Vintage Radio

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The curse of audio transformers

Next to valves and electrolytic capacitors, the most likely cause of a fault in old valve receivers is an open-circuited winding in an audio transformer. Many of the inter-stage audio transformers used in battery sets are particularly prone to this problem, along with early speaker transformers.

Few faults are more effective in silencing elderly receivers than open circuited transformer windings — an unfortunately all too common occurrence. Valve failures and defective audio transformer primary windings were by far the most common faults encountered in early battery receivers. Later, moving coil speaker output transformers frequently suffered from the same problem.

Until quite recently, supplying replacement transformers provided winding firms with steady incomes, especially from districts exposed to high humidity. But unfortunately for the vintage radio enthusiast, in most areas this service no longer exists.

Troubleshooting

First, a couple of hints on transformer troubleshooting, especially for beginners. Output transformers are often labelled with a resistance value like 7000 ohms. This can be a trap. It does NOT refer to the resistance of the winding, but to the reflected voice coil impedance that the transformer presents to the output valve. The resistance measured with a multimeter is unlikely to be more than 10% of the impedance.

The beginner may not be sure if he has a transformer problem, but a resistance measurement with a multimeter will soon find an open circuited winding. A good loudspeaker transformer primary will have a resistance (depending on size) of somewhere between 350 and 750 ohms, and interstage transformer windings are unlikely to measure more than 5000 ohms.

CAUTION: Do not try to operate a receiver with an open circuited output transformer primary. To do so can damage the output valve, because the absence of anode current can cause the screen grid dissipation to become excessive.

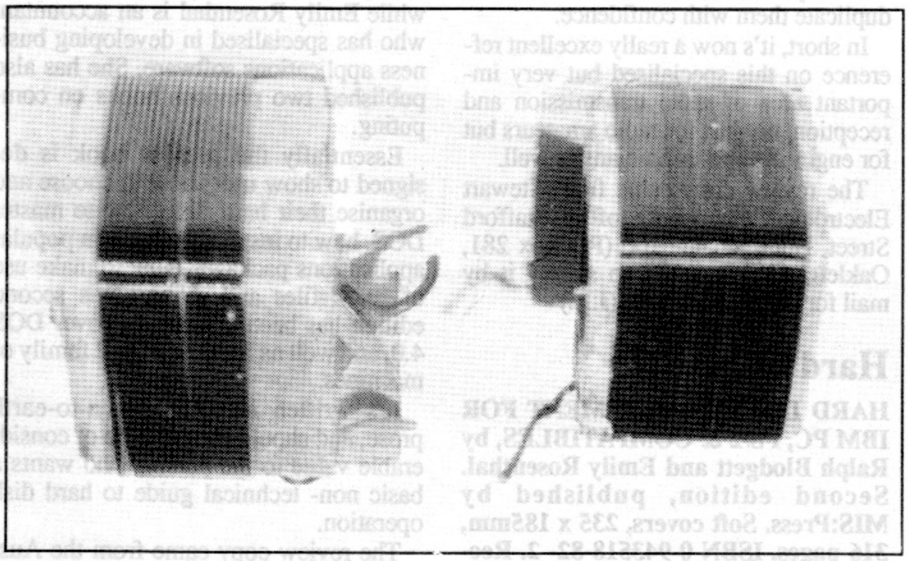

Fig.1: Two partially dismantled speaker transformers with traditional interleaved windings. That on the left shows the heavy secondary winding and interlayer paper. At the right, the secondary has been removed to show the fine primary wire. Acid reaction with the copper via pinholes in the insulating enamel frequently caused open-circuited primary windings.

Various insulations

Long before the advent of radio, winding wires were commonly insulated with natural fibres, such as silk or cotton. The threads were wound spirally along the wire, frequently in two counter-directional layers, giving rise to the descriptions Double Silk Covered (DSC) or Double Cotton Covered (DCC). Cheaper and less reliable wire used single layers of insulation, SSC and SCC.

Silk is costly, but, being finer, takes up less space than cotton. Often dyed green, it complimented the handsome appearance of the brass and mahogany 19th-Century instruments.

Generally cotton was left undyed, but completed windings were varnished or shellaced to keep out moisture. Later, synthetic fibres reduced the cost of 'silk' insulation. The most common radio applications for DCC and DSC wire were not in audio transformers, but tuning coils and large gauge windings on mains transformers.

Multi layer windings using textile insulated wires are evenly wound, layer upon layer, with very reliable results, but these wires are very expensive to produce, and in the finer sizes, the insulation occupies a large percentage of the winding space. With the 20th Century came advances in electrical technology and an increasing variety of applications for electrical windings; accordingly efforts were made to produce insulations that were more economical in space and cost.

Coating the wire with enamel proved to be a satisfactory answer. Enamel is much cheaper and thinner than silk or cotton and can be applied quickly. However early enamels had problems. Inevitably, there were pinholes, and the

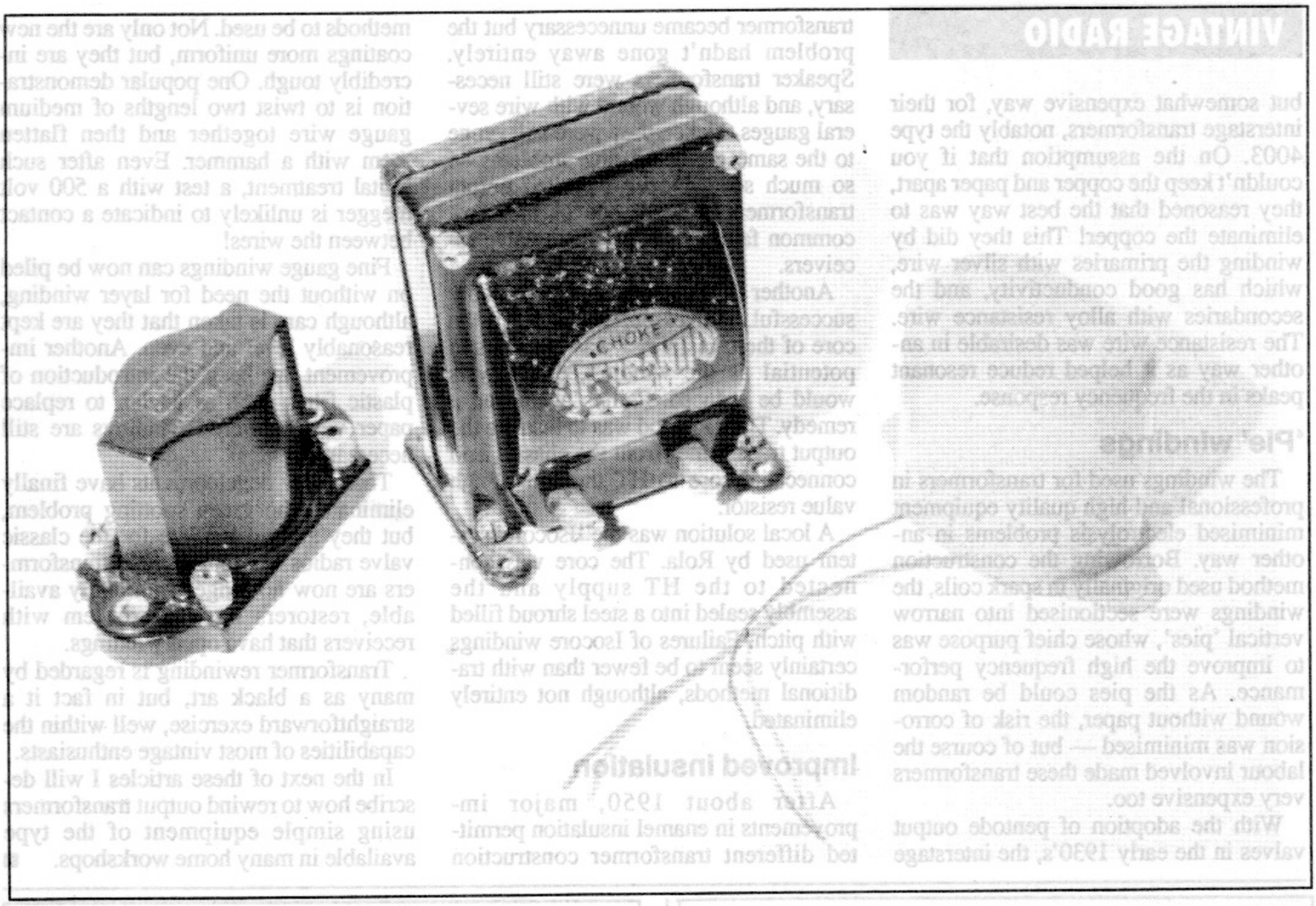

Fig.2: Representatives of three different approaches to the problem of 'green spotting'. The Philips interstage transformer on the left has a silver wire primary and an alloy resistance wire secondary; the Ferranti in the centre uses windings in narrow random-wound 'pies', not requiring interlayer paper; while the Rola 'Isocore' speaker transformer on the right uses conventional winding methods but has the core connected to the HT supply, insulated by potting it in the can with pitch.

breakdown voltage was much lower than that of the earlier coverings. The answer was to interleave each layer with 'craft' paper and then impregnate with wax or varnish. The likelihood of adjacent turns having pinholes is remote and the paper prevents interlayer breakdown.

The large numbers of mains transformers wound in this manner that are still sound after half a century confirms that enamel insulation with paper interleaving can be a very satisfactory method of construction.

Enamel, paper problems

The combination of enamel and paper was an obvious choice for the interstage audio transformers used in early radios. Not only was it cheap, but the reduction in wasted winding space resulted in more compact windings with improved high frequency response. To further reduce size as much as possible, these transformers were wound with very fine wire — commonly 44swg, which is only 0.08mm in diameter!

Unfortunately, there were serious problems not found in transformers wound with heavier wire. Audio transformers became notorious for failing, often before receivers were out of guarantee. Invariably the fault was an open circuited winding, and an autopsy always revealed the same problem: a spot of corrosion had eaten right through the thin wire. This condition was soon to be called 'green spotting'.

Eventually, the cause was found. Provided the enamel insulation was intact, there was no problem. However, pinholes were practically unavoidable, and could permit bare copper to be in contact with the interleaving paper — which, despite being made specially for transformers, still contained traces of acid.

It was usual to leave batteries permanently connected, and as switching the high tension supply was unnecessary, the primary windings had a constant positive voltage present, causing leakage through the bare spot to the paper. Although the currents involved were microscopic, a form of electrolysis resulted and unfortunately the copper suffered. Significantly, green spotting was less common in grid windings where the voltage was negative.

Various remedies

Naturally, remedies were researched. Attempts were made to exclude moisture. Sealing the assembly in pitch only locked moisture in. Saturating each layer of wire with varnish would have been more successful, but to stop a winding machine to apply a coating dozens of times to each transformer would have been prohibitively expensive. The next best thing was to impregnate the windings after completion with varnish or wax. This was a good idea and helped, but the impregnant could not be relied on to penetrate all layers.

Following on from this, windings were heated in an evacuated tank to expel all moisture and then hot wax was run in. Although this method improved reliability further, and was about as far as many manufacturers went, there were still too many failures.

Philips solved the problem in a novel

but somewhat expensive way, for their interstage transformers, notably the type 4003. On the assumption that if you couldn't keep the copper and paper apart, they reasoned that the best way was to eliminate the copper! This they did by winding the primaries with silver wire, which has good conductivity, and the secondaries with alloy resistance wire. The resistance wire was desirable in another way as it helped reduce resonant peaks in the frequency response.

'Pie' windings

The windings used for transformers in professional and high quality equipment minimised electrolysis problems in another way. Borrowing the construction method used originally in spark coils, the windings were sectionised into narrow vertical 'pies', whose chief purpose was to improve the high frequency performance. As the pies could be random wound without paper, the risk of corrosion was minimised — but of course the labour involved made these transformers very expensive too.

With the adoption of pentode output valves in the early 1930's, the interstage transformer became unnecessary but the problem hadn't gone away entirely. Speaker transformers were still necessary, and although wound with wire several gauges thicker, they were still prone to the same green spotting problems — so much so that open circuited output transformers are still one of the most common faults encountered in valve receivers.

Another approach proved reasonably successful. The reasoning was that if the core of the transformer was at the same potential as the winding, electrolysis would be reduced. Philips again had a remedy. Their method was to insulate the output transformer from the chassis, and connect its core to HT through a high value resistor.

A local solution was the 'Isocore' system used by Rola. The core was connected to the HT supply and the assembly sealed into a steel shroud filled with pitch. Failures of Isocore windings certainly seem to be fewer than with traditional methods, although not entirely eliminated.

Improved insulation

After about 1950, major improvements in enamel insulation permitted different transformer construction methods to be used. Not only are the new coatings more uniform, but they are incredibly tough. One popular demonstration is to twist two lengths of medium gauge wire together and then flatten them with a hammer. Even after such brutal treatment, a test with a 500 volt megger is unlikely to indicate a contact between the wires!

Fine gauge windings can now be piled on without the need for layer winding, although care is taken that they are kept reasonably level and even. Another improvement has been the introduction of plastic films such as Mylar, to replace paper where layered windings are still necessary.

These new developments have finally eliminated the green spotting problem, but they arrived too late for the classic valve radios. As replacement transformers are now no longer commonly available, restorers have a problem with receivers that have open windings.

Transformer rewinding is regarded by many as a black art, but in fact it a straightforward exercise, well within the capabilities of most vintage enthusiasts.

In the next of these articles I will describe how to rewind output transformers using simple equipment of the type available in many home workshops. ■