

Rework of Mixed Lead-Free Alloys - A Guide

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ABSTRACT

This report provides practical guidance to rework and product labeling good practice in light of the introduction of lead free solders. The impact of lead-free implementation into the re-work arena will potentially involve the mixing of a wide variety of alloys in the resulting joints, thus implications of reworking with alloys other than that of the original joint are also covered.

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Approved on behalf of Managing Director, NPL, by Dr C Lea,
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CONTENTS

1	INTRODUCTION.....	1
2	ORIGINAL MANUFACTURING ISSUES.....	1
3	REWORK EQUIPMENT ISSUES	2
4	COMPONENTS IN REWORK ISSUES	2
4.1	Thermoplastic components	2
4.2	Ceramic chip capacitors	2
4.3	Moisture ingress ion	3
5	REWORK ALLOY ISSUES	3
6	CONCLUSIONS	4
7	ACKNOWLEDGEMENTS.....	5
8	REFERENCES.....	5

1 INTRODUCTION

The electronics industry world-wide has begun the move to eliminate lead from its manufacturing processes. Driven by impending European legislation and by consumer preferences for environmentally friendly products, industry has already made great strides towards finding alternative alloys for solder (SnPb), for Pb-containing printed circuit boards finishes and is beginning to address the issues of component termination finish.

However, the introduction of these alternatives is likely to be relatively un-harmonized across the printed circuit assembly industry, with different manufacturers potentially utilising a range of alternative alloys. Thus for those reworking parts of a circuit board, it may be difficult if not impossible to determine the original alloy of manufacture. Where sub-assemblies are manufactured at various locations and possibly reworked or repaired with different solders, the possibility of creating solder mixtures will be high. Some of these mixtures have the potential to be of lower reliability than the original construction.

Additionally, the temperatures at which these alloys will need to be reworked is approximately 30°C above that for SnPb or SnPbAg alloys. This has implications for rework equipment and possible component damage. This good practice guide covers recommendations for original equipment manufacture, rework equipment, alloys and fluxes, as well as component issues.

2 ORIGINAL MANUFACTURING ISSUES

Two issues need to be addressed at original manufacture that may affect rework. The first of these is very simple. It is recommended that the alloy used for original assembly should be clearly and indelibly marked on the assembly during manufacture. Two benefits can accrue from this. Firstly, if any alloy mixes are deemed to be detrimental to circuit performance, then these can be avoided during rework. The second benefit may occur at final equipment disposal. Should legislation be introduced to ban Pb-containing alloys from disposal in land fill sites, then the cost of disposing of suitably marked Pb-free assemblies may be significantly lower than unmarked assemblies, the latter being difficult and costly to prove the alloy composition is free of lead.

The second area of concern for original equipment manufacture concerns design of assemblies. Design for rework, i.e. allowing enough space between components to allow correct tool access and prevent reflow of adjacent components, is already an area which is neglected in favour of high packing densities, particularly in mobile equipment markets. However, this issue will only become worse with PbF manufacture because of the higher rework temperatures required. It will be more critical to use the correct tool for rework to prevent damage to the component being reworked (see section 4), and adjacent components will reach higher temperatures than for SnPb, thus also creating the potential for damage to these components.

3 REWORK EQUIPMENT ISSUES

During a number of projects involving PbF manufacture at the National Physical Laboratory, most common rework tools have been used to undertake rework without modification to the equipment. These include heat tip soldering irons, stored energy irons, hot air pencils and hot gas rework equipment. The typical increase in PbF alloy melting point of 30°C, has been insufficient to invalidate any of these pieces of equipment. However, other workers have reported that soldering iron tips do wear out quicker when used at elevated temperatures and therefore it would be prudent to consider and cost for their earlier replacement.

4 COMPONENTS IN REWORK ISSUES

The suitability of electronics components for PbF soldering is a difficult area. Most manufacturers only supply soldering profile data suitable for Pb-containing alloys. Very few suggest parameters for hand soldering or rework and those that do generally don't recommend either of these actions if they can be avoided. When manufacturers do give rework data is generally also related to Pb-containing alloys.

4.1 Thermoplastic components

During investigations at the National Physical Laboratory, the increases temperatures associated with PbF rework have caused problems with SOT23 components. These have been damaged during rework as shown in figure 1, the plastic body can become bloated and distorted. Such devices are manufactured from thermoplastic rather than epoxy thermoset resins and can have a softening point as low as 280°C. Rework operators should also be retrained to ensure that wherever possible, they use a non-contact rework tool (i.e. hot air pencil) on thermally sensitive components.



Figure 1. Distorted SOT23 after PbF rework

4.2 Ceramic chip capacitors

Another component type which needs to be treated with care, is the multilayer ceramic chip capacitor (MLC). "Thermal shock is common in MLCs that are manually attached or reworked with a soldering iron (reference 1)". Some

manufacturers already recommend the use of hot air soldering tools rather than soldering irons and if a soldering iron has to be used, (it is often the case that on densely populated assemblies, it is the only tool which will reach a solder joint), then there are restrictions such as those suggested by AVX :

“If rework by soldering iron is absolutely necessary, it is recommended that the wattage of the iron be less than 30 watts and tip temperature be $<300^{\circ}\text{C}$. *Rework should be performed by applying the solder iron tip to the pad and not directly contacting any part of the ceramic capacitor*”.

These recommendations have been available for some time and are therefore intended to cover SnPb soldering. They will need to be applied unaltered to PbF soldering. The restriction of 300°C on tool temperature will not prevent PbF rework, but it will increase the time that it takes. Should operators simply be allowed to increase iron temperatures to cope with PbF alloys, then the result will undoubtedly be increased damage to sensitive components, higher scrap levels and perhaps more worryingly, more field reliability problems. As stated again by AVX “*direct contact by soldering iron tip often causes thermal cracks that may fail at a later date*”.

4.3 Moisture ingress

Care may also need to be taken with moisture sensitive devices if these are to be reused after rework has been undertaken on them. If the rework is conducted more than 24 hours after reflow, depending on the storage environment, the device may have ingressed sufficient moisture to cause damage during the heating cycles associated with rework. This may result in pop-corning (rapid expansion of moisture within the package causing package cracking, which may lead to contaminant ingress over time) and consequential device failure. The increased maximum temperatures and temperature ramp rates of PbF rework will cause more frequent occurs of this problem. If in doubt, a pre-bake to remove moisture from the package is advisable before any large thermal excursions. This would typically be 125°C for 4 hours or similar.

5 REWORK ALLOY ISSUES

A recent study at NPL² investigated the effects of mixing common lead based and lead free alloys together to form composite solder joints. The reliability of the resulting joints representative of a rework environment with mixed alloys in use was assed using thermal cycling in conjunction with continuity monitoring and shear testing. Permutations in ratios of 25, 50 and 75% of the following alloys were included in the study:

- SnPb
- SnPbAg
- SnAgCu
- SnAgBiCu
- SnCu

Importantly a main conclusion from the work was that joints formed from the alloys mixtures had remarkably good reliability, indeed they were more reliable than the reference SnPbAg and SnCu alloy joints in the study.

This surprising conclusion is explained by that fact that intermetallic precipitates form in the more complex compositions of the mixtures (for example AgSn_3 and Cu_6Sn_5) that impart additional structure and strength to the solidified joint.

Eutectic or near-eutectic alloys are used in reflow and wave soldering due to their small 'pasty range' as they melt and solidify. The eutectic alloy is not chosen for any specific reliability reasons.

Be aware that solidification may take place over wider range of temperature with mixtures than with the eutectic alloys. This involves partial solidification as the joints form in separate phases increasing the risk of fillet lifting. In NPL studies², however, whilst fillet lifting was observed it had no effect on joint reliability. The fillet lifting is a benign defect.

The work was performed with a thermal cycle over -55 to $+125^\circ\text{C}$, a severe cycling regime, and on 2512 resistor joints, chosen for their geometry which induces high strain. Consequently the testing can be considered representative of a worst scenario.

Data collected to date suggests that the mixing of alloys will not be problematic in terms of joint reliability.

6 CONCLUSIONS

- Design for rework should be considered during original equipment manufacture as higher rework temperatures will increase the need for correct rework equipment choice (often dictated by proximity of adjacent components) and increase chances of damage to adjacent components through overheating
- Alloy of original manufacture should be clearly and indelibly marked on assemblies to ensure correct rework alloy choice and possible reduce end-of-life disposal costs
- Investigate if there are any rework restrictions on components used in manufacturing your products
- Consider retraining of rework operators so that they understand use of non-contact rework tools on thermally sensitive devices and that PbF rework may take longer to achieve and should not be hurried

- When costing implementation and manufacture of new PbF product allow for higher scrap levels, more rapid rework tool wear out and possible operator retraining
- Pop-corning due to moisture ingress is more likely to occur in PbF rework so pre-bake of assemblies to be reworked may be required if the device is to be reused
- **Joint reliability will not be adversely affected by the mixing of common solder alloys in surface mount application**
- It is advantageous to use the original alloy for rework to minimise the pasty range of the solder which may increase the chance of fillet and pad lifting in through hole joints
- Fillet and pad lifting in through hole joints was not detrimental to joint reliability in the NPL study² but is still a concern if traces are broken

7 ACKNOWLEDGEMENTS

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