Even minor temperature changes can increase polymerization and oxidation.

One of the more difficult cleaning problems is the complete removal of burned-in flux residues from complex assemblies. Manufacturers often quickly adopt aggressive wash settings to compensate for inadequacies in cleaning process performance. In the few cases where this tactic results in success, it is usually obtained at the upper limits of extremely aggressive wash settings. The process window is too narrow to provide the necessary cleaning consistency required in a high-reliability application, and intermittent residues begin to surface. Further, material compatibility issues not previously encountered under relatively mild conditions often arise, and sensitive metals, labels, inks and markings may be affected. Widespread use of high melting point alloys and the exposure of assemblies to multiple thermal cycles have made removal of burned-in fluxes one of the most common problems fielded by our application technology department. Therefore, the thermal effects on the nature of flux residue and the impact on cleaning continues to be a focus of investigation.

As manufacturers have transitioned toward Pb-free processes, much discussion has been devoted to the relationship between reflow temperature and the impact on flux removal. In fact, manufacturers and cleaning agent suppliers have learned that relatively minor increases in reflow temperature or subtle differences in profiles can have a disproportionately negative effect on the ability to remove burned-in flux residues. With Pb-free solders reflowing at temperatures commonly exceeding 230°C and high lead solders peaking around 350°C, the risk of thermal flux decomposition, polymerization and oxidation reactions increases. Thus, an otherwise easily cleanable flux transforms into a “rock” that cannot be fully cleaned under the relatively mild wash conditions previously employed to remove the residues generated in a leaded process.

On a complex highly dense assembly with low-standoff devices, these hard resinous structures provide significant barriers, altering the fluid flow mechanics in the space beneath components and effectively decreasing the exposure time of the cleaning agent to the targeted residues. To overcome this problem, increases in chemistry concentration, wash temperatures, exposure times and mechanical energy have been adopted to aggressively penetrate the capillary spaces and solubilize the flux.

In general, each thermal cycle makes cleaning increasingly more difficult and, in some cases, residues baked in by repeated exposure to multiple thermal cycles become even harder to remove than those created in the high-temperature processes, despite exposure to lower peak temperatures. Depending on flux type, cleaning may or may not be required, as is the case in some no-clean processes. However, if defluxing is a requirement, the question of whether to clean after each thermal cycle or at the end of multiple thermal cycles arises. Often, manufacturers aim to avoid multiple cleaning steps and elect to follow the latter route. In fact, many manufacturers have implemented a single cleaning process at the end. While this offers theoretical advantages such as cost savings, increased throughput and reduced handling/exposure of the assembly to cleaning agents, forgoing intermittent cleaning steps until

after multiple thermal cycles often introduces unforeseen problems by creating the need to adopt more aggressive cleaning parameters, and the theoretical advantages of a single pass cleaning process may quickly erode.
The cornerstone of a successful single pass cleaning process to remove burned-in flux residues is a cleaning agent that rapidly solubilizes the polymerized flux residue. This minimizes the need to expose assemblies to excessive temperature, concentrations, exposure time and pressure. An example **(Figure 1)** from a recent study we conducted highlights the importance of the cleaning agent's role in removing these thermally evolved flux residues, as well as the impact of repeated thermal cycles, including a two-hour bake (125°C). The study employed the use of various flux types (OA, RMA and no-clean) and boards designed to fail cleaning were used to represent a worst-case scenario and ensure differentiation between cleaning agents.

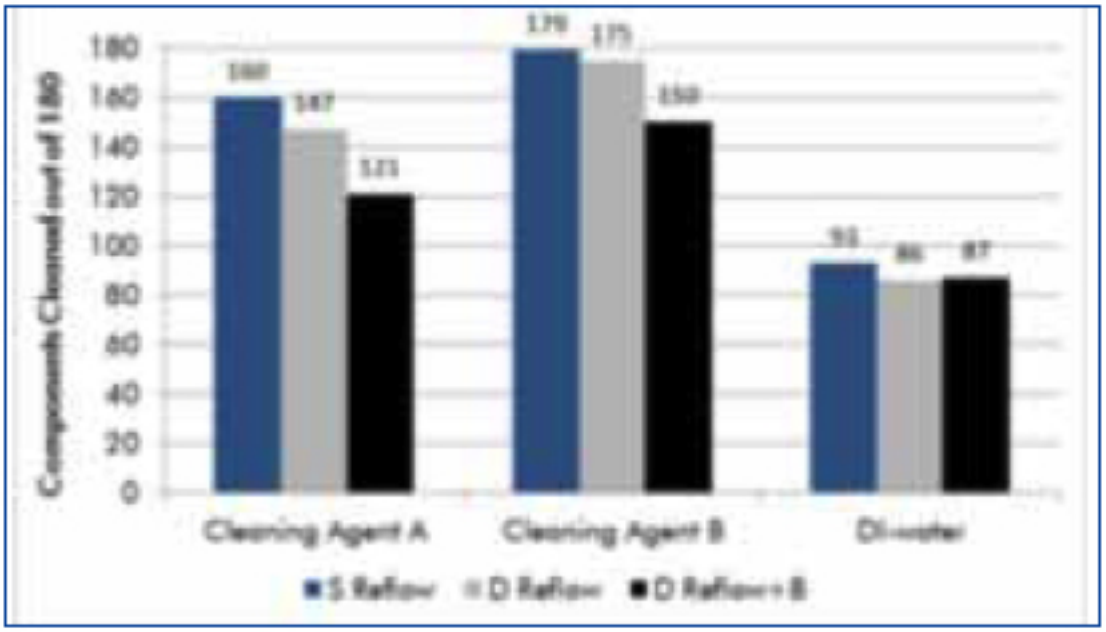

FIGURE 1. Impact of multiple thermal cycles on underneath cleanliness for OA solder paste.

The use of aggressive upper limit wash settings, customized spray bar and nozzle designs were excluded to further increase the burden on the cleaning agents and to represent a reasonable process window. A leading cleaning agent (A), a developmental cleaning agent (B) and DI water were all screened to examine effectiveness in the removal of burned-in fluxes from underneath the components. The number of components fully cleaned was counted and those with even trace amounts of residues were considered failures and not counted.

The data illustrate a few points relevant to this discussion. First, even a relatively easy to clean OA flux can become extremely difficult to fully remove from beneath low-standoff devices once it has been exposed to multiple thermal cycles, thereby presenting significant challenges to both DI water and chemistry-assisted processes. Next, flux removal is negatively impacted by each thermal cycle, as expected. Not surprisingly, the cleaning effectiveness of DI water remained

flat, as it is well documented that DI water displays limited ability to remove single-reflowed OA flux from underneath low-standoff devices of challenging assemblies such as those used in the study.

There is no simple solution. Each process is unique and critical decision criteria vary depending on the requirements of each manufacturer. Cleaning agent innovations, paste formulations with enhanced thermal stability and equipment design changes continue to evolve at a significant pace, however, and complete removal is achievable without adopting unnecessarily aggressive wash conditions that may introduce more problems or sacrifice material compatibility.

Michael McCutchen is managing director, North America and South Asia of Zestron (zestronusa.com); m.mccutchen@zestronusa.com .