Lead-free Hand-soldering – Ending the Nightmares

Most issues during the transition seem to be with Hand-soldering

As companies transition over to lead-free assembly a certain amount of hand-soldering will always be there. An article from Tech Search International last year did say that in Asia where lead-free is highly used, hand-soldering was more of a problem than lead-free SMT or wave soldering.

Kester has been getting numerous calls in reference to hand-soldering with lead- free in recent months. In fact most problem calls and requests for training through Kester University are related to lead-free hand-soldering and rework. In many cases the assemblers are using materials from various solder suppliers with similar issues occurring in all cases. Often the problems are more than material issues.

Switching to lead-free on Monday morning when Friday operators were soldering with leaded solder is not recommended. Although this seems easily understood some assemblers have attempted this, with line stoppages occurring only a few hours into lead-free hand-soldering. Operator complaints, loss of reliability and poor joint quality were experienced. This could be a production engineer's nightmare but it need not be this way if the basic concepts of hand-soldering are revisited, some experience gained prior to the transition and adequate training of operators is performed before and after the switchover.

Here are some questions often asked by assemblers in reference to hand-soldering with lead-free solders. These are in fact also some of the issues addressed during the lead-free hand-soldering on-site audit done through Kester University.

Which alloys and fluxes are compatible with lead-free hand-soldering?

The limiting factor with lead-free solders is probably its availability in wire form; some alloys are not easily drawn into wire, as is the case with tin-bismuth solders.

At this time the most popular alloys used to make wire are tin-silver-copper and tin-copper based solders. This compliments the industry well at this time where 68% of SMT assemblers and 50% of wave assemblers have chosen tin-silver-copper (SAC) solders. In wave soldering 20% have chosen tin-copper (SnCu) based solders due to the cost of lead-free solder bar. Wire solders for hand-assembly are therefore readily available in these two alloys.

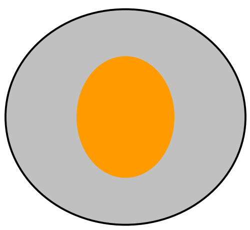
The main differences between SAC and SnCu solders are the melting points; the melting temperatures are approximately 217ºC and 227ºC respectively. From a soldering performance perspective, SAC wets more readily than SnCu based solders, so flow with SAC solders, everything else being equivalent, will be better.

Both SAC and SnCu solders are available in no-clean, water washable and rosin based flux formulas. No-clean accounts for over 85% of the total wire usage while water washable is less than 15% and rosin based fewer than 5%. These numbers apply to North America. In other parts of the world no-clean is dominant.

What are the key variables in choosing a good lead-free solder wire?

By far the flux content in the wire will be a critical factor in determining wetting behavior. Lead-free solders such as SAC, SnCu and the higher temperature option tin-antimony SnSb wet a little slower than 63/37 when compared using similar conditions in wetting balance tests.

Lead-free solder wires should contain **at least 2% flux by weight**. Leaded solders are available with lower flux percentages as low as 1% wt/wt; this low flux volume will not work well with lead-free.



Typical flux distribution in a solder wire, the density of the flux is close to 1 g/cc; therefore the volume is more obvious in the cross-section. Multiple cores are used at times but the percent is usually 2 or 3 % for lead-free. Less flux results in more difficulties during soldering.

If wetting is still too sluggish 3% flux in the wire may be tried but this will give higher residues, not always cosmetically appealing in no-clean applications. The addition of flux using a squeeze bottle is normally not acceptable due to over application issues. This is not acceptable for no-clean applications.

Another important point is to insure the flux is designed for lead-free applications and therefore it should be able to withstand higher soldering tip temperatures without charring, spattering and decomposition. Some fluxes may smoke more when using hotter tip temperatures.

When choosing a solder wire make sure to observe the flux IPC classification. Many no-cleans meet the ROL0 classification meaning they are rosin based, low activity and halide free. These are the most reliable and meet the SIR and corrosiveness tests in the IPC specification. With lead-free there is a tendency to use higher activity to compensate for the reduced wetting; this is not always a good idea.

Water washable fluxes will be more active classed often as ORH1 and do better with lead-free soldering. However insure the residues are still completely removable in hot water; doing ionic contamination testing is recommended. If ionic contaminants still remain after water washing, a clean process change may be warranted such as increasing the cycle time, water temperature or a change of the cleaning agent.

In comparative studies done with SAC and SnCu wetting balance tests indicate that using the same flux types that SAC out-performs SnCu solders in the time required to reach maximum wetting. This applies also to SnCu solders with dopants of nickel, cobalt or other additives.

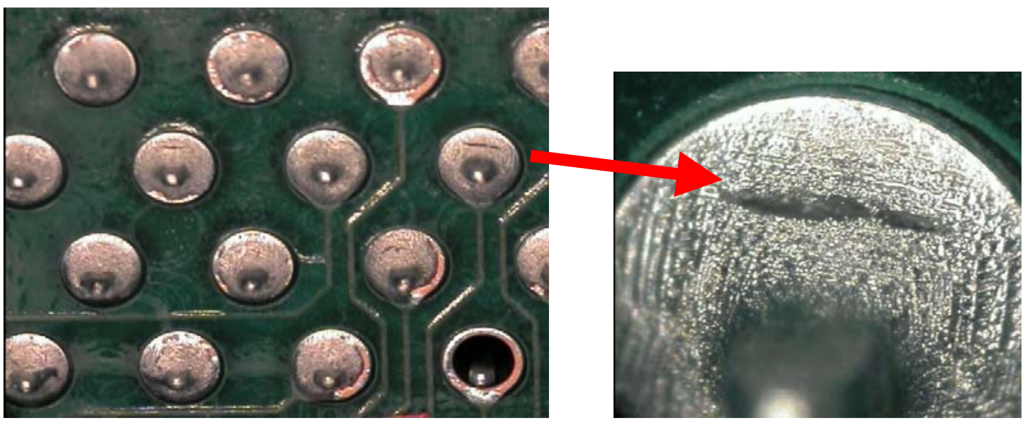
In choosing an alloy it is important to determine the overall solderability of the parts to be assembled. If the parts are older, more oxidized, manually handled SAC solder may be a better choice.

What are the main changes associated with lead-free hand assembly cosmetics?

Lead-free solders flow a little slower than 63/37 using the same activation levels for the fluxes. The contact angles are slightly larger and feathering out of the solder is therefore less pronounced. The solder joints tend to be less reflective than 63/37 solder. Some re-training is required prior to a full transition to lead-free is done.

In some cases certain shrinkage effects as described in Section 5 of the IPC-STD-610D occur. The IPC-610 classifies these as soldering anomalies and not necessarily defects.

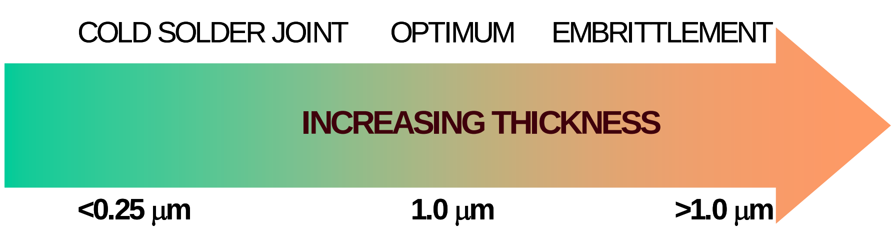
As mentioned on page 5-22 of the above document, it is not a defect for Class 1, 2 and 3 if the tear bottom is visible and the shrink hole does not contact the lead, land or barrel wall. See the photos below for examples taken from the Kester laboratory.



What is the best soldering tip temperature for lead-free SAC and SnCu?

The temperature of the tip or contact temperature is very important to ease the lead-free hand-soldering operation. When using 63/37 solders temperatures as low as 650ºF have been used but with lead-free 700-800ºF is best. The higher temperature does compensate for the slower wetting exhibited with these lead-free alloys.

Above 800ºF issues of board and component damage may arise; at lower temperatures cold solder joints and flagging are the normal complaints.



COPPER/TIN INTERMETALLIC

Higher temperatures and longer contacts with the parts to be soldered may also increase the intermetallic bond layer. So avoiding prolonged contact and repeated rework is not recommended. The above diagram shows what happens as the bond layer increases in thickness a higher risk of embrittlement occurs.

The risk of de-wetting also increases with higher temperatures.

How about the soldering tips with lead-free solders?

Lead-free tips are required however just as important is the choice of tip design. Lead-free is less forgiving and the right tip for the job will go a long way in prevent defects.

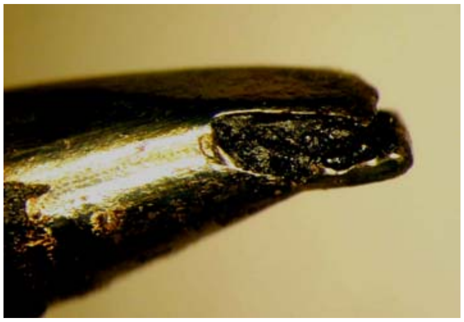
Chose a tip with enough heat delivering capacity. Fine point tips cannot be used in all applications and in some cases a tip such as a chisel type is best suited to deliver sufficient heat to the parts to be soldered.

See the diagram below for examples of correct tip selection criteria.

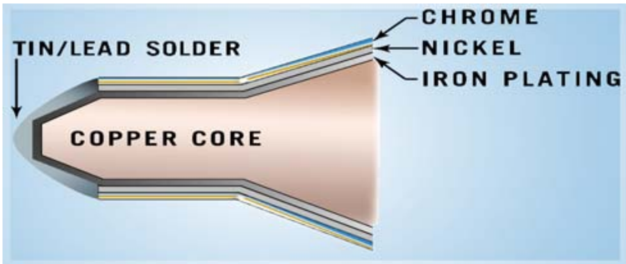
How about tip life with lead-free solders?

Tip life will be reduced with lead-free solders and it is important to choose tips really designed for lead-free soldering. Many tips are only tinned with lead-free solder and the iron plating is no different than traditional soldering tips. High tin solders like to dissolve iron and this reduces tip life. Some assemblers have reported important reductions in tip-life for example a manufacturer reported that with 63/37 the tips lasted 3 months with lead-free the tip-life was only 3 weeks.

Not all soldering tips are equal when comparing dissolution rates so choosing tips carefully and asking for more compatibility information is a good practice.



Lead-free tip failure after 3 weeks



Cross-section of typical solder tip, with lead-free the solder is lead-free

How can a good lead-free hand-soldering process be had, which will ease the lead-free soldering operation?

In a recent study, which appeared in the Lead-free Update by Tech Search International in December 2004, hand-soldering was found to be more problematic to implement when compared to lead-free wave soldering and SMT.

The reason could be that hand-soldering is more operator dependant than reflow and wave soldering but also the surface tension in lead-free solders is slightly higher. Wetting or spread is also a little slower when compared to 63/37.

To reduce operator issues and reduced wetting proper optimization of the soldering process is key. To avoid issues use a flux content of 2-3% by weight in the solder wire, use a solder tip temperature of 700-800º F. Also Tin-Silver-Copper (SAC) solder will flow more readily than Tin-Copper (SnCu) solder.

The main issues encountered with lead-free hand-soldering are cold solder joints, poor wetting, flagging and de-wetting. These can be avoided.

A step-by step process transition would be as follows:

- Insure the tips are designed for lead-free
- Insure the temperature is set to 700-800 ºF
- Insure the flux content in the wire is a least 2% wt/wt
- Use LF tips with the longest life
- Use the correct tip for the job
- Insure the parts are easily solderable with the chosen flux
- Avoid prolonged contact times
- Avoid needless reworking of the joint
- Avoid the use of additional liquid flux

Which defects or issues can appear and how can they be avoided?

The common issues reported with lead-free are:

- Grainy joints
- Cold solder joints
- De-wetting
- Flagging
- Poor wetting and wicking
- Flux charring and darkened residues
- Difficulty with the cleaning of residues

Grainy joints can be due to too high a tip temperature and the dissolution of the metals to be joined.

Cold solder joints can be due to several things such as too low a tip temperature, too weak a flux or insufficient flux in the wire.

De-wetting can be caused by prolonged tip contact and the dissolution of the plated metals, exposing a less solderable surface. Too high temperatures can also cause this.

Flagging can be caused with the use of too high soldering tip temperatures or the use of solder wires with low volumes of flux. Flux activity may be low also and prolonged contact with the iron is de-activating it.

Flux charring with no-cleans and cleaning difficulties especially where water washable is used can be due to soldering temperatures being to high or the flux is not properly designed for the higher temperatures required for lead-free. Avoiding prolonged contact and using lower soldering temperatures can help with this situation.

My soldering iron tips are charring, turning black and de-wetting when I use lead-free solder wire, what can I do?

Not all fluxes are created equal and some are thermally incapable of sustaining the higher soldering temperatures used with lead-free solder. A recent video clip from OK International demonstrates this well when two solder wires are compared side by side and this is called the “black tip syndrome”. Less thermally stable resins turn the tip black and makes re-tinning more difficult also.

Once “black tip syndrome” occurs the reduction in heat transfer makes lead-free hand soldering difficult, tip life is reduced, tip costs and operator frustration goes up and reliability goes down.

Proper flux selection, using lead-free tips and lead-free hand solder process training for operators will offset these costs. The important points to help avoid these problems are listed below.

- Use lead-free solder wires with lead-free designed fluxes
- Avoid using too high temperatures
- If tip-tinner is used, wipe excess tinning material on a clean sponge
- Do not use pressure to compensate for lack of wetting
- Use the right tip geometry
- Use the correct wire diameters
- Segregate work areas for lead-free and leaded
- Identify lead-free irons and work stations
- Train all operators on the expectations

These are some of the questions asked by customers moving forward with lead-free assembly. A little training goes a long way in avoiding costly issues with the hand-soldering process.

Although the process is more operator dependant using the tech tips mentioned above can make hand-soldering less frustrating for the operators and engineers. Maintaining the same levels of reliability they are accustomed to with leaded soldering is therefore very achievable with no nightmares of poor joints or reduced production output. .

About the author:

Peter Biocca is Senior Market Development Engineer with Kester in Des Plaines, Illinois. He is a chemist with 24 years experience in soldering technologies. He has presented around the world in matters relating to process optimization and assembly. He has been working with lead-free for over 9 years.

He has been involved in numerous consortia within this time and has assisted many companies implement lead-free successfully. He is an active member of IPC, SMTA, and ASM. He is the author of many technical papers delivered globally. He is also a Certified SMT Process Engineer.

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