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Recycling Lead-free *Solder Residues*

The electronics industry's migration to lead-free solders has proven to be a technical challenge, with many new problems, and some old ones that need to be addressed in new ways. The same is true for the companies that recycle solder residues. This article is intended to describe the transition to lead-free solders from the recycler's perspective, offer guidance to electronics manufacturers so that they can maximize their return on recycled residues, and answer some frequently asked questions about the recycling of lead-free solder residues such as dross, paste and wipes.

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Recycling Process Issues

Tin/lead solders have been around a very long time, but their use to affix components to printed circuit boards is relatively recent. A wide variety of solder alloys, all containing tin and one or more other metals (including lead) are currently available. The residues derived from solders have been recycled for several decades, and a substantial infrastructure for solder recycling exists, both in the United States and around the world. The volume of recycled solder residues is very large; we estimate that as much as 25,000,000 lb per year of solder residues were recycled in 2003 in the US alone. There are no producers of primary tin (from mined ores) in North America, so that any tin used in solder that is not recycled must be imported, primarily from South America.

The technical challenges posed by lead-free solders have been described in a number of previous articles in this newsletter. The technical challenges faced by recyclers are similar in scope and magnitude. The major issue, over the long term, will be maintaining strict separation of tin/lead and lead-free solders to avoid contaminating the lead-free residues with lead. In the near term, while volumes of lead-free residues are limited, the lead-free residues will almost certainly be added to the general flow of tin/lead solder residues. However, as the volumes of lead-free residues increase, at some point this may no longer be economically feasible. Processing tin/lead and lead-free solder residues separately in the same facilities will be a major challenge for recyclers, and will require significant capital investment for separate processing equipment. Major changes in operating procedures will also be required to prevent contamination of lead-free alloys with lead. Some recyclers may choose to decontaminate their facilities and make a complete change-over to lead-free, rather than install separate equipment.

Lead-free solders are generally alloys of tin, which contain one or more alloying metals at concentrations below 10%. The presence of several different alloying metals significantly increases the metallurgical complexity of lead-free residues. For example, the two lead-free alloys which currently appear to be the most widely used are SnAg(3-4)Cu(0.5-0.7) and Sn(99.3)Cu(0.7). The ranges in silver and copper concentration (expressed as %) represent the range of alloy specifications, not the range of acceptable concentrations in a single alloy. These alloy specifications for silver and copper are substantially tighter than those for traditional tin/lead alloys. Where lead-free residues are recycled without mixing them with tin/lead residues, it may be necessary to completely separate the silver and copper from the tin and re-alloy the pure metals in order to reliably and reproducibly produce specific alloys for lead free solders.

Regulatory Issues

Lead-free solders and associated residues also present a new set of regulatory uncertainties. The regulatory burden may be significantly reduced with the removal of lead from the solder alloys, but this is not a certainty. For instance, the typical definition of lead-free solder allows up to 0.1% lead! Some alloys also contain significant amounts of silver, another metal which may cause some residues (spent materials such as paste and wipes) to be classified as hazardous wastes even if they are recycled. It is therefore very important for consumers of lead-free solder products to determine the regulatory status of the residues produced from each product they use. The residues produced from each type of solder product from each supplier may need to be individually tested to do so.

At first glance, the worst case scenario would seem to be that lead-free residues would need to be managed just as tin/lead residues are currently managed. However, in the near term, if lead-free solders produce non-hazardous spent materials, it may actually be more problematic to simultaneously manage tin/lead spent materials as hazardous and lead-free spent materials as non-hazardous. Unless generators can be 100% certain that lead-free spent materials have not been contaminated with tin/lead residues, it may be simpler to manage both as if they were hazardous. Tin/lead and lead-free residues should, however, always be managed to keep them completely separate, as this will, at some point, have a dramatic impact on the economic return from the lead-free residues.

Long-term, to the extent that lead-free residues pass the TCLP test, management should be simplified, particularly the movement of residues across state and national borders.

Economic Issues

The economic value of solder residues is directly proportional to the value of the metals in them, and inversely proportional to the cost of recycling and purifying them. The cost of recycling is determined by:

- ✦ Metallurgical complexity (the concentration and type of impurities they contain)
- ✦ The quantity shipped in each lot.
- ✦ The recycling process employed
- ✦ The specifications of the alloys to be produced from the recycled metals
- ✦ The concentration of the metals which are present as oxides

Only the first two of these can be controlled by the generator through solder alloy selection and management practice. The size of each lot shipped is important since each lot, regardless of size, must be sampled, assayed, and tracked through the recycling process. These costs are significant and essentially the same regardless of lot size, so the larger the lot the lower the cost per pound. Lead-free solders, as noted above, have relatively tight specifications, and this will mean that recycling cost will be higher per pound than for tin/lead solder residues.

Since tin is more easily oxidized than lead, both the quantity of dross produced per lb of solder used, and the percentage of oxide in the dross will be higher than for tin/lead solders, leading to substantially higher dross ratios for lead free solders and higher per pound costs for the recycler. It has been reported that lead-free solders will produce 1.5-2 times more dross than tin/lead solder per pound used.

The presence of lead above 0.1% in lead-free residues will severely and negatively impact the value of lead-free residues at any facility which is recycling lead-free residues separately from tin/lead residues, because tin and lead are extremely difficult to separate from one another. It is important to note that solder will dissolve small quantities of almost any metal it comes in contact with. It is common, for example, for drosses to contain small, but significant concentrations of nickel, iron, and other metals which have been dissolved from circuit board components. Unless all components in the board assembly facility are lead free, drosses from lead free solder may also dissolve lead from components which are not lead free.

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The economic value of lead-free drosses will be substantially higher than tin/lead drosses because of the higher tin concentrations they contain. Copper, because of its relatively low value and concentration, will not to be a payable metal in lead free solder residues. Silver at concentrations >1-2% may be payable in lead free solder residues. The return, if any, for silver will depend upon the lot size, the lot composition (the concentration of both silver and impurities), and the silver price. Silver is very difficult to separate from tin, so mixing silver bearing dross or residues with any residues which do not contain silver will result in a substantial increase in recycling cost. This increased cost will be passed on to you by the recycler.

Summary

Conversion from conventional to lead free solders will present significant technical and regulatory challenges to both electronics manufacturers and recyclers. However, appropriate operating procedures can minimize the impact of this change. In general, manufacturers must ultimately do three basic things to maximize their economic return on lead free solder residues and, at the same time, ensure continued compliance:

- ✦ Segregate each type of residue in a separate container, with a unique identifier like color, at the point of generation.
- ✦ Maximize the size of each lot of an individual residue.
- ✦ Know the composition and regulatory status of each lot and provide this to the recycler.

Dr. Nelson Mossholder is Vice President of Technology at ECS Refining. Comments or questions pertaining to this article can be sent to nmossholder@canadus.com.

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