

# High Reliability and Low Variability Results with Benchtop PCB Cleaning

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## Abstract

The purpose of this study is to determine whether or not aerosol benchtop cleaning can consistently and reliably clean reworked boards. Different variables that play a role in the effectiveness of aerosol benchtop cleaning were examined. These variables include straw attachment, spray technique, spray angle, handheld cleaning tools, brush attachments, and a final rinse. While no approach to aerosol benchtop cleaning was found to be 100% effective all of the time, the study did yield good information that can be used as general guidelines to improve benchtop cleaning processes.

## Introduction

Historically, dip-and-brush, often with isopropyl alcohol (IPA), was the most common method used in benchtop (manual) cleaning of printed circuit boards (PCBs). More stringent cleaning standards, necessitated by miniaturization, have caused many to question tried-and-true methods. Even no-clean residues have raised questions; should they be cleaned? Or should they be left alone as the name implies? The dip-and-brush method was innately flawed and even more problematic when used on more tenacious no-clean flux residues. Boards were cleaned with contaminated solvent and brushes held onto contaminants, leaving the question as to how much residue was removed from the board by this process and how much cross-contamination was introduced through this process. Did you end up cleaner, dirtier, or no better, no worse than when you started?

By its nature, aerosol cleaning eliminates both of these problems. Aerosol cleaning introduces a continuous supply of clean, or virgin, solvent throughout the entire cleaning process. Aerosol cleaning prevents the introduction of new contaminants. While there are some obvious pros of aerosol cleaning, questions remain as to whether this method of benchtop cleaning can consistently and reliably clean a board. This paper examines the role that different variables play in aerosol cleaning and offers guidelines to improve an aerosol cleaning process.

## Method

Boards were built using Kester's FL250D (Sn63Pb37), no-clean paste to attach two QFNs and one QFP (*see Figure 1*). The boards were reflowed using a handheld heat/air gun. The boards were then cleaned in an Aquatherm Batch Cleaning System by Austin American Technology using Techspray's Eco-dFluxer SMT100 (part #1550), a water-based inline and batch flux remover, at 15% concentration. Per a visual inspection, only one board showed signs of residue after cleaning; all others were visually clean. Two components (QFN B and QFP) were fluxed, with Amerway #100 Type "R" Non-Activated Rosin Flux, to simulate rework. QFN A was untouched to act as a control and also so that it could be checked for cross-contamination. Two drops (from glass pipette) of flux were added, one to the top and one to the bottom of QFN B. Four drops were added to the QFP, one to each side. The board was rotated so that the side of the component being fluxed was always the top side; this allowed the flux to flow up under the component. The boards were then reflowed using the handheld heat/air gun at 400°F for two minutes, the gun was held approximately one inch from the board's surface (*see Figure 2*).

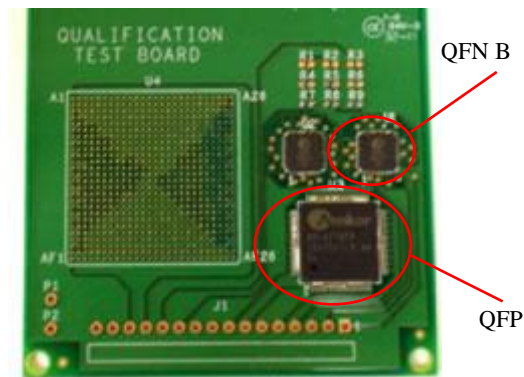
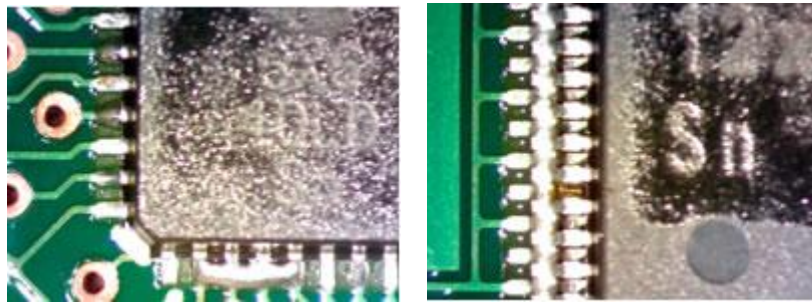


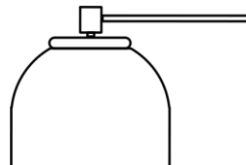
Figure 1: Qualification test board, with components reflowed to simulate rework highlighted



**Figure 2: Components (QFN B and QFP, respectively) with additional flux**

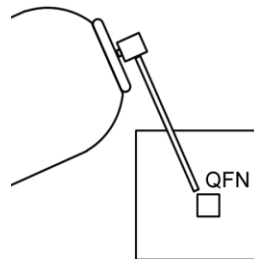
G3 Flux Remover aerosol was then used for benchtop removal of the flux. This solvent was chosen due to its cleaning effectiveness of Type "R" Non-Activated Rosin Flux, the flux used to simulate rework. The objective was to use a solvent with a known cleaning effectiveness in order to study the impact of the solvent delivery. Board cleanliness was determined by a visual inspection under 64X magnification. The following variables were examined during the benchtop cleaning trial:

- Straw attachment (*see Figure 3*)
  - With straw
  - Without straw



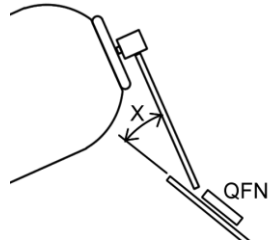
**Figure 3**

- Spray technique (*see Figure 4*)
  - Spraying component corners
  - Spraying component sides
  - Oscillating spray
  - Stationary spray



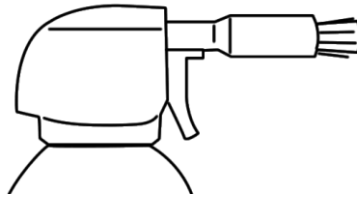
**Figure 4**

- Spray angle (*see Figure 5*)
  - 30°
  - 60°
  - 90°

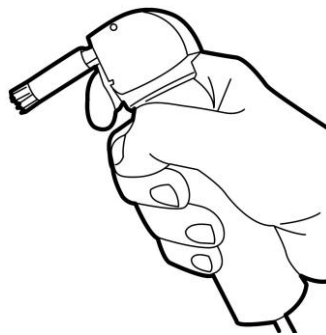


**Figure 5**

- Cleaning tools
  - Swabs
  - Brushes
- Brush attachment
  - With brush (*see Figure 6*)
    - Without brush
  - With brush system (*see Figure 7*)



**Figure 6**



**Figure 7**

- Final flush / rinse
  - With flush
  - Without flush

## Results and Discussion

### Straw Attachment

The use of the straw attachment allowed for a more controlled spray, thus eliminating excessive solvent waste. The straw was also useful in directing exactly where the solvent went. This allowed the user to guide the solvent under the component. Without the straw attachment, solvent was sprayed at the target area (for instance, the sides of the component); however, much of the material was wasted on areas surrounding the target and very little ended up traveling under the component (*see Figure 8*).



**Figure 8: Visual comparison of an aerosol spray without (left) and with a straw attachment.**

### Spray Technique

Best results were obtained when both corners and sides of each contaminated component were addressed, as opposed to focusing on only one or the other, corners or sides. Directing solvent directly into the corners helped to break up any flux dams located there. Because the corners were cleared first, when the sides of the components were addressed, the number of channels opened to allow solvent to pass was greater than it was when corners were not addressed first. The more open channels available, the greater the opportunity for the flux to be exposed to the solvent, and as a result the higher likelihood that all flux trapped under the component will be able to flow out from under the component.

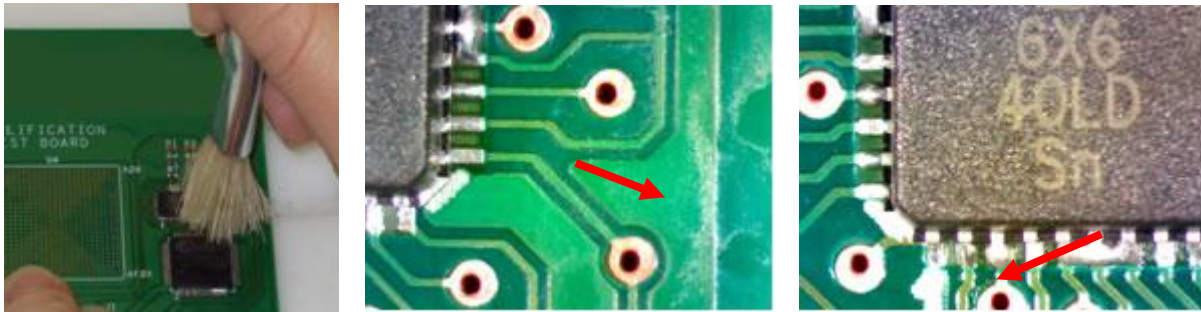
The choice to use an oscillating or stationary spray was dependent on the size of the component. For a small component it was sufficient to use a stationary spray on the component sides; however, for larger components a cleaner board was achieved when the spray was oscillated back and forth across each side of the component. This oscillating spray gave the solvent the opportunity to flow up, under the component from many angles, similar to the way that the flux had.

### Spray Angle

An exact straw angle of 30°, 45°, or 60° to the board had no impact on the cleanliness of the board. General downward or upward angles were sufficient. In order to make the most of the straw, think about the direction in which the residues need to travel. When trying to remove residues from under a component, spray close to the board at an angle that guides the solvent under the component. When all of the residues have been removed from underneath the component, spray from on top of the component, angling out along the edges to push any residues out, away from the component.

### Cleaning Tools

Handheld brushes and swabs left the board looking dirtier than it started. Brushes and swabs spread partially solvated flux around the components which then dried, leaving a white residue. None of the polyurethane foam swabs held-up well in this application. Foam swabs became flimsy when saturated with aggressive solvents and were easily torn. Another problem with handheld tools was that the solvent evaporated too quickly. Best results were achieved when a final rinse was utilized (*see Figure 9*). The key is not to let the board dry out. When the board dries, the partially solvated flux dries leaving the white residue mentioned earlier. A slower evaporating solvent, like IPA, would avoid the evaporation issue, but should be followed by a rinse (*see more details on rinsing below*). In addition, some solvent may travel under the component during scrubbing, but without the force of an aerosol spray, the likelihood that the residues under the component will be pushed out is slim.



**Figure 9: Board cleaned with handheld brush. The components were wetted, and then the brush was wetted and used to scrub the contaminated area. The board in the first picture did not undergo a final rinse. The board in the second picture did (Note: all flux was not removed).**

#### Brush Attachment

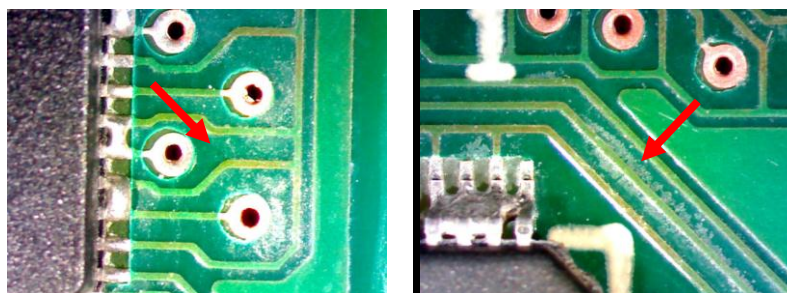
Some solvent cleaners come with a brush that attaches directly to the spray head, and the solvent flows through the brush as a slow rate (*see Figure 10*). This is particularly common in defluxers available in Europe. Brush attachments produced results that were a step above handheld tools, due to the benefit of a constant supply of virgin solvent. However, they did not produce the same level of cleanliness observed in aerosol only cleaning. The brush attachment allowed for scrubbing problem areas, which can be beneficial. However, the force of an aerosol through a straw attachment produced similar results.

Brush attachments, like handheld tools have the potential to introduce new contaminants. In addition, for a brush attachment to reach its full potential, a separate aerosol is required for cleaning under components and for the final rinse. Like handheld tools, without the force of an aerosol spray, some solvent may travel under the component during scrubbing; however, the likelihood that the residues under the component will be pushed out is slim. Because the use of a brush attachment requires that the target area remain saturated, the target area remains in a solvent pool throughout the cleaning period. This increases the likelihood that residues may only be relocated on the board instead of being removed completely. A final rinse, then, was found to be especially important, to ensure that all of the residues were removed from the board (*see Figures 11 and 12*).

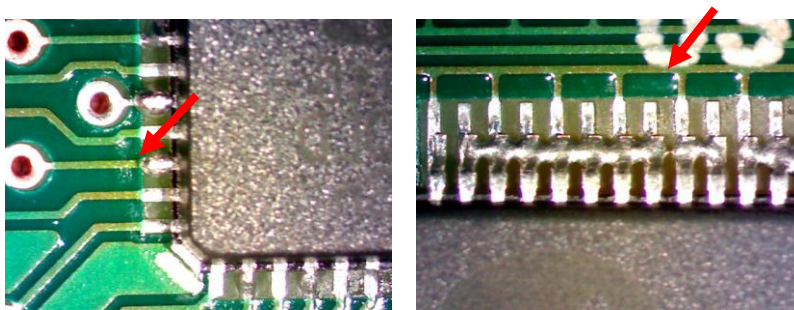
There is a commercially available brush system that provides a separate brush mechanism for cleaning, which is continually fed by the aerosol can. No cleaning advantages to this system were observed compared to a brush attachment. A brush system or attachment is often used to reduce solvent usage, but this advantage is greatly decreased if a proper rinse is applied.



**Figure 10: Brush attachment**



**Figure 11: Board cleaned with brush attachment (no separate aerosol was used). No pre-rinse or final rinse utilized. White residue shown around QFN B and QFP, respectively.**



**Figure 12: Board cleaned with brush attachment (separate aerosol was used for pre-rinse and final rinse). Some white residue shown around QFN B and QFP, respectively.**

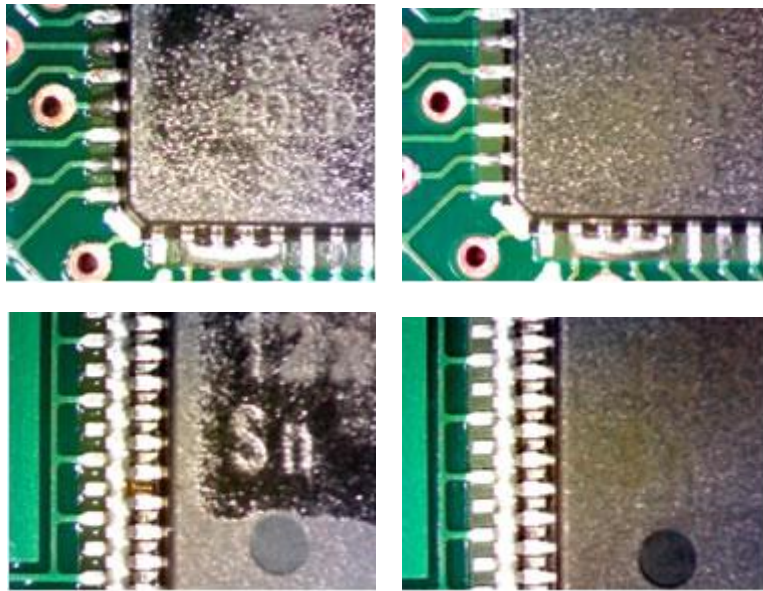
#### Final Flush / Rinse

The final rinse was found to be a necessary step. This step ensures that all of the solvated flux residues, which have been removed from under and around components, flow off the board completely, and are not simply relocated.

#### **Conclusions**

There is no “one size fits all” approach to aerosol benchtop cleaning. There are too many variables involved in benchtop cleaning that prevent developing a method/formula for cleaning that appears to be (per visual inspection) 100% effective all of the time. That being said, some methods do work better than others, and selecting the correct combination and formalizing the process will reduce variability. The following information is intended to be used as a general guide to improve benchtop cleaning effectiveness.

1. First, boards should be held in an upright position for cleaning, at a slightly backward angle (approximately 30° was used in testing).
2. As the board is cleaned, keep the board in this same upright position, do not rotate the board. This board position helps to ensure that all residues move in the same direction throughout the entire cleaning process, down, and eventually off of the board.
3. Using an aerosol with a straw attachment helps to focus the solvent spray; thus, eliminating excessive waste.
4. A pre-rinse should be utilized; wetting the entire area to be cleaned from top to bottom. This step begins solvating the flux residues.
5. The next focus should be on the corners of each of the components to be cleaned. A short burst under each corner (down into top corners and up into bottom corners) will help to break up any flux dams located there. It is important that this step comes early in the cleaning process, as clearing the corners of the components of flux residue opens the number of paths the solvent can travel as it works its way under the component. When spraying corners, work from top to bottom.
6. Attention should be given to each side of the contaminated components by spraying back and forth across each side of the component. To keep all residues moving in the same direction, down and off, work your way around the components moving from top to bottom. For each side, keep the straw angled so that it is spraying under the component. This step is an opportunity to remove flux residues from under the components. It is better to slightly overdo this step. If you underestimate and don't use enough solvent here, you will only move the residues around, not out from under the component.
7. Spray each component surface, angling the straw to spray away from each side of the component. This helps to move residues away from the component and ensure that no residues are trapped between the leads.
8. The last step is the final rinse. Again, working from top to bottom spray the affected area to rinse all residues completely off of the board. See Figure 13 for an example of a board cleaned using the above guidelines.



**Figure 13: Before cleaning and after cleaning pictures of QFN B (top) and the QFP (bottom), using the cleaning guidelines described above. (Note: markings were not removed, but are more prominent in the before pictures due to the sheen from the flux.)**

Although this process seems elaborate, the total time averaged 60 seconds per board. Additional cleaning tools intuitively make sense, but did not increase cleaning performance and slowed down the process. For critical cleaning, this technique should be used to achieve an acceptable level of cleaning effectiveness and repeatability, similar to automated methods.

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# **High Reliability and Low Variability Results with Benchtop PCB Cleaning**

# Purpose of The Study

- Cleaning is more critical due to miniaturization
- Automated cleaning methods are well understood
  - Vapor-degreasing
  - Batch cleaning
  - Inline cleaning
- Benchtop (manual) cleaning methods not fully studied
  - Repeatable methods
  - Effectiveness of cleaning tools (e.g. brushes)
  - Techniques

# Benchtop Cleaning

- Manual cleaning process common for low volume production and rework
- **Immersion** (bucket cleaning)
  - Pan, drum-in-a-sink
- **Hand cleaning** – Wipes, brushes, swabs
- **Aerosols** – Spray can provide agitation, straw for impingement



**FOCUS OF  
STUDY**

# Variables in Cleaning Process

- **Reactivity with soil** – e.g. solvency or saponification
- **Temperature** – disadvantage of aerosol
- **Contact time**
- **Physical agitation**



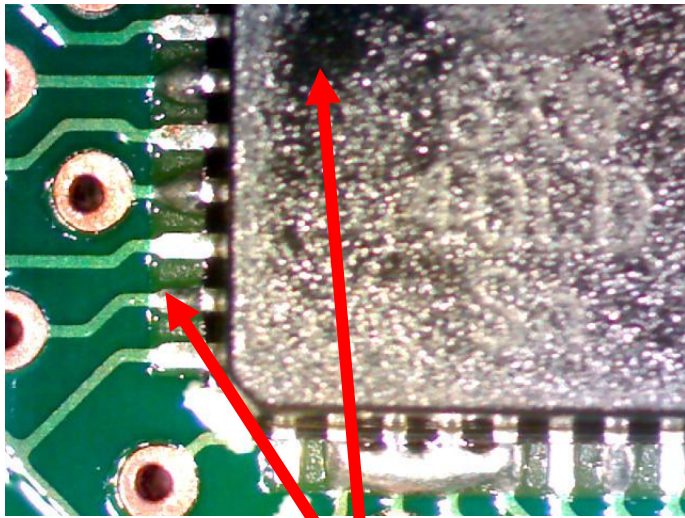
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# Test PCB Vehicle

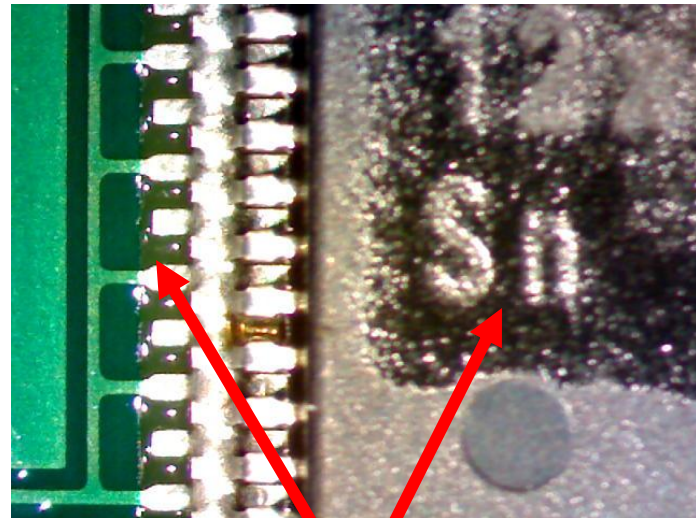
- Flux & solvent fixed
  - Techspray G3 Flux Remover in 16 oz. aerosol can
  - Amerway #100 rosin flux
  - 99-100% cleaning efficiency
- Delivery & agitation methods varied
- Tested over 75 combinations
- PCB test vehicle reflowed
- PCB cleaned in batch cleaner
  - AAT Aquatherm with Techspray Eco-dFluxer SMT100
- Inspected at 64X
- Flux added to QFN & QFP
- QFN left unfluxed



# Test PCB Vehicle

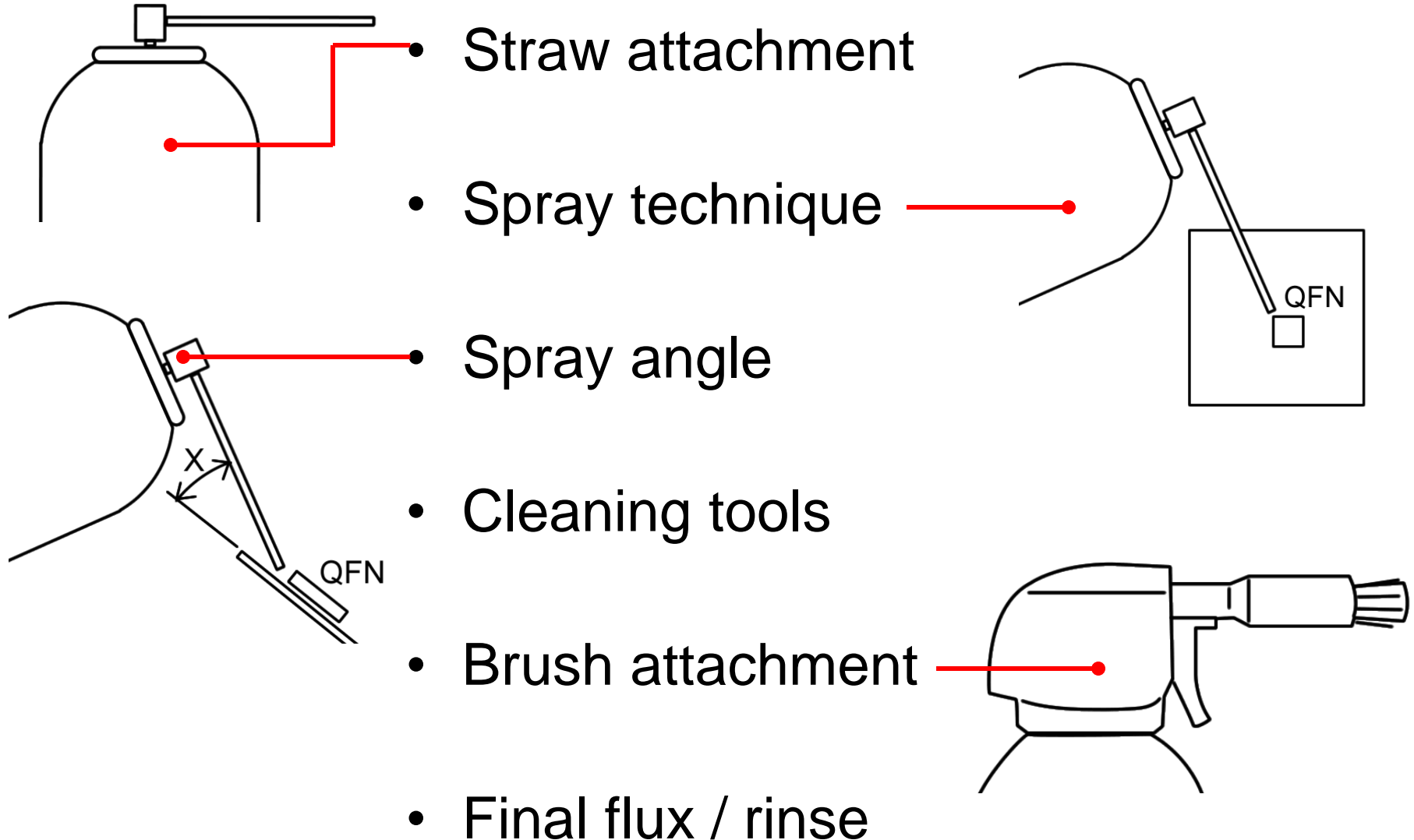


FLUX



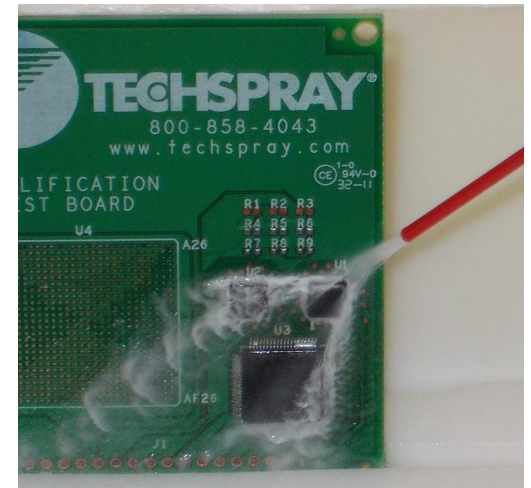
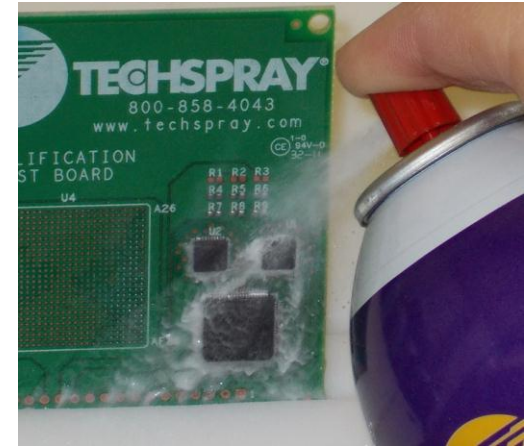
FLUX

# Delivery & Agitation Methods



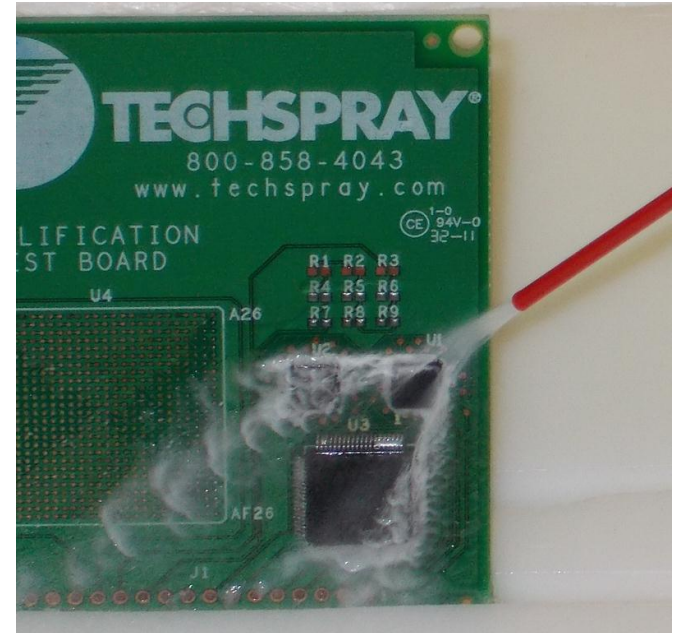
# Straw Attachment

- Straw attachment recommended
- Directs spray with higher precision
- Greater agitation in focused area
- Reduces solvent waste



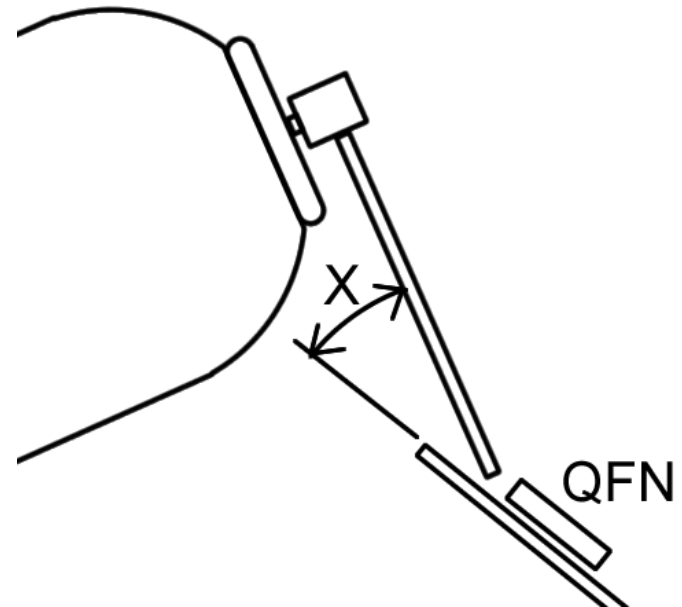
# Spray Technique

- 4 corners + 4 sides
  - Start with corners
  - Then spray sides
- More effective than just corners or sides alone
- Channels through flux dam & increases contact area
- Multiple directions prevent shadowing
- Oscillating movement beneficial on large components



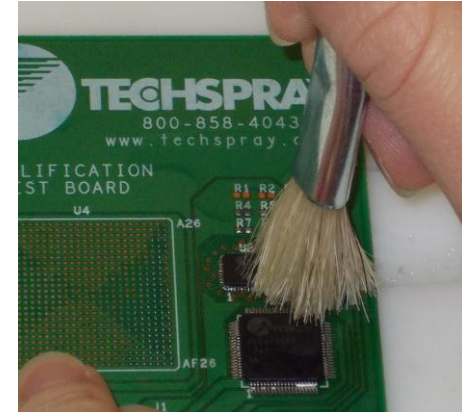
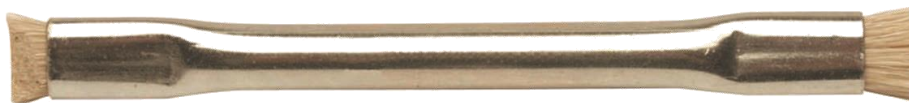
# Straw Angle

- Impingement angle critical for inline systems
- Exact angle is not critical
- Need 20°-70° to clean under components



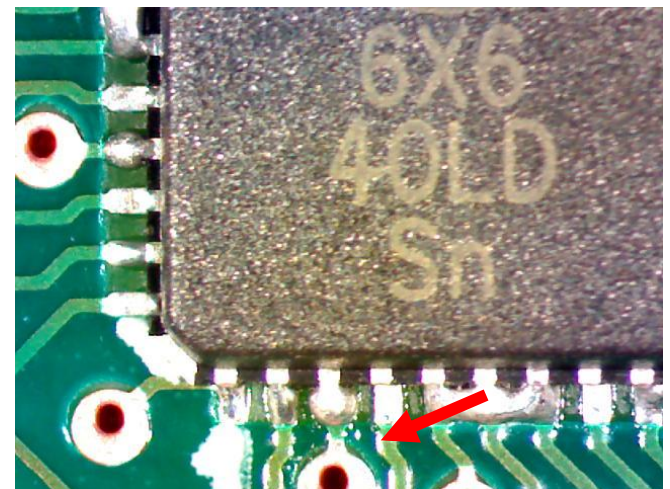
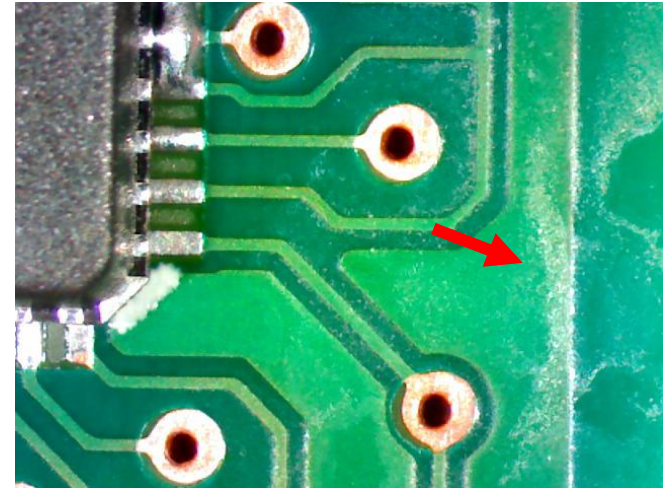
# Cleaning Tools

- Various brushes & swabs tested
- Pro: direct agitation
- Con: cross contamination

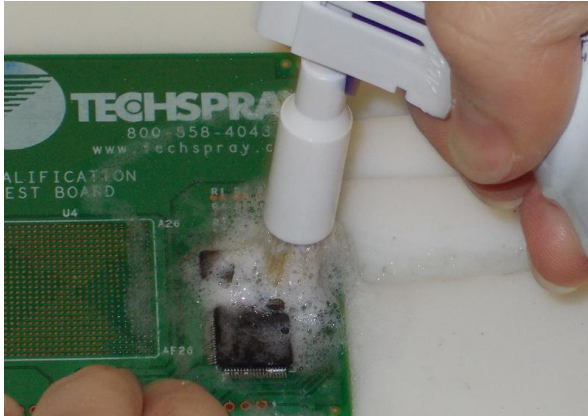


# Cleaning Tools

- Important to keep saturated
- Smears & moves residues
- Slower evaporating solvent recommended
  - e.g. 70% IPA
- Swabs too delicate
- Risks cross contamination
- Not effective in tight areas & under components
- Rinse highly recommended

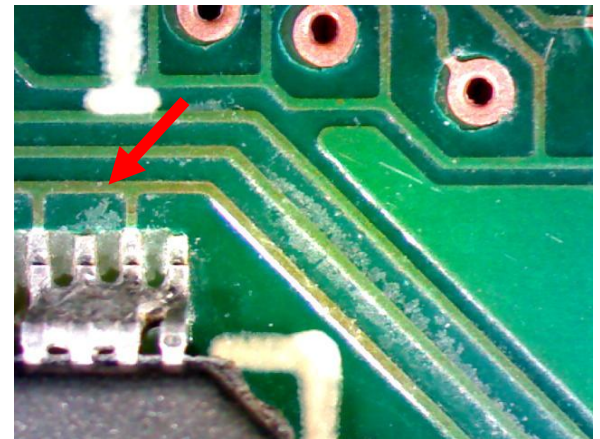
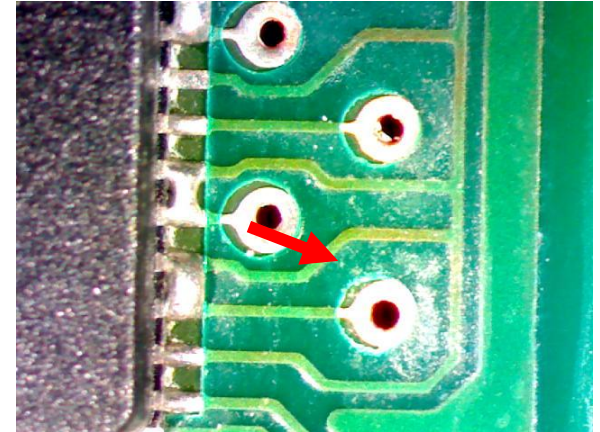


# Brush Attachment



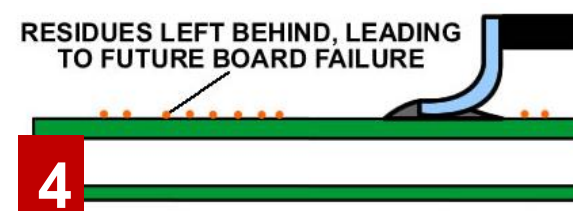
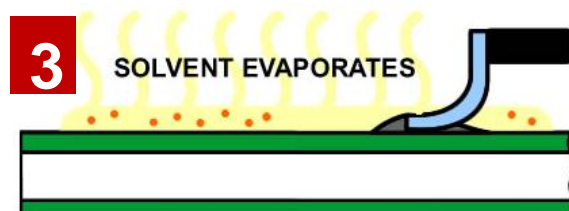
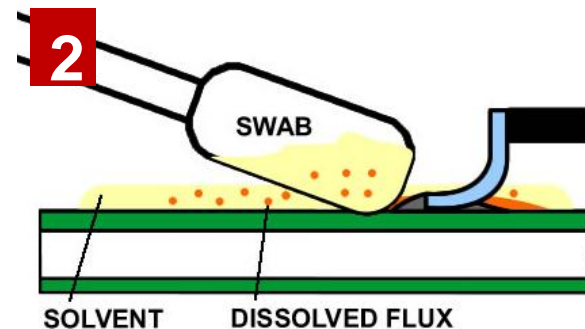
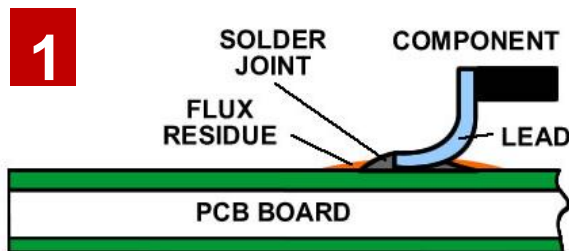
- Actuator attachment & brush system
- System no cleaning advantage

- Brush continuously saturated
- Faster evaporating solvent can be used
- Not significantly better than separate brush
- Rinse w/o brush highly recommended



# Final Flush / Rinse

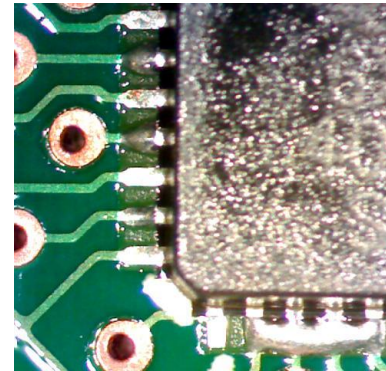
- Most important step in all methods
- Residues must flow off of PCB
- Prevents redeposition & cross contamination
- Choose direction of spray carefully



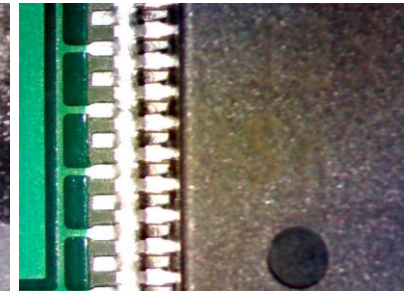
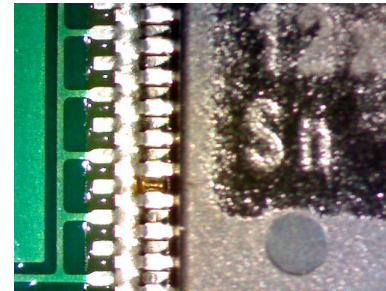
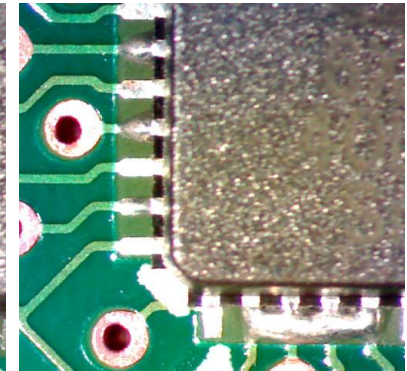
# Ideal Benchtop Cleaning Process

1. Angle PCB 30°
2. Keep same position, work from top to bottom
3. Use straw attachment
4. Pre-rinse
5. Spray 4 corners of each reworked component
6. Spray 4 sides
7. Spray surface of components angling to move residues away
8. Final rinse

BEFORE



AFTER



# Conclusion

- 60 second process
- No tools prevents cross-contamination
- May reduce time for easier soils
- Visual standard generally ok for no-clean fluxes
- For rosin & OA flux or for class 2 or 3 – higher level of cleanliness testing may be necessary
  - ROSE
  - Ion chromatography (IC)
  - SIR
- Later study will test by IC w/steam extraction

QUESTIONS?