COLLABORATIVE CLEANING PROCESS INNOVATIONS FROM MANAGING EXPERIENCE AND LEARNING CURVES

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Abstract

Moore's Law infers that the number of transistors on a chip doubles approximately every two years. Consistent with Moore's Law, high reliability electronic devices build faster processing speed and memory capacity using increasing smaller platforms. The trend toward highly dense assemblies reduces the spacing between conductors while yielding a larger electronic field. As the industry moves to higher functionality, miniaturization, and lead-free soldering, studies show that cleanliness of the assembly becomes more important. Residues under low standoff components, with gaps less than 2 mils, represent an increasingly difficult cleaning challenge. Collaboration from cleaning equipment and cleaning material companies has led to innovations for improving throughput and complete residue removal under low standoff components. The purpose of this paper is to report both mechanical and chemical innovations that open the process window.

Introduction

The pace of surface mount technology development and innovation is a response to market pressures for higher functionality, cost reduction, cycle time reduction, and improved quality.[1] To achieve increased functionality; today's circuit assemblies pack more performance into smaller board designs. Advanced package designs require an increasing number of interconnects to support power requirements and bandwidth. With active and passive component size reduction, area array pitch and standoff off height also reduce, which increases cleaning difficulty.

Technology-based market pressures increase reliability demands as electronic assemblers move upstream from conventional designs and toward threshold and leading edge technologies. Over the past two decades, conventional surface mount technologies successfully adopted low residue no-clean soldering practices. Today's challenge for printed circuit board manufacturers hinges on density and miniaturization.[1] High performance electronic assembly designs will be driven by multi-chip density, increasing number of I/O's, decreased area array pitches, and tighter component standoff heights.

Problem Statement

IPC TechNet Blog addresses the question of no-clean relevance and the hidden factors involved with successful implementation of no-clean assembly processes.[2] The social network author's noted that no-clean soldering technology was developed when circuit designs had increased spacing from component leads and terminations. With increased board density and miniaturization, no-clean flux technology may no longer be a viable technology alternative to support leading edge technologies. To quantify risk of no-clean soldering, process and design engineers are supplementing bulk ion extraction and electrical studies with site specific studies to determine the risk of residues under components.

The move toward lead-free soldering and miniaturization represent two force fields converging that increase no-clean complexities.[3] Higher lead-free melting temperatures requires the use of fluxes with greater thermal stability. The problem, lead-free alloys exhibit poorer wetting properties, which require higher flux capacity and strength to improve wetting and flow. Flux technology also plays an important role in reduced voiding by increasing the need for high oxidation resistance, oxygen barrier capability, high thermal stability, and low volatility. Miniaturization requires the flux to be more stable at peak reflow to prevent oxidation, which requires a higher content of resin or rosin. Reducing flux volatility has a tradeoff of greater amounts of circuit assembly flux residue. Halide free flux materials will require higher levels of weak organic acids, which increase the level of ionic materials that can form an electrochemical cell.

Electrolytic corrosion, electrochemical migration, and electrical leakage occur when electronic circuits are exposed to humid conditions (moisture), electrical potential (bias), and ionic residue (flux disassociation).[4] Figure 1 shows the failure region, that illustrates the risk of voltage, humidity, and ionic contamination when they intersect. Miniaturization, high density, and lead-free soldering trends raise the question of whether the failure region increases. To address this concern, leading edge designers are moving away from no-clean soldering processes and back into cleaning all visible and entrapped flux residues under components.

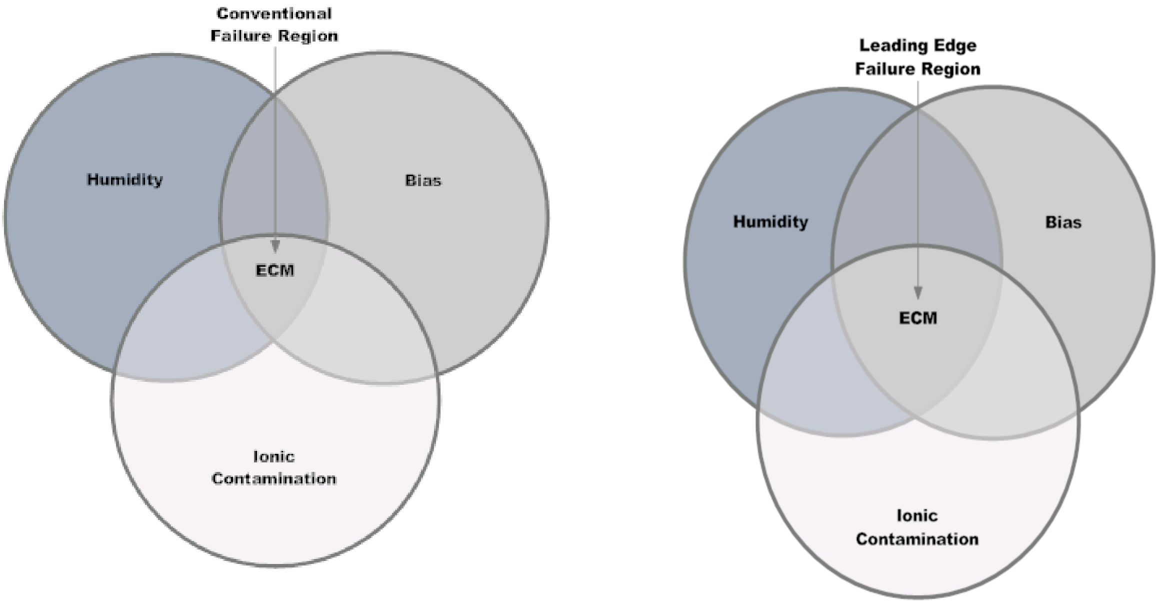


Figure 1: Electrochemical Migration Failure Ranges

Customer – Cleaning Material – Cleaning equipment Collaborations

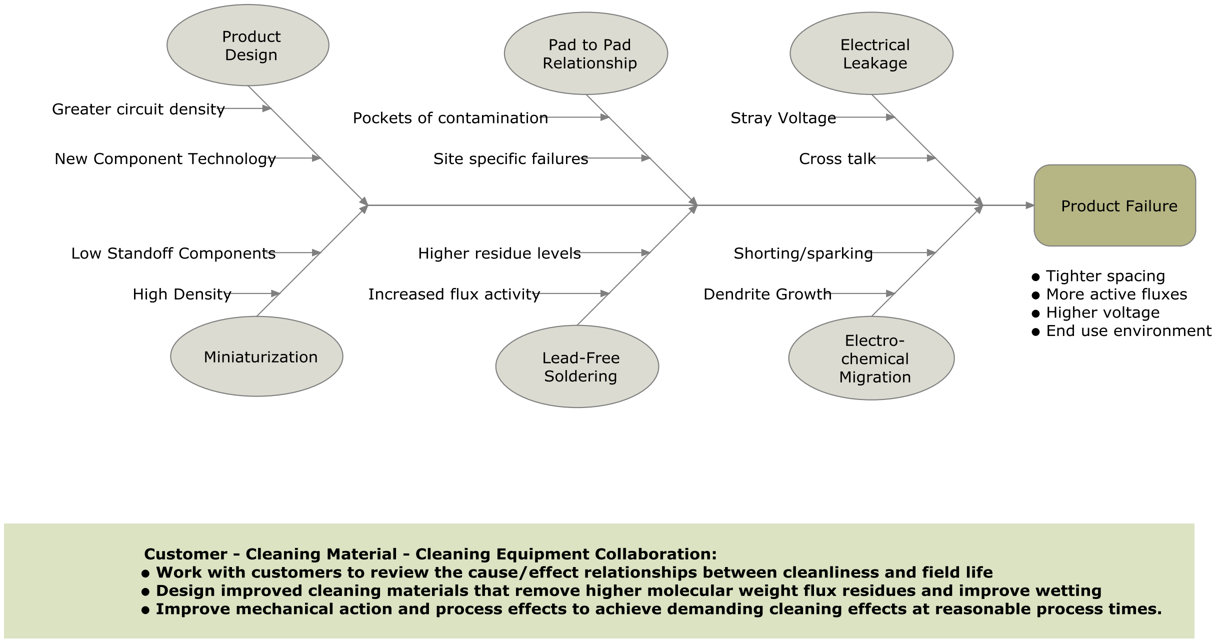
The pace of technology development and innovation has changed the way customers and suppliers communicate and interact on a global scale. To understand the jobs that customers need done, suppliers identify customer needs that cannot be done satisfactorily with current solutions.[5] Working from the outside-in, companies who supply pieces of the process collaborate by looking at the world from the customer's perspective to understand what the customer is trying to do and identify product or process characteristics for solving the customer's job. Starting with a deep insight into the job the customer is trying to accomplish shifts the focus from solutions that customers use to the fundamental issues the customer is trying to solve.

The IPC/SMTA High Performance Cleaning Symposium, held in October 2008, was a user driven conference comprised of OEMs, contract assemblies, and material supply companies. The user presentations highlighted a number of cleaning jobs that customers were trying to get done when building high reliability conventional and leading edge printed circuit assemblies. A medical equipment supplier noted, "Our products require clean circuit boards to function correctly."[6] This particular customer is building heart monitors. Residues under active and passive devices can "short-out" the device when exposed to humid conditions. The high impedance device requires all flux residues removed to obtain greater circuit performance in order to detect heart conditions and direct therapy. The problem is that denser designs use smaller components such as flip chip, QFNs, BGAs, and small chip cap resistors/capacitors, which are extremely difficult to remove flux residue trapped under the component.

Other users presented on the risk of cleanliness when leaving flux residues under low stand-off components and large area array packages. Customers are now measuring and quantifying flux residues underneath site specific components on a printed circuit board, which may risk electrochemical migration, leakage, and corrosion.[7] A military subcontractor talked about the use of high impedance circuitry and their sensitivity to small levels of flux residue left under components.[10] Leadless chip carriers have standoff heights less than 2.0 mils off the board. During the soldering process, the surface tension of the flux propagates between the center of the ground pad and power source, which creates a reliability concern. Additionally, vias under the component entrap pockets of residue that can cause field failures.

Lower standoff heights for mounted flip chip die result in higher I/O counts and lower I/O pitches.[8] There are specific challenges created by the disruptive influences for underfills; fluxes, flux residues, and the interaction between underfill and flux residue. The transition to high tin, lead-free solder technology creates problems for no-clean flux residues under flip chip die. As the gap heights and bump pitches reduce, less flux is available to remove oxides needed to join the flip chip die to the substrate. To address this concern, high temperature stable flux materials with increased activation are needed. Circuit designers find improve performance from removing the flux residues post soldering.

IPC-CH-65A provides guidelines for cleaning printed circuit boards and assemblies.[9] Conventional printed circuit assemblies used larger components. The standoff heights on many conventional printed circuit board components are greater than 10 mils off the board. As this research notes, leading edge printed circuit boards now use components that have standoff heights less than 2 mils, and in the case of flip chip, chip cap and QFN components, flux becomes trapped and shielded from the cleaning process. To accomplish this demanding cleaning job, customers, cleaning material, solder paste, and cleaning equipment companies have collaborated to develop new products and process optimization to meet these demanding cleaning challenges. The cause/effect diagram in Figure 2 summarizes some of the effects that cause product failure and created the need for improved cleaning processes.



Customer - Cleaning Material - Cleaning Equipment Collaboration:
- **Work with customers to review the cause/effect relationships between cleanliness and field life**
- **Design improved cleaning materials that remove higher molecular weight flux residues and improve wetting**
- **Improve mechanical action and process effects to achieve demanding cleaning effects at reasonable process times.**

Figure 2: Cause/Effect Diagram for Leading Edge Printed Circuit Assemblies

Cleaning Material Innovations

Electronic assembly cleaning materials are designed to remove a broad array of flux technologies including organic acid, rosin, resin, and polymeric structures from mixed technology circuit boards. The building blocks (Figure 3) used to formulate these cleaning materials are solvency to dissolve resin structures; reactive agents to buffer and saponify soils; wetting agents to lower surface tension and improve penetration under low standoff components; and minor ingredients to improve materials compatibility and control foam propagation under high pressure. Cleaning materials come in three families, solvent, semi-aqueous, and aqueous designs.

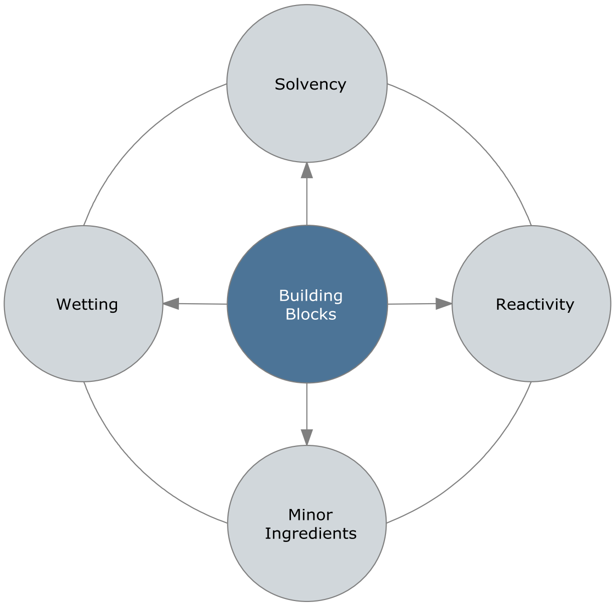


Figure 3 Electronic Assembly Cleaning Material Building Blocks

Solvency*:* Oxygenated organic materials dissolve rosin and resin (solute) structures naturally present in many flux types. The interaction of resin/rosin with solvent(s) increases the dissolution rate. Solvents are selected on the basis of “like dissolves like” commonly referred to as the solvated state, whereby organic resin flux residues are dissolved by oxygenated solvent molecules. Solvent dissolution is a kinetic process and is quantified by its rate. The rate of dissolution depends on the solvent and solute, temperature, impingement pressure, and interfacial surface tension.

For aqueous and semi-aqueous electronic assembly defluxing, the solvent materials interact with the polar solvent, water. Solvation involves different types of intermolecular interaction: hydrogen bonding, ion-dipole, and dipole-dipole attractions. The hydrogen bonding, ion-dipole, and dipole-dipole interactions occur from the water and water’s interaction with oxygenated solvents. The oxygenated solvents interact with water to improve dissolution of rosin, resin, and organic acid ions necessary to leave an ionically clean assembly.

Builders: For aqueous cleaning fluid designs, mild alkalinity provides two important functions: 1. To improve the cleaning rate, and 2. Maintain a consistent pH by forming a strong buffer. Rosin, commonly used in flux compositions, is a solid form of resin obtained from pine trees and some other plants. To improve the cleaning rate, mild alkaline materials are used to react (saponify) with the rosin/resin to increase the rate of dissolution. Additionally, the alkaline source is used to react with a weak acid to form a buffer that keeps the pH at a nearly constant value. An optimal pH range of 9-11 prevents redeposition of flux soils and ionic constituents onto the circuit assembly after the cleaning process.

Wetting: Wetting agents lower the surface tension of the cleaning fluid, by reducing the droplet size, improving spreading, and lowering the interfacial surface tension. Surface active agents form micelles that contain a lipophilic end to dissolve oily soils and hydrophilic ends to hydrogen bond with water. Wetting agents reduce surface tension of water by adsorbing at the liquid-gas interface. These materials reduce the interfacial tension between oil and water by adsorbing at the liquid-liquid interface. When micelles form in the cleaning solution, their tails encapsulate an oil droplet, and their ionic polar heads form an outer shell that maintains favorable contact with water. Wetting agents improve penetration under the Z-axis to remove flux residues under components.

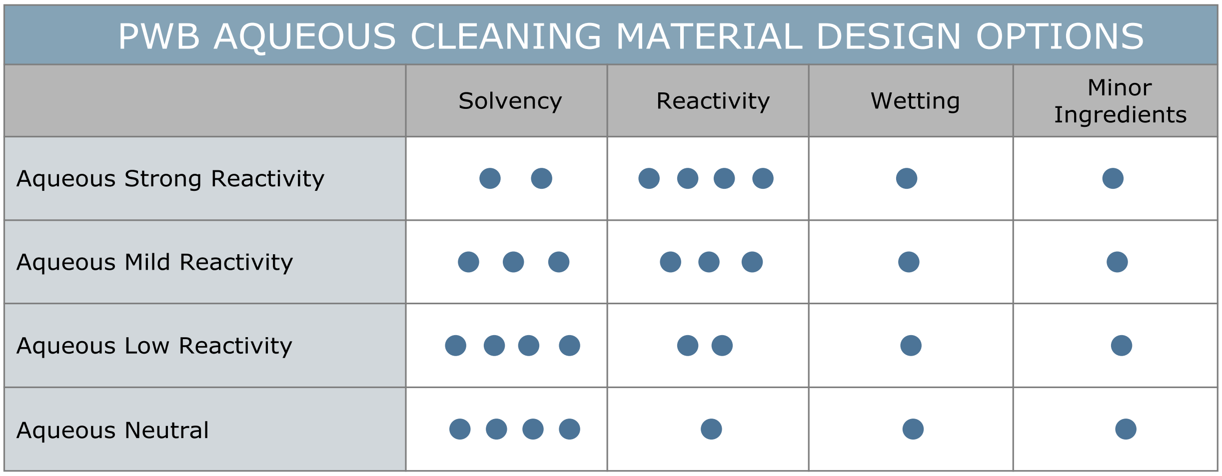
Minor Ingredients**:** This category of materials address two important functions: 1. Control wash bath foam when processing in high pressure equipment and 2. Decrease the rate of metal alloy corrosion. Foam is a substance that is formed by trapping many gas bubbles at the liquid interface. Rapid turn over of the wash tank and high pressure jets create a condition to trap and grow gaseous tight foam. To break or retard foam, antifoaming agents are added to the engineered composition to inhibit foam formation.

The second class of minor ingredients includes materials that decrease the corrosion rate of tin, lead, aluminum, and yellow metals. Alkaline cleaning materials chemically react with soft metals. Corrosion inhibitors form a passivation layer - a thin film on the surface of the alloy(s) that stops access of the corrosive substance to the metal. Properly designed inhibition packages reduce oxidation and reduction reactions. Solder joints, aluminum heat sinks, anodized aluminum and copper are protected from exposure to the cleaning media.

Using the Building Blocks to Improve Aqueous Cleaning Performance under Low Standoff Components: Aqueous cleaning materials are engineered concentrated fluids that dissolve with water. Aqueous cleaning materials are non-flammable and processed in high energy machines. Aqueous concentrated products work based on the *"Cleaning Rate Theory"* that holds: The static cleaning rate (rate at which the cleaning material dissolves the flux residue at its temperature and concentration in the absence of impingement energy) plus the dynamic rate (energy and time in the cleaning machine) equals the process cleaning rate.[11]

Aqueous cleaning materials fit four classifications (Figure 4):

1. Aqueous high reactivity: Product contains greater than 30% active free amine (Note: there are several amine structures commonly used by formulators) reactive materials that saponify the flux residue to improve rate. The benefits of highly reactive aqueous cleaning fluids are lower operating concentration and aggressive interaction with rosin, resin, and weak organic acids. The tradeoffs of highly reactive aqueous cleaning fluids are materials compatibility, short bath life, and lower effectiveness on low-residue flux residues.
2. Aqueous mild reactivity: Product contains greater than 10% but less than 30% active free amine reactive materials. Mild reactivity formulation designs improve rate using higher solvency combined with reactivity. The benefits of mild reactivity aqueous cleaning fluids are improved material compatibility, longer bath life, and greater effectiveness on low-residue flux residues. The tradeoffs are lower bath life and lower effectiveness on higher molecular weight resins used in lead-free flux compositions.
3. Aqueous low reactivity: Product contains less than 10% active free amine reactive materials. Low reactivity formulation designs improve rate using a combination of solvating materials combined with reactivity. The benefits of low reactivity aqueous cleaning fluids are long bath life, good material compatibility, and highly effective on both eutectic and Pb-free flux residues. Aqueous low reactivity provides best in class technology due to high solvating power and excellent material compatibility.
4. Aqueous neutral: Product contains less than 2% active free amine reactive materials. Aqueous neutral formulation designs improve rate using solvency. The benefits of aqueous neutral formulation designs are very good materials compatibility, long bath life, and excellent cleaning on a broad range of flux materials. The tradeoffs of aqueous neutral formulation designs are higher wash concentration that may result in higher consumption.



PWB AQUEOUS CLEANING MATERIAL DESIGN OPTIONS

	Solvency	Reactivity	Wetting	Minor Ingredients
Aqueous Strong Reactivity	● ●	● ● ● ●	●	●
Aqueous Mild Reactivity	● ● ●	● ● ●	●	●
Aqueous Low Reactivity	● ● ● ●	● ●	●	●
Aqueous Neutral	● ● ● ●	●	●	●

Figure 4: Aqueous Cleaning Material Design Options

Best in Class Aqueous Cleaning Material for Cleaning under Low Standoff Components

Cleaning process optimization requires a balanced of chemical and mechanical effects. The job of the cleaning material is to remove flux residue and ionic contaminants. As previously discussed, aqueous cleaning material designs contain reactive materials at various concentration levels. On certain flux types, higher reactivity increases the static cleaning rate, but can cause other issues. When cleaning flux residue under low standoff components, longer wash time is needed. Highly reactive cleaning materials create several compatibility concerns in the form of solder joint attack, anodized aluminum attack, dry film solder mask removal, part marking removal, component attack, polymer/adhesive attack, and a range of other issues. Highly reactive cleaning materials saponify rosin, which can create a foam condition as the wash bath loads.

Best in class cleaning materials exhibit other important properties. The vapor pressure of each material used in the compositional make-up influences evaporative loss rates. The dissolution rate on higher molecular weight resin structures used in low residue and lead-free flux compositions influences the static cleaning rate. The rate of cleaning material solvency in water can influence the cleaning rate and defoaming properties. The cleaning material wetting forces is critical to penetrating low standoff gaps. Properly designed, the cleaning material rapidly dissolves rosin /resin structures, wetting low standoff gaps, inhibits solder joint attack, overcomes compatibility concerns, works at low concentrations, and provides long bath.

Aqueous Low Reactivity cleaning material designs provide improved cleaning under low standoff components. The driving forces that improve performance come from the mixture of solvating materials that rapidly dissolve resin and rosin structures; low reactivity improves the cleaning rate but does not cause compatibility concerns on components, board laminates, flex, anodized coatings, plastics, and metallic's; wetting lowers surface tension effects; and minor ingredients control foaming and protect solder joint finishes. Innovative designs run at lower wash bath concentrations ranging from 10-13%. The aqueous design uses very low vapor pressure materials that condense and return before being evaluated out the exhaust stack, thus consuming very low levels of cleaning fluid over time. Users report consumption at less than 50% that of traditional aqueous cleaning materials.

Aqueous Inline Cleaning Machine Innovations

The cleaning machine design is equally important. Fluid management is critical in maintaining an economic cleaning process. Individual module containment and specifically with the wash chemistry is essential. Fluid delivery is critical for penetrating and rapidly breaking the flux dam under low standoff components. Air management is critical to reducing chemical odors in the workspace while minimizing the amount of wash fumes exhausted from the machine. Fluid storage is critical for long wash bath life. Fluid control is critical in maintaining the proper wash bath concentration within the cleaning process tolerance.

Cleaning equipment design issues in any of these areas can and will upset the cleaning process over time. Issues such as high wash consumption, steam out of the machine, foaming in the wash and or rinse, exhaust losses, and poor cleaning all result from an imbalance caused by one or more of these factors. Process issues may not show up when the machine is initially charged with cleaning chemistry and started up, but slowly creep in over time. Lack of process optimization results in higher defect rates, which typically render white residue formation and unacceptable levels of ionic residues on the surface and under component gaps.

Fluid Delivery: To improve cleaning under low standoff components, research data indicates that fluid flow, pressure at the board surface, directional forces, and time in the wash improve the process cleaning rate. The wash section of the cleaning machine is highly important. Research data findings indicate that flux not adequately removed in the wash will ***not*** be removed in the rinse sections. Cleaning data studies show that high levels of fluid across the board surface decrease needed cleaning time. Directional forces that provide a 360° impingement pattern during the wash exposure decreases time in the wash. Maintaining pressure with flow also decreases the amount of time required in the wash section.

Wash impingement effects can be generated using various nozzle and pump technologies. To improve cleaning efficacy, boards are initially sprayed in the pre-wash section using fan jets. The pre-wash zone brings the circuit card up to process temperature, which starts the flux softening process. In the wash section, nozzle jets provide uniform wash coverage. Board geometry, density, and component types are impinged upon using a combination of nozzle technologies that provide various levels of fluid flow, pressure at the board surface, and directional forces. Printed circuit boards with increased density and component shadowing require a longer wash time to allow wash fluid to penetrate blind gaps.

To remove all flux residues under gaps less than 2 mils, time in the wash and wash temperature are critical parameters. The wetting effects of flux during the reflow soldering process cause the flux to penetrate under small component gaps and create a flux dam (Figure 5). To break the flux dam, the cleaning fluid and impingement energy must first dissolve the residue to create an opening for the wash fluid to flow under the component. Hard flux residues take longer time to dissolve than do soft flux residues, which increases wash complexity. The static cleaning rate (dissolution in the absence of impingement energy) of the wash chemistry is driven by the cleaning material compatibility with flux soil, rate of dissolving the flux soil, concentration, part fixturing, and wash temperature effects. The cleaning material static cleaning rate may vary on different flux residues. To address these complexities, best in class cleaning material designs are formulated to work on most flux residue types, but the rate varies for both hard and soft flux residues, with the key variable representing time in the wash stage.

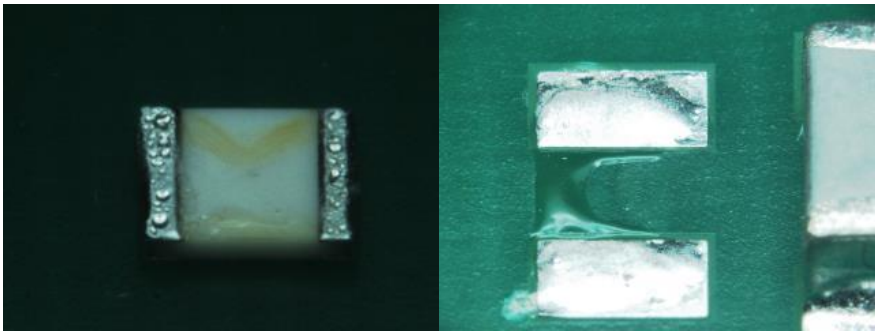


Figure 5: Flux Dam Illustration

Fluid Storage: The size of the wash holding tank is often overlooked in the cleaning equipment design (Figure 6). The wash tank surface area (width x length) and tank volume (x depth) are an important cleaning machine design criterion. High fluid flow nozzles increase the level of wash turns per minute of operation. If the wash tank capacity is too small, rapid tank turnover can cause air bubbles to migrate deeper into the wash tank. When this condition exists, foam build is greater than foam break. Additionally, rosin/resin-based flux soils saponify with the reactive agents in the cleaning material, which can couple or emulsify the anti-foam minor ingredients. The combination of these two factors allows air to eventually reach the pump intake with the result of a highly stable foam condition. Foaming leads to pump cavitation or micro air pockets which reduce the machine’s operating spray pressures, the effectiveness of the wash process and costly mechanical pump seal failure.

Figure 6: Wash Tank Illustration

Wash Bath Life: The volume of the wash tank is also important in maintaining a long wash bath life. The affinity of the wash fluid to hold another substance in solution is bound by the volume of the available fluid and critical soil loading limitation. Critical soil loading represents the contamination level at which cleaning is not longer acceptable. The dynamics at work when running an inline cleaning process find losses through evacuation (ventilation effects) and drag-out. As soil is introduced, the wash holding tank will start to accumulate contamination. Larger wash tank volume provides a wider processing window for holding the flux contaminants introduced to the cleaner. As water and wash chemistry are replenished, the ideal condition occurs when the cleaning material additions maintain a wash tank volume below the critical soil loading limitation.

Fluid Management: One of the risk factors from high fluid flow, high impingement pressure, and directional force nozzles is spray deflection into the chemical isolation section. Shorter wash sections have less distance from the spray manifold to the chemical isolation section. Deflecting wash fluid into the chemical isolation section can cause high wash chemistry consumption. To address this issue, larger wash sections provide distance from the final spray manifold to the chemical isolation section entrance. Wash spray deflected into the chemical isolation zone must be captured and returned to the wash tank. Chemical isolation innovations dramatically reduce wash chemistry consumption and good fluid management designs are the keys to reducing chemical consumption and operating cost.

The chemical isolation module provides the ultimate fluid management by separating the wash and rinse sections. The conveyor belt, circuit cards, and fixtures are wetted with the cleaning fluid. As these wetted components leave the wash section, they are carried into chemical isolation section. One of the objectives of the chemical isolation section is to remove and return the wash solution from the conveyor belt, circuit boards, and fixtures back to the wash tank. Recent equipment innovations strip off the wash fluid from parts as well as capture defected wash spray that enters the chemical isolation section. This important economic function reduces chemical usage and saves operation cost.

At the entrance of the chemical isolation section, an air knife above and below the conveyor belt removes wash fluid mechanically from the conveyor belt, circuit boards, and fixtures. A bulkhead is positioned within the chemical isolation section after the air knife but in front of the chemical isolation spray rinse manifolds (Figure 7). The bulkhead isolates deflected spray carried into the chemical isolation section. The front isolated area is equipped to collect and drain wash chemistry removed from both the air knives and deflection back into the wash tank.

The next management tool used in a well designed chemical isolation module is the wet spray section. This wet spray ensures the dilution of chemistry that remains in and around tightly spaced components and underneath low standoff devices missed by the isolation air knives. This wet section manifold is powered from the rinse module pump which provides high quality third use water for wet isolation. The slip stream from the rinse improves rinse quality and prolongs carbon and ion exchange purification media. This cascade function allows the rinse tank to be replenished and regenerated by the gravity cascading final rinse.

The last important section of the chemical isolation is another set of air knives above and below the conveyor belt. These air knives mechanically strip the wet section spray from the circuit board and conveyor belt before entering the rinse section. This prevents any diluted chemistry from reaching the recirculating rinse and is especially important when running a closed loop rinse. Even if the rinse tank is not closed looped, chemistry carryover can lead to rinse section foaming and excessive consumption. When close looping the rinse, the chemical isolation spray section is a must to ensure DI filter columns are not degraded due to chemistry contamination.

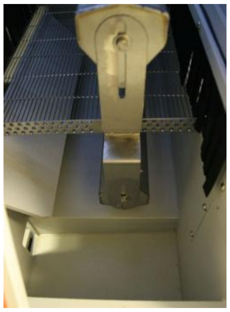


Figure 7: Chem Iso Bulk Head with Drain to Wash Holding Tank

Air Management: *Ventilation:* Air flow management prevents steam from exiting the entrance or exit ends of the machine. Cleaning machines that run wash chemistries require a separate exhaust plenum for managing the wash section and a separate exhaust plenum for managing the dryer sections. The air must be balanced to provide a slight negative draw at both the entrance and exit ends of the machine. Excessive air draw in the wash section can cause wash fluid fumes to be evacuated to the roof. Excessive air draw from the dryer vent can draw wash fluid fumes into the rinse section, which can cause rinse foaming. Properly balanced, the system does not fill the room with wash odors and manages the air flow so that minimal wash fluid is evacuated. Mist arrestors are commonly used to condense the wash fumes, which allow much of the cleaning solution to be returned to the wash tank (Figure 8).

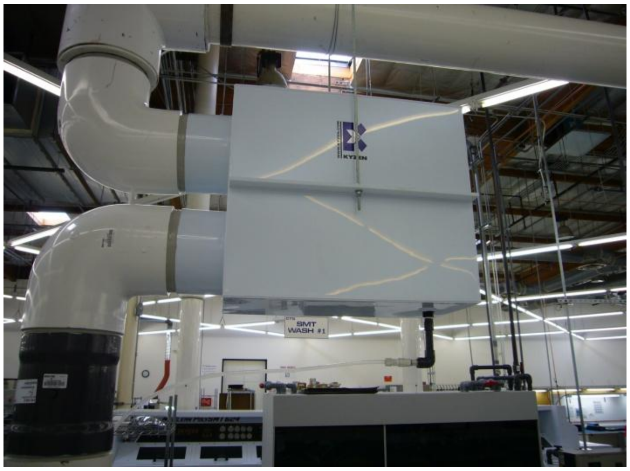


Figure 8: Mist Arrestor Illustration

Fluid Control (Controlling the Wash Chemistry): To achieve a tight quality range, wash tank chemistry control is critical. A properly balanced wash tank provides cleaning consistency over time and increases the life of the chemistry. New generation cleaning fluids work well at lower cleaning concentrations and readily condense, which reduces ventilation losses. The benefit for users is much lower cleaning material consumption, which equates to lower cost of ownership. For example, when running a 10% wash concentration, only 1-2% cleaning fluid additions is need to maintain the 10% concentration over time.

Typically, an inline will consume from 3-10 gallons of wash fluid per hour of pump time operation. Since new generation cleaning chemistries losses are minimized by the cleaning material design, very little cleaning chemistry is needed to maintain wash concentration. The problem, without a consistent add of cleaning material with water additions, excessive amounts of water can be added over time diluting the wash bath concentration. Without the consistent addition of wash chemistry with make-up water additions, the wash tank will eventually lose strength and cleaning performance will drop off. To prevent this condition, a chemical proportioning device should be used to maintain the wash tank concentration to process specifications. Proper additions increase cleaning consistency over time and increase wash bath life (Figure 9).

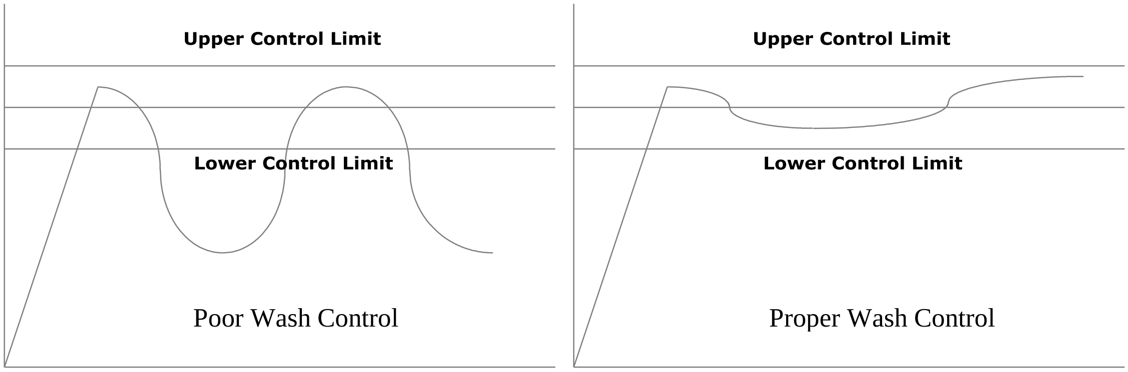
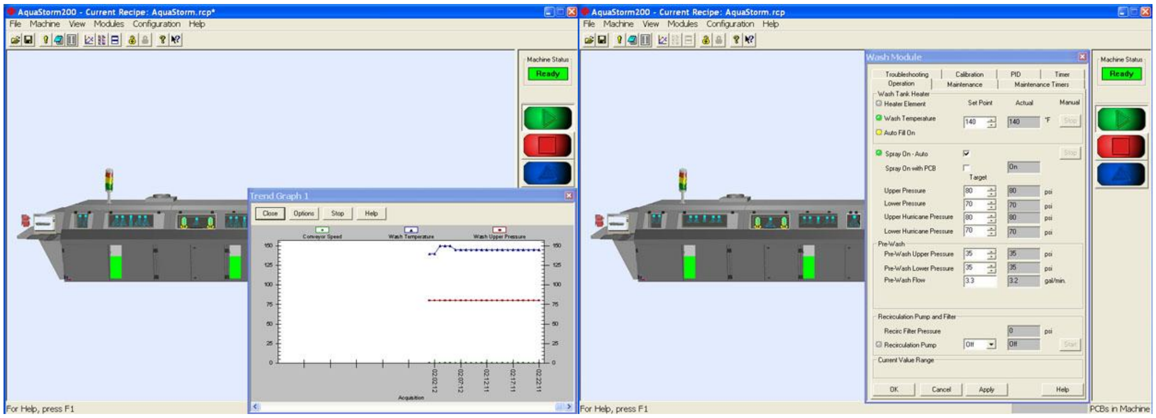


Figure 9: Process Control Illustration

Automated Monitoring and Control: More and more high reliability products are being cleaned that require full time data logging of the monitoring and control of the wash bath concentration. These capabilities are being driven by governmental agencies and OEMs that require product traceability all along the manufacturing process. Process control systems with these capabilities can be easily integrated with the machine wash tank. Proportional injections of chemistry can be accomplished based on feedback from automated monitoring methods. This automation reduces the requirement for manual concentration monitoring freeing process engineers for other important duties. The process control system will maintain the wash bath concentration keeping the cleaning process within the determined tolerance with minimal effort and with captured data.

Process Monitoring: With current and future electronic assemblies becoming densely populated with miniaturized components, qualifying a cleaning process has become a long and costly procedure. Highly dense assemblies populated with low standoff components not only create difficult areas for fluid penetration during the cleaning process but also when cleanliness tests are conducted. The days of validating a cleaning process solely utilizing an Ionograph are over. This is due to the lack of sufficient agitation and averaging of surface area when looking at ionic contamination levels. The vast majority of electronic manufacture's are now sending assemblies to analytical labs for localized Ion chromatography and SIR testing when validating cleanliness levels of a new product or a new cleaning process. While this method provides the manufacturer a higher level of accuracy when checking assemblies for ionic contamination, this form of validation is too costly to be used as a standard quality assurance test. Another reliable method used is a destructive test in which components are removed to visually check for residues. This again can be costly; products being cleaned are usually expensive in nature, so again this is not a cost effective method for frequent quality assurance testing.

This has lead to the implementation of a new control system for monitoring and tracking cleaning data. The new control system is a Windows-based computer with powerful yet simple user interface software that utilizes digital and analog I/O control. This system provides complete control that tracks all process set points for the entire cleaning process. The system can be configured to data log process parameters per board for future process traceability, or can be set as a time-based function. This logged information provides application and quality engineers with quantifiable data. The collected data can be reviewed to ensure that the cleaning process is operating within the upper and lower control limits that were originally developed from SIR and ion chromatography cleanliness results. This provides manufactures with a cost effective means for frequent quality assurance checks and reviewable board based data which can also be used for process troubleshooting.



Wash Tank Heater	Set Point	Actual		Manual
Heater Element				
Wash Temperature	140	140	°F	Stop
Auto Fill On				
Spray On - Auto	☑			Stop
Spray On with PCB	☐	On		
	Target			
Upper Pressure	80	80	psi	
Lower Pressure	70	70	psi	
Upper Hurricane Pressure	80	80	psi	
Lower Hurricane Pressure	70	70	psi	
Pre-Wash				
Pre-Wash Upper Pressure	35	35	psi	
Pre-Wash Lower Pressure	35	35	psi	
Pre-Wash Flow	3.3	3.2	gal/min.	
Recirculation Pump and Filter				
Recirc Filter Pressure		0	psi	
Recirculation Pump	Off	Off		Start
Current Value Range				

Drying: Dryer innovations remove all moisture from dense substrates using high velocity, high temperature regenerative blower technology with ElectroAir knives to mechanically strip the water from the board. This high temperature air helps maintain a constant board temperature from the final rinse to the convection zones[12]. Two independently temperature controlled convection zones are then used to evaporate the remaining water from the board. The use of heated convection drying provides manufacturers with test ready assemblies at high throughput rates and a lower cost of operation when compared to most standard air knife dryers. The dryer design is free from the typical belt driven blowers that are used in most inline cleaners. The technology utilizes direct drive blowers, which provide manufacturers with a more reliable process along with less down time and maintenance.

Smaller inline cleaner footprint: With more OEM's outsourcing Class 2 and 3 assembly products to the highly competitive contract electronic manufacturing industry, every aspect of cost is considered, including floor space. In low volume / high mix environments, such as the medical and military electronic manufacturing sectors, process flexibility ranks higher than shear throughput. Is smaller better? Just as technology advancements are made in electronic assembly designs, cleaning machine innovations allow greater performance and speed in a smaller package. Cleaning machine advancements reduce footprint by incorporating a high level of performance and reliability into a smaller package.

The problem with the majority of small footprint inline cleaning systems is their performance limitations. Many users push the cleaning machine design limitations by running right on the edge of a very narrow process window. Previously small aqueous-based chemistry inline cleaners were designed by reducing the footprint of a larger design, but at the cost of lower functionality and performance. Data testing indicates that wash time is a critical variable when removing flux residues from highly dense circuit assemblies. This limiting factor forces greater consideration of the wash section and chemical isolation zones when designing an optimal smaller footprint cleaning machine.

The design of the small footprint cleaner that addresses performance limitations utilizes the core platform used on standard machines. The small footprint cleaning machine design maintains the appropriate wash footprint while incorporating advancements in the pump, nozzle and chemical isolation systems to provide a highly effective cleaning process. The reduction in footprint was carefully designed ensuring a proper balance within each section of the cleaner, thus providing users with a reliable and wide process window. One of the technology advancements in the rinse section is the use of oscillating nozzles that deliver a large amount of kinetic energy to the product at lower pressures, which allows for size reduction in the rinse zones. The machine design provides users with a large process window without reducing performance by maintaining comparable pump, nozzle manifold and dryer configurations.

Conclusion

The pace of technology development and innovation has changed the way customers and suppliers communicate and interact on a global scale. To understand the jobs that customers need done, suppliers identify customer needs that cannot be done satisfactorily with current solutions.[5] Working from the outside-in, companies who supply pieces of the process collaborate by looking at the world from the customer's perspective to understand what the customer is trying to do and identify product or process characteristics for solving the customer's job. Starting with a deep insight into the job the customer is trying to accomplish shifts the focus from solutions that customers use to the fundamental issues the customer is trying to solve.

Cleaning process optimization requires a balance of chemical and mechanical effects. The job of the cleaning material is to remove flux residue and ionic contaminants. Aqueous cleaning material designs contain reactive materials at various concentration levels. Aqueous Low Reactivity cleaning material designs provide improved cleaning under low standoff components. The driving forces that improve performance come from the mixture of solvating materials that rapidly dissolve resin and rosin structures; low reactivity improves the cleaning rate but does not cause compatibility concerns; wetting lowers surface tension effects; and minor ingredients control foaming and protect solder joint finishes. Innovative designs run at lower wash bath concentrations ranging from 10-13%.

The cleaning machine design is equally important. Fluid management is critical to containing and keeping the wash chemistry within the wash section. Fluid delivery is critical for penetrating and rapidly breaking the flux dam under low standoff components. To improve cleaning under low standoff components, research data indicates that fluid flow, pressure at the board surface, directional forces, and time in the wash improve the process cleaning rate. The wash section of the cleaning machine is highly important. Research data findings indicate that flux not adequately removed in the wash will ***not*** be removed in the rinse sections.

The pace of innovation in the electronics field is staggering. This research paper highlights collaborative innovation in action. In today's rapidly growing global economy, customers *kaisen* (continuously improve) their processes. Listening and working closely with customer and supply partners who make up the ecosystem is how innovations that meet customer needs take place. Over the past several years, cleaning chemistries and cleaning machines have continuously improved to meet the challenges of cleaning highly dense and miniaturized circuit assemblies.

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