SPRAY NOZZLE CONFIGURATIONS IN AN INLINE CLEANER AND ITS EFFECTS ON CLEANLINESS

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Background

Cleaning electronic assemblies, or PCBs (Printed Circuit Boards), has been essential for many years. As PCB board density has increased and standoff height has decreased, so have cleaning challenges. Numerous technical studies published over the years have confirmed that post reflow flux residues resulting from No Clean, RMA and Water Soluble solder pastes can lead to failure mechanisms such as leakage current, electrochemical migration and dendritic growth, an unacceptable consequence particularly for high reliable electronic applications.

Cleaning systems have also evolved over the years as well as the cleaning agents available. In recent years, engineered aqueous based cleaning agents have become prominent due to the safety of use and reduced environmental impact as compared to solvent options. Thus, spray in air cleaning equipment is widely used throughout the electronics industry.

Given plant logistics and production demands, inline cleaning machines are frequently selected for PCB defluxing applications. In general, these machine types offer high throughput per square foot of surface area and excellent cleaning results.

The major sections of an inline cleaner include pre-wash, wash, chemical isolation, rinse and dry. Key to the inline cleaning performance lies within the prewash and wash sections. Utilizing a combination of thermal (cleaning agent temperature), chemical (ability of the cleaning agent to solubilize residue) and mechanical (impingement force of the cleaning agent on the PCB surface) energy, residues are contacted, solubilized and removed. These energy sources combine to achieve the effective removal of post reflow flux residues.

Thermal and chemical energy effectiveness results from cleaning agent selection. Mechanical energy effectiveness is based on the cleaning equipment design and particularly the cleaning agent delivery system. Factors to consider include immersion vs spray, cleaning agent contact time, number of spray bars, number and type of nozzles selected, and spray bar pressure.

Numerous designs have been developed and utilized including:

- Spray Under Immersion (SUI)
- High Volume V-Jet Nozzle (HVVJ)
- Standard Intermix Nozzle (SI) – Alternating V-Jets and JIC spray bars
- Intermix High Volume Nozzle (IHV) – Alternating V-Jets and JIC spray bars

SUI technology was developed in the 70s for cleaning PCBs with through hole components. Spray-in-air V-jet technology was developed in the 80s with the advent of SMT components as testing confirmed that greater impingement force was required for this PCB design. In the 90s, as SMT components were more widely used as compared to through hole technology greater increases in impingement force was required. This led to the development of higher volume spray-in-air V-Jets, water curtains and coherent nozzles (solid liquid stream through a single hole). In the early 2000s, use of SMT components on PCBs continued to increase and various nozzle technologies were combined with immersion.

Within the mid 2000s assemblies consisted mainly of SMT components, increased board density decreased standoff with bottom terminated designs all combining to greatly increase cleaning challenges. Testing proved that a combination of spray technologies was still required however, with nozzles that provided even greater flow rates. This led to the development and introduction of high volume intermix nozzles.

The various spray bar manifolds are comprised of different spray nozzle technologies such as Solid Stream (JIC) and V-Jet spray nozzles. The JIC is the simplest nozzle type designed to apply maximum mechanical energy of any nozzle independent of pressure. The nozzle can be adjusted to disperse liquid via pin point or sheet pattern dependent of the process requirements.

V-Jet nozzles provide a V-shaped spray pattern. The spray pattern size is determined by the spray angle and flow rate. The V-Jet spray patterns can be assembled to meet at the process level or slightly overlap in a long flat spray pattern. Utilizing a flooding action to the PCB, residues are softened through chemical and thermal energy. However, when compared to other designs, these nozzles offer the least amount of mechanical energy delivered to the PCB.

In summary, an efficient cleaning process requires the optimization of thermal, chemical and mechanical energies. Specifically when optimizing mechanical energy, it’s critical to consider the spray manifold design and configuration as well as the spray nozzle type and quantity.

The focus of this study was to assess the influence of the various spray manifold configurations on inline cleaning performance and efficiency.

Methodology

This study was developed to evaluate the effectiveness of the various spray manifold designs to clean post flux residues from PCBs. A spray-in-air inline cleaner utilizing a micro phase cleaning agent was selected to conduct all cleaning trials. The inline cleaner included pre-wash, wash, chemical isolation rinse and final rinse and dry sections. Four spray bar manifold designs were evaluated. These are:

- Spray Under Immersion (SUI). Figure 1
- High Volume V-Jet Nozzle (HVVJ). Figure 2
- Standard Intermix Nozzle (SI) – Alternating V-Jets and JIC spray bars. Figure 2
- Intermix High Volume Nozzle (IHV) – Alternating V-Jets and JIC spray bars. Figure 3

Figure 1. Spray Under Immersion SUI)

Figure 2. Standard and High Volume V-Jet (HVVJ)

Figure 3. Intermix High Volume (IHV)

Table 1. Spray Bar and Nozzle Design Details (manifold)

Configuration	Pre Wash Upper Pressure (PSI)	Pre Wash Upper Pressure (PSI)	Wash Upper Pressure (PSI)	Wash Upper Pressure (PSI)
Standard Intermix Nozzle	55	45	70	45
Intermix High Volume Nozzle	55	45	70	45
High Volume V-Jet Nozzle	55	45	60	40
Spray Under Immersion	55	45	60	40

In order to assess the effectiveness of the spray manifold designs, the ZESTRON® Test Vehicle (Figure 5) was used and populated with SMT low standoff components. Five (5) components of each chip-cap type were populated on each test vehicle for a total of 45 components per substrate (Table 2).

Figure 4. ZESTRON® Test Vehicle

Table 2. ZESTRON® Test Vehicle Component Type Population

Component Types Used		
SOT23	0805	6032
1210	0603	1812
1206	0402	1825

Utilizing the populated ZESTRON® Test Vehicle, three (3) lead-free solder paste types were considered: Paste A – Water Soluble (OA), Paste B – No Clean (NC) and Paste C – RMA. All pastes were reflowed per the manufacturers recommended profiles.

Following the cleaning process, cleanliness assessment was made via visual inspection per IPC TM-650 and Ion Chromatography analysis per IPC-TM-650 2.3.28. Thus, two test vehicles were required for each trial or a total of sixteen boards for each paste type considered (2 boards x 2 belt speeds x 4 spray manifolds). For visual inspection, all components were removed to enable component cleanliness assessment. Average under-component cleanliness determined for each trial. All results were plotted in bar graphs and with Minitab software.

Results - Visual inspection

For each paste type, conveyor belt speed and spray manifold considered, one test vehicle was analyzed for component inspection. All components were removed and under-component surface rated as per cent clean. The cleanliness level for all components was averaged per board. For each scenario, 45 components were considered (Reference Figure 4).

No Clean Cleanliness Results

Intermix HV produced the best results (98%) at 5.3 minute dwell time. This was followed by Std Intermix (96% at 5.3 min dwell), and V-Jet HV (86% at 5.3 min dwell). SUI resulted in 86% at 10 minute dwell time.

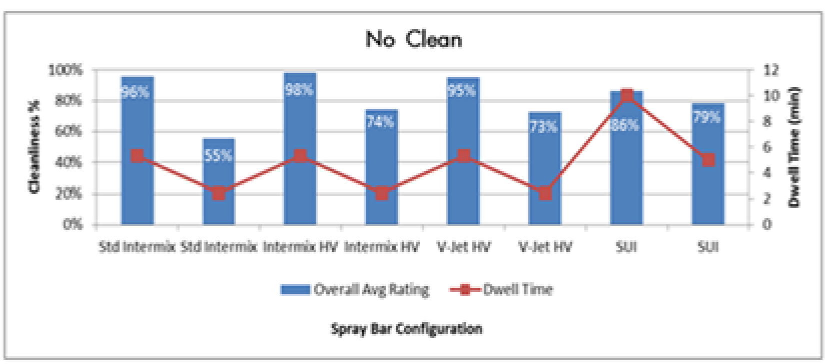

Figure 5. No Clean Paste B Visual Cleanliness Results

Result Summary – Visual Inspection

Paste A - Water Soluble Review:

As one would expect, the Water Soluble pastes were easiest to clean. Best results were achieved using the V-Jet HV at 0.55 min dwell (99%). At 1.06 min dwell cleanliness results were: Intermix HV (99%), Std Intermix (97%); SUI (99%), but at 2 minute dwell time.

Paste B – No Clean

Best results were achieved with Intermix HV (98%) at 5 minute dwell time. Std Intermix and V-Jet HV results (96%) and (95%) respectively at 5 minute. dwell time; SUI (86%) at 10 minute dwell time.

Paste C – RMA

Best results were achieved with Intermix HV (99%). Std Intermix and V-Jet HV results (97%) at 5 minute dwell and SUI result (98%) at 10 minute dwell time.

Part 2: Ion Chromatography Results

Twenty four (24) boards, one for each dwell time, nozzle configuration and solder paste type were used for ion chromatography analysis. All boards passed the ion chromatography test for the ion species were below the maximum recommended contamination levels.

Conclusion

For any cleaning process, optimizing thermal, chemical and mechanical energy is critical to achieving best cleaning results. This study focused on optimizing mechanical energy while maintaining thermal and chemical energy constant. Utilizing the same test vehicle populated with components using OA, No Clean and RMA solder pastes, four spray manifold designs were considered and cleanliness results evaluated using visual inspection and IC analysis.

Test results confirmed that spray bar configuration, nozzle design and utilization impacts mechanical energy generated and the degree of cleanliness achieved. Cleaning is also impacted by the component types used for under-component cleanliness. It is more difficult to achieve under-component cleanliness with larger surface area components as compared to those with smaller surface area.

Within this DOE, Intermix HV spray manifold achieved the best results at a 5 minute dwell time for No Clean and RMA and at 0.55 min for water soluble. All SUI results required twice the dwell time as compared to the other spray manifold configurations with results less than what was achieved with Intermix HV.

Although for all cleaning trials IC analysis yielded passing results, under-component cleanliness varied with each spray manifold configuration. In order to ensure the best possible results and minimize risk of field failures, care should be taken to maximize mechanical energy within a spray-in-air cleaning process and select the most efficient spray manifold configuration. Within this DOE, Intermix HV achieved the best results within all scenarios considered.

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For a full copy of the DOE, please contact Jody Saultz at jsaultz@speedlinetech.com