Soldering: Is The Automotive Assembler Really Different?

by Mike Fenner,
Indium

About 40 years ago, automotive manufacturers started to use solid-state devices to replace electro-mechanical voltage regulators. The use of electronics has grown inexorably from those simple two transistor devices. Today, electronics are fundamental to the safe and efficient operation of every vehicle, with over one third of a car's value represented by electronics.

Solders, and the soldering process, are an intrinsic part of any electronics assembly. We take a look at the requirements of the automotive assembler and how these are met. Arising from the transition to Pb-free and the EU RoHS Directive, legislative, safety and environmental compliance issues now exercise a dominant role and must be addressed.

In the 1960's, automotive electronics consisted of an optional radio. The electrical manufacturer's expertise was concentrated in a near unique skill set to manufacture intricate metal pressings, springs, coils, and contacts. Today, that same manufacturing expertise is centred on modern electronics assembly using much the same equipment as the rest of the world's electronics manufacturing industry. The electrical joining requirements are reduced to terminations and connections with few areas unique to automotive.

So what makes automotive manufacturing different? The key word is *reliability*. Modern electronics are intrinsic to safety and to the car's critical functions, including brakes, steering, airbags, and seatbelts, as well as engine management and transmission systems. These have to work 100% of the time in all conditions for a designed life of 20 years. This performance requirement extends not just to the functionality of products in service but to the supply chain as well. The high duty cycle and performance requirements, coupled with the need for reliability – equivalent to aerospace or defence requirements (but without the high unit costs common in those industries) – means that component and material suppliers need to be at the peak of their game.

These strict requirements resulted in the automotive industry's Technical Specification, TS-16949. TS-16949 is the synthesis of a number of motor industry corporate quality management standards and was jointly developed by International Automotive Task Force (IATF) members. It is perhaps best understood as an enhancement of the ISO standard, ISO 9001:1994. The result is an industry specific document leading to:

- Improved product and process quality
- Simplified global sourcing
- Realignment of supplier resources to quality improvement
- Common approach through the supply chain for multiple suppliers
- Reduction in multiple customers approvals
- User/customer orientated focus
- Continuous process improvement

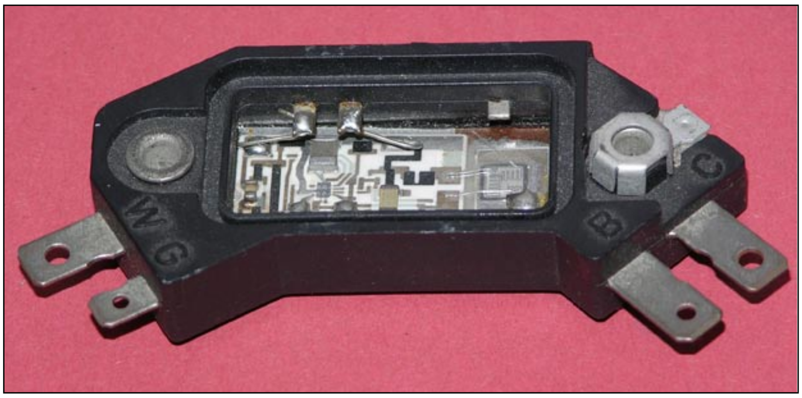


Figure 1 – Picture of early thick film module (Joseph Lucas)

Supply logistics

The majority of automotive electronic assemblies are SMT (Surface Mount Technology) using solder paste. Solder paste is a time-limited product and has to be shipped and used under strict FIFO (first in, first out) standards. To avoid line downs and ensure a continuous and continuing supply, most suppliers in Europe appear to use a modification of the systems they have traditionally used in the rest of the electronics industry. That is, product is made to stock against a forecast and then shipped to the end user from that stock. To guard against shortages, which may develop as a result of manufacturing, quality or shipping problems, further safeguards are taken to keep additional supplies at locations close to the manufacturer. This is an expensive and cumbersome solution, requiring time-sensitive material to be stocked at multiple locations and additional FIFO management processes.

Component	Alloy Combination	Other conditions	Impact on reliability
BGA	Sn/Pb ball/ Pb-free paste	Pb-free profile	Voids
	Pb-free ball/ Sn/Pb paste	Reflow <217°C	Early cracking at joint interface
	Pb-free ball/ Sn/Pb paste	Reflow >217°C	Negligible if joint homogenised
SMT reflow	Sn/Pb finish/ Pb-free paste	SAC paste	Pb may concentrate in last cooled zone = early failure
		Bi/Sn paste	Early failure due to Sn/Pb/Bi ternary
SMT wave	Sn/Pb finish/ Pb-free wave		fillet lifting top side
	Precious metals/ Pb-free finish/ Sn/Pb wave	volume ratios of finish to solder important	Neglible unless excess Ag Au Pd dissolves into joint
	Pb-free finish/ Sn/Pb wave		Negligible

Figure 2 – Chart showing compatibility of diverse soldering materials (Sn/Pb and SAC unless otherwise specified). Based on work by Dr. Ning-Cheng Lee, Indium Corporation

Key factors in implementing TS-16949:

• Continuous improvement – this is applied to all processes and systems in the company from opening contract review though manufacturing to final shipping
• Statistical Process Controls (SPC) and streamlined processing – application of SPC to provide feedback highlighting areas of possible improvement
• Quality ethos and commitment – quality cannot be imposed; the entire company has to have a quality mindset
• Design – products have to be designed (formulated) to be easy to make; not just easy to use.

Compliance issues

In the last 5 years, the European Union has issued a number of directives aimed at reducing the environmental impact of manufacturing processes and improving ease of recycling. The most momentous of these from a reliability and manufacturing perspective, has been RoHS. RoHS eliminated six groups of chemicals including lead – a major component of nearly all electronic solders. Although the motor industry is presently exempted from RoHS, the majority of the electronics industry is not. However, this in itself presents a problem. While the automotive industry can continue to manufacture their electronic assemblies using non-compliant parts, they may find it more and more difficult to find suppliers for those non-compliant materials.

From a materials perspective, there are several logistical and organisational concerns that automotive manufacturers are facing, such as the availability and identification of Pb-containing and Pb-free components and their compatibility, and the long-term reliability of Pb-free assemblies.

Therefore, some companies have decided that it is easier to transition to RoHS compliance than to continue to use their exemption. Others will continue to find other ways to reduce their risks.

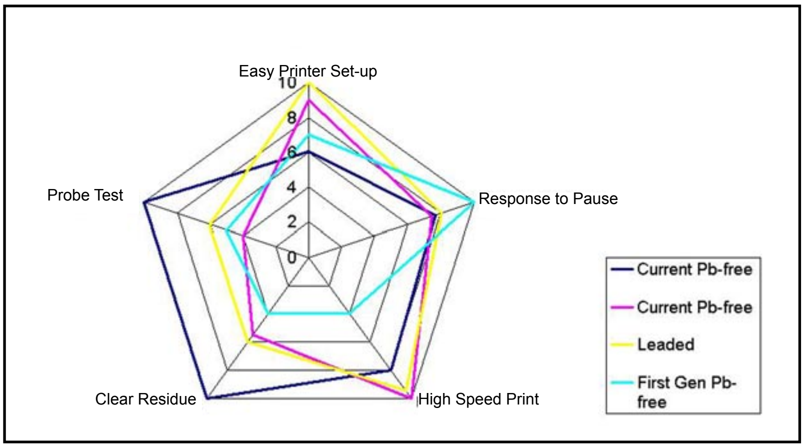
Compatibility of Pb-containing and Pb-free components

Most RoHS compliant component finishes are compatible with both Pb-free and Sn/Pb solders. One exception to this is with area array devices, or BGAs (ball grid arrays). This is because the BGA has a solid solder sphere termination as opposed to a thin fusible coating or plating on a base metal. These thin coatings dissolve into the solder. If the composition of the component's finish is Pb-free then the effect on Pb-containing or Pb-free solders is merely a minute adjustment to the joint's compositional balance. If the finish contains Pb there is the possibility of a Pb rich zone in the solder joint, which can cause an early failure of the component.

With a BGA, the mass of solder in the termination is greater and creates an entirely different scenario that is the possibility of two similar volumes of solder of different types coming together. Unless the resultant mix is homogenous, there can be a weakness at their interface that can result in an early failure (Figure 2).

One benefit that the automotive industry has in not being an early adopter is that they can take advantage of the natural progress of technology. This is illustrated in part by Figure 3. This spider diagram shows the relative handling and mechanical performance characteristics of some of the more advanced Pb-free solder pastes com-

Figure 3 – Some attributes of Pb-containing and Pb-free solder pastes



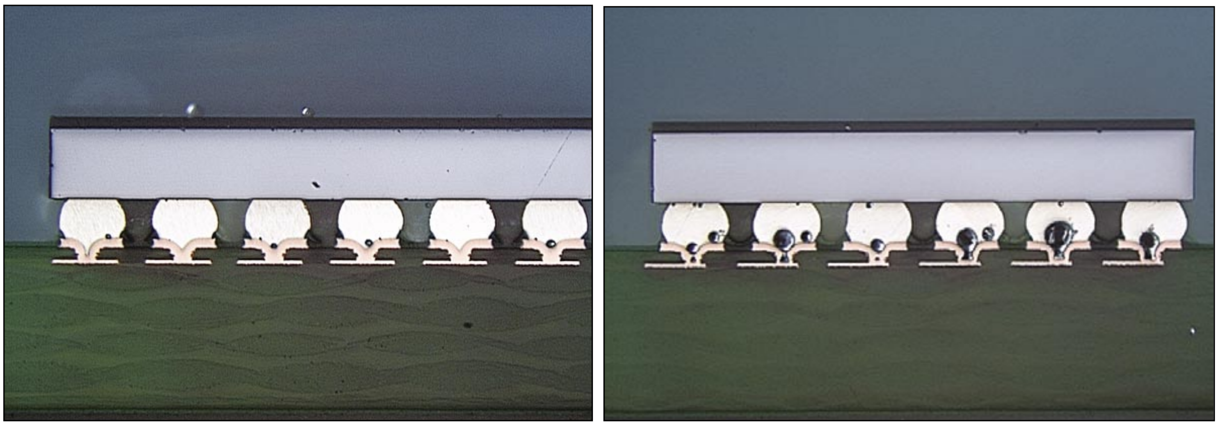
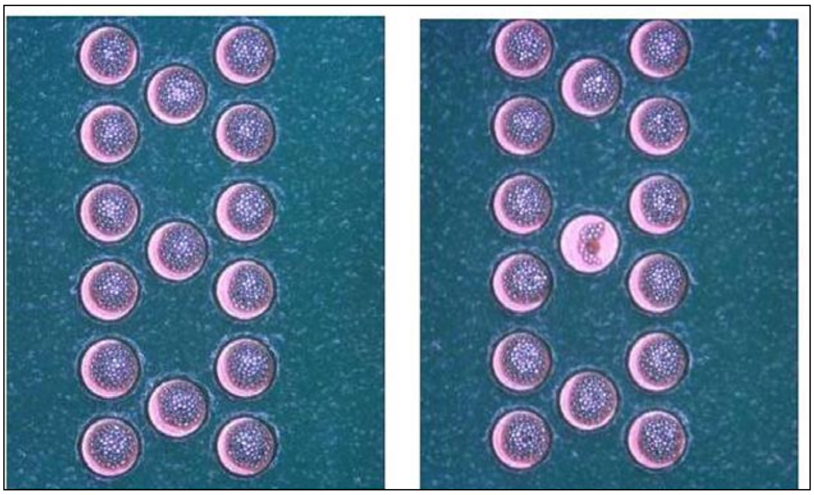


Figure 4 – Reduced voiding with modern Pb-free pastes (left picture shows Pb-free paste)

pared to the first generation materials and to an industry standard Pb-containing paste.

What this shows is that current Pb-free pastes are now equal to, and in some cases have exceeded, the properties of the best Pb-containing materials. In fact, research and development efforts have now moved from compliance to continuous improvement. At the same time, the industry continues to move toward smaller assemblies and greater functionality per unit of board area.

The result is increased use of finer pitch devices requiring smaller, closer pads and corresponding print openings; greater use of area array devices (BGA/CSP) and an increased use of via in pads.



Figures 5 – Improved transfer efficiency of modern Pb-free pastes (left picture shows Pb-free paste)

The paste formulators' response is therefore to concentrate on improving paste transfer efficiency on printing, and void reduction on reflow. Effectively, we are now where we would have been regardless of the Pb-free switch (Figures 4 and 5).

The next step for automotive manufacturers

The automotive industry has more demanding requirements than most of the volume electronics manufacturing industry. However, these demands can be met with a careful program of process improvement and by adopting the industry's own quality standard. Changing to Pb-free should not result in a loss of process capability in soldering materials.

Wave Height Monitor For Process Stability

ACE Production Technologies announces a breakthrough in precision solder wave control through the development and integration of a new wave height monitor and control module. This new control feature, installed on ACE's Kiss line of selective soldering equipment, can maintain solder wave heights to within +/- 0.013mm (0.005"), which is critical when selectively soldering the smallest, tight pitch components in high volume automated production environments. The monitoring methodology incorporates resistive measurements of wave height relative to a known reference. This is performed at programmable intervals during extended production runs, and closed-loop feed-back is then used to automatically adjust solder pump speeds and therefore wave heights.

ACE Production Technologies
Tel. +1 509 924 4898
sales@ace-protech.com
www.ace-protech.com