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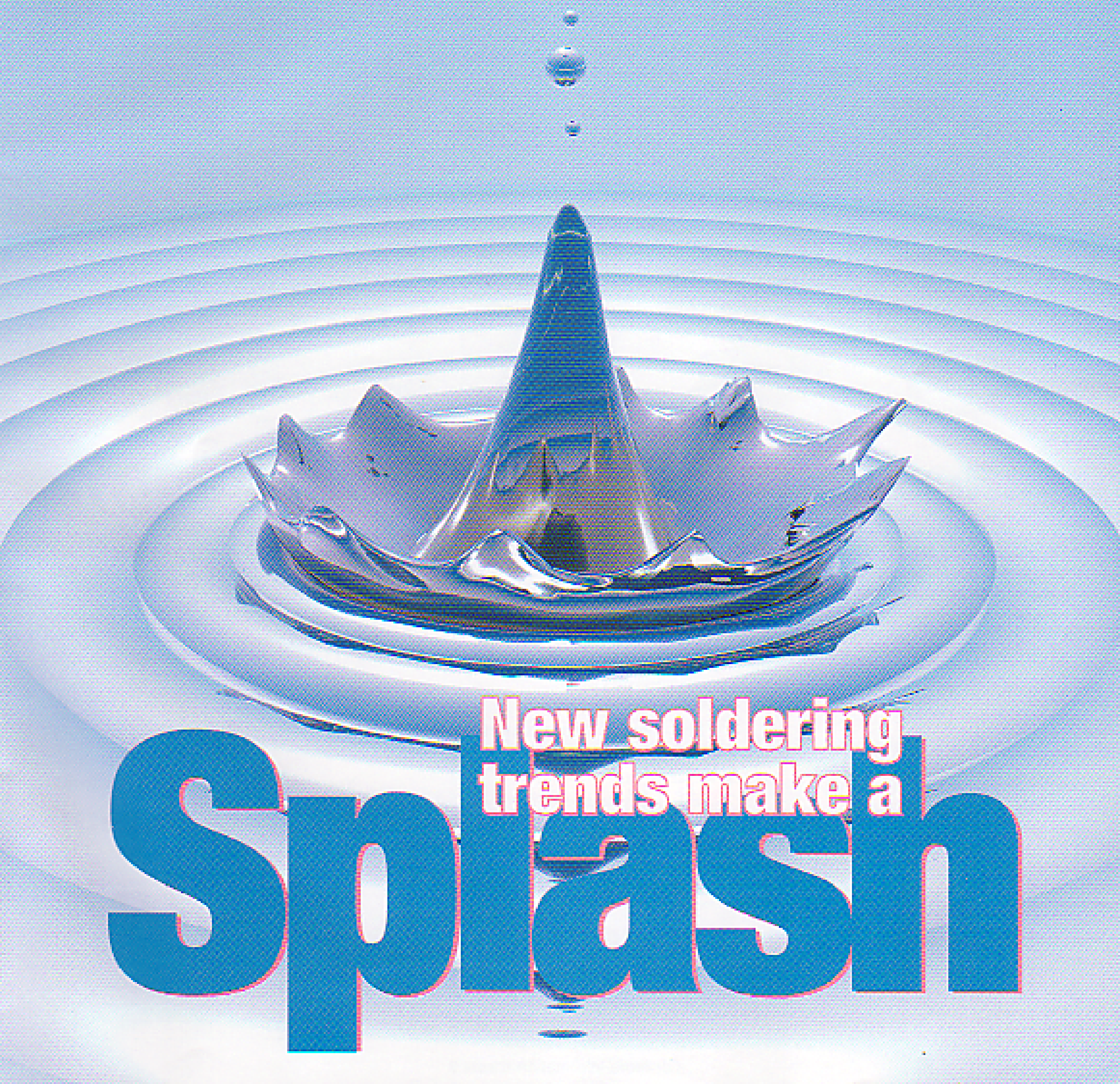

New soldering trends make a Splash

New Avenues for Wave Soldering and Lead-free Conversion

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Introduction

There are several areas that need researching when switching to lead-free solders. So far, most projects have concentrated on the properties of the new solders and the reliability of the joint, as this is of immediate importance. Far less information, however, has been accumulated from a manufacturing point of view. Process parameters, as well as defect rates, are of particular interest to manufacturers. In addition, the capabilities of current process equipment are also of relevance, particularly in wave soldering, in order to meet the requirements of higher temperature and higher tin content of most lead-free solders.

Contrary to many statements found in the 'relevant' literature, the introduction of lead-free wave or flow soldering is not as straightforward as one is usually led to believe. Many small, and also some major problems, will arise that may cause the process engineer to wish for the 'good old times' of lead solders.

Introducing lead-free wave soldering normally requires the user to cope with two major changes: a higher tin-content of the solder and a higher process temperature. Whereas the eutectic lead solder contains approximately 60 percent tin, the lead-free versions offer more than 90 percent. The melting point of the eutectic SnPb solder was close to 180 ºC, but the lead-free solders' melting points are in the vicinity of 220 – 250 ºC. Assuming that the solder pot temperature has to increase by about 50 K, the soldering temperature would be around the 280 ºC [1].

Let's list just a few of the obvious problems:

- **Oxidation:**
  The new alloys all need higher process temperatures, as the increased amount of tin in the solder heightens the tendency to oxidize. Although the higher tin content would lead one to believe that wetting could be improved, this is generally not true. As a result, the 'process window shrinks'.

- **Residues Level and Cleaning Process:**
  Longer dwell in preheat and higher pre-heat temperature require changes in flux composition, which chemists suggest increase the rosin content and decrease the solvent part. More colophony will help to protect the activators but also will leave more residues. More rosin will also be in the pot. Due to higher temperatures and longer exposure times, the residues will be harder to clean [2].

- **Dross:**
  Although some reports want us to believe that the generation of dross will not be increased, more trustworthy research has indicated that we may expect five or even

seven times as much when operating in air. As 90 percent of the cost of bar solder derives directly from metal cost, the higher metal cost will be felt immediately. More dross also means more maintenance.

- **Nitrogen:**
  N2 is typically justified for SnPb solder by a cost calculation on dross for SnPb alloys. The quality and reliability are normally a bonus. With higher dross and much higher alloy prices, nitrogen will be a definite "must" situation for lead-free solders. Alternatives include, raising the superheat temperature or increasing flux strength, but these pose significant process challenges [3].

- **Solder Pot Protection:**
  The new alloys have lower density. Bolts, components, and tools that used to comfortably swim on the SnPb solder may now sink. This can lead to solder contamination or jam the mechanical pumps.

- **Cooling:**
  The exit from the machine may have to see changes too: cooling of the product will require more time or additional cooling means. Assemblies may be hotter and thus cannot be handled immediately.

However, the real surprises come when the new solders are put into 'old' equipment – assuming that one actually got rid of all the lead. After a few weeks or months, things start to happen. Soldering becomes difficult and wave height is no longer achieved. All this is due to the aggressiveness of tin at high temperatures. The tin in the solder starts to attack the material of the pot and pump – although one might think that 216 steel would be impervious to such action. Wherever friction and movement between solder and steel is particularly pronounced, the attack is most obvious. Hence, it is first the pump and the impeller that shows deterioration. Pitting is followed by real corrosion and the impeller of the pump is 'eaten' away. Pumping action deteriorates. Then pitting occurs in the pot walls, which may lead to pinholes and liquid solder spurts forth. As the tin dissolves the iron in the stainless steel, iron intermetallic is formed in the solder as a contaminant. The soldering difficulties are thus explained. [One company using SnAg solder for several years now – because of high reliability demands (automotive) – changes the solder every month, the pump every 6 months and the pot every year].

Experiments have revealed that under the above temperature settings SnAgCu solder shows iron intermetallic needles after eight hours of operation in new stainless steel pots. Solder equipment manufacturers had been warned of such occurrences early and in a valiant effort researched materials for pots or, alternatively, coatings for existing steels that would avoid such problems. Alloys do exist that withstand tin scavenging, however, they are extremely expensive and very hard to work with. Several coatings have been identified that also could offer a solution under certain circumstances.

Despite this brave endeavor, the user still faces the cost of an entirely new piece of equipment that frequently does not even have a convincing track record as manufacturers have generally opted to develop totally new equipment. Mass production with lead-free solders is still relatively rare and mostly limited to companies that worked with ‘better’ solders rather than intentionally targeting ‘lead-free’. And since no fundamental change in the concept has been achieved, neither the pumping principle nor the pot volume has changed.

An Alternative Solution

For many years, a specialized European company has produced soldering machines on a completely different principle. Instead of the common impeller pump with pressure chamber -or channel- they relied on a highly ingenious electromagnetic or induction pumping principle.

With this technology, an electric current circulated around a magnetic coil induces a magnetic field. The combination of the current and the magnetic force creates the necessary pump action to push solder through the nozzle. Requiring a much smaller solder volume (50 kg / 110 lbs) and not producing the feared vortex around the pump shaft, electro-magnetic pumps have no moving parts. This results in a flexible wave, yet stable with a high reach up to 28mm (Figure 1).

This technology requires that the pot is non-conductive, which forced the manufacturer early to develop a coating on their cast iron pot that is non-conductive and resistant to attack by tin. In addition, these soldering units require protection from oxidation as dross reduces greatly the performance of the system. The electromagnetic wave was traditionally equipped with oil dosage systems since the design was not suitable to nitrogen inerting. The usage of oil with the associated inconvenience, as well as the fact that only relatively narrow widths of the wave were marketed, limited its popularity. Nevertheless, such soldering machines have been in operation for many years.

With the reintroduction of the lead-free debate a few years ago, these systems have generated renewed attention - particularly in Japan where Pb-free is at the forefront. The traditional unit has been improved in several ways. A nitrogen inerting system now replaces the messy oil intermix. Since the North American market in particularly demands wider waves, pots have been developed that feature up to 500 mm / 20 inches wide flows. The nozzles and nitrogen elements are made of titanium and the pot of coated cast iron as it has stood the tests of lead-free soldering for a long time now. Such units have now been made available as retrofit solder pots. They provide top performance with regard to PTH and SMD components soldering and are fully compatible with lead-free solders. Their proven track record makes these systems an attractive choice for lead-free wave soldering.

System in Operation

After initial trials at the equipment manufacturer’s lab to test the improvements, the system was tested in production at an automotive components manufacturer. The unit was initially placed on a line with SnPb solder where it was further tested and fine-tuned. Once the system performed satisfactorily, it was cleaned and assigned to a lead-free (SnAgCu) line. Automotive products requiring high temperature resistance were assembled on that line.

After several months in production, the general opinion is highly positive, as the quality of the joints appears to be excellent. The defects levels under lead-free conditions compares favorably to those of a similar product soldered on a different line but with SnPb alloys. Particularly, the use of nitrogen seems to have improved the performance of the new system. Besides reduced maintenance and very little dross, nitrogen also enhanced wetting. Assemblies that had required additional flux deposit are now soldered with half as much flux and still show significant defect reduction. Although extremely low oxide production was met, the long time assessment of an optimization procedure finally settled on a nitrogen consumption level of around 14 Nm3/h / 500 scfh. At that gas flow, the average dross collected was 27 grams/h (1/2 lbs per shift!) under lead-free (Figure 3) vs. 12 grams/h initially obtained with SnPb alloys.

These excellent results have prompted the application of this technology as a lead-free soldering machine retrofit. The entire system was lifted from its piece of equipment and redesigned in order to make it retrofittable into practically any existing soldering machine. The small size of the pot, including the electro-magnetic pump, represents a plug-in soldering engine of high and proven performance at a fraction of the cost for a new piece of equipment. Companies that want to experiment with or start producing lead-free product now may do so with the existing equipment by simply removing their solder pot (pump and all) and replacing it by the retrofit pot assembly. The system combines proven full lead-free compatibility with nitrogen inertion. It is very compact and thus will fit even into smaller frames. The ingenious pumping systems allows for much smaller pot volumes, decreasing the cost of lead-free alloy fill. At last, there is an easy entry into lead-free technology.

Reference:

[1] Baggio T., Suetsugu, K.; Guidelines for Lead-free Processing; SMT, Sept. 1999.

[2] Kenyon W.G.; Potential Impact of Lead-free Solders on Cleaning; SMT/Nov. 1998.

[3] Hunt C. et al.; Evaluation of the Comparative Solderability of Lead-Free Solders in Nitrogen; APEX 2002.

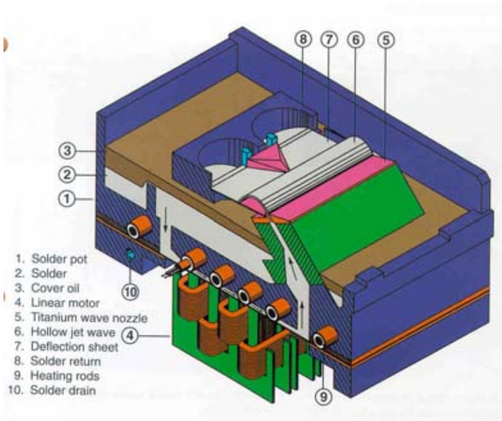

Figure 1: Electromagnetic Wave Soldering Technology

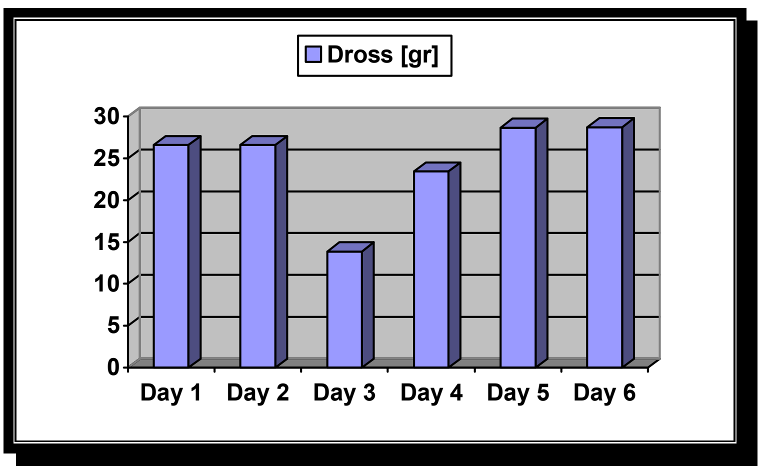

Figure 2: Lead-Free Dross Production. Hourly Average Production.