AB Automotive Partners with Multicore & Metcal to Investigate Lead-Free Process

As part of EP's ongoing series examining the key issues surrounding the lead-free debate, we explain how one major automotive manufacturer has successfully introduced a lead-free process capability for its existing boards, as Charles Green explains.

One of the hottest debates in the European electronics industry is the expected ban on lead and other harmful substances in 2008 by the EC's proposed Waste in Electronics and Electrical Equipment (WEEE) directive.

Although many manufacturers are still waiting to see whether this proposal will, in fact, become a legislative reality before committing themselves, it is widely expected that the move to lead-free manufacturing processes is inevitable.

Indeed, the successful elimination of leaded petrol means that consumers are already acquainted with the toxic hazards and health risks posed by lead, and how lead-laden end-of-life products buried in landfill sites can contaminate the water supply chain.

However, the burning questions for any manufacturer faced with the prospect of switching to lead-free are: what will it demand in terms of equipment, materials, processes and, most importantly of all, cost?

Although it is a daunting prospect, the experiences of the TT Group are encouraging.

Comprising some 60 operating sites worldwide, the TT Group is a £700million global manufacturer of high quality products for the automotive, telecommunications and industrial engineering markets.

In a typically market leading fashion, the TT Group has taken the lead-free issue very seriously and after committing substantial resources into exploring the feasibility of switching to lead-free within several of its constituent companies, is on the brink of demonstrating this capability to its customers.

"After extensive evaluations, we found the lead-free trials to be challenging yet possible," says TT Group engineer, Ben Kennard. Kennard co-ordinated the lead-free process trials at the Group's AB Automotive Electronics subsidiary at Cardiff in Wales, UK. This site specialises in the design, development and manufacture of climate control systems, and safety critical body electronic modules and switchgear for passenger vehicles.

"In fact, with the right choice of assembly tools and materials, the temperature requirements of lead-free soldering of up to 40ºC higher can be met using standard equipment and processes," continues Kennard.

The automotive operating environment is extremely harsh and demands PCBs, components and assembly materials that can cope with both high operating temperatures and continuous vibration, while meeting exacting automotive safety specifications and standards.

“AB Automotive Electronics is a forward looking company that appreciates the positive environmental impact that a move to lead-free represents”, adds Kennard. “We needed to ensure that the quality, performance and reliability of these trial lead-free products were not compromised in any way”.

AB therefore decided to perform extensive trials that included assembling two different existing automotive board types. One was mixed technology single-sided, and the other was mixed technology double-sided.

The boards measure 10cm x 10cm and 10cm x 15cm in size and feature between 120 and 160 components, ranging from large ICs and transformers down to 0805 chip devices. The mixed technology boards contain some 70 through hole (TH) devices and, in addition to being reflow soldered, require approximately 140 joints to be manually soldered.

AB then set two types of selection criteria: one for selecting a suitable lead-free solder paste and wire, and one for selecting the required manual soldering equipment.

“We were looking for a lead-free solder alloy that, in addition to offering standard characteristics such as good electrical conductivity, a desired melting point range and good wetting properties, was also able to cope with the demands of a harsh operating environment,” explains Kennard.

Achieving a desired melting point range was therefore vital for AB who had to discount every alloy with a melting point below 183ºC. This immediately excluded the use of low melting point elements such as bismuth.

“But in order to avoid heat damage to our existing boards and components, and to be able to use our existing reflow oven, the melting point also couldn’t be too high,” continues Kennard. “We had to rule out lead-free alloys based on tin-copper formulations, as they melt at around 227ºC and demand a reflow heating profile of up to 250 to 260ºC. This is the upper limit to which the majority of our components are qualified and would almost certainly have caused damage through over-heating.

“Although we did try to source some new higher temperature components, we found that the component suppliers weren’t responsive to our needs. As yet they do not freely offer components with lead-free compatible finishes that are capable of withstanding the higher end temperatures required for lead-free soldering.”

Another concern for AB was the fact that many potential lead-free replacement solder alloys use expensive elements such as silver and indium which significantly increase their cost over traditional tin-lead formulations.

Given this extensive range of challenges, AB Automotive Electronics set out to find whether a suitable lead-free solder alloy existed that could meet all SM reflow soldering and TH hand soldering needs. After extensive investigations, AB found that one supplier, Multicore Solders, offered the perfect alloy for its needs.

The Multicore Ecosol® TSC lead-free solder is a highly cost-effective alloy based primarily on tin with small amounts of silver and copper added. With a 217°C melting temperature, that is only 34°C higher than AB’s traditional tin-lead eutectic solder, it

allowed AB to retain the entire range of existing components on the new lead-free boards.

Furthermore, in addition to offering the required wetting, fluxing, mechanical strength and fatigue resistance properties, AB gained further confidence when it found that the Multicore alloy formulation is recommended by the National Electronics Manufacturing Initiative (NEMI) and Soldertec, a lead-free division of the International Tin Research Council (ITRI).

Through their own independent research, these organisations have deemed tin-silver-copper as the most suitable lead-free replacement solder alloy formulation for tin-lead in terms of processability, reliability, recyclability, availability and melting point temperature.

Because some areas of AB's boards were inevitably more temperature sensitive than others, they had to develop a special reflow profile to ensure that no components would be exposed to excessive heat during soldering. "This was extremely challenging, but with Multicore's help we were able to develop an optimal tin-silver-copper lead-free reflow profile that did not risk component heat damage effects such as 'popcorning' cracks," says Kennard *(see diagram 1- reflow profile)*.

The next major challenge for AB was to find the right equipment for hand soldering the TH joints onto the mixed technology boards. "Again, because of our exacting automotive specifications, we realised that we needed a soldering iron that could deliver an unusually high level of accuracy to a traceable standard. We also wanted a reliable, hassle-free production tool that could be used to solder our lead-free boards immediately without needing to be continually re-calibrated to meet the higher temperature requirements of lead-free soldering," states Kennard.

The Metcal MX-500 soldering iron, featuring Metcal's unique SmartHeat technology, met these criteria and was selected for all the hand-soldering operations. It was felt it would provide the exact amount of thermal energy required to achieve high quality solder joints.

Metcal's SmartHeat technology is an established method for guaranteeing soldering iron tip temperature. In a conventional soldering iron, the heat delivered to an iron's tip (and therefore a solder joint) is determined by remote circuitry that does not compensate for the varying thermal demands of individual PCBs and components.
As a result, when the tip temperature naturally falls during soldering, operators tend to over compensate by increasing power and tip temperature, which dramatically increases the risk of component and board damage. *(photo 2 – hand soldering with the Metcal MX-500).*

With Metcal's SmartHeat technology, the risk of thermal damage to boards and components is eliminated by the self regulating laminate heater that automatically adjusts the power required to maintain the tip at a constant soldering temperature. This means that the tip cartridge is able to sense the required thermal input for each solder joint and instantly deliver just enough extra power to melt the joint without overshooting the required melting temperature, as is the case with conventional irons.

"The Metcal iron solved an important technical issue -- that of soldering heat sensitive components at the increased temperatures demanded by lead-free alloys,

without allowing any unnecessary overheating that could risk damaging the mechanical integrity, mouldings or innards of more sensitive devices, or delaminating or scorching our standard FR4 board substrates," says Kennard. " And as we didn't need to increase power there was no reduction in tip life".

To verify the quality of both its SM and TH lead-free solder joints, AB Automotive Electronics also conducted extensive validations on its trial boards which included rigorous power temperature cycling (PTC), thermal shock, sinusoidal and random vibrational analysis.

"The PCBs were powered-up and monitored in a PTC test for a duration of 840 hours at the Group's independent Test house at Abercynon in South Wales," continues Kennard. "This included ramping up their temperature to 85°C and then cooling them to –40°C (to 20 and 10min dwell times respectively). All the PCBs were then functionally tested and all finished 100% operational."

In order to confirm the quality of the lead-free solder joints, Multicore, at their Technical Support Centre in Hemel Hempstead, in conjunction with the AB Test House, then conducted a series of microscopic micro-section examinations. These were then compared to control samples of normal tin-lead soldered joints to demonstrate the reliability of AB's lead-free soldering process.

"Micro-sectioning was deemed the most suitable method for confirming the performance characteristics of the lead-free alloy, as it can vividly confirm such key performance traits as the wetting to different solder finishes like Cu, Sn, NiPd and Ag; how the joints perform after physical and thermal validation tests; and detect any hidden defects such as solder joint fatigue, cracks and voids," says Multicore's European Market Development Manager, Trevor De'Ath.

"Although the results of these tests are bound by a confidentiality agreement, the Ecosol® TSC alloy provided all the wetting properties, solderability and the mechanical reliability required on AB's boards for both reflow and hand soldering with the Metcal MX-500 iron, and all solder joints exhibited the desired shape, mechanical strength and functionality," he concludes.

Two generic sections comparing a lead-free and standard tin-lead joint are shown in *(figure 2 – micro-sectioning test results).* The difference in meniscus is notable with the lead-free meniscus being straighter due to the alloy's higher surface tension. It is also important to note the appearance differences and the fact that the lead-free alloy also has a grainy, granular-like finish and is not as shiny as normal tin-lead.

AB Automotive Electronics has now successfully demonstrated its ability of being able to offer its customers lead-free products. And both Metcal's MX-500 SmartHeat soldering iron and Multicore's Ecosol® TSC tin-silver-copper lead-free alloy have proven themselves in a demanding lead-free automotive application. AB Automotive's trials suggest that the long-term reliability of lead-free PCBs will be no less than that of conventional tin-lead boards.

"Thanks to the excellent customer service, technical support and partnership offered by both Metcal and Multicore, we now feel that we have the full capability and technology to implement lead-free soldering to a high degree of confidence when our customers require," summarises Kennard.


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