Alternative technologies for lead-free de-fluxing

There are several steps in determining IF and HOW to implement a de-fluxing strategy. Lead-free soldering and reflow environments mandate a more critical de-fluxing due-diligence process.

The purpose of this paper is to discuss the various steps to make the following determinations:

The first thing one must consider is whether or not to clean. Is the flux left on the board after reflow inert? Is the appearance of the assembly important to the end-user? Will there be liability issues if the board fails due to the presence of flux residues? How important is the assembly's reliability?

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Surface contamination issues in the electronics industry lead to lost productivity, reduced reliability and increased liability. The need to remove flux residues from post-reflowed circuit assemblies has never been greater. High component densities and low stand-off heights increase the likelihood for flux entrapment.

Lead-free soldering applications increase the necessity for cleaning due to several factors, including:

- More complex flux formulations, where activity levels of lead-free solder paste fluxes are more aggressive.
- Higher reflow temperature requirement for proper wetting, where there is a negative cosmetic appearance caused by higher (as much as 50° higher) reflow temperatures.
- Rework, where there is an increased requirement for post-reflow rework increases likelihood for cleaning.

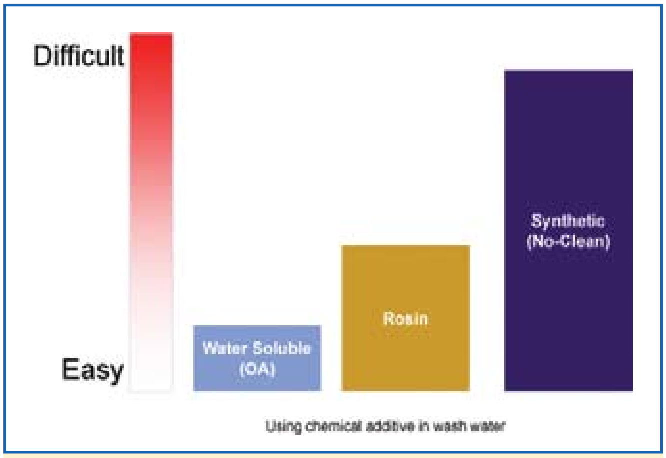

Figure 1. Cleaning difficulty comparison of the various flux types.

The implementation of lead-free alloys increased both the benefits of cleaning and the difficulty of cleaning *(Figure 1)*. If one were to assess de-fluxing based on the level of difficulty, one would determine that water soluble flux residues are among the easiest to remove while so-called no-clean flux residues are among the most difficult to remove. Ironically, while no-clean fluxes remain the most difficult to remove, they are also the most common flux removed by de-fluxing equipment.

Because of the transition to lead-free alloys, an increasing number of assemblers are implementing de-fluxing technologies to remove increasing volumes of residues left on post-reflowed assemblies reflowed with no-clean pastes *(Figure 2)*.

Leaving post-reflowed flux residues on the assembly may lead to reliability and subsequent liability issues.

There are several factors to consider when choosing a de-fluxing method.

- Through-put requirements
- Flux type
- Solder alloy
- Effluent restrictions
- Budget

Let's begin with an overview of the current (conventional) technologies.

Manual de-fluxing

Overall, manual de-fluxing methods provide the worst-case scenario with respect to cleanliness, consistency, and operator safety. Manually based de-fluxing processes involve dipping a board into a solvent-based de-fluxing chemical or, more commonly, spraying a de-fluxing chemical onto a board, applying mechanical energy by way of an acid brush. This process is normally but

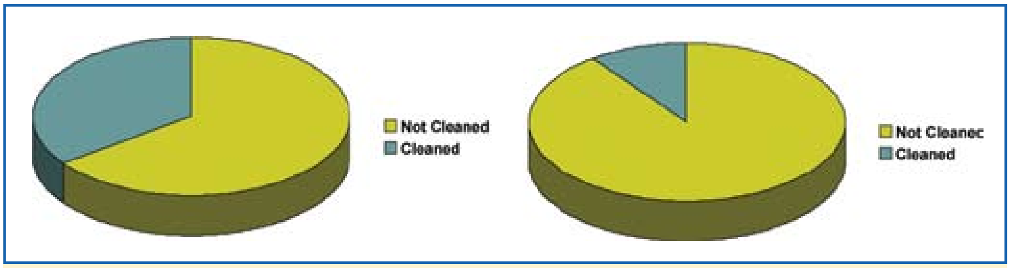

Figure 2. Increasing volumes of residues are left on post-reflowed assemblies when no-clean flux is used.

Table 1. Throughput of batch and inline machines based on board size and number of chambers.

Board Size (mm)	Boards per Hour Single Chamber Batch / Inline	Two Chamber Batch / Inline	Three Chamber Batch / Inline	Four Chamber Batch / Inline
127 x 127	112 / 288	224 / 288	336 / 288	448 / 288
203 x 203	56 / 180	112 / 180	168 / 180	224 / 180
304 x 304	28 / 120	56 / 120	84 / 120	112 / 120
457 x 457	28 / 80	56 / 80	84 / 80	112 / 80

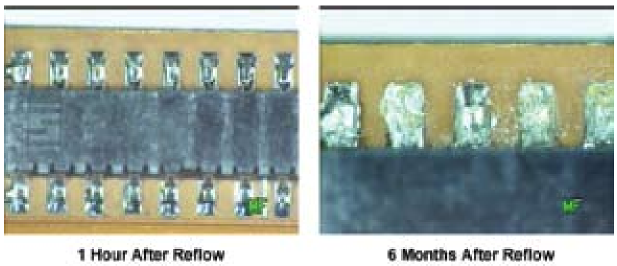

Figure 3. Post-reflow flux residue's effects on an assembly.

not exclusively followed by a rinse, either by dipping the assembly into a pan of water or by placing it under a running faucet.

In nearly all manual cleaning scenarios, flux is merely diluted and spread around the board. Flux is frequently trapped under components as the manual application of the cleaning agents can not adequately penetrate under the component. Additionally, in most manual cleaning environments, inadequate rinsing is frequent, trapping highly conductive and corrosive cleaning agents under components.

Automatic de-fluxing

Modern automatic de-fluxing equipment eliminates the common deficiencies associated with manual cleaning operations.

To properly determine the correct automatic de-fluxing technology, one must consider the aforementioned factors.

There are two common automated de-fluxing technologies in use today; batch format and inline format. Each technology has specific advantages and disadvantages, strengths and weaknesses.

Step 1 - Determine technology based on throughput requirement

As a rule, batch machines have historically been utilized in lower volume applications while inline de-fluxing equipment has been associated with high throughput environments. Today, with advances in batch-format throughput technology called 'Multi-Batch', throughput yields between batch and inline are closer than ever before *(Table 1)*.

Step 2 - Determine flux removal capabilities

What kind of flux will be removed? What kind of alloy will be reflowed? When de-fluxing assemblies the 'alloy-based rules' shown in *Table 2* generally apply.

Step 3 - Determine effluent (discharge) restrictions

Although today's de-fluxing systems and associated chemistries are generally considered environmentally safe, many users of such equipment have implemented voluntary discharge restrictions to eliminate the possibility of liability caused by changing environmental legislation. All conventional de-fluxing equipment requires the need

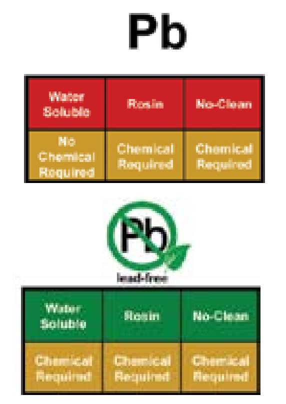

Table 2. Alloy-based rules for eutectic and lead-free solder pastes.

for a water supply and a drain. Closed-loop configurations are available for water soluble de-fluxing applications but are not suitable for chemical required applications such as the removal of no-clean or rosin-based fluxes.

Check with municipal, state, and federal regulators as well as your in-house facilities or health and safety department regarding the suitability of direct-to-drain discharge. Direct-to-drain discharge is a popular choice if the de-fluxing system is equipped with a wash-solution recycling system. By recycling and reusing the wash solution, only rinse water is directed to drain, reducing both the volume and negative environmental content of the effluent.

If a zero-discharge configuration is required or preferred, consult with your de-fluxing equipment manufacturer. Most manufacturers offer zero-discharge configurations (most commonly via evaporation systems).

Step 4 - Determine facility restrictions

Factors including a machine's footprint, water consumption, voltage requirements, chemical usage, etc all require scrutiny.

Batch, Multi-Batch, and Inline de-fluxing technologies all consume specific facility capabilities. One should carefully consider all relevant equipment requirements prior to purchase. Often, specific requirements including actual operational expenses are overlooked until after purchase, leading to unexpected shortfalls in resources *(Table 3)*.

Step 5 - Determine process control and statistical process control requirements

There are multiple published military and commercial cleanliness standards. These cleanliness standards provide quantitative contamination detection techniques. Working under specific cleanliness standards and other quality control standards such as ISO, TQM, Six-Sigma, etc one must utilize specific methods of determining cleanliness.

Although post de-fluxing cleanliness testing techniques are commonplace, in-process cleanliness testing performed within the de-fluxing equipment will prevent unexpected and undesired results. Although inline format de-fluxing systems are not equipped with in-process cleanliness testing technology, some batch and multi-batch technologies are equipped to actually modify the cleaning parameters to meet a predefined cleanliness setpoint. By controlling the cleaning process based on desired cleanliness, post de-fluxing cleanliness testing the requirement is reduced.

Some batch and multi-batch technologies provide Statistical Process Control (SPC) data logging capabilities. The SPC data logging function allows users to verify specific cleanliness parameters, including cleanliness results, historically, eliminating cleanliness-related defects as a potential cause of failures.

Table 3. Floor space, water and energy consumption, and chemical costs need to be taken into consideration.

Facility Requirements	One Chamber Batch	Two Chamber Batch	Three Chamber Batch	Four Chamber Batch	Inline
Floor Space (mm)	1200 / 1500	1200 x 2500	1200 x 3500	1200 x 4500	1800 x 6100
Water Requirement (liters per hour)	90	180	270	360	1135
Voltage Requirements	12kW	25kW	36kW	48kW	162kW
Chemical Usage*	USD $ 26.00	USD $ 52.00	USD $ 78.00	USD $ 104.00	USD $ 416.00

Step 6 - Determine cleanliness requirement

For batch format de-fluxing technology, the machine's cycle time is affected by the cleanliness requirement. That is to say, the higher the cleanliness specification, the longer the cycle. With inline-format de-fluxing technology, the machine's physical length contributes to the cleanliness capability of the machine. The longer the machine is, the more washing, rinsing and drying time is available to the assembly. Care should be exercised to ensure adequate throughput capability of a batch cleaner operating under a specific cleanliness expectation while equal care should be exercised to ensure adequate facilities requirements (footprint, utilities and expenses) to operate an inline de-fluxing system. An inline de-fluxing system that is too short may not provide cleanliness results that meet a specific expectation.

Conclusion

Regardless of whether flux is removed or not, it is safe to say that cleaning adds value. Whether the value is appreciated is a factor of the specific application for which the assembly will be placed. Will a board failure be catastrophic? Is the board expected to operate in uncontrolled environments (i.e. high temperature, high humidity)? Is a decrease in product liability worth the cost of de-fluxing? These questions can only be answered by evaluating the specific application, reliability expectation, cost of failure, liability exposure, and cost of cleaning.

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