FORUM

Conducted by Jim Rowe

Oxygen-free copper: more than just marketing hype?

Increasingly, makers of hifi amplifiers and other equipment are claiming the use of "oxygen-free copper" as a feature of their products. Some amplifiers even use this kind of copper wire for internal wiring. It sounds impressive as a selling feature, but exactly what does it achieve apart from that?

This is actually the second time I'm having to type in this month's column – by sheer bad luck, both the hard disk and floppy disk backup copies of my original file were destroyed by water and soot in our fire. Luckily I had made a "hard copy" of about half of it on paper, which was safely stowed in my bag. So at least I've had that to remind me of what I wrote the first time!

Anyway, here we go again, and I hope it doesn't read too much like a rehash:

Some months ago, when I was reviewing an advance sample of one of the new DAT recorders, I noted with some bemusement that the manufacturer placed emphasis on the fact that oxygen-free copper or "OFC" was used in various parts of the equipment. This included the winding wire inside the power transformers, some of the internal wiring – and even the metal pillars on the underside of the case, if I remember correctly.

It all sounded suitably plausible, yet I was a bit dubious.

Like many of our readers, no doubt, I'd noticed the recent appearance of OFC among the selling features for hifi and other gear – especially that made in Japan. The term "oxygen-free copper" was obviously meant to imply that the *ordinary* copper used in other equipment had significant oxygen content, and that this somehow resulted in inferior performance – both electrically, and perhaps mechanically. So that be using OFC, you presumably got a better result.

Somehow the image we were all being invited to imagine seemed to be of ordinary copper as being riddled with little bubbles of trapped oxygen, a bit like a Swiss cheese. And presumably the more trapped bubbles of oxygen there were, the less of your genuine solid copper metal there would be to provide good electrical conduction and mechanical strength. By using solid copper that was free of those pesky trapped bubbles, you'd obviously be avoiding these troubles.

Mind you, none of this was actually explained in so many words. In fact there was very little overt explanation at all. The use of OFC was simply listed as one of the features, seeming to imply that its benefits were self-evident – or perhaps alternatively, in the hope that we'd draw the above naive inferences.

Now I'm certainly not a metallurgist, but it all sounded a bit glib. I guess I was mildly skeptical – and I'm sure I wasn't the only one.

At the time, I wasn't sufficiently concerned about the matter to pursue it further with the experts. As I suggested in the review concerned, the *benefits* of using OFC might well be open to some conjecture, but at least there didn't seem to be any *disadvantages*. At least judging from the performance of the DAT recorder concerned, which was very impressive.

Since then, though, I've received a fairly long letter from a reader – picking up on the subject and exploring it in depth. And as the reader concerned is quite knowledgeable in this area – he's a chartered engineer and metallurgist, in fact – I thought it might be a good change of topic this month to pass on his comments and explore the topic of OFC further.

The reader concerned is Mr Dick Burns, who for a long time was technical manager of the Copper and Brass Information Centre in Sydney. The Centre itself is no longer operating, but it gave advice to the local electrical and electronics industries for many years, as well as providing information links with overseas bodies concerned with copper sourcing, refining and supply. So Mr Burns should certainly know his copper.

Now I'm going to have to boil down the content of his letter, because he does go into the subject in detail and at considerable length. But as I understand it, the story seems to be as follows.

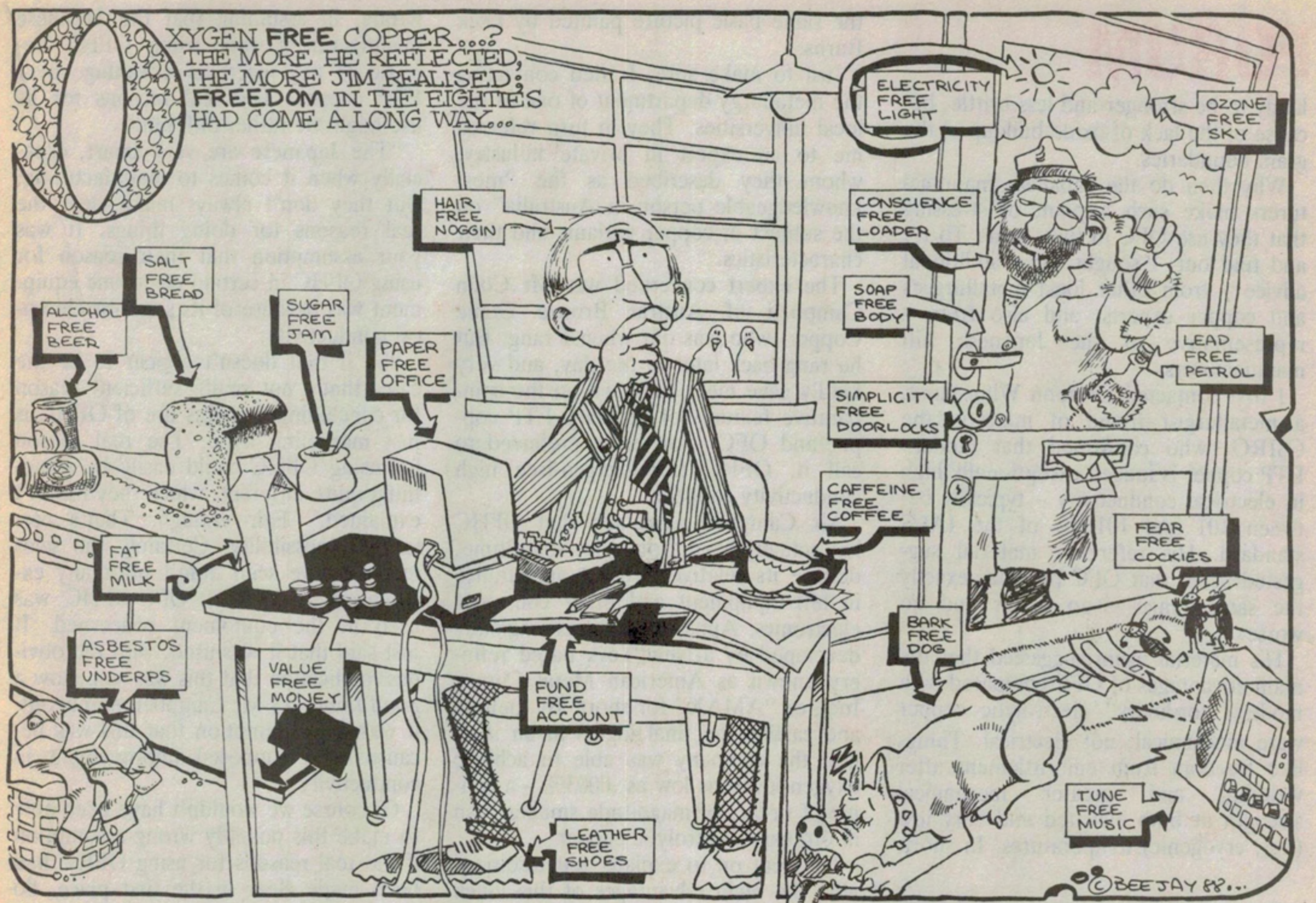
Basically, four standard grades or varieties of copper are recognised for electrical/electronic use by our own SAA and similar standards bodies around the world. As defined by the SAA in its Specification 1279-1985, these are summarised as shown in Table 1.

As you can see, despite their somewhat oddball names (which are apparently related to the refining methods used to produce them), they all have remarkably similar electrical characteristics. Each has a rated copper content of 99.9% or better, while all four have virtually the same *maximum* resistivity of 0.15328 ohms per metre at 20°C.

Similarly in each case their *minimum* conductivity relative to the International Annealed Copper Standard or "IACS" is specified at 100% – presumably meaning that they're all equal to or better than the best grade of electrical copper available when the IACS standard was prepared.

Dick Burns notes that most present-day coppers exceed the IACS standard, due to the fact that refining techniques have improved since it was prepared. Typical modern coppers (like those made in our own refineries at Mount Isa) have a conductivity figure of up to 101.5% of the IACS standard – not all that far below the theoretical maximum figure, which he says is 102.5%. Not bad considering that some 7 million tonnes of refined copper are produced world wide each year!

By the way, the "A" suffix in the type number for the first three copper listed in Table 1 means that they are



made in Australia, while the rest of the number relates them to the appropriate international specifications.

Apparently oxygen-free copper isn't specified in the SAA specification, and according to Dick Burns this is because it isn't made in Australia. Apparently it requires a special refining process, with the copper surrounded by a vacuum or protective inert gas environment during the final "freezing" into solid copper.

To compare OFC with the coppers shown in Table 1, it is therefore necessary to use data prepared by the Conseil International Pour Le Development Du Cuivre (CIDEC), based in Geneva. And when you do this, according to Dick Burns, it turns out that OFC has virtually the same conductivity range as the type 110A copper shown in Table 1 – from 100% to 101.5% of the IACS standard.

In other words, there doesn't seem to be any signifianct difference between OFC and say "ordinary" Aussie-made 110A *Electrolytic Tough Pitch* or "ETP" copper, in terms of electrical conductivity at least.

How much oxygen?

But just how much oxygen is there in ordinary copper, and what else might it do? Well, Dick Burns says that modern ETP copper has an oxygen content of .05% maximum. Most of this is apparently concentrated at the boundaries of the copper grains, in the form of copper oxides.

According to Mr Burns the main effect of this is to produce a tendency for the copper to become brittle, especially in environments where it will be subjected to high temperatures and/or where reducing gasses will be present. I gather this tends to make OFC preferable to ETP copper for things like lead-in wires for high power thermionic valves, rotor windings for high power motors and alternators, and so on.

So far then, it begins to look as if the main advantages of OFC are mechanical rather than electrical. It looks as if it's

TABLE 1: STANDARD TYPES OF COPPER

Code	Name	Copper content min. (%)	Electrical Resistivity (ohms/m) at 20 C	Conductivity % of IACS minimum
110A	Electrolytic Tough Pitch	99.90	0.15328	100
110A	Fire Refined High Conduct.	99.90	0.15328	100
116A	Silver bearing tough Pitch	99.90	0.15328	100
119D	Phosphorised High Conduct.	99.93	0.15328	100

A table supplied by Mr Burns, comparing four main types of copper. As you can see, there are few differences.

likely to be stronger and less brittle, because of the lack of oxide buildup at the grain boundaries.

Why then do the Japanese manufacturers make such a point of stressing that they use OFC in their gear? To try and find out, I sought some additional advice – from other local metallurgists and copper experts, and also from a representative of the Japanese hifi manufacturers.

I first contacted Dr John Wilmshurst, a metallurgist friend of mine in the CSIRO, who confirmed that modern ETP copper is indeed exceptionally high in electrical conductivity – typically between 101 and 101.5% of the IACS standard. His reference material suggested again that OFC provides exactly the same range – no better and no worse.

His material again suggested that the main advantages of OFC compared with modern "ordinary" electrolytic copper were mechanical, not electrical. Things like freedom from embrittlement after welding, and greater mechanical strength at both elevated and very low (i.e., cryogenic) temperatures. In short, the same basic picture painted by Dick Burns.

Just to make sure, I tried contacting the metallurgy department of one of the local universities. They in turn referred me to an expert in private industry, whom they described as the "most knowledgeable person in Australia" on the subject of copper variants and their characteristics.

The expert concerned was Mr Colin Campbell of Austral Bronze Crane Copper, who was out when I rang. But he rang back later in the day, and very kindly gave me a rundown on the comparative features of ordinary ETP copper and OFC – or as he preferred to call it, OFHC (for oxygen-free high conductivity copper).

Mr Campbell explained that OFHC has actually been around for some time, despite its relatively recent appearance in hifi equipment and other consumer electronics. Apparently it was originally developed by a New York based refinery known as American Metal Climax Inc., or "AMAX" for short. By melting and casting the final ingots in an inert gas, the company was able to achieve oxygen levels as low as .0003% – a couple of orders of magnitude smaller than in ordinary electrolytic copper.

He went on to explain that traditionally, the main edvantages of this much lower oxygen content (in the form of copper oxides) were mechanical. One was freedom from "hydrogen embrittlement" following welding; another was greater ductility – the ability to be drawn into much finer wires, without breakage or weakening. And thirdly, he noted that an important feature of OFHC is that it has a very tightly bonded layer of oxide on the *outside surface*, presumably because of the lack of oxides inside.

It is this characteristic which apparently makes OFHC particularly suitable for glass-metal seals, such as those required where wires must pass through the glass envelope of a valve.

But what would be the advantage of oxygen-free copper for ordinary electronic components and wiring? Mr Campbell agreed that there is virtually no difference between the electrical conductivity of OFHC and standard electrolytic copper of the type produced at Mount Isa. So that superficially, he too was unable to explain what possible advantage OFHC might have for electronic components, or the wiring inside a hifi amplifier or DAT recorder.

He was cautious about drawing any firm conclusions from this, however. In fact he suggested that we could well be wrong, in assuming that the Japanese manufacturers were using OFHC because of any electrical advantage over ETP copper. The real reasons for its use might be rather different:

"The Japanese are very smart, especially when it comes to manufacturing. But they don't always make clear the real reasons for doing things. It was your assumption that their reason for using OFHC in certain electronic equipment was because of its superior electrical conductivity."

"So if that doesn't appear to be the case, that's not really sufficient reason for concluding that this use of OFHC is just marketing hype. The real reason for using OFHC could easily be something quite different, which they haven't explained." Fair enough. That's certainly a possibility. Certainly the sales material I've seen didn't offer any explanation as to *why* OFC/OFHC was used in the equipment concerned. It just said that it *was* used, with the obvious implication that this was somehow a *good thing*. As Mr Campbell points out, it was our assumption that this was because of a supposed improvement in conductivity.

Of course we wouldn't have been able to make this possibly wrong assumption if the real reasons for using OFHC had been made clear in the first place. So the manufacturers themselves seem to have contributed to our mistaken inference, if that's what it is.

The real reason?

What then is the *real* reason for using OFHC in this equipment, if it isn't for improved conductivity?

I approached the Australian subsidiary of one of the main Japanese hifi manufacturers, to try and get the answer. The good people there admitted that they didn't know all of the fine details, but undertook in turn to send a query to Japan, to find out from the design engineers themselves.

Unfortunately by the time I had to send this month's column away for typesetting, the answer still hadn't come back from Japan. So I guess we'll all have to wait until next month, for the definitive answer!

Tingles and bites

To end up this month, I've received a couple of letters already following on from my column in the July issue about double insulated appliances that give you a "tingle" – and how to find out if they're really dangerous or not.

The first letter was from Phil Allison, a service technician who deals with a lot