

**On The Forefront: June 2001**

**by Phil Zarrow**

## **The Real Cost of Lead Free Soldering**

*"You give up something for everything you gain,  
So pay for your ticket and don't complain."  
Bob Dylan*

Yet another article on Lead-Free Soldering. It's not going to go away - too much is at stake here - ecologically, financially, emotionally, politically. There is a lot of information regarding the implications of lead-free - as well as mis-information and dis-information. Of course, this is typical of issues of this wide a scope and impact.

My associate, Jim Hall, and I are currently involved in a study regarding the real costs of "going lead-free". Our objective is to look at the issue from the perspective of PCBA manufacturers and assess what the financial impact will be across the board.<sup>1</sup> Objectivity is the key word here - we are not getting involved in the politics of the issue. This is an examination of the costs of the lead-free approach to circuit board assembly.

As we all know, the whole idea behind banning lead from circuit boards is the fear of the lead of discarded circuit boards leaching into the water table. We are all also aware that the electronics industry accounts for less than 1% of lead usage.<sup>2</sup> Nevertheless, the move towards lead-free ponders on with pending legislation in Europe (WEEE and ITRI) and, more recently, Japan (JEDA).

This month's column will examine particular aspect of the cost of lead-free. The impact on the cost of manufacturing lead-free solder material by the solder manufacturers will be discussed. Bear in mind that, while we are focusing on solder, the lead-free initiatives also affect circuit board finishes, component leads and internal component interconnections. As is the case with the issue in general, there is a lot more than meets the eye.

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<sup>1</sup> Pun intended.

<sup>2</sup> I still contend that I see a lot more dead car batteries discarded improperly than circuit boards.

Product	Consumption (%)
Storage Batteries	80.91
Other Oxides: paint, glass and ceramic products, pigments, and chemicals	4.78
Ammunition	4.69
Sheet Lead	1.79
Cable Covering	1.40
Casting Metals	1.13
Brass and Bronze billets and ingots	0.72
Pipes, Traps, Other extruded products	0.72
Solder (non-electronic)	0.70
<b>Electronic Solder</b>	<b>0.49</b>
Miscellaneous	2.77

*Table 1: Lead Consumption (Worldwide) by Product (Source: Advancing Microelectronics, September/October 1999 p. 29)*

## Materials

Of course the cost of materials will affect the cost of solder and, ultimately, the cost of the assembly. Most people tend to think that this is the only impact on solder cost that will be brought about by conversion to lead-free solder alloys. It isn't but it is a major factor.

Lead is relatively inexpensive and, for the most part, none of the replacement metals are as economical. Accordingly, if we convert from a Tin-Lead alloy to a Tin-Silver-Copper as it appears the most favored direction is leading, silver as well as copper are more expensive than lead. While we may not be going from 37% lead to 37% silver but rather less than 5% silver, as Table 1 enumerates, the relative costs of tin, silver and copper do add up.

Element	Metal Cost per Pound (approx.)	Density at 25°C (Pounds per Cubic Inch)
Lead	\$ 0.45	0.410
Zinc	\$ 0.50	0.258
Copper	\$ 0.65	0.324
Antimony	\$ 0.80	0.239
Bismuth	\$ 3.40	0.354
Tin	\$ 3.50	0.264
Silver	\$ 84.20	0.379
Indium	\$125.00	0.264

*Table 2: Cost of Metals (approximately) (Source: Wall Street Journal Metals Cost February, 1999)*

## Material Density

Table 2 examines the resulting cost of some of the solder and finish alloys being considered. When we look at the price of the alloys by volume, we notice quite a difference in price from the baseline Sn63/Pb37 solder alloy. This brings up another very interesting aspect. Solder is not purchased on a basis of volume but rather by weight - solder paste by kilograms, bar and wire solder by the pound. Looking at the Density column in Table 1, we observe (not to anyone's surprise) that the substitute metals are far less dense than lead. Table 2 shows the density of the particular alloys being considered. The difference in density, for example, between Sn63/Pb37 and Sn96.3/Ag3/Cu0.7, the alloy currently most favored as the replacement for reflow soldering, is almost 20%. Thus, if 1 kilogram of Sn63/Pb37 yields 1000 jars of solder paste, 0.8 kilograms of Sn96.3/Ag3/Cu0.7 will yield the same 1000 jars of solder paste. A solder pot on a wave solder machine that requires 800 lbs. of Sn63/Pb37 will now only require about 640 lb. of Sn96.3/Ag3/Cu0.7. However, in both cases, the cost to manufacture the soldering material is the same, excluding the cost of metals, even though 20% less by weight will be made since the same amount of material by volume is being produced. Hence, the method of selling solder by weight aggravates the perceived increase of the actual cost.

Why is solder sold by weight? Likely some ancient tradition that has long become obsolete since we measure solder deposition and joints by volume. Here is an opportunity - a second chance, if you will, to do it right. Of course that will mean re-educating everyone, especially purchasing people. Industry conversion to lead-free is Herculean enough but that last aspect may be downright impossible.

Alloy	Melting Range (deg. C)	Metal Cost / lb (US\$)	Density at 25 deg.C (lbs/in <sup>3</sup> )	Metal Cost per in <sup>3</sup> (US\$)	Metal Cost per Δ Sn63/Pb37
Sn62/Pb37	183	2.37	0.318	0.75	0%
Sn42/Bi58	139	3.44	0.316	1.09	+45%
Sn77.2/In20/Ag2.8	179-189	30.06	0.267	8.02	+970%
Sn91/Zn9	199	3.23	0.263	0.85	+13%
Sn91.8/Ag3.4/Bi4.8	208-215	6.24	0.272	1.70	+125%
Sn90/Bi7.5/Ag2/0.5Cu	186-212	5.09	0.273	1.39	+85%
Sn96.2/Ag2.5/Cu0.8/Sb0.5	213-219	5.48	0.267	1.46	+95%
Sn95/Ag3.5/In1.5	218	8.15	0.268	1.58	+110%
Sn93.5/Ag3.5/Bi3	216-220	5.92	0.269	1.59	+110%
Sn96.5/Ag3.5	221	6.32	0.368	2.33	+125%
Sn99.3/Cu0.7	227	3.48	0.264	0.92	+23%
Sn95/Sb5	232-240	3.37	0.263	0.88	+17%

**Table 3: The most commonly considered alloy alternatives.** (Source: Internal Research)

## **Manufacturing Processes**

Currently, when solder is produced, metal ingots of each of the alloys are put into the solder manufacturer's solder pots in the proper ratio. For example, if the manufacturer wishes to produce bar solder of the alloy Sn60/Pb40, he fills the capacity of the pot with 60% tin ingots and 40% lead ingots. They are melted together and the bars we put into the solder pots of our wave solder machines are formed from this. He can take that same alloy and extract wire for wire solder. If Sn63/Pb37 solder paste is to be made, he again puts into a solder pot 63% tin ingots and 37% lead ingots and the resulting solder is atomized by a special process, usually using a series of sieves to derive the powder of the specified diameter (for example between 38 and 53 microns for Type 3 paste).

However, tertiary and quaternary alloys being considered will require far more accuracy and control of composition. Rather than simply adding the individual metals at the point of manufacturing (of the solder), the manufacturer will most likely have to add an additional step of pre-composing the alloys. Composing an alloy with 96.3% of one metal, 3% of another and 0.7% of a third element demands more precision than might be expected to be carried out at the pot. These metals will have to be combined under tightly controlled conditions and that resulting alloy sent to the machine center where the solder will be manufactured. This extra step and handling results in additional cost of manufacturing.

Bear in mind not everyone is going to switch over to lead-free simultaneously and when they do, not necessarily to the same alloy. This puts a burden on the solder manufacturer to carry a far more extensive product line, albeit with diminishing volume on many alloys. This adds a lot of in-process work including "sanitizing" the solder pots and other equipment used in between runs of different alloys to maintain purity.

Finally, the higher liquidus point of all of the leading lead-free alloys will require significantly more energy to alloy and process. In some cases, this energy requirement may more than double due to the low volume of the individual alloys and the need to potentially melt the alloy more than once to make the final product due the aforementioned smaller production runs.

## **Patents**

As discussed in an earlier column<sup>3</sup>, the National Electronics Manufacturing Initiative's (NEMI) lead-free solder roadmap was attempting to derive a "standard" for a lead-free

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<sup>3</sup> Zarrow, Phil, "Lead-Free: Don't Fight a Fact - Deal With It!", Circuits Assembly, August, 1999

alloy that was not subject to a patent. The motive was that an industry standard should not allow an individual to profit simply by virtue of intellectual property. Noble or not, this turned out to be somewhat altruistic - such a path turned out to be a jaunt through a minefield. There are patents originating in North America and Japan. Virtually all of the best alloys in terms of soldering, manufacturing and reliability characteristics are covered by patents. All the key combinations of tin, silver, copper, bismuth and antimony are spoken for, including SnAgCu.

The result is that we can most likely expect part of the cost of a lead-free solder alloy to be royalties to some person or entity. This will likely add somewhere between 2 - 8% to the cost of the alloy. Hey NEMI, thanks for trying.

It should be noted that, regardless of the extent of adaptation of lead-free solders and finishes, recycling and reclamation is still a very viable direction. Instead of developing and trashing a better and now more expensive class of waste products, let's recycle what we have. Remember, we're all in this together.

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