VINTAGE EQUIPMENT

AVO Valve Tester Restorations

By Ian Batty

My article last month covered the history of AVO valve testers and described the seven different types that were made over the years and how they worked. I have some hands-on experience with five of those types. I have repaired or calibrated four, but there was some bad news regarding the original Valve Tester. I also have some general advice about repairing and calibrating these instruments.

Warning: Electrocution Hazard

All AVO valve testers apply AC voltages with peak values ~1.57 times the indicated voltage on the voltage selectors. From the MkI onwards, they can apply AC voltages with peak values exceeding 600V. Even the initial Valve Tester can apply peak voltages close to 400V. Exercise care with all AVO Valve Testers. Never touch any exposed contacts on valve socket panels. Be careful when measuring voltages.

The five models I have personal experience with, in order of decreasing age, are the original Valve Tester, the VCM MkII, VCM MkIV, my CT160 and a VCM163. I have checked out each one, and here is what I found.

Original AVO Valve Tester

I was offered a Valve Tester to check out. It needed a good clean, but it's one of those jobs where over-eager cleaning can damage finishes such as control paint markings from the late 1930s. I opted for a light touch on the basis that it was over 80 years old and should retain the marks of age.

I tested several 6.3V valves: a 6J5 triode, a 6SH7 pentode and a 6V6 beam tetrode. As I was uncertain of its calibration, I set the mains tapping for 230V and adjusted my bench variac to give 6.3V on the heater of the valve under test. I got consistent readings, all low (Photo 8).

Photo 8: The meter scale on the original AVO Valve Tester. The 0-10 scale could read out either the g_m directly or a proportional value where 10 represented the expected g_m. Interestingly, valves with a gain as low as 56% of nominal were still considered 'good' – presumably due to the expense of replacing them.

As noted last month, all components are passive linear types except the backing-off rectifier. That means they can be easily tested. The general construction of the AVO is robust and reliable, so what might be wrong?

Transformers can have open-circuit windings that give no output, high-resistance connections that allow the output to fall under load, or internal shorted turns that commonly lead to overheating and smoking. I couldn't find any sign of these problems in T1 (the high/grid voltage transformer) and T2 (the filaments/heater transformer).

There are just eight fixed resistors, and only the values of R1-R6 affect measurements. All tested good.

There are two variable resistors, with RV2 being a dual-gang special type. All three sections tested good.

It would be odd to find one of the switches, plugs or sockets causing a low-sensitivity fault (Photo 9). They all tested OK.

Photo 9: The inside of the socket panel of the Valve Tester. The wiring is quite busy, but the good news is that it rarely goes wrong. Note the copper-plated springs used to create the detents on the thumbwheels.

I was really hoping there was nothing wrong with the meter (Photo 10) as it would be a nightmare to fix, and finding a replacement would be almost impossible without buying a whole new instrument. It moved freely, without hesitation going to full scale or coming back to zero. And it settled to the zero mark without any tapping or jiggling. So it seemed to be mechanically OK, but what about electrically?

Photo 10: The meter movement is a high-precision instrument, but unfortunately, it's exposed to the inside of the case in the original Valve Tester. So you have to be careful not to contaminate or damage it if you open the unit up. Note the magnetic adjustment tab visible at the back; this gives a 5% or so FSD adjustment range.

Disconnecting it, I found its coil resistance to be correct, but for full-scale deflection (FSD), it needed just on 1mA.

The movement is specified for a 700μA FSD, so it was giving only about 70% of its usual indication, explaining the under-reading of transconductance measurements. I chatted with some instrument tech mates, wondering whether the permanent magnet had weakened with age. They agreed that this was a possibility.

I recalled a method of magnetising the small magnets in telephone earpieces from my training days. The iron polepieces were set into a jig containing a multi-turn, low-resistance coil. Then the coil was connected, in series with a fuse, across a 24V battery.

The fuse blew, of course, but not before it had allowed a pulse of current that induced (via the coil) just the right amount of magnetism into the pole pieces.

The idea of using this technique to restore the Valve Tester's magnet seemed plausible. Still, I had two concerns: how was I to know which polarity I needed to increase the AVO's magnetisation, and how large a current pulse was required to do the job?

Having worked for an instrument company back in the late 1960s, I had some appreciation of the fine touch needed with moving-coil meters, so I wasn't going to risk experimenting on a rare and valuable piece of gear such as the Valve Tester.

The UK Vintage Radio Repair and Restoration has an informative thread on meter remagnetisation: siliconchip.au/link/abew

The meter is a very fine piece of precision engineering. The internal photo of the meter shows a small moveable tab above the polepiece area. It's a variable magnetic shunt that changes the movement's sensitivity by some 5%. Regrettably, the loss of sensitivity in this example was well outside the meter's adjustment range.

VCM MkII clean-up

I was also asked to check a VCM MkII out by a fellow HRSA member (see lead photo and Photo 11).

This version has the high-sensitivity meter most of us will come across. The VCM uses a fully-enclosed meter, making work on it much easier. This VCM's meter appeared 'sticky'. It showed some hesitancy in moving up to and down from full scale. It was also erratic in settling, not always returning exactly to zero without a gentle tap on the case.

Another HRSA member, a former instrument technician, agreed to overhaul the meter for us.

Removing the meter proved to be an adventure, demanding the removal of all control knobs and the front panel before I could draw out the meter forwards from the main chassis. As the similar photo of the MkIV shows (Photo 12), the VCM's case is 'well-populated' with components. Repairs may demand extensive disassembly and desoldering.

I also discovered that some of the control knob grub screws had slotted heads, others hex. Take your time to check before attacking them. They are not making spare parts anymore.

When the former instrument technician returned the meter to me, it was much cleaner and in working condition. A quick check confirmed that it now smoothly reaches FSD with the appropriate current applied.

Replacing the meter and carefully bringing the mains up on my variac, I was rewarded with a functioning MKII. That was, until I turned it off, then on again. Splat!

As Euan McKenzie notes, selenium cartridge rectifiers have a high failure rate after ageing, and this one had gone out on me. I replaced both the grid circuit rectifiers with modern silicon diodes, and the AVO came back to life.

With the meter in working order and the VCM re-assembled, I checked its calibration. Euan McKenzie's excellent Radio Bygones article has the complete procedure. Here's my short-and-sweet version.

First, check the meter movement FSD is 410μA. Then check the meter reading near FSD. It was a bit low, but adjusting the RV7 pot (sensitivity) made it indicate correctly; the AVO's meter reading of 100mA measures 50mA using a multimeter in series with the valve anode.

Checking the grid voltage, its magnitude was too high at around -67V DC with the Grid Volts set to 100V. It should be -52V, but I couldn't get it close enough to 0V by adjusting the VG calibration pot, RV6.

I figured out that adding around 4kΩ in series brought the adjustment in range, so I connected two 8.2kΩ resistors in parallel between the 'hot' end of the grid supply and RV6. I could then set the grid voltage to -52V/-5.2V.

With the TEST function activated, the grid voltage should become 0.52V more positive when the g_m button is pushed, so the -5.2V reading should change to -4.68V. Adjusting RV5 (GM CAL) brought it into calibration. I then checked it using a calibration valve, and its measurements were good.

Next, I checked the meter indication

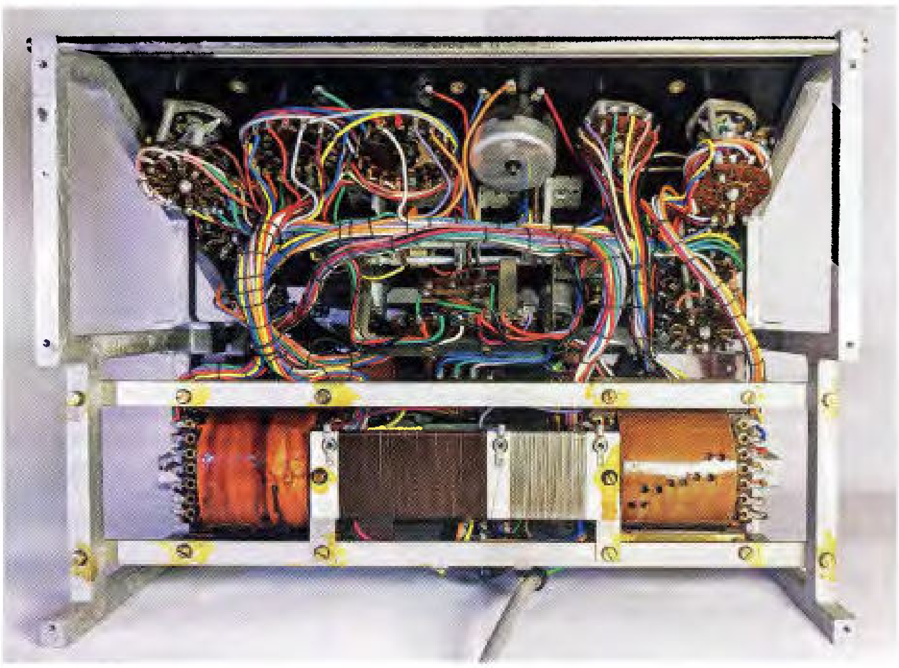

Photo 11: the rear interior of the MkII. The only real problem with this sample was that the meter was 'sticky'. It's a sealed unit in this version and quite a bit of work to remove. Rather than open it up and risk damaging it, I handed it over to someone with experience to fix it and then I reinstalled it.

on the CH(Cold) position. This is the Mains Adjust function, so a correct indication is the vital first step in any measurement. The reading was too low. With all presets in calibration and the test valve reading correctly, what could be wrong?

Following calibration, the meter FSD (affected by the setting of RV7) was 549mA. Ohm's Law shows that R4 (125kΩ) should be around 114kΩ to get the 84% deflection current of 455mA. Shunting R4 with a 1.8MΩ resistor brought the meter onto the calibration mark, at 84% of FSD.

Given the repeated cautions about not messing with the Mains Cal circuit, why did I end up here? The inclusion of RV7 means that you cannot rely on AVO's assumption that the meter's sensitivity will be exactly 440μA as noted in the circuit diagrams.

In providing RV7 to allow FSD adjustment as part of the calibration procedure, AVO did not foresee the need to make R4 adjustable to compensate for calibration adjustments in RV7.

Photo 12: The VCM MkIV is a powerful instrument, but it's challenging to work on because many of the components are packed close together or inaccessible.

MKIV clean-up

Another request from a fellow HRSA member was to clean up a MkIV VCM. The MkIV is the pinnacle of the design, but I found it the most difficult to use.

I found it hard to get the expected results and finally considered the SET~ (mains voltage adjustment) indication. The manufacturer's circuit drawing was confusing, and it took some effort to discover that the drawing did not show how the calibration circuit was connected. Rather than trace out the wiring, I persisted and found a revised circuit (still incomplete) that I could decipher.

The photo of the MkIV interior shows that it's built on a frame, with the bottom rails carrying the overload relay and three mains transformers. From left to right, these are the filament/heater transformer, grid supply transformer, overload relay and anode/screen transformer.

The SET~ calibration relies on the rectified, unfiltered supply taken off the high-voltage winding of T2 (grid bias/transconductance supply). This feeds to a voltage divider, with its top resistor being calibration pot RV4.

The tap between RV4 and the rest of the divider then feeds to the meter via two series-connected 1.48MΩ resistors (confusingly marked as a single 2.96MΩ resistor, R19). Accurate calibration relies on T2 working correctly, the setting of RV4 and the correct value of R19.

As with the MkI, I accepted that the transformers would be the most reliable components in the instrument. T2 is fed from the 200V primary tappings of the multi-tap transformer T1, so I set my Variac for 230V and adjusted the mains input selectors to get 200V at T2's primary.

This gave an incorrect calibration indication, so I reasoned that the fault was in the calibration circuit. RV4 lacked sufficient range to correct the calibration indication, so I checked R19. Its value had gone high. Shunt resistors (to a final value of 23.9MΩ) brought the combination down to its correct value and brought the calibration within the range of VR4.

Drift in the value of R19 (and its equivalents in other Marks) is a known cause of calibration errors.

But don't just head for R19 (or its equivalent in other models) if you have this problem. The MkIV circuit includes a number of our ancient enemies (capacitors) and some silicon diodes. I expect the diodes to be reliable, but they are early releases of silicon technology and are almost 60 years old.

Also, be alert to 'previous repairs'. Hopefully, the prestige and value of AVO VCMs have been enough to deter inexperienced repairers from just launching in with no understanding or respect for the subtleties and complexities of the AVO valve testers.

CT160 calibration

I bought my CT160 at a Defence clearing sale back in the 1990s, and it has served me well since then. I decided to check it out for this article.

Later versions replaced the two duo-diode 6AL5s with silicon diodes for extended lifetime and reliability. These versions are easily identified: there is no warm-up time, as present with my 6AL5-equipped version (see Photo 13).

I carefully checked the meter FSD and found it to be 30.4μA, accurate enough given that its most recent Navy calibration was in 1988.

The instrument passed the manufacturer's calibration procedure. Tested against a calibration valve, it was within 3%.

VCM163 clean-up

Another HRSA member loaned me this, the "ultimate AVO" (Photo 14). It had been repaired and only needed calibration. That is pretty straightforward: set the mains indication, set the grid voltage and adjust the transconductance measurement circuitry.

To calibrate the mains indication, I set the incoming mains to exactly 240V AC using a variac, set the mains voltage selector to midrange and adjusted RV2. That was easily done.

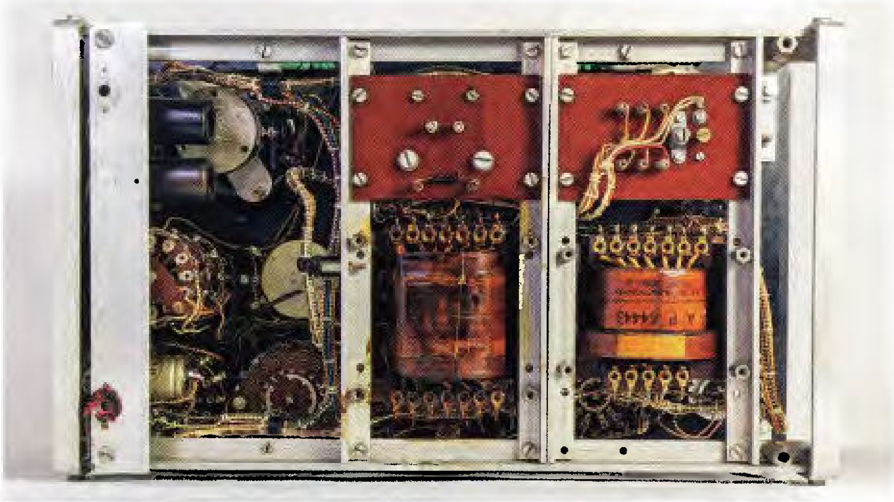

Photo 13: The interior of the CT160.

For the grid voltage, I used RV3 to set the voltage at the top of the Grid Voltage potentiometer to -52V using an average-reading meter. I then checked that, for the Grid Voltage pot set to half-scale, the measured grid voltage is precisely half the pot's full-scale indication, on all grid voltage ranges.

While the full-scale voltage was correct, none of the half-scale voltages were. Close examination showed that the control knob did not sit exactly at the 10V mark when fully clockwise. The Grid Voltage pot's shaft lacks the usual flat to allow a grub screw to lock the knob to the shaft. Instead, the pot's smooth shaft is gripped by a collet inside the knob.

While this does allow precise adjustment of the knob relative to the shaft, it can allow the knob-shaft relationship to drift, as had happened here. Realigning the knob so that full rotation settled exactly at 10V fixed the problem. Be aware that this problem is not described in the service notes.

The final check confirms the transconductance measurement. My calibrated 12AU7 showed a lower g_m than the 4.3mS I had found when setting it up. Remembering that transconductance is anode current dependent, I opened the anode current link and checked. For a test current of 16mA, I should have read an average current of exactly 8.0mA, but I measured 7.42mA instead.

Adjusting the grid voltage to give a measured 8.0mA, my 12AU7 showed a g_m of precisely 4.3mS.

This could only mean that the anode current meter was too sensitive. I thought about this – I've noted that meter sensitivity can fall with age, as a field magnet weakens, but I could find no explanation for this meter's increase. Online conversations led me to accept my guess.

There is no way of altering the meter's sensitivity, as it uses a conventional milliammeter circuit with fixed-value, switched shunts. I opted to add a small preset pot in series with the meter movement. This corrected the error, and could easily be removed if my repair method proves to be inappropriate.

Be aware that the VCM163's switch position numbering differs from all previous models. All valve data books give the correct voltage and current settings for all VCMs, but you will need to interpret switch settings if your book does not include the VCM163's unique numbering scheme.

With the anode current indication corrected, the VCM163 was included in my talk at the Melbourne HRSA's May meeting. It will be available on our website: https://hrsa.org.au

Instrument accuracy

AVO's initial justification for using the valve to do rectification was that they could build transformers with much better regulation than any DC power supply.

So, how true was this? The most likely error will be low heater voltage due to the high currents drawn by output/power valves. Correctly calibrated, the CT160 gave the following heater voltages for various heater currents.

Valve	Heater	Voltage
- - -	0A	6.75V
6J5	0.3A	6.65V
6V6	0.45A	6.6V
6AG7	0.65A	6.5V
6DQ6	1.2A	6.35V
EL34	1.5A	6.3V

Most 'receiving types' draw 0.45A (6V6) or 0.3A (6SH7). These do not load the heater transformer heavily, so the applied heater voltage is higher than the nominal 6.3V. I reset the calibration to give 6.3V for these types. I found that this lowered the voltage for the high-current EL34 to only 5.95V.

Testing a group of five EL34s gave an average g_m about 20% low compared to readings for the same group with the correct 6.3V heater supply.

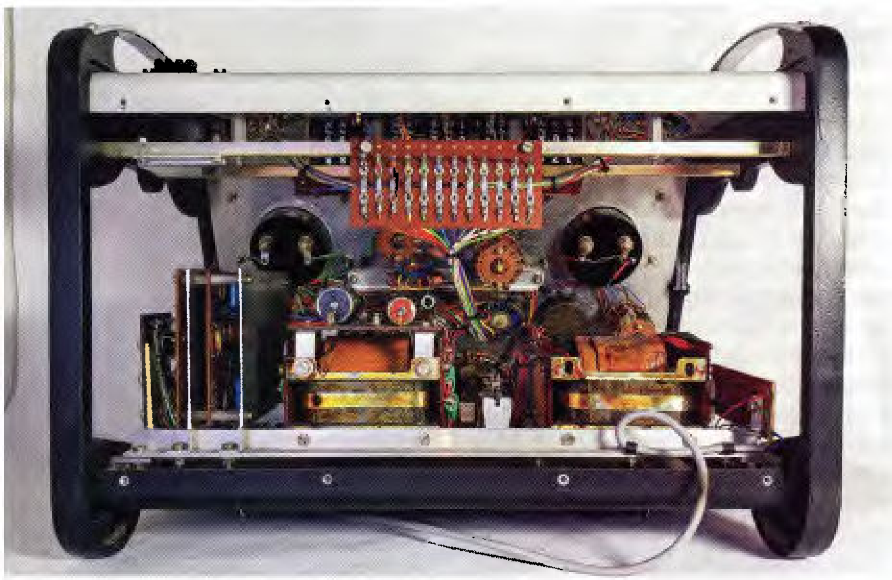

Photo 14: the interior of the VCM163. ***Thanks to Jerry Aldrich – UK Vintage Radio Repair & Restoration Forum, & British Vintage Wireless Society***

Taking a 6SH7, I found that, from a high heater voltage of 6.7V to a low of 5.9V, the g_m reading changed by +5%/ -7%. The 6SH7's 'low heater' g_m reading has a much smaller error than for the EL34 (-20%).

So high-power valves are more sensitive to heater voltage than receiving types, and high heater voltages give smaller reading errors than low voltages. Thus you should use the AVO calibration method unless your application demands highly-accurate readings.

How good are the Testers?

The original Valve Tester is great for its day, but the application of zero grid bias means that it cannot give the comprehensive testing needed with modern valves. And you can only measure g_m; there's no indication of anode current.

On the other hand, the VCM MkI to MkIII are winners on any day. You can set a valve up for the specified control grid, screen grid (tetrodes and pentodes) and anode voltages and measure the valve's anode current. As mentioned above, it's possible to chart a valve's complete electrical characteristics on this instrument.

But if you're just testing valves for correct operation, you can get a direct readout of the transconductance.

The MkIV, though, is not my favourite. As an instrument, it's excellent, but its ergonomics/user interface is confusing. Both grid voltage and mA/V are set by the combination of a range switch and a pot. This does give quite precise adjustments, for example, over the range of 0~5V bias. If you need -17V, you select the 15V position on the switch and then set the variable dial to 2V.

The Coarse Setting (grid volts, mA/V) indicator discs are set behind transparent covers. I found I needed to be looking pretty well perpendicularly at them – difficult to impossible if you are standing at a test bench of standard height. And the calibration marks are in red on a black background. The graphic artist in me was shouting 'luminance values!' until I went out and took a break.

Also, AVO cut the use of terminal strips to the absolute minimum. So they mounted minor components such as resistors on inoperative wafers of the various switches (Photo 15). This puts some parts out of easy reach and, in the worst case, out of sight. Be really sure to get the full service manuals if you need to dive into the innards of any VCM, especially the MkIV.

But with the VCM163, the backing-off circuit's removal and the provision of simultaneous anode current and transconductance indications make it the instrument of choice. Its only downside is the removal of bases such as the UV/UV4~7 series. But you can either get or make adaptors. The long story short is that you should probably get one if you're working with valves.

Calibration

AVO recommend making up a calibration valve. You'll find a description in AVO instructions and other places. One description calls for plotting the characteristics of a 12AU7 as follows.

Strap both sections in parallel. Apply a grid bias of -7V with an anode supply of 200V. Measure the anode current, which should be around 16mA, and adjust the grid voltage to give exactly 16mA anode current. Increase and decrease the grid bias by 1V, measuring the anode current at each point. Divide the anode current swing by two, giving the transconductance in mA/V (mS).

For example, observed anode currents of 13mA and 21.5mA give a total swing of 8.5mA for a g_m of 4.25mS.

You can use this method to create other calibration valves – you might want to use a 6L6/EL34 if you regularly test power output types. You will need to set the relevant voltages. For a 6L6, set the anode to 300V, screen to 200V, grid to -12.5V and the anode current should be about 50mA, giving a g_m of about 5.3mS.

Place the calibration valve in the VCM, set the relevant voltages grid and check that the VCM gives a g_m value matching that of your calibration valve. As mentioned above, the 12AU7 must have both sections connected in parallel when used to calibrate a VCM. Do this using switch settings 641 226 413, which connects the two anodes.

Repair advice

As touched on above, the meters used in the MkI-IV are highly-specialised, sensitive instruments with exacting specifications. Glomping any old ohmmeter into a low-resistance circuit can dump tens of milliamps through the test leads. That presents a real danger of damage to a VCM, especially those in the MkIII, MkIV and CT160, which have a full-scale sensitivity of only around 33µA.

The electrode selector/roller switches are often hard to turn. Do not use oily lubricants on them, as these will further jam the mechanisms.

Clean the instruments well with a totally evaporating cleaner that is safe on Bakelite and the painted lettering, then use a silicone lubricant. If you're unsure which products are safe, spray a little on your fingers and rub them together. A safe lubricant will dry off rapidly, but your fingers will glide easily over each other due to the coating.

Purchasing advice

I have a CT160 that I bought at a Defence clearing sale back in the 1990s, so I'm happy with what I have. A recent HRSA auction saw a MkIV sell at $1400, so I'll need to save up if I want one. Expect to pay at least $1000 for any working VCM. SC

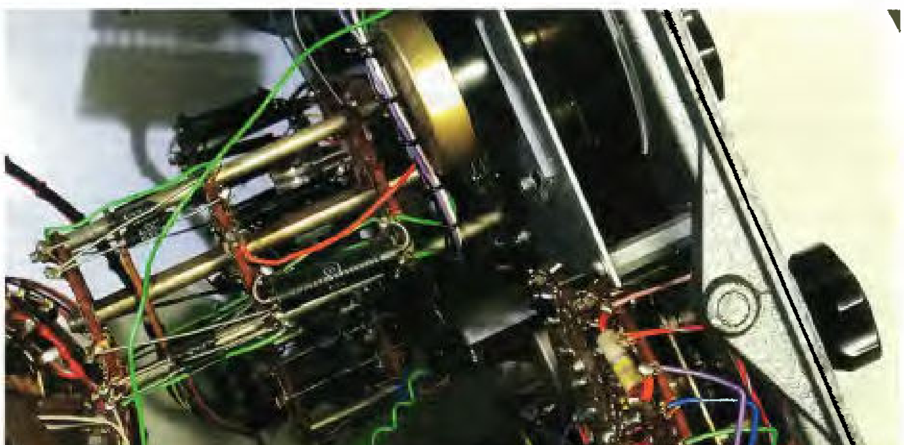

Photo 15: To save on tag strips, some of the components in the MkIV are soldered across unused contacts on the wafer switches. This only compounds the problem of difficult servicing!