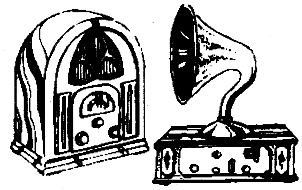
Vintage Radio

by PETER LANKSHEAR



Old power transformers

Last month, we related some experiences in the resurrection of a large 1930 model American Columbia TRF receiver. However, as we ran out of space, the complex subject of dealing with the power transformer had to be carried over until this month. As well as looking at transformer rewinding, we also look at how to work out the voltage and current ratings required.

In the early days of radio, prior to the early 1930's, there were improvements to be made in the design of power transformers. Wire sizes were often a bit on the light side, and insulation (especially enamel) had weaknesses. This was often exacerbated by transformers in American receivers having been designed for 60Hz mains rather than our 50Hz, with the result that there could be 20% less wire and/or steel than conservative operation called for.

Sometimes (and this was quite possibly the case with the Columbia) during attempts to fire up a receiver, the 240 volt mains may have been connected to a transformer intended for 110 volts. Whatever the cause, the evidence of melted pitch around the Columbia's transformer case was sufficient warning that it was highly likely a rewind would be necessary.

Why were the old transformers subjected to the messy business of being buried in a box of pitch anyway? This practice was not confined to power transformers either. Frequently chokes, audio transformers and capacitors were treated similarly.

The major reason was protection from moisture — but filling of chokes and power transformers has another benefit. Unless core laminations are very tightly clamped, there is a chance that they will hum and buzz, and in some cases can be very hard to silence. Encasing in pitch will silence practically any laminated core.

A suitable sealant must have a reasonably high melting point, be non hygroscopic and inexpensive. Also it must flow easily, so as not to leave voids during filling. Although not a very attractive material, pitch meets these requirements quite well. In more recent times, it was common for professional grade transformers to be potted in a pitch based compound. Today, other materials such as potting resins are used as well.

Difficulties

Whatever its virtues, when it comes to dealing with a transformer that has failed, pitch can be a frustrating 'pain' to deal with. Not only can it be messy, but the very properties that make it such a good potting material also make it hard to remove from a can.

In the past, many servicemen have understandably sidestepped the problem by simply substituting a stock replacement transformer and throwing away the original — thereby leaving a problem for the restorer who demands authenticity. Similarly, a rewinder can hardly be blamed if he declines to rewind a transformer embedded in a black gooey mess! Some transformer rewinders do have access to Trichloroethylene vats or the like, but most are likely to appreciate and charge correspondingly less if they do not have to perform the chore of cleaning out the pitch first.

Fig.1: As well as being somewhat antisocial, using the kitchen oven for exposing a pitch encapsulated transformer is not completely effective. There is still a tenacious coating which is very resistant to mechanical removal.

Therefore, a transformer in need of a rewind may well have to be unpotted by you. But to try and simply dig the windings out of the can at room temperature is a hopeless proposition.

One method is to arrange for the family cook to go on holiday for a couple of days and, when the coast is clear, the transformer is suspended for a few hours over a suitable container in the kitchen oven, heated to a moderate temperature. This will melt out the pitch, but unless there is an efficient ventilating fan in the kitchen, the smell can linger for a long time — and bitumen is not flavour of the month in most households. Furthermore, the transformer is likely to be left with a tacky black coating, typical of that in Fig.1.

There is a better way. When very cold, most grades of pitch become brittle, with a consistency much like that of coal. The cases of most filled transformers have one side that is either open or removable. This should be removed and the transformer put in the coldest part of a deep freezer for a few hours. The pitch may then have shrunk sufficiently to allow the contents to slide out of the can.

In any event, unless it is a very soft grade, the pitch, will be sufficiently brittle to crumble readily with a few taps of a piece of wood or a hammer, exposing a relatively clean winding as shown by the example in Fig.2. Any remaining traces of pitch can be cleaned off with a petrol soaked rag. Save the pitch, as it will be needed later. The transformer can now be packed off to your favourite rewinder. Don't forget to include as much information as possible.

For rewinders

This next section is directed mainly to readers who are prepared to tackle, or are involved in transformer winding. To determine the specifications for a new winding, the conventional approach is to count the turns and measure the gauges of the wires originally used.

For a proven design of transformer that failed due to external causes this is the correct method; but as pointed out previously, American transformers were frequently designed for 60Hz mains supplies, and often had 110V primaries which, for convenience in Australasian conditions, may as well be replaced by a 230/240V winding.

Transformer design is quite complex, but for satisfactory operation there must be sufficient steel in the core and turns of wire in the windings or the transformer will be inefficient and overheat. One vital parameter governing the number of turns is the magnetic characteristics of the steel, but this will generally not be available. Fortunately a rule of thumb has been worked out that has proved satisfactory for most old cores.

Area of core

The critical parameter is not the total amount of steel in the core, but rather the cross-sectional area of the centre leg which determines the number of turns per volt. It has been found that for a transformer with the type of steel used in old power transformers, and operating at 50Hz, with one square inch of core cross sectional area, eight turns per volt is satisfactory. (This allows for the thickness of the insulation on the laminations etc., and I have used imperial measurements as these were usedinmostoldtransformers).

The formula is simply to multiply the voltage of the winding by eight and divide the result by the core area in square inches. For example, a typical old core with a centre leg of 2.0 square inches, should have windings with a minimum of four turns per volt.

Therefore a quick check is to count the number of turns on one of the old windings — say for example the 5.0 volt rectifier filament winding, and use the formula (turns on winding/winding voltage) x area of core in square inches. If the result is less than eight, it would be advisable to increase the number of turns in the new windings. In most cases, especially when using modern insulation, this will not be a problem as the older cores usually had plenty of window space.

A weakness of these old transformers can be that of undersized wire for filament windings. However, advantage can be taken of the fact that many used cotton-covered wire, and larger diameter enamelled wire can be used for the replacement winding occupying the same space.

With the transformer rewound and reassembled, and ready to be put back into service, it is very tempting to wedge it into its box without the hassles of replacing the pitch; but unfortunately, to do so is inviting trouble.

Enclosing a transformer in a relatively airtight box will cause overheating. Air is a very poor conductor of heat, and consequently air cooling of transformers is dependent on free and rapid air circulation. Pitch is a much better heat conductor than air, and readily transfers heat to the surface of a case where it can be dissipated.

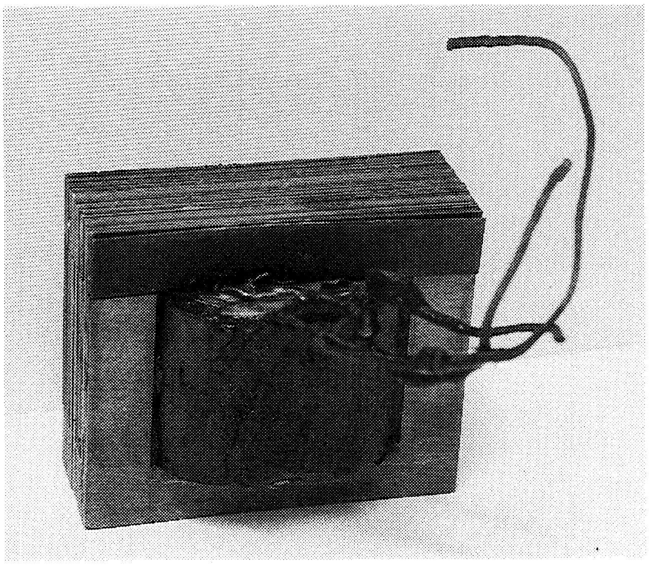


Fig.2: The same transformer after a spell in a deep freeze. A few taps with a hammer shattered the brittle coating and the residue was cleaned off with a petrol soaked cloth.

Refilling essential

If the original transformer case is to be retained, there is therefore no option but to refill it with pitch. This can be quite easy. The melting point varies, but is somewhere in the region 100 - 150°. A large tinned fruit can is a suitable container and any reasonable source of heat, including a gas barbecue can be used. For my own workshop I picked up for a few dollars a small used table-top electric cooker, with a six inch hot plate and simmerstat control. The same safety precautions should be taken as with hot cooking oil, and be careful not to overheat the pitch, or there could be damage to the transformer windings. Use only sufficient heat for it to flow readily.

Extra pitch is likely to be needed to replace inevitable wastage. One source of supply would be roofing contractors, but some time ago I obtained sufficient to last me a lifetime by asking at the local Municipal Electricity Department store for some of the compound used in underground cable boxes. I was given a two gallon tin of what is really highly refined pitch, perfect for the job.

What voltage?

Last month, I promised to explain how I determined the HT voltage for the rewound power transformer of the Columbia receiver. While experienced vintage enthusiasts will be familiar with the procedures involved in calculating the operating conditions of receivers, newcomers may be interested in the methods that I used.

Radio manufacturers were generally very coy about publishing the HT winding voltages of receiver power transformers. There are several likely reasons. One was that 60 years ago, few servicemen were equipped to measure high AC voltages accurately. Another was that in the highly competitive radio industry, design knowledge was valuable, and therefore such information was what we today call 'commercially sensitive' — referred to then as 'trade secrets'.

Many circuits did provide valve pin voltages other than for the rectifier, and these are usually sufficient to base calculations on. However, in the case of the Columbia receiver, the circuit provides no voltage clues at all and some assumptions will have to be made. For easy referral the circuit has again been printed.

The first step is to estimate the likely main HT voltage. Fortunately, it is not at all critical and approximations are quite sufficient. As the output stage valves normally have the highest voltages, in this receiver the HT supply to the anodes of the 45's is a good place to start. Reference to early RIA tube manuals which provide comprehensive data for these valves shows their maximum anode voltage is 275 volts, and give details for operation at 250 volts. There is little merit in operating old valves at maximum ratings, and an analysis of a number of circuits indicates that a majority of designers settled for 250 volts.

The anode or plate voltage ratings of valves refers to the anode to cathode potential, NOT anode to earth. In the Columbia, as was the usual method, grid bias for the output valves is derived from the anode current voltage drop through an 800 ohm resistor between the filaments and earth, and is given by the Manual as 50 volts. This voltage, plus the drop in the output transformer, must be added to the anode voltage to arrive at the HT figure.

The anode current of 62.5mA for a pair of new type '45 valves can be calculated by the simple formula Bias Volts/Bias Resistor, or 50/800 = 0.0625. Assuming that the valves are not brand new, a current of 30mA each is quite close enough.

The resistance of each half of the output transformer was measured at about 300 ohms, so that the voltage drop in each side would be about 10 volts. Thus the main HT at point (A) should be 310 volts.

RF stage operation

The next step is to estimate the proposed operating conditions for the RF stages. Their voltages are set by the voltage divider formed by the 3000 ohm speaker field and the two 1500 ohm resistors.

Note that in these early sets, the speaker field did not double as a filter choke as became later standard practice. The total resistance of the network of the speaker field and the 1500 ohm resistors is 6000 ohms, permitting a current flow with 310 volts applied of approximately 50mA, which would be a reasonable amount of excitation for a speaker of this type.

However, the current taken by the RF amplifiers must be taken into account. To achieve absolute accuracy, this becomes quite complex as the valves themselves constitute a dynamic load. We have a roundabout wherein the current drawn is dependent on screen voltage, which in turn is dependent on the current through the voltage divider and the volume control setting — varying from practically zero to 10mA or so.

The mathematics involved would be a candidate for one of Peter Phillips' 'What??' puzzles.

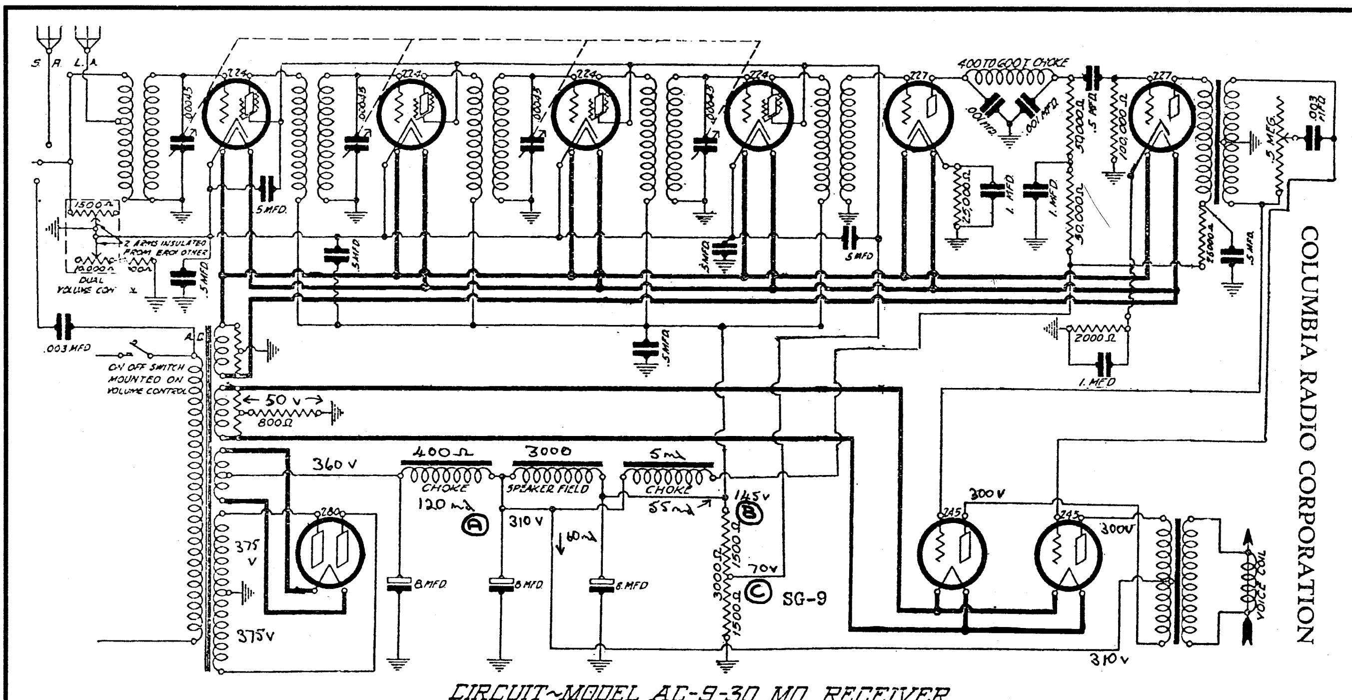
Fortunately in practice, and because of other factors such as valve ageing, varying mains voltages, and component tolerances, extreme precision becomes academic. In any event, the heavy current through the speaker field and dividing resistors will have a considerable stabilising effect.

Assuming therefore, that the current for the RF stages under typical operation is 5mA, the total current through the speaker field will be 55mA. Added to this is the 60mA for the output stage and a nominal 5mA for the detector and audio valves, to give a total HT current of 120mA.

The voltage drop through the speaker field will be .055 x 3000 = 165 volts, giving a voltage at (B) for the anodes of the RF stages of 310 - 165 = 145 volts. It then follows that as the screens are fed from point (C), which is conveniently half way between the anode supply point and earth, they should have a potential of about 145/2 or about 70 volts.

At full volume, with the extra current drain, these voltages would fall slightly to be very close to the traditional 135 volts HT and 67 volts for the screens — figures very commonly specified for battery powered receivers. This could be taken as confirmation that the voltages chosen are close. Although 24A's can be operated at higher voltages, it is unlikely that four cascaded stages would remain stable if run at full ratings, and it is likely therefore that our estimated conditions are correct.

In any event, receivers are rarely dependent on precise operating voltages and the heavy current through the voltage divider masks the variations in the currents drawn by the valves. For critical situations, gaseous regulators were used to stabilise voltages, but these were rarely used in domestic radios.



Here again is the circuit of the Columbia SG-9/AC-9-30, but with the addition of the estimated voltages and currents, and the resistances of the components involved.

WINDING TEMPERATURE

The operating temperature of transformer windings is important as it affects reliability and safety. With standard class A insulating materials, the maximum allowable temperature at any point is 105° C. Allowing for various factors, the maximum temperature rise above ambient in a winding should not be more than 45° C.

With exposed cores, the time honoured rough and ready test is that if a hand can be held on the core comfortably for 5 seconds, the temperature is satisfactory, but how can a potted transformer be checked? The fourth edition of the Radiotron Designer's Handbook in Chapter 5, Section 5 (v) describes a simple method of finding the temperature rise by comparing the cold and hot resistances of the winding. Based on the temperature coefficient of copper of 0.00393 the change of resistance can be calculated using the formula.

$$\text{Temperature Rise} = \frac{R\ hot - R\ cold}{R\ cold \times 0.00393}$$

A correction should be made for any change in ambient temperature during the test.

As a practical example, the primary of a Majestic 90B pitch encapsulated power transformer was tested. During a 5 hour run, the resistance rose from 10.1 Ω to 11.3 Ω, while the ambient temperature rose by 7° C.

$$\text{Temperature Rise} = \frac{11.3 - 10.1}{10.1 \times 0.00393} = \frac{1.2}{0.03969} = 30.23°$$

Subtracting the rise in ambient temperature, the operational rise was therefore ; 30.23° - 7° = 23.23°.

As this is well below a rise of 45°, the transformer in this example is quite satisfactory.

While touch is a commonly used gauge of temperature, it is not very accurate, and is obviously of little use for potted transformers. Here is a simple and more precise method which can be used for any winding on any transformer.

Transformer voltages

We are now at the stage where the voltage and current at the output of the filter choke is 310 volts at 120mA. The voltage drop in the filter choke is the next calculation. As its resistance is 400 ohms, the voltage drop is simply the current by the resistance; 0.12 x 400 = 48 volts, or 50 volts in round figures. This is added to the 310 volts at the input to the speaker field to arrive at a figure of 360 volts across the first filter capacitor.

Now, at last, it is possible to determine the transformer HT winding. Referring to the Tube Data book again, and by reading off the graph for a capacitor input filter for the type 80 rectifier, we find that for an output of 360 volts at 120mA the input to each of the rectifier anodes should be 375 volts. The HT winding specification is therefore 2 x 375 = 750 volts centre tapped, at 120mA into a capacitor input filter.

The specification for the filament windings is simply a matter of adding up the individual currents. The main filament winding supplies two type 27 and four type 24A, each 2.5 volts at 1.75 amperes or 10.5 amperes total! The winding for the output stage feeds two type 45 valves, each requiring 2.5 volts at 1.5A. Finally, the rectifier filament winding for a single 80 is 5.0 volts at 2A.

The transformer was duly rewound to these specifications, with a gauge heavier wire than used originally, but with a 240 volt primary to suit local conditions. As always, it seemed a bit of a desecration to bury it in molten pitch, but as we have seen, there was no real alternative.

With the transformer installed, the receiver was fired up, and the various voltages measured. They all proved to be very close to the calculated values, and the receiver is performing well.

One of the great satisfactions of vintage radio restoration is to have a major project like this work out as intended. Somehow, filling a printed circuit board with solid state components just isn't the same!

There is still a lot that can be written about transformers and power supplies, but as space has once more run out, we will have to continue in the not too distant future. ❖