will produce assemblies that measure a lower post-defluxing weight than pre-defluxing.

#### *General Equipment Guidelines (Chemical Compatibility)*

Obviously, the equipment must be compatible with the defluxing chemical. There are two levels of compatibility, material and process.

Material compatibility requires that all wetted surfaces of the equipment be compatible with the defluxing chemical. All seals (pumps, doors, covers, etc) must be compatible. Materials such as rubber, Buna, Viton, and other similar materials are not generally compatible with many defluxing chemicals. Materials such as Teflon, EPDM, and EPR are widely compatible.

The defluxing machine must also meet the process requirements of the chemical. If a chemical requires heat, so will the equipment. If the chemical requires mixing

before use, the equipment must be equipped with a mixer. Other considerations such as ventilation, chemical re-use capabilities, dosing requirements, foam-control, and other factors need to be considered when choosing a defluxing machine.

#### *General Equipment Guidelines (Operator Safety)*

Operator safety is paramount. Fortunately, modern aqueous defluxing chemicals, while maintaining their ability to remove all flux types, are non-flammable. The use of non-flammable chemicals has greatly increased the overall safety of cleaning equipment. Additional desired safety features include hands-free chemical dosing, over-heat protection devices, and keyed maintenance functions.

#### *General Equipment Guidelines (Environmental Safety)*

Today's defluxing chemicals and equipment are widely considered environmentally responsible. Many defluxing machines utilize evaporators to eliminate any discharge of effluent (wash or rinse solution) into the drain. While most municipalities allow the discharge of effluent from modern defluxing systems, zero-discharge configurations are becoming widely preferred as they eliminate the concern of unknown future environmental regulations.

#### *General Equipment Guidelines (Process Control)*

The big question is "Who Controls Your Process?" Best in Class equipment provides a level of process control that ensures a predictable and consistent result. The operator interface should be clear and intuitive. Closed-loop process feedback eliminates operator panic (Did I press start? Is the water turned on? Is there chemical in the machine?). Password protected sections of the interface prevent both unintentional and unauthorized process changes. Statistical Process Control (SPC) data logging allows cleanliness analysis and historical review of process trends.

### **RESEARCH HYPOTHESES**

H<sub>1</sub> – The standoff height is directly correlated to removal of all flux residues under the QFN component.

H<sub>2</sub> – Flux compositions and soldering processes that form soft residues post soldering are directly correlated to removal of all flux residues under the QFN component.

### **METHODOLOGY**

The designed experiment inquires into the problem of removing all flux residues from under OFN components following the rework process. The research hypotheses were tested in order to determine predictive process variables. The objective of the research is to quantify the relationships between the variables of standoff height and flux type. All aspects of the study were carefully designed before data was collected. This correlational research attempts to determine whether and to what degree, a relationship exists between standoff and flux types for cleaning under QFN components. Best in class cleaning equipment and cleaning agent were selected for evaluating the test variables.

The test vehicle (Figure 1) used for this study was designed by B.A.E. Systems located in Johnson City, New York

(Patent Pending). The test vehicle was build out of FR-4 laminate. Stainless steel pins were place at specific standoff heights and positioned to place 1"x1" glass slides that are 2 mils thick. Two pins were inserted to lock in two corners of the die and prefabricated tension holders were designed to lock in the remaining two sides of the die. The test vehicle provides ten standoff heights (1mil, 2 mil, 3 mil, 4 mil, 5 mil, 6 mil, 7 mil, 8 mil, 9 mil, and 10 mil).

**Figure 1: Test Vehicle**



Eight paste fluxes used in commercial solder paste products were tested. Three of the solder pastes represented water soluble technologies, two rosin technologies, and three no-clean technologies. Two milliliters of the flux was applied to each of the test sites. The slides were placed and locked in. The test vehicle was reflowed using the standard eutectic tin-lead reflow profile (Figure 2).

**Figure 2: Test Vehicle Reflow**



Following the reflow process the test vehicle was placed in the batch dishwasher cleaning equipment (Figure 3).The equipment utilized for the experiments utilized several of Best in Class equipment design characteristics.

#### *Wash Technology:*

Two rotating spray bars (one above and one below the assemblies). Each spray bar was equipped with ten stainless steel spray nozzles. The nozzles produced a flat spray with a fifteen degree diffusion angle. Fluid was pumped through the nozzles with a three horsepower stainless steel dual

impeller Gould (ITT Industries) pump, producing 65 PSI manifold pressure.

The nozzles were mounted on the spray bars in an asymmetrical manner which produced overlapping nozzle flow pattern coverage while eliminating direct nozzle flow collisions (which would otherwise result in a reduction of impact pressure).

A stainless steel sump tank equipped with 10.5 kW stainless steel heaters provided the necessary power to heat the wash solution to the required set point and maintain the temperature throughout the wash cycle.

The assemblies were presented to the spray systems vertically with a fifteen degree off-vertical angle. The equipment was equipped with an oscillating device that transported the assemblies 19 mm forward then 19mm rearward during the wash and rinse cycles to reduce shadowing.

#### *Rinse Technology*

The rinse cycle utilized the same spray bars and nozzles as did the wash cycle. Each rinse used a unique eleven liter volume of de ionized water. The spray pump was mounted in an inverse vertical manner, allowing the previous wash solution and each volume of rinse water to be completely purged from the pump. An on-board resistivity monitor detected ionic contamination levels within each rinse cycle, ensuring the complete removal of wash solution (and the flux contained therein).

#### *Dry Technology*

The equipment's drying technology consisted of a blower with a rating of 1,500 CFM. The equipment was equipped with a convection heating system consisting of three 2kW

stainless steel tubular finned air heaters (6 kW total). In addition, a 5kW watt stainless steel heater was mounted in the process chamber acting as a radiant heater.

The process recipe used to evaluate cleaning was as follows:

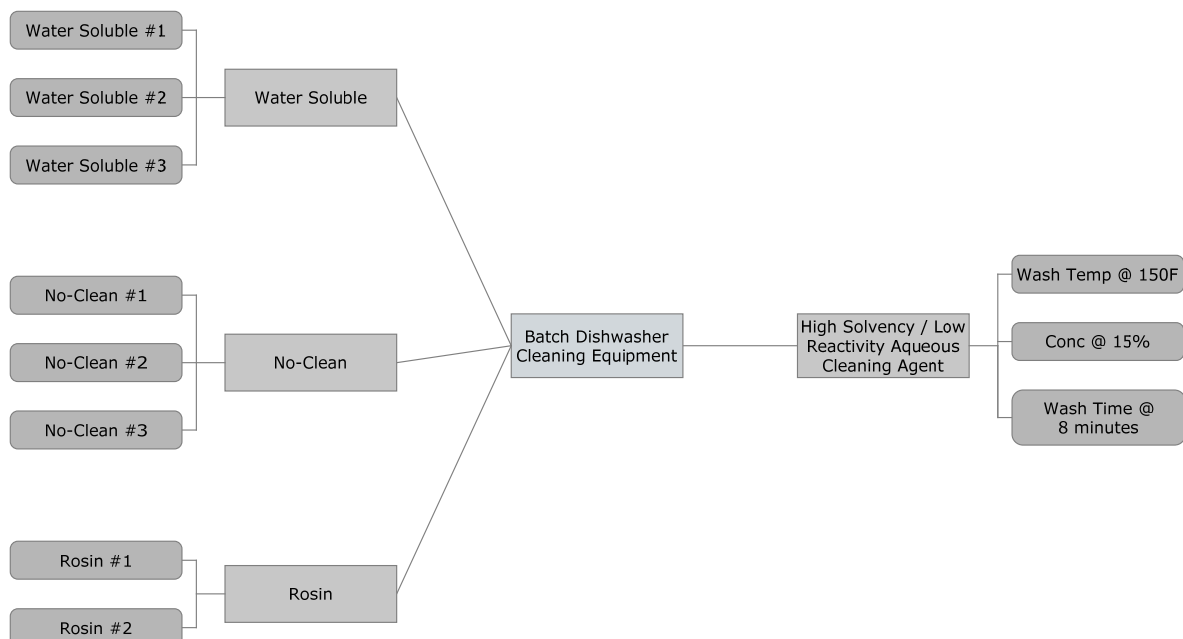
- ◆ Cleaning agent: High Solvency / Low Reactivity
- ◆ Cleaning agent concentration: 15%
- ◆ Cleaning agent temperature: 150°F
- ◆ Wash Time: 8 minutes
- ◆ Rinse Cycles: 4
- ◆ Rinse Temperature: 140°F
- ◆ Convection Drying: 5 minutes

**Figure 3: Position in Batch Cleaning Equipment**






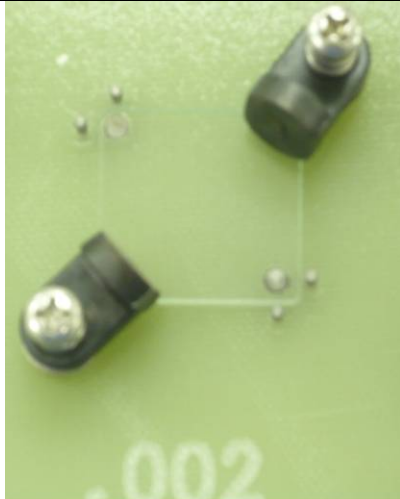

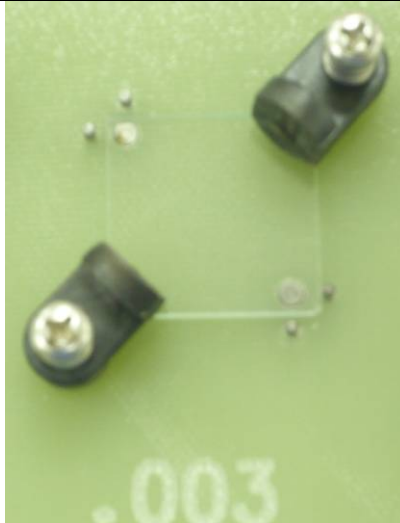
Figure 4 illustrates a visual overview of the designed experiment.

**Figure 4 Designed Experiments**





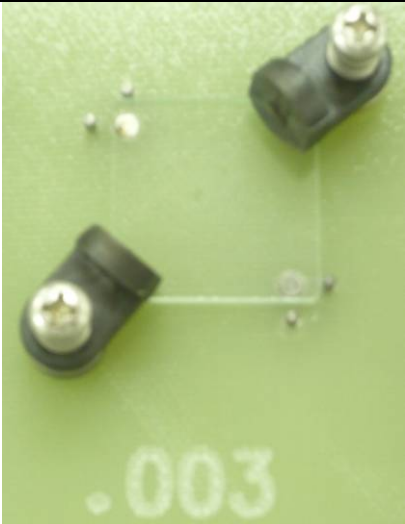





## DATA FINDINGS




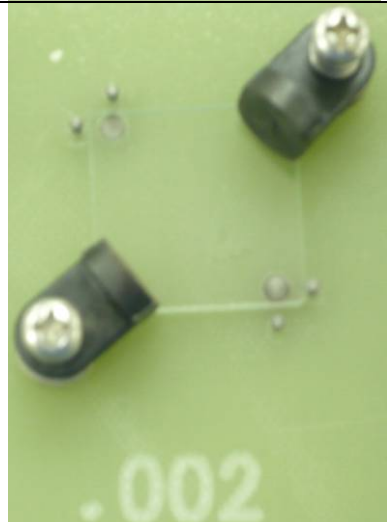

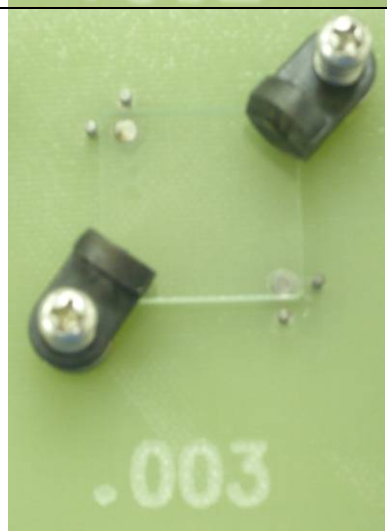
Water Soluble Solder Paste #1	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
1 mil Standoff  Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
2 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
3 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		

Residue remained under 1 mil standoff die for water soluble paste #1 but all die with larger than 1 mil gaps were clean. The wash time was extended to 15 minutes but did not show improvement under the 1 mil gap.



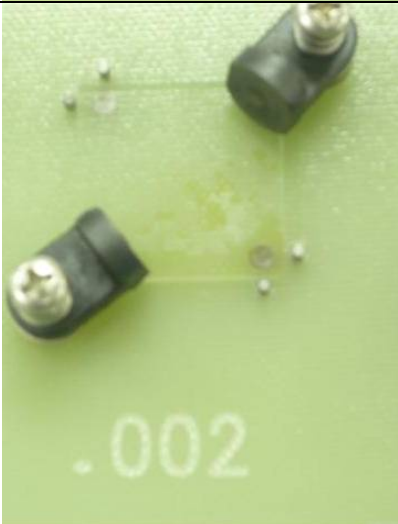
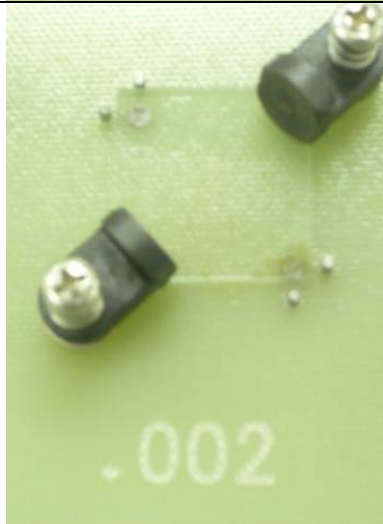
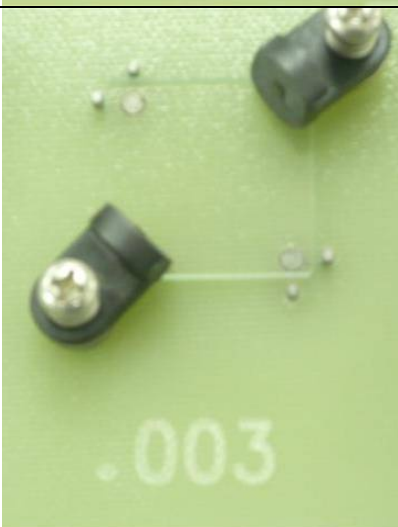
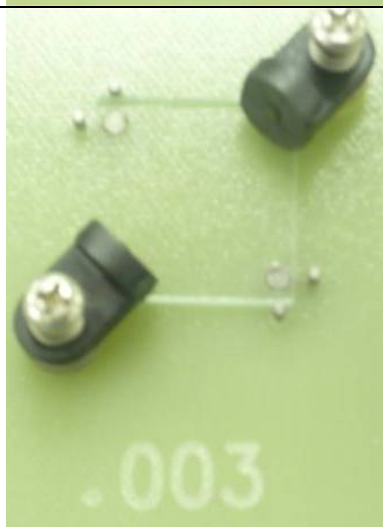
Water Soluble Solder Paste #2	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
<p>1 mil Standoff</p> <p>Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>2 mil Standoff</p> <p>No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>3 mil Standoff</p> <p>No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		

Residue remained under 1 mil standoff die for water soluble paste #2 but all die with larger than 1 mil gaps were clean. The wash time was extended to 15 minutes but did not show improvement under the 1 mil gap.

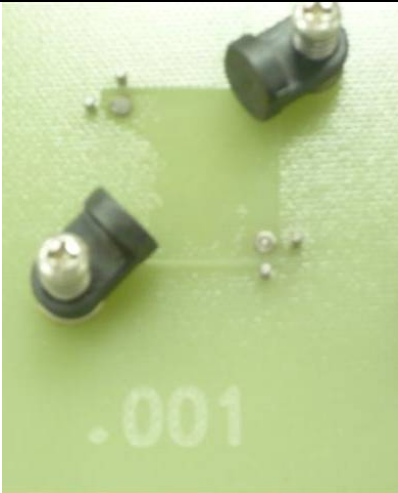



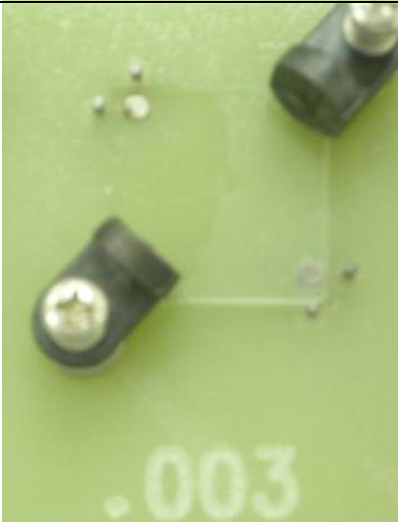



Water Soluble Solder Paste #3	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
1 mil Standoff  Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
2 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
3 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		





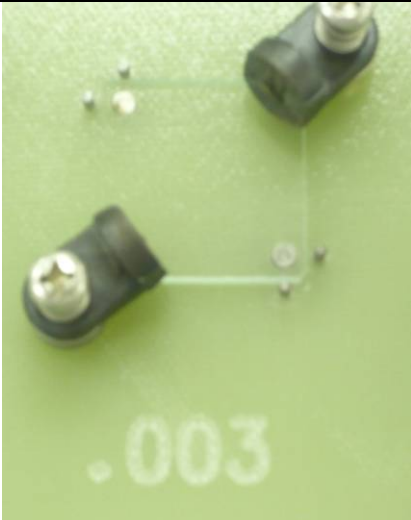

Residue remained under 1 mil standoff die for water soluble paste #3 but all die with larger than 1 mil gaps were clean. The wash time was extended to 15 minutes but did not show improvement under the 1 mil gap.

Rosin Solder Paste #1	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
1 mil Standoff  Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
2 mil Standoff  Minor Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
3 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		

Residue remained under 1 & 2 mil standoff die for rosin soluble paste #1 but all die with larger than 2 mil gaps were clean. The wash time was extended to 15 minutes and improved cleaning under the 2 mil with very limited residues remaining.







Rosin Solder Paste #2	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
<p>1 mil Standoff</p> <p>Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>2 mil Standoff</p> <p>Minor Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>3 mil Standoff</p> <p>Flux Residue Remained under the die cleaned at 8 minutes but was totally cleaned when increasing the wash cycle to 15 minutes</p>		

Residue remained under 1, 2, & 3 mil standoff die for rosin soluble paste #2 but all die with larger than 4 mil gaps were clean. The wash time was extended to 15 minutes and improved cleaning with gaps larger than 3 mil with no residues remaining. This example illustrates how some solder pastes are more difficult to clean and the importance of selecting a solder paste that is both cleanable and compatible with the cleaning agent.

No-Clean Paste #1	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
<p>1 mil Standoff</p> <p>Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>2 mil Standoff</p> <p>No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		
<p>3 mil Standoff</p> <p>No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes</p>		






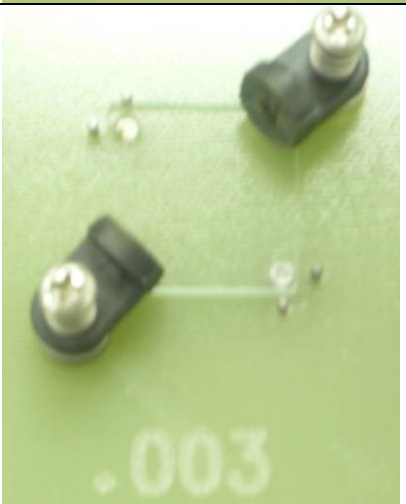
Residue remained under 1 mil standoff die for no-clean soluble paste #1 but all die with larger than 1 mil gaps were clean.



No-Clean Paste #2	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
1 mil Standoff  Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
2 mil Standoff  Trace Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
3 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		

Residue remained under 1mil standoff die with trace residues under 2 & 3 mil standoffs for no-clean soluble paste #2 but all die with larger than 3 mil gaps were clean. The wash time was extended to 15 minutes with no real improvement in cleaning by extending the wash time.



No-Clean Paste #3	8 Minute Wash Time After Cleaning	15 Minute Wash Time After Cleaning
1 mil Standoff  Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		
2 mil Standoff  Flux Residue Remaining under the die cleaned for 8 minutes but clean under the die cleaned for 15 minutes		
3 mil Standoff  No Flux Residue Remaining under both dies cleaned at 8 and 15 minutes		

Residue remained under 1 & 2 mil standoff die for no-clean soluble paste #3 but all die with larger than 2 mil gaps were clean. The wash time was extended to 15 minutes and improved cleaning under the 2 mil with no residues remaining.

## INFERENCES FROM THE DATA

H<sub>1</sub> – The standoff height is directly correlated to removal of all flux residues under the QFN component.

The data findings accept the first hypothesis that standoff height is directly correlated to removal of all flux residues under the QFN component. Standoff heights lower than 1 mil were not cleaned using the DOE research factors and levels. At standoff heights greater than 1 mil, most of the flux compositions in this study were successfully cleaned.

This data finding highlights the importance of some level of clearance needed to successfully remove flux residue under the Z-axis™. The positive aspect of these findings was the successful results when QFNs are placed with standoff heights greater than 2 mils. The research findings indicate that QFNs with standoffs greater than 2 mils can be cleaned using the cleaning agent and cleaning equipment at the research process conditions.

H<sub>2</sub> – Flux compositions and soldering processes that form soft residues post soldering are directly correlated to removal of all flux residues under the QFN component.

The data findings accept the second hypothesis that flux residue types and reflow processing conditions directly correlate to removal of all flux residues under the QFN component. Leading edge circuit designs are increasingly smaller and highly dense. As the space between conductors diminish, the importance of removing flux residues increases. Cleaning must be a consideration when designing for manufacturing.

Miniaturization imposes a great challenge on the chemistry of fluxes, due to the increasing amount of oxides and requirements for no-clean lead-free applications.<sup>3</sup> The decreased size of components and the conductor spacing generates more heat during operation. Problems arise from boards with greater mounting density resulting in electrochemical reactions, metal migration, and reduction of surface resistance.<sup>5</sup>

Flux compositions designed for lead-free consist of multiple polymer species and property modifying additives.<sup>3</sup> These additives affect the mobility of the system, solvent retention properties, long and short term dielectric properties, and thermal behavior. The key to maintaining all desired product attributes, as well as maximizing topside fillet performance, lies in a thorough understanding of the interactions between these polymers and certain properties of the modifying additives.

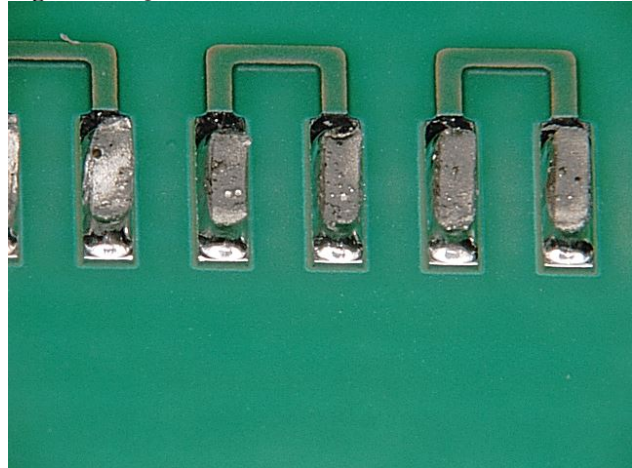
Many factors go into the selection of a solder paste. The data findings strongly correlate cleaning under low standoffs with residues that easily dissolve in the cleaning agent. Optimizing the reflow process to prevent oxidation and charring are also important factors to consider.

## Confirmation of the Data Findings

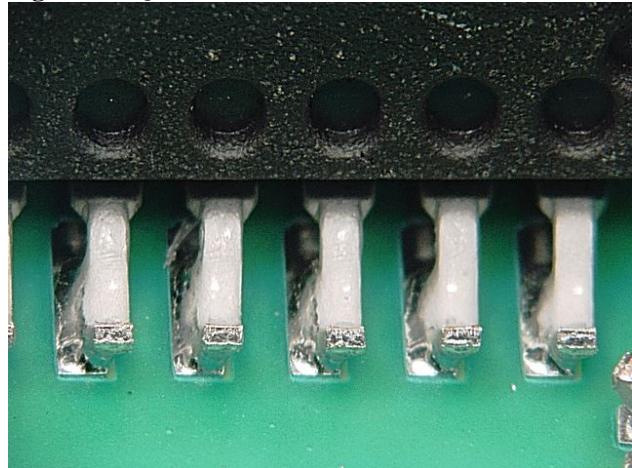
Three Practical Component Test Boards were assembled using QFN components. The standoff clearance under the component was between 3 and 4 mils. One board was soldered with water soluble solder paste, one with rosin solder paste, and one with no-clean solder paste. The boards were processed using best in class cleaning agent and cleaning equipment discussed in this research study.

The QFN components were removed from each of the test boards. No visible flux residue was left from the three solder paste technologies evaluated. Figures 13, 14, and 15 illustrate the visual cleanliness under the QFN components.

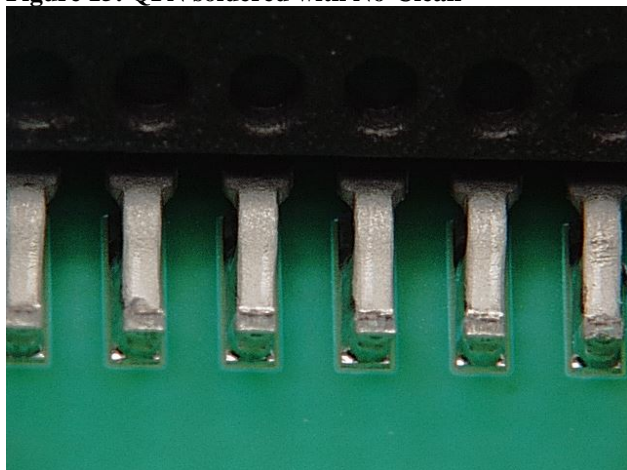
**Figure 13: QFN soldered with Water Soluble**



**Figure 14: QFN solder with Rosin**



**Figure 15: QFN soldered with No-Clean**



### CONCLUSIONS AND RECOMMENDATIONS

The assurance that the product works for its designed life expectancy is an important issue when reworking electronic assemblies. Flux residue under Quad Flat Pack No Lead (QFN) components can impact performance when conductive ions migrate within the electrical field.<sup>1</sup> The common cleaning equipment used for rework operations is the dishwasher style aqueous spray-in-air machine. Engineered cleaning materials are needed to dissolve flux residues commonly used in the rework operation. To successfully clean all flux residues under the QFN, process factors must be understood.

Cleaning under low feature components requires an optimized process. Neither the cleaning agent nor the cleaning equipment accomplishes the cleaning need in unison. Integrating the right cleaning agent with the right cleaning machine and other process factors are the key to cleaning leading edge circuit assemblies. The data presented in this paper builds from this premise.

When designing optimized QFN rework processes, the authors recommend that users view cleaning as an integrated process. Cleaning agent and cleaning machine science has dramatically improved with time. Integrating best in class technologies provide proven performance that accomplishes this demanding cleaning need.

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