As advances in surface mount soldering are made, the user and the vendor are continually faced with key technical challenges to improve the process. Most challenges are user-driven and are met by the enhancement of associated equipment and materials used in the process.

For example, during the ’80s the viability of infrared (IR) mass heating vs. vapor phase mass heating and the enhancement of solder paste formulation were leading topics. Those issues have been confronted and, for the most part, solved through the process of continuous technological evolution.

**Challenges for the ’90s**

In simplest terms, during the ’90s the most pressing challenges to SMT soldering will likely result from two key trends:

- The continued reduction of the use of CFC compounds.
- The increasing utilization of more complex SMT circuit assemblies incorporating complex component distributions.

It is necessary, therefore, to take a closer look at the potential impact of these trends in reference to specific equipment, materials, and processes. In this way, engineers should be able to institute an SMT soldering process capable to adjust to future trends.

**Consequences of CFC Reduction**

Most understand that the environment will benefit from the continued reduction in the use of chlorofluorocarbons (CFCs). However, a frequently-asked question is, "Why should the removal of chemicals associated with the process of post-solder cleaning pose a technical challenge to the SMT soldering process?"

Quite simply, if we must remove a family of chemicals used for years to reliably clean circuit assemblies, other chemicals must be found to do the same job. Since any substitute cleaning solvents may require modifications for dealing with existing solder flux/solder paste formulations to be effective, modified formulations could, therefore, have profound effects on future soldering processes.

As it turns out, however, the most promising CFC substitutions (water/saponifier and terpene/water) do not and should not by themselves necessitate the use of special flux formulations. Rosin-based solder fluxes will most likely suffice. Following this line of reasoning, it would be easy to expect these substitutes to have little impact on the SMT soldering process. However, this is not the case.

The desire to reduce or eliminate CFCs has produced a renewed interest in removing the environmental drawbacks associated with cleaning. CFC reduction has therefore spurred the development of simple, safe, and reliable no-clean soldering processes and appears to be the resulting challenge for the immediate future.

**No-Clean Wave Soldering**

In recent years, a no-clean SMT wave soldering process has been achieved by introducing a nitrogen cover gas atmosphere in conjunction with the use of low solids, synthetic rosin fluxes.
Figure 1, top, how component density per board (average) has increased exponentially in recent years.

Figure 2, bottom, interconnection density, more gradual in its rise, foresees an expanded use of reflow soldering in this decade.
throughout critical portions of the system. However, the flux formulations tended to volatilize or decompose when exposed to high temperatures.

Currently, work is proceeding on a no-clean process that does not require a cover gas. Initial users have reported significant success. However, further improvements to current synthetic flux formulations so that no visible residue remains are continuing. Nitrogen atmospheres would only be used to enhance solderability or to minimize the formation of fumes, a feature which also reduces cost and process complexity.

No-clean processes that depend on formic or adipic acid-reactive atmosphere mixtures instead of flux will probably never gain acceptance for several reasons. First, formic acid is hazardous. Since it has a low OSHA threshold limit value of 5 ppm, the cover gas induction system must be extremely tight. This level of atmosphere containment is very difficult to achieve in a continuous conveyor soldering system. Second, if heating elements are exposed to a reducing environment, the oxide coatings that protect them from further oxidation could be removed, possibly causing premature failure. Third, since flux is not present, different interfacial surface-tension relationships exist and solder joint wetting angles may not always meet existing specifications. Lastly, these processes are complex and costly to control.

Other, more elaborate reactive gas options will most likely be evaluated in the coming years. However, many of the logical choices appear to have additional undesirable aspects, such as low flash points.

No-Clean Reflow Soldering

The same concerns about reactive gases also exist for the development of a no-clean SMT reflow soldering process. As with wave soldering, synthetic resin formulations should be part of the final no-clean solution for reflow soldering.

In recent years, a few production no-clean reflow processes have been instituted using a "slightly" modified rosin-based solder paste and no special processing cover gases. This approach has produced adequate cleanliness levels. However, since isomerized rosin tends to have a caramel color that makes its presence quite noticeable, this process is not likely to satisfy everyone. Additionally, rosin-based solder pastes do not exhibit significant tendencies to volatilize.

Recent research work indicates that reflow soldering is essentially incompatible with no-clean solutions that utilize hazardous or explosive gases. Also, engineers are not receptive to using solder paste formulations so radical in formulation that screen printing and reflow become difficult to control. For this reason, solder paste suppliers are trying to develop a material that can be processed in an air atmosphere reflow oven without causing major changes in the screen printing process.

These developments will involve screen-printable synthetic resin paste formulations that volatilize during heating. Unfortunately, none of the formulation experience gained during the development of no-clean wave soldering fluxes can be directly applied to solder pastes. Solder paste development is a much more complex formulation problem, which may cause a dependence on the introduction of nitrogen cover gas for the first several years of solder paste development.

Depending on the specific formulation, required residual oxygen levels in ovens will vary between 100 and 10,000 ppm, measured at (unloaded) conveyor level. However, the consensus among major solder paste manufacturers is that nitrogen atmospheres will not ultimately be required. Thus, nitrogen atmospheres should again be relegated to a role of solderability preservation, especially in certain double-sided processing operations.

Complex SMT Assembly Processing

Based on trends seen by major SMT users, as shown in figures 1 and 2, the expanded use of reflow soldering on larger, higher-mass multilayer substrates in conjunction with complex component distributions should continue. This means wave soldering usage will decline in all market segments except those not driven by weight or space restrictions.

As this decade progresses, more SMT assemblies are likely to be double-sided and reflow soldered on both sides. High-volume assembly equipment has already been enhanced to handle substrates up to 18" wide and to place components at rates of 24,000/hours. It appears that the '90s should prove to be the decade in which complex high-volume reflow soldering processes will begin to dominate.

A heavy burden will be placed on many traditional reflow soldering methods because of increased SMT assembly usage. Ovens will be required to perform at higher production rates while delivering greater heating uniformity. Technologies such as T-3 lamp, infrared dominant mass heating, and radiant panel natural convection/infrared mass heating may have a hard time competing. Already, the fallout is beginning to be seen. New mass-heating strategies are currently changing the soldering equipment marketplace.

The newest technology to offer improved capabilities is recirculated, all-zone, forced-gas convection heating. This near equilibrium, contact heating technology has simply incorporated some of the more positive thermodynamic principles of vapor phase condensation heating (uniform heating) while enhancing the beneficial attributes of traditional continuous ovens (i.e., low cost of operation and ease of use).

Full-forced convection systems utilize a first order linear heating technique throughout each heating zone. This makes assembly heating profiles uniform and predictable from one board to another in consideration of overall mass and conveyor speed. Profiling can be significantly simplified in comparison to traditional ovens. Also, since the convective flow in each zone is constantly recirculated, a large energy reserve is available to circuit assemblies as they pass through the heating chamber. This approach makes these systems highly repeatable in production. Operating variance is typically less than 5°C.

One area not addressed in this approach is cover gas introduction. Most suppliers have shown little interest in including this capability. As discussed, this capability is not required, but may offer improved processing flexibility, especially as no-clean solder paste formulations mature.

All-zone, forced-gas convection systems are currently being used by major contract manufacturers and some of the world's...
largest computer manufacturers. This relatively new reflow soldering technology should see continued growth during the '90s.

Although not much has been published regarding the use of silver-bearing adhesives in place of solder, much development work is taking place. It appears that conductive epoxies will likely not replace solder since they tend to cure “hard” and cannot be easily reworked. On the other hand, conductive thermosetting adhesives, which are reworkable, screen printable, and have only a slightly higher cost per gram than traditional solder pastes, show significant promise.

If conductive adhesives are to replace solder on circuit assemblies, they must be able to meet or exceed currently specified thermal shock, coefficient of thermal expansion (CTE), temperature-humidity, and temperature cycling tests. Presently, these adhesives are only used in specific consumer product applications.

Fortunately, most conductive adhesives can be cured in all types of conveyor ovens. Also, since the profile required is a moderate “ramp” to curing temperature, followed by a time-specified “hold” at a given temperature, problems such as assembly heating uniform and temperature exposure are minimized. Unfortunately, many formulations cannot presently be cured in vapor phase systems, since typical heating rates do not match the heating rate or cure time requirements of currently existing materials. However, this aspect should also change as more research is conducted.

Conclusion
The future of soldering, especially during this decade, looks quite interesting. No-clean wave soldering is essentially already a reality. The development of a viable, cost-effective, no-clean reflow soldering process that does not depend on a cover gas should be possible within a few years. The increasing demands for heating uniformity and repeatability in reflow soldering equipment should cause a “shakeout” in this market segment.

Combining these developments with the possibility of converting many processes to conductive adhesives leads to the conclusion that more research is needed in all areas of the soldering process.

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