AVO
VALVE TESTER Type 160A
AND
ADAPTOR UNIT Type 160A/1

OPERATING INSTRUCTIONS, VALVE DATA
AND
MAINTENANCE MANUAL

AVO Ltd

AVOCET HOUSE, DOVER, KENT, ENGLAND.

AVO CT160A Operating Instructions and Service Manual

This AVO CT160A manual is the result of combining (and editing) two different sets of photocopies of AVO CT160A manuals and also from information from the original AVO CT160 manuals. This AVO CT160A manual has been kept as original as possible, even though some photocopies of the AVO CT160A pages have been replaced with AVO CT160 pages where the text did not differ in any point, but where the quality of the CT160 scanned pages was much better than the CT160A scanned pages. All figures and photos have been kept in their original shape although most have had to be edited due to the poor quality of the original photocopies.

The schematics at the end of the manual have been extended with three new sets where the first is an unaltered original redrawn schematic, the second schematic is a redrawn and corrected schematic and the third is a redrawn, corrected and modified schematic. The second schematic has been corrected in the following areas:

> D2: Changed from 66V RMS winding to 99V RMS winding, calculating the current in the circuit shows that the 99V RMS winding is necessary for the circuit to work correctly.
>
> R4 & R41: Changed places in schematic, the component list on page 17 of the Service Manual and also the component list on the page before the original schematic shows this as the correct order, as well as an internal component placement comparison between a CT160A and a CT160.
>
> R37 & R37 shown as R37A and R37B as per component list on page 18 of the Service Manual, consisting of one 13 Ω "selected" resistor each.
>
> SH6: Ground connection for tags 2-5, was missing from original CT160A schematic but can be found in later CT160 schematics and also in the original CT160A & CT160 testers.
>
> WIRES & COMPONENTS: Moved for clarity.

The third schematic has been modified in the following areas:

> All of the corrections above from the second schematic plus:-
>
> D5, R42 & R38: Anode voltage rectification added, components used D5 = D1, R42 = R38 = 100 kΩ ± 10% 1 W – this modification has been tested and proved to work in an original AVO CT160 and is also used by AVO in the AVO Mk IV.
>
> D6, D7 & C4: Meter protection circuit added, D6 = D7 = D1, C4 = 8µF / 63VDC Non polarized (preferably Polypropylene) – this modification has been tested and proved to work in an original AVO CT160 and is also used by AVO in the AVO Mk IV.

If you want to read more about the inner workings of the AVO Valve Testers including the AVO CT160 and AVO CT160A I recommend that you visit the "**UK Vintage Radio Repair and Restoration Discussion Forum**" **here** http://www.vintage-radio.net/forum/index.php and read the threads:

"Everything you wanted to know about the inner workings of an AVO Mk IV Valve tester!"
"Some more that you wanted to know about the inner workings of an AVO Valve tester!"
"All that you wanted to know about the inner workings of an AVO CT160 Valve tester!"
"AVO CT160 - anode current measurements, calibration resistors and the meter workings!"
"AVO CT160A – Special edition of the AVO CT160 - comparison!"

I have included adapted versions of the CT160A and CT160 texts above in this document.

The work of editing and testing the corrections and modifications in the AVO CT160A manual, and writing of the articles above, has been performed by Martin Forsberg, Sweden, and Euan MacKenzie, Australia.

Sweden 2010-11-18

The following texts are adaptations done to the texts published by me, Martin Forsberg and Euan MacKenzie, at the "**UK Vintage Radio Repair and Restoration Discussion Forum**" and contain important information about the AVO CT160A Valve Tester as well as important information on the AVO CT160 Valve Tester which the AVO CT160A is based on.

AVO CT160A – Special edition of the AVO CT160 - comparison!

This text will endeavour to explain how the AVO CT160A works in certain areas in comparison to the well known AVO CT160. Some of the information comes from Mr. Yutaka Matsuzaka who kindly sent me a copy of the AVO CT160A Operating Instructions and calibration Instructions. Mr. Yutaka Matsuzaka have published some information on his website, http://www6.wind.ne.jp/yutak/avo_ct160/index.htm, about calibration of the CT160A and also a comparison of the CT160 and CT160A. I have also been given photocopies of another version of the CT160A manual by Frank Philipse which he received from Wim De Grotte, these copies have recently been published on Frank Philipse's website: http://frank.pocnet.net/instruments/AVO/index.html .

Some of the modifications that AVO did to the CT160A have already been mentioned in the article: "AVO CT160 - anode current measurements, calibration resistors and the meter workings!" on the "**UK Vintage Radio Repair and Restoration Discussion Forum**", which also follows this text. But the differences will be described in more detail in this article.

The AVO CT160A has been referenced to as the Dutch Military versions in a few places and I have found no other mentions of it.

Please also understand that I have not had access to an AVO CT160A myself for this article, only to second hand pictures and information plus photocopies of AVO manuals. However the modifications are not complicated once you understand how an AVO CT160 and an AVO Mk IV works under the hood.

Any errors are my own, but I have made my best to check everything before publishing it here.

Part 1: Modifications done by AVO

AVO have updated the AVO CT160A to work more like the later AVO Mk IV in many areas, but not all. Apart from the looks on the front panels and the extra valve holder panel connected via the new contact on the original valve holder panel most modifications are easy to describe and understand if you understand how the original AVO CT160 works. Modifications that AVO have done to the AVO CT160A are:

A. All valves have been replaced with Silicon diodes. (D1 – D4), making it necessary for further modifications described below to compensate for different voltage drop than valves, and also for different behaviour compared to valves.

B. The range for current capabilities for rectifier valves have been extended up to 180mA, this simple modification will be described below in the part describing the over-current relay modification as they are closely connected. (R40 + modifications for over current relay RL3)

C. Since the valves have been disposed of the 6.3V (marked as 5.8V in the AVO CT160 schematic) winding for the heaters have been removed from the schematic for the Heater voltage transformer.

D. The 500 Ω resistor in the D/R circuit have been replaced with two 1 KΩ resistor to handle the higher current range. (R12 & R13)

E. The overcurrent relay winding RL3 have been shunted with a resistor for the 120mA and 180mA ranges, an extra switch wafer for the SET Ia & DR switch have been added for this modification. (R37 & SJ1, unfortunately, in my opinion, re-numbered by AVO to SJ1 as it would logically have been SJ5 as SJ1 – SJ4 are already present in the AVO CT160)

F. The grid volts control have been modified with a switch for the capability of doubled voltage up to 80V, the circuit have also been modified, more details of this in the text below. (R4, R39, RV5 and SL1&2 have been introduced plus a new winding on the Anode & Screen volts transformer)

G. The calibration resistor circuit have been modified due to the modification done to the grid Volts control, this modification is also described below. (D2, RV6, R41 and R3 plus 99V RMS winding from Anode/Screen volts transformer – old R4 removed from circuit)

H. The Anode Current controls have had the series resistor changed to compensate for the current through the circuit when a Silicon diode have been inserted. (R6)

I. The Silicon diode in the Screen volts circuit have made it necessary to introduce an extra resistor to ground. (R38)

In all other aspects the modification status of the AVO CT160A corresponds to the last modification status of the AVO CT160 up to resistor R36 for the Grid to Cathode connection.

Modification A & C:

Replacing the valves with Silicon diodes meant that the extra heater winding is not necessary any more and it has been removed from the schematics, but since no actual AVO CT160A have been available for check it is not known by me if the winding is still there or not. The Silicon diodes also means that some circuits will have to be compensated since they have a lower voltage drop than the valves.

Modification B, D & E: Current measuring range for rectifier valves increased up to 180mA.

To measure rectifier valves on the 180mA range AVO have modified the CT160A in the same way that the AVO Mk IV is designed, with one extra resistor on the SET Ia & DR switch for the measuring range and also a resistor, R37, which is connected in parallell with the over current relay coil RL3. This extra resistor, R37, is working as a shunt making less current run through the relay coil so it will not actuate as before on the old 120mA range and on the new 180mA range. This is necessary so rectifiers with a higher current capability can be measured, the relay would otherwise actuate to early. The 500 Ω resistor R12 on the D/R circuit in the AVO CT160 have been replaced with two resistors, R12 & R13 at 1 KΩ in parallell making 500 Ω, to be able to handle the current flowing through them at the higher current ranges for rectifiers.

Modification F:

The Grid Volts control have had its range extended by a switch which makes it possible to double the voltage on the scale, in the X1 position you have 0-40V and in the X2 position you instead have 0-80V. This modification has been done by introducing a new winding on the Anode/Screen volts transformer. This winding now have three taps, ground, 55V RMS and 120V RMS. The switch SL1&2 for the X1 and X2 range switches between the 55V RMS and the 120V RMS windings plus it also inserts or shorts resistor R39 which compensates the gm measuring voltage circuit. When the 120V RMS winding is selected resistor R4 and potentiometer RV5 is connected for calibration purposes of the 0-80V range in the same manner as RV3 is used for the 0-40V range. The biggest change to the circuit is that the negative voltage which earlier was used from an out of phase winding of 66V RMS has been removed all together! This is then contradicting AVOs text in the patent that this voltage is necessary for the valve not to form a diode between the grid (or screen) to the cathode when the valve under test is not conducting. Maybe this is a trade-off for some reason, maybe it was more expensive to have it there and have it changed in step with the grid volts switch, or maybe AVO found that it was not necessary to have that voltage there.

Modification G:

Here AVO have changed the calibration resistor circuit introducing a potentiometer, RV6, for calibration purposes and also changed resistor R3 to 1.22 MΩ. AVO also changed the circuit by introducing a resistor (R4, wrongly named R41 in the original schematics) to ground, this has earlier been mentioned as necessary for shorting the charge buildup inside the Silicon diode when it is not conducting. At the same time the winding which supplies this circuit has been changed to the 99V RMS winding, this is necessary to ensure that the same current as in the AVO CT160 is driven through the circuit for the measuring purposes.

The calculation for the 99V RMS winding becomes:

99V RMS equals 89.13V Mean, the conversion factor being 1.1107.

99V RMS / 1.1107 = 89.13V Mean.

This voltage is half-wave rectified which results in half the voltage after the rectification, minus the voltage drop of the diode, which can be assumed to be 0.7V.

89.13V Mean / 2 – 0.7V = 43.87V

When this voltage is divided by the current necessary in the measuring circuit, which has earlier been shown to be 35.775µA the resulting calibration resistance will be:

43.87V / 35.775 µA = 1.226 MΩ, with a +/-1% 1.22 MΩ resistor which ranges from 1.207 MΩ up to 1.232 MΩ you might end up just outside the range possible to adjust with the 20 KΩ potentiometer RV6 so it is best to use a resistor close to 1.22 MΩ.

Modification H:

This modification, of series resistor R6, has already been described in the earlier article on AVO CT160 modifications and Anode Current control" in the **UK Vintage Radio Repair and Restoration Discussion Forum**" and only confirms our calculations there. The current through the Anode Current controls needs to be exactly 12.5mA and when the valve is replaced with a Silicon diode with a much lower voltage drop the difference in voltage drop will have to be compensated for with an increase in resistor R6.

Modification I:

AVO also changed the circuit by introducing a resistor R38 in the Screen Volts control to ground, this has earlier been mentioned as necessary for shorting the charge buildup inside the Silicon diode when it is not conducting.

As has earlier been mentioned it is possible to insert a Silicon diode in the Anode Volts circuit just after the Anode Volts switch before the Electrode Selector switch, plus an extra resistor of 100 KΩ +/-10% at 1 Watt – this resistor needs to be there for the same reason as R38 above.

New Valve Sockets:

The extra Valve Holder panel that is connected via a cable to the Valve Holder panel on the CT160A box have been equipped with the following valve sockets:

Pencil Tubes, 5 Wires in Line, Flying Lead, 7 Wires in Line, B7A, B9D, Special Base for 2C39, Acorn, Nuvistor, F8 and B8D

This finishes the current comparison between the AVO CT160 and the AVO CT160A.

Part 2: Modifications done by AVO to the over-current relay protection

Here is some more new information as I have studied the, soon finished, AVO CT160A manual in some more depth! By finished I mean that I have soon finished cleaning up all the pages.

While AVO was changing the current range for Diodes and Rectifiers, by adding the 180mA range, they also changed which voltages that are used for testing Diodes and Rectifiers. In the AVO CT160 they used the windings for 40V, 75V and 125V to cover the ranges from 1mA up to 120mA but in the AVO CT160A these windings have been changed to 40V, 75V, 150V and 200V. The two higher voltages are used in conjunction with the added Switch SJ1 which connects resistor R37 in parallel with relay coil RL3 for over current protection. From reading the component list I could also see that AVO used two resistors to make up the resistance of R37, which is stated as 13 Ω each. This will then make R37 to have a resistance value of 6.5 Ω.

With a coil resistance close to 5 Ω, which Euan MacKenzie has helped me to measure, for RL3 this means that you will have roughly a 57% decrease in sensitivity in RL3 as the current is divided between the two resistors making up R37 and the relay coil. The maths for this is simply:

13 Ω in parallel with 13 Ω gives you 6.5 Ω. This then gives the current through the relay coil RL3 to be:

6.5 Ω / (6.5 Ω + 5 Ω) = 6.5 / 11.5 = 56.5%

This figure of 57% corresponds fantastically well with what AVO did in their AVO Mk IV tester on the current ranges for Diode and Rectifier testing on the ranges 60mA, 120mA and 180mA. Here AVO used two 3.9 Ω resistors in parallel with the relay coil RL3, which has a resistance close to 1.5 Ω in an AVO Mk IV, this will also mean a 57% decrease in current sensitivity. The maths for this is simply:

3.9 Ω in parallel with 3.9 Ω gives you 1.95 Ω. This then gives the current through the relay coil RL3 to be:

1.95 Ω / (1.95 Ω + 1.5 Ω) = 1.95 / 3.45 = 56.5%

If you check the calculations above and take all decimals into account you will actually see that these two calculations give exactly the same result, the factor between the numbers is exactly three and one third (3.333.....). That was what I meant with the fantastically well correspondance between the AVO Mk IV and the AVO CT160A here in this circuit!

Is this just a coincidence or something that AVO planned? My guess is that it is planned but the resistance for the resistors and RL3 will of course vary between each tester, but in the AVO CT160A service manual AVO says that these resistors will be "selected", which probably means that they are selected to work in each AVO CT160A tester being built. AVO stated the tolerances for these resistors to be +/-10% in the AVO Mk IV and +/-20% in the AVO CT160A.

AVO CT160 - anode current measurements, calibration resistors and the meter workings!

This text will endeavour to explain how the AVO CT160 works in certain areas, especially the Anode Current controls, the calibration resistors and the meter circuit. It will explain how to replace the rectifier valves with Silicon diodes, as AVO did in their later model, the CT160A; and also explain why there is a slight modification to the circuit as a consequence. It will also explain how you can improve the calibration, by making a further slight modification to the calibration circuit. It will also explain how you can place a Silicon diode in the Anode voltage circuit and a small modification that this entails. All of these modifications have actually been tried out on an AVO CT160 (Serial No. 4087 YF) and the modification do not change the results in any way; you get exactly the same results when comparisons to a standardised valve (a CV455) are made, both before and after the modifications were performed. There is also a short description of the function of R14 and SW3, which are used in the SET ZERO position on the mA/V dial. The protection of the meter is also discussed and a comparison with AVO's other Valve Characteristic Meters is made.

This text is a collaboration between me, Martin Forsberg, and my friend Euan MacKenzie, where I have written most of the text and Euan have made most of the measurements and all of the modifications in his AVO CT160. Euan has helped me with proof reading of the text and also supplied indepth information about components and mathematics.

It is quite long, but I really hope that you find it worthwhile to read through to the end!

There is more to come in the future with a look at the Dutch Military special edition of the AVO CT160 named AVO CT160A. The AVO CT160A might have been used by others too but it has been referenced to as the Dutch Military versions in a few places and I have found no other mentions of it.

Part 1: Anode Current Controls; and replacing the CV140 valves with Silicon diodes:-

In the AVO CT160 the anode current is measured by means of a Potentiometer, which is a laboratory instrument for the precision measurement of an unknown voltage. If you did Physics in the sixth form at school, you would have encountered the Potentiometer; in its simplest form it is comprised of a 1m length of Nichrome wire, alongside a 1m wooden ruler; driven by a 2V lead acid cell and calibrated using a galvanometer in series with Weston Standard cell, to detect the null. It is a common misconception that the CT160 is a Bridge; it is not, because a Bridge has four arms, whereas the Potentiometer only has three. In the CT160, the anode current flows through a 200Ω sensing resistor, the voltage drop produced across this resistor is then compared to a known voltage; which is developed in a separate circuit, comprised of a constant current flowing through nine switched resistors, R15 to 23, and one variable resistor, RV4; which are labelled the 'ANODE CURRENT' controls.

The anode current controls perform the same action as the backing-off controls do in the AVO Mk III and Mk IV, they effectively balance out the large standing anode current, which is flowing through the 200Ω resistor in the anode circuit. This makes it possible for the meter to show the small current change produced by the mA/V control, when the mA/V measurement is being performed. In the CT160, the anode current controls are designed in such a way that you have to read the anode current, which is flowing through the valve, on the scales provided on the controls, not on the meter. Whereas in the AVO Mk III and Mk IV, the backing off controls are not provided with any scales, and the anode current is indicated on the meter.

The anode current controls (or backing-off circuit) act as a power supply, which is designed to produce exactly one volt for each step from 0mA (0V) to 90mA (9V) on the rotary switch, or coarse anode current control; plus the variable 0mA (0V) - 10mA (1V) from the fine anode current control; (in fact, the maximum on the fine anode current control is actually 11.25mA, or 1.125V). Thus makes it possible to 'balance out' a maximum of 10.125V; which corresponds to an anode current of 101.25mA. The small extra voltage on the fine anode current control is intended to produce a small overlap on each range; since it is possible to turn the fine control past the 10 on the scale. This is provided so you can see if the current is slightly higher than the maximum on that current range, or if you should switch to a higher range. When the maximum (indicated) anode current of 100mA is being measured, in reality only 50mA is flowing through the 200 Ω anode current resistor; because the valve works as a half wave rectifier for the applied AC voltage to it. Now 50mA flowing through 200 Ω produces a voltage drop of 10V across the anode current sense resistor; which is then compared, using the Potentiometer, to the voltage produced by the anode current control circuit.

In the coarse anode current control, the voltage drop in each step of the rotary switch must equal exactly 1V; since each step has a resistance of 80 Ω, then there must be a constant current of 12.5mA flowing through the circuit. Now this value exceeds the manufacturer's maximum value of 9mA for the CV140/EB91/6AL5 valves, which AVO used for rectification in the CT160, and is likely to lead to a shortened service life. These particular valves were actually designed as FM detector diodes, not as current rectifiers!

As you will have no doubt noticed, the maximum available screen voltage in the CT160 is 300V; this is due to the valve manufacturer's PIV limit of 330V, (now referred to as Repetitive Reverse Maximum, RRM). Fitting suitable Silicon diodes will remove this limitation; so if you do wish to utilise a higher screen voltage, you could disconnect the 125V wire from the screen voltage selector switch; as this is the 'odd one out', in the sense that 125V is not available on the anode voltage selector switch. Then move the higher voltages back one tag on the screen switch wafer, and then connect the last tag to the 400V tap on the HT transformer. AVO marked the taps on their HT transformer with the 'mean voltage', so it is labelled as 'H400' (instead of using the customary rms value, ie 440V). The screen selector options will then be exactly the same as on the anode voltage selector.

As for suitable Silicon diodes; don't fit any old diodes that just happen to be lying in your scrap box; it is well worth fitting soft recovery diodes, which are designed to minimise circuit switching oscillations; for example Philips' BYW96E, which is rated at 3A and 1kV Vrrm. Admittedly, we don't require a forward current of 3A, however the lower current soft recovery diodes don't seem to have a sufficiently high enough Vrrm; 800V would be sufficient.

If you are going to replace the valves in the CT160 with Silicon diodes, you will have to alter the series resistance R6 (730 Ω according to the legend, but in reality 750 Ω was used) which is used to obtain the correct current flowing through the anode current controls, so that the voltage across each 80Ω resistor will still be exactly 1V. If you place a standard Silicon diode in place of each valve diode (remember the CV140 is a double diode, so one Silicon diode will be needed for each diode) then you will have to increase the series resistor, R6, to approximately 935 Ω, in the anode control circuit. The calculation for this is as follows:- the anode current control circuit is supplied from a transformer winding of 50V rms; which is equivalent to a mean voltage of 45.02V; (the ratio between rms and mean voltages being 1.1107 for a sinusoidal waveform; which gives us 50V RMS ÷1.1107 = 45.02V Mean). Now the approximate forward voltage drop for a Silicon diode is 0.7V; however for a CV140 it is 2.2V (as measured at the manufacturer's maximum current of 9mA); so the value of R6 must be increased.

The anode current control circuit requires an exact current of 12.5mA (derived from the 1V volt drop across each 80Ω resistor, 1V ÷ 80Ω = 0.0125A or 12.5mA). After rectification by the Silicon diode, you then have a voltage of 45.02V ÷ 2 - 0.7V = 21.81V DC mean. (The 45.02V has to be divided by 2, because it is a half wave rectifier; the mean voltage following half-wave rectification is obviously halved, and the figure of 0.7 Volt comes from the forward voltage drop of the Silicon diode).

The total resistance in the circuit will then have to be 21.81V ÷ 12.5mA = 1744.8Ω; from this we must subtract the existing resistors in the anode control circuit = 9 x 80Ω + 90Ω = 810Ω; thus the new value of R6 = 1744.8 - 810 = 934.8Ω. You could, if you prefer, use a small variable resistor in series with a larger resistor, so that you can adjust the mean current to precisely 12.5mA. Alternatively, you might choose to use a combination of resistors, either in parallel, eg 1.1k // 6.2k; or in series, eg 910Ω + 24Ω, to adjust the total current.

If you wanted to measure the current, you could insert a current meter in series with the circuit, but you would then have to adjust the circuit for the additional resistance introduced by your current meter, as it will also produce a voltage drop. It is therefore easier to measure the voltage drop across each resistor with a digital multimeter, as that will have a high input resistance, typically 10MΩ, which will not affect the circuit as much as the current measurement would do – quite apart from that, you do not need break the circuit for voltage measurements!

This also means that if you need to replace the 90Ω anode current potentiometer, with another value, say 100Ω (since 90Ω will be hard to find nowadays) you can do that, but then you will need to reduce the series resistor, R6, by the additional resistance in the new potentiometer, in order to keep the current at 12.5mA through the backing-off circuit; in this example, by 10Ω. However you will need to make a new scale for the anode current potentiometer, and you will get a larger overlap on each range, but it will still give the correct measurements for anode current. The practical minimum value will be close to 90Ω, as it was originally. If for any reason, you need to go lower than 80Ω, then you will have to lower each 80Ω resistor, and increase the current, to maintain exactly 1V. A typical reason for replacing it would be that the old one is open circuit, or perhaps has become non-linear, due to wear, or is otherwise damaged. Making a new scale is quite easy if you use a 360° protractor, together with a multimeter to measure out each step of either 0.1V, or 8Ω, and mark them on the protractor, then transferring them to a paper scale. Or, alternatively, you can drill a hole through the centre of a fairly large protractor, or a piece of PCB, then fasten the potentiometer in the hole and using a large knob on the potentiometer, and as you turn it, mark each point on the protractor/pcb, which you can then transfer to a paper scale.

NB:- There is one case that has not been checked thoroughly so far, and that is whether the gm measurements will be affected, if the potentiometer is changed to any value other than 90Ω! There is only a slight risk of that, since each of the three 240Ω resistors, R24 to R26, are used to compensate for the anode current control resistances - this should be investigated further, before I can recommend changing the potentiometer for another value; but my guess is that the change doesn't matter, as it is the voltage delivered between the two points that form the backing-off circuit, is what the measurement is compared with, and since that is unchanged, so then is the current and resistance in that circuit path.

However, there also the possibility to put a potentiometer with a higher value in, and then shorting out the last part of the track above 90Ω, and then make a new scale to fit the new potentiometer; then this will work just as well as the old one, except that the new scale will be more cramped!

For the anode current control measurements to be accurate, you must ensure that the remainder of the components in the AVO CT160 are within tolerance, and also that the tester is calibrated; however for the anode current controls in themselves to be accurate, you must ensure that a voltage of 1V Mean DC is developed across each of the 80Ω resistors.

The other diodes in the CV140 valves, V1 & V2, can also be replaced with Silicon diodes, and fortunately the value used for the SET Vg potentiometer, RV3, is large enough so that nothing needs to be changed or added there. Each rectifier in the CV140 has a forward voltage drop of approximately 2.2 - 2.9 V, at the currents involved (which range from close to 11mA, to up to 14mA, through each diode), whereas a Silicon diode has close to 0.7V at these currents. The difference between these voltage drops will be taken up by RV3 as it has enough resistance for this adjustment.

A quick calculation of this follows:- 55V RMS is equivalent to 55 ÷ 1.1107 = 49.52V Mean, which half wave rectified, becomes 49.52 ÷ 2 = 24.76V Mean DC.

For SET Vg calibration purposes, AVO state in their calibration procedure that a voltage of 20.8V Mean DC should be present across the Grid Volts control, RV2; this then means that the diode in the CV140 plus the SET Vg potentiometer has a total voltage drop given by 24.76V - 20.8V = 3.96V Mean DC. If we replace the CV140 diode with a Silicon diode, with a forward voltage drop of 0.7V, that leaves 3.96V - 0.7V = 3.26V mean DC to be accommodated by the RV3 potentiometer. The current through this circuit is 20.8V ÷ 1937.9Ω = 10.733mA (the total resistance of the grid voltage control circuit is 1937.9Ω - I leave that as a calculation exercise for you to perform by yourself! (Or you can cheat, and look at the appendix at the end of this message!). This voltage drop and current through the circuit then necessitate a resistance for RV3 of approximately 304Ω, which is well inside the 500Ω value of RV3.

Part 2: Gm measurements, resistor R14 and switch SW3 on the mA/V control:-

When the mA/V control is in its resting position, the mA/V potentiometer, RV1, is turned to a position where the wiper (which is connected to common ground) is connecting the positive side of the negative grid voltage supply to the common ground (and at the same time shorting R5). This is done so that the extra voltage from the mA/V control, which is added during the gm measurements, will be zero when the large standing Anode current is balanced out; which in itself, is a necessary prerequisite for the gm measurements to be performed.

When the large standing current has been balanced out by the Anode Current controls, (or backed-off) the gm measurement can commence. When the mA/V dial is in its resting position, ie turned fully anti-clockwise by the spring mechanism, the switch SW3 is closed and R14 is shorted. When the mA/V dial is moved to the 'SET ZERO' region, the switch SW3 is opened, and the resistor R14, 22 kΩ, is inserted in the Anode Current circuit; this results in a very small voltage drop from the current then flowing through the circuit, usually below 1µA. For example, a current of 1µA will result in a maximum voltage drop of 22mV, which corresponds to a standing Anode current of 0.22mA. If the balancing out of the Anode Current controls has been exact, then no current will flow. However, if this is not the case, any residual current flowing in the circuit can now be balanced out by fine adjustment of the Anode Current control, thus enabling the balancing out procedure to be more precise. This will ensure that when the gm measurement is performed, when the mA/V dial is turned into the gm measurement zone, the measurement will be more exact. You will also be able to get a more precise measurement from the Anode Current controls, after this fine adjustment have been performed.

This fine adjustment procedure in no way effects the large standing current flowing through the valve during the testing, as the large Anode current is still flowing, as long as the tester is in the 'TEST' position; as only in this position the Anode voltage is applied to the valve under test. So releasing the dial and letting it go back to the resting position still leaves the large standing Anode current flowing through the valve; the only difference in the position of the mA/V dial, is how much the grid voltage is changed, from zero to 0.260mV - this is the extra voltage necessary for the gm measurement to be performed.

Part 3: Calibration resistors:

To make sure that it is possible to calibrate the CT160 (and this also applies to the AVO Mk III and Mk IV) you will need to ensure that all the components are within the tolerance levels that AVO specified; not only the calibration resistors, but it is obviously worthless to have the correct value for the calibration resistors, if the rest of the tester is not within tolerance (especially the meter, anode current controls and 200Ω resistor in the anode circuit).

The calibration resistors in all of the AVO CT160, Mk III and Mk IV family are equally important as they provide the same function in all of these testers - letting a predetermined current flow through the meter; so the meter needle indicates either on, or very close to, the red 'SET ~ ' line on the meter scale. This will ensure that the setting for the transformer primary (and therefore the secondary) voltage is correct, so that all the subsequent measurement will also be correct. In addition, the leakage and insulation tests also rely on this current through the calibration resistors.

In the AVO CT160, and also the Mk III and Mk IV, the same current is supposed to flow through the meter at the centre of the SET ~ calibration region on the meter scale. The centre of this area is usually marked by a red line, which is aligned with the 90mA line, or 90% of FSD.

However on some meters this red colour may have faded completely, so you have to use either the centre of the black area as a reference, or use the 90mA line. Alternatively, you could test your meter to check that it is giving the correct deflection, compared to the scale; then you can mark your own point on the scale where the needle shows 90% of FSD.

What is it we really we wish to accomplish with the calibration resistorsΩ The important thing to understand is that the calibration resistors are not part of the actual measurement done on the valve in the TEST or GAS positions, only in the other leakage and insulation tests. The calibration resistors are not only there to give you a reading that tells you that your tester is still in working order, compared to the last time it was calibrated, and that you have chosen the correct mains voltage setting (for the measurement that you intend to perform) but also to deliver a current that is used for other measurement purposes! Measurements may be performed when the needle is within the black area of the SET ~ region, but it should be close to the red line in the centre for the ‘best’ correlation to the calibration performed previously. However the current through the calibration resistors is also used to perform the insulation and leakage tests; so in order for these to give the correct results, the calibration current must also be correct.

The valve, V1(B), is supplied by the voltage from the 55Vrms winding; as that voltage is in phase with the Anode and Screen voltage, and the valve under test itself acts as a rectifier in the AVO CT160, and in the Mk III. (However, in the AVO Mk IV, the Anode voltage is already rectified by a silicon diode). The voltage from the 66V rms winding is only used to keep the grid negative, during the half cycle where the anode of the valve is driven negative by the AC Anode voltage, and is not used for any measurement purposes in the TEST and GAS positions. According to the AVO Patent No. 606707, this is to ensure that no current is drawn through the diode formed by the grid and cathode, when no anode current is flowing, which could damage the valve’s emission.

This means that it is very important to make sure that the Anode and Screen voltages are correct, by means of the SET ~, and then set the grid voltage correctly via RV3. The additional voltage from the 66V RMS winding means that there are two voltages that need to be correct on the transformer, for the needle to read the calibration region. This then works as an extra measure to ensure that the transformer voltages are correct. Since the 66Vrms winding is part of the Anode/Screen voltage windings, you have thus ensured that they are also correct (apart from a possibility of open circuit somewhere else in the transformer). In the AVO Mk III and Mk IV, the additional voltage is also taken from the Anode/Screen volts windings, so you have the same function there.

In the AVO Mk III and Mk IV, you have an extra potentiometer in the SET ~ calibration circuit, which means that you can adjust the deflection of the needle when you have made quite sure that the grid voltage control and Anode & Screen voltages are correct. However in the AVO CT160 you do not have such a potentiometer; so it is even more important here that you have checked that the Anode, Screen and Grid control voltages are correct, (apart from all the other components of course), otherwise you will not get the correct reading on the meter.

All this means that you need the calibration resistors for two purposes, one is to ensure that the voltage settings are correct, so that the Anode, Screen and Grid voltage controls will deliver the correct voltages in the TEST and GAS positions, and also to ensure that the current at the other measurement positions is correct.

This dual purpose means that you need these calibration resistors to have the correct resistance for the measurements to be correct.

There is really only one value of these calibration resistors that will work, as you need the correct current through the meter. By performing the calculation backwards, and comparing the result with the AVO CT160 Service Manual, it will hopefully give you an understanding of the necessity for the required resistance in the calibration resistors.

Let us first check the calculations, with the values given by AVO for their calibration resistors. The meter resistance is 3,250Ω (nominally) and the meter shunt, R9, is a resistor of 10kΩ; these are connected in parallel and have a total resistance of 2452.8Ω. The current through the meter, when the needle is aligned with the calibration mark at 90% of FSD, corresponds to 27µA. This current of 27µA passing through the resistance of the meter causes a voltage drop of 87.75mV (3,250Ω x 27µA = 87.75mV). This means that the current flowing through the meter shunt, R9, is 8.775µA (87.75mV ÷ 10kΩ = 8.775µA). The total current flowing through the meter circuit is therefore 35.775µA (27µA + 8.755µA) at the red line. This current will require a voltage 47.223 volts across the calibration resistors R3 & R4 (35.775µA x 1.32MΩ = 47.223V); add this to the voltage drop across the meter, 87.75mV and you therefore require a total voltage of 47.3108V. In the calibration part of the AVO CT160 Service manual, AVO simply state that, with the Grid voltage link connected, you should have 47V DC across the grid volts potentiometer; which is exactly the same as taking the measurement across the calibration resistors and meter, since they are connected in parallel. So we did the calculation correctly, only backwards and arrived at the correct voltage drop; although AVO did not stipulate any decimal places here, but 47.3V is the correct voltage from the calculations. NB: it is another common misconception with the CT160, that R3 & R4 comprise a matched pair of 1.32MΩ resistors; what AVO meant was that the values of R3 & R4 should be matched, so as to give an overall resistance of 1.32MΩ.

NOTE: There is no reason why a Silicon diode could not also be placed in the Anode voltage circuit, somewhere after the Anode voltage selector switch. This is exactly what was done by AVO in their Mk IV; the circuits are more or less identical in every other aspect. Two minor points though, firstly it is difficult to access the anode voltage selector switch, (without having to remove a lot of the mechanical structure) so the easiest place to fit the diode is at one of the tags for the anode current relay coil, RL3. It is the middle row of the six tags, and the anode coil has a much lower resistance than the two other coils, between 5 and 6Ω. Secondly, as AVO discovered, it is necessary to fit a 100kΩ resistor to earth, after the diode; in order to avoid any spurious voltage readings; presumably due to charge stored in the reverse capacitance of the diode.

In the AVO Mk III and Mk IV there is an extra potentiometer for adjustment of the SET ~ current, so it is possible to put the needle exactly on the red centre line of the SET ~ region. While I did the calculations for the AVO CT160, I realised that it would be beneficial, if you were to put such a potentiometer in the CT160’s 66V rms circuit too; as it would then give you the same means of adjustment that is available in the AVO Mk III and Mk IV (the Mk III is more or less the same tester as the CT160, apart from some minor differences in both electrical and mechanical design). Without this potentiometer in the 66Vrms circuit, there is inevitably a compromise between the negative Grid voltage calibration and the calibration of the SET ~, and their combined current through the meter at that point. This will become more evident, if you use Silicon diodes, instead of CV140s; since the difference in their forward voltage drops then becomes more apparent. In the CV140/6AL5/EB91 valves, the forward voltage is more dependent on the current flowing through the valve (particularly as AVO were using the valves beyond their recommended current range!) than the forward voltage drop of a Silicon diode, which is relatively constant in these circumstances. The forward voltage drop curve is flatter for the valve than for the Silicon diode, so it varies more when the current through the diodes is varied. I have seen two AVO CT160s which have been modified with a Silicon diode in the Anode circuit, and the owners have not reported any adverse effect; although they had not done the modifications themselves and had no information as to by whom, or when, the modification had been done. I have never seen any modification for the 66Vrms winding, but my calculations and the fact that AVO used it on their other Valve Characteristic Meters show that it is a modification worth doing, and calculations show that it will give a better calibration result, and it will also make the calibration easier to perform, without having to go back and forth between the different steps.

But remember, the most important thing is that the voltages are correct on the secondary side of the transformers; only after that should any modifications to the calibration circuit be performed!

Part 4: the Meter:

For the meter to give correct readings, the movement must have the correct resistance of 3,250Ω, which includes the internal swamp resistor. In addition, it also needs to have the correct deflection at two particular points, namely 22.2µA and 27µA. Obviously it needs to give the correct reading across the whole scale, but those points are used during calibration of the meter and tester. The 22.2µA point corresponds to the 1mA/V mark on the green scale, and the 27µA point is the red centre line of the SET~ region.

If you can, I recommend that you remove the meter and test it, to check that the FSD is correct, and that it gives correct readings right across the scale. Quite often, these meters are known to have lost some of the flux in the magnets over the years, so that they no longer give the correct readings. The only company that I know of that can re-magnetise the meter is Herts Meter Co Ltd., Unit 10, Berry Road, Hatfield, England AL10 8BJ, but of course, there may be other companies around.

Alternatively, if you are competent and confident enough to tackle it yourself, you can fit a pair of the modern Neodymium (one of the rare earth series of elements) disc magnets, (the ones Euan used were 10Ø x 3mm thick, but smaller diameters would be just as suitable, it’s the thickness that is the more critical parameter) on the outside of the existing ferromagnetic poles. Fortunately, it is easy to determine the correct polarity, set up a mid scale deflection on the meter with a suitable external circuit, eg a 1MΩ resistor in series with a variable transistor power supply; then with a very firm grip on the disc magnet, slowly approach the pole piece. If the indicated current rises, it’s the correct pole; if it falls, then it’s the wrong pole. Final trimming, to give the exact FSD value of 30µA, is done via the magnetic shunt, which is located under the RHS needle stop. It is a hinged plated steel arm, which is mounted on a neoprene bush; it ‘shorts out’ some of the magnetic flux across the pole gap. It is, or it should be, cemented to the existing ferromagnet; you will need to break the cement, in order to adjust the shunt, and then re-cement it when the adjustment is correct.

If you need to change your meter, for example, if the moving coil is burnt out, you will have to ensure that you find a 30µA meter with an internal resistance lower than the stipulated 3,250Ω, so that you have some leeway to correct it upwards; AVO state below 1,600Ω in their Service manual, but I have never found one below 2,400Ω in of all of those that I have tested. If you have to replace the meter with one which has some other value of current and internal resistance, then you will need to recalculate all of the resistors in the measuring circuits in order to get it to work correctly; that is too much work to do here. However, I have been given such a schematic of an AVO Mk III, which I will come back to in the future, after I have checked it thoroughly. Another method is to install an OP-AMP meter amplifier and a new meter movement. If all resistors need to be recalculated in the measuring circuit the total resistance in the measuring circuit will be altered and that will make differences to the measurements as it then necessitates a change of the Anode measuring resistor resistance and the whole Valve tester will now have an altered internal resistance from the view of the valve.

There is also a superb webpage which shows you how to put a small magnet on the meter magnet to help it to get back to the correct flux so it will have the correct deflection again, on Mr. Yutaka Matsuzaka's website here: http://www6.wind.ne.jp/yutak/avo_ct160/mk4-2.htm , Mr. Yutaka's main site can be found here: http://www6.wind.ne.jp/yutak/avo_ct160/index.htm . There is a lot of other interesting information on calibration of the AVO CT160 there too. The elusive AVO CT160A (which does incorporate Silicon diodes and also has an additional switch, which doubles the Grid voltage range) is shown in some small detail there! If you use Google Translate, you can read most of the information on Mr. Yutaka's webpage translated into English, for instance.

I have included a PDF-file for making meter movement measurements of the CT160 30µA FSD moving coil meter, the schematic shows a simple means of measuring the FSD and the internal resistance of the meter. Before you make any measurements in this circuit, you should short the two connections where the CT160 meter will be tested, so you can set the maximum current in the circuit with the DMM/AVO connected in series with the circuit. This will protect the CT160 meter from overload if you have set the potentiometers too low, which could result in a too high current flowing through the circuit, possibly destroying the CT160 meter.

The meter FSD can be checked with the switch SW1 in the open position and the internal resistance of the meter can be checked with switch SW1 closed. This is done by first having switch SW1 open and setting the FSD of the meter and then by closing SW1 and adjusting the potentiometer across the meter until the meter shows 50% of FSD with the needle pointing straight up, then open switch SW1 again and measure the resistance of the potentiometer, which will correspond exactly to the internal resistance of the meter. This will give you the exact figure for the internal resistance, since the meter and potentiometer work as a current splitter, letting exactly 50% of the current flow through each branch, which Ohm's law dictates that the resistances must be the same, as the voltage drop across the resistance and meter is the same when they are connected in parallel.

When you are going to make the measurements on the AVO CT160 meter, I recommend that you use a small 1.2V NiMH battery, a few 1% resistors and three potentiometers (preferably 10 turn models for easier adjustment), one switch, plus a DMM (or an AVO 8) and some cables with crocodile clips for a quick hook-up of all components to check the meter movement.

The meter in the AVO CT160 has a total internal resistance of approximately 3250Ω. So to protect the meter from overload, by a too high current, you will need to have a total resistance in the measuring circuit that will only allow a maximum current close to 30µA to be drawn. With a standard 1.2V NiMH that means a total resistance of 40kΩ; when the meter resistance is subtracted that leaves 36,750Ω. With the following resistors in series, R1 at 18kΩ, plus R2 at 15kΩ, plus a trim-potentiometer, RV1, with a resistance of 10kΩ you can vary the resistance from 33kΩ up to 43 kΩ, which means that the current can be varied from 26µA to 33µA. Then you put another 10 kΩ 10 turn potentiometer in series with this, so that you can make fine adjustments to the current through the meter to check the FSD value. It is best to use a trim potentiometer for RV1 so you don't accidentally change the current to a too high a value, and use regular 10-turn potentiometers for RV2 & RV3. If you wish, you could use a locking nut on these, adjusted so that there is just sufficient friction to prevent any accidental rotation, when you let go of the shaft.

Now you should short the points where the CT160 meter will be connected later, and set both of the 10 kΩ 10 turn potentiometers to their minimum values and connect the DMM in the position shown in the schematic. Set the DMM to its minimum current range (which is usually 200µA) then adjust RV1, the first 10 kΩ 10 turn potentiometer, so that the current is 32µA. Now try RV2, the second 10 kΩ 10 turn potentiometer, to see that you can vary the current below 30µA, and then leave it in a position below 30µA. If this works ok you can remove the short and install the CT160 meter, note which connection should go to the electrode closest to the battery, the positive one, and which should go to the DMM side of the connection, the negative one.

By adjusting the second 10 kΩ 10 turn potentiometer and looking at the meter you can adjust the FSD point and then check the DMM/AVO for the current drawn.

If you can't obtain FSD with RV1 set at 32µA, then you will need to adjust your meter; either by having it sent to a professional company to be re-magnetised, or by trying to add extra magnets as is described earlier.

Part 5: Meter protection:

Since the circuit of the AVO CT160 is more or less the same as the AVO Mk III and not very different from the later AVO Mk IV, it is possible to protect the meter by the same means used in these other AVO testers. You can fit the exactly the same circuit, as used by AVO in the Mk IV, to protect the meter somewhat, without affecting the readings in any way. You will have to use Silicon diodes across the meter, not Germanium diodes, as those have a too low voltage drop, which will affect the meter reading, making it non-linear. As in the AVO Mk IV, you fit two Silicon diodes, one in each direction, across the meter and also a non-polarised capacitor. With AVO's microammeter removed, a measured current of '100mA' was set up in the anode circuit (a 4kΩ load on '400V') and both ANODE CURRENT CONTROLS were deliberately left on zero. With the protection circuit installed, using a DMM, the maximum measured voltage across the meter terminals was 0.27V; with the DMM set to current instead, the corresponding current through the meter was 86µA. However, without the protection diodes, the maximum voltage was 3.03V, and the current was 0.30mA; a ten times overload.

You can use an 8µF capacitor, preferably a polypropylene type, or failing that, a non-polarised electrolytic; just be sure to use a good long life model with very low leakage. AVO originally used a small 8µF 12V electrolytic; this is not recommended, as there is insufficient polarising voltage, so they rapidly become leaky. Note: there is nothing magic about the value of 8µF, just remember it was a standard value in the industry at the time. The time constant is 3,250Ω//10kΩ x 8µF = 20ms; so using a modern 10µF will not make any discernible difference. The diodes can be the same Silicon diodes as used elsewhere in this document, such as the BYW96E, as these will work just as well here.

There have been some suggestions that Silicon diodes do not work in the CT160 meter circuit; additionally it has also been alleged that using these diodes upsets the measurements. I can assure you that there is no problem in making these modifications to either an AVO Mk III or the AVO CT160, which are more or less the same construction. Both I, and many other people, have tried this modification and it has been successfully used for many years, without causing any discernible reduction in the meter reading. AVO themselves made these modifications to their later models of the Mk IV and also the VCM163. Admittedly the early models of the Mk IV did not have this meter protection, the circuit then only shows one Silicon diode in one direction and no capacitor across the meter either. However they introduced the capacitor modification in April 1960, and the two diodes across the meter in October 1960 (see the AVO Mk IV Service Manual, p38).

Part 6: What to do when FSD current is not 30µA or the needle "sticks" on the AVO meter:

If you are unlucky and have a meter that does not have an FSD current that is 30µA, either lower or higher or your needle "sticks" at certain points while moving over the scale you need to have that meter serviced before you do any calibration or use your tester. It is very common that the meter needs a higher current at the FSD point and across the whole scale and this is due to that the magnet has lost some magnetic flux over the years. If your meter needs a higher current or "sticks" you can send it to the only company that I know of that can re-magnetise the meter which is Herts Meter Co Ltd., Unit 10, Berry Road, Hatfield, England AL10 8BJ, but of course, there may be other companies around. Herts Meter Co Ltd. Will also clean your meter, fix the balance and the needle/jewel bearings and treat the glass with antistatic spray and also re-glue the glass if necessary. A meter that has been refurbished by Herts Meter Co Ltd. is like new when you have it back from them.

There is some information on the Internet which says that there are two types of meters in the AVO Valve Testers, one at 30µA FSD and one at 33µA and with different internal resistance than the stated 3,250Ω. To the best of my knowledge and from what I have been told by people who have either been employed at companies who serviced AVO Valve Testers or by people who were employed by AVO themselves there was only one FSD and that was at 30µA, all other meters are broken or damaged meters and they probably suffer from a weakened magnet. One more piece of information that speaks against the idea that there are two different meters is that there have not been any modifications done to the AVO Valve Testers to accommodate such a meter in the test circuit, it would have been necessary to correct the shunt resistor and the rest of the circuit to get a correct reading. A meter that shows the symptoms of a higher FSD current is most probably suffering from a weakened magnet and needs to be re-magnetised.

If your meter for some reason needs a lower FSD current it is most probably suffering from a wrong adjustment of the magnetic shunt arm inside the meter, or it could have been stored in a place where the meter has been exposed to a powerful magnetic field which have affected the magnet although this is not such a probable cause. In this case it is also better to send the meter to Herts Meter Co Ltd than to fiddle around with it yourself as they are so easily damaged. The magnetic shunt arm is situated on the magnet and looks like an L letter and is usually glued to the magnet and screwed tight on the left pillar holding the screw with the scale. You need to open the meter, remove the scale (while not bending the needle which might break it off from the moving coil if you are not very careful while removing it). You will then have to loosen the magnetic shunt from the glue and at the same time make sure that you do not get any of the glue residue inside the meter as it will disturb the movement of the moving coil. Moving the magnetic shunt up and down a miniscule amount will adjust the magnetic flux in the magnet circuit and that will result in a higher or lower FSD current necessary for the moving coil to reach the FSD point. But you might have a meter that has a too strong magnet anyway and this might not be enough to get the correct reading so I still recommend you to have the meter sent to Herts Meter Co Ltd. for a proper adjustment and refurbishing.

The internal resistance of the AVO meters also differ between different meters, I myself have seen the internal resistance of the meter ranging from 3,180Ω up to 3,304Ω but when these meters where shunted with the internal shunt of the corresponding AVO Valve Tester where they came from the total resistance was very close to the necessary resistance of 2,453Ω (3,250Ω in parallel with the shunt at 10,000Ω is 2,452.83Ω). It then looks like AVO selected the shunt resistance to match each meter instead of correcting the internal resistance of the meter as long as the meter had the correct FSD current at 30µA. This is only an observation I have made and not something that I could verify with the sources I have been in contact with.

So as long as your meter has an internal resistance somewhere between 3,000Ω and 3,500Ω and an FSD current at 30µA and does not stick while moving along the scale you should be able to adjust the shunt resistor accordingly to have the meter work as designed in your tester. Adjusting the shunt resistor is simple, only use the rule for resistors in parallel connection to calculate the new shunt resistor. Use the wanted internal resistance of 2, 452.83Ω and your meter internal resistance to calculate the new shunt resistor value. An example, lets say your meter has an internal resistance of 3,180Ω, then the new shunt resistor should have a resistance of: Rshunt = 1 ÷ (1 ÷ 2,452.83Ω – 1 ÷ 3,180Ω) = 10,726.5Ω. The shunt resistor makes sure that exactly 39.75µA is flowing through the meter and shunt resistor which is necessary for the metering circuit to work properly.

NOTE: Never ever adjust the resistors inside the AVO Valve tester around the metering circuit if you are not absolutely sure of what you are doing! Changing one value will almost always affect all other values for all other ranges. Never change the Anode circuit measuring resistor at 200Ω as that affects all of the resistors on all ranges as that resistor is the resistor used for measurement purposes.

Appendix:

The calculation of the total resistance of the Grid voltage and mA/V control circuit:

The meter has a total (internal) resistance of 3,250Ω, which is in parallel with the shunt resistor; R9 (which has a resistance of 10kΩ) results in a total resistance of 2,452.8Ω. The two calibration resistors have a combined resistance of 1.32 MΩ, add these together and you have a total resistance of 1,322,453Ω in this leg.

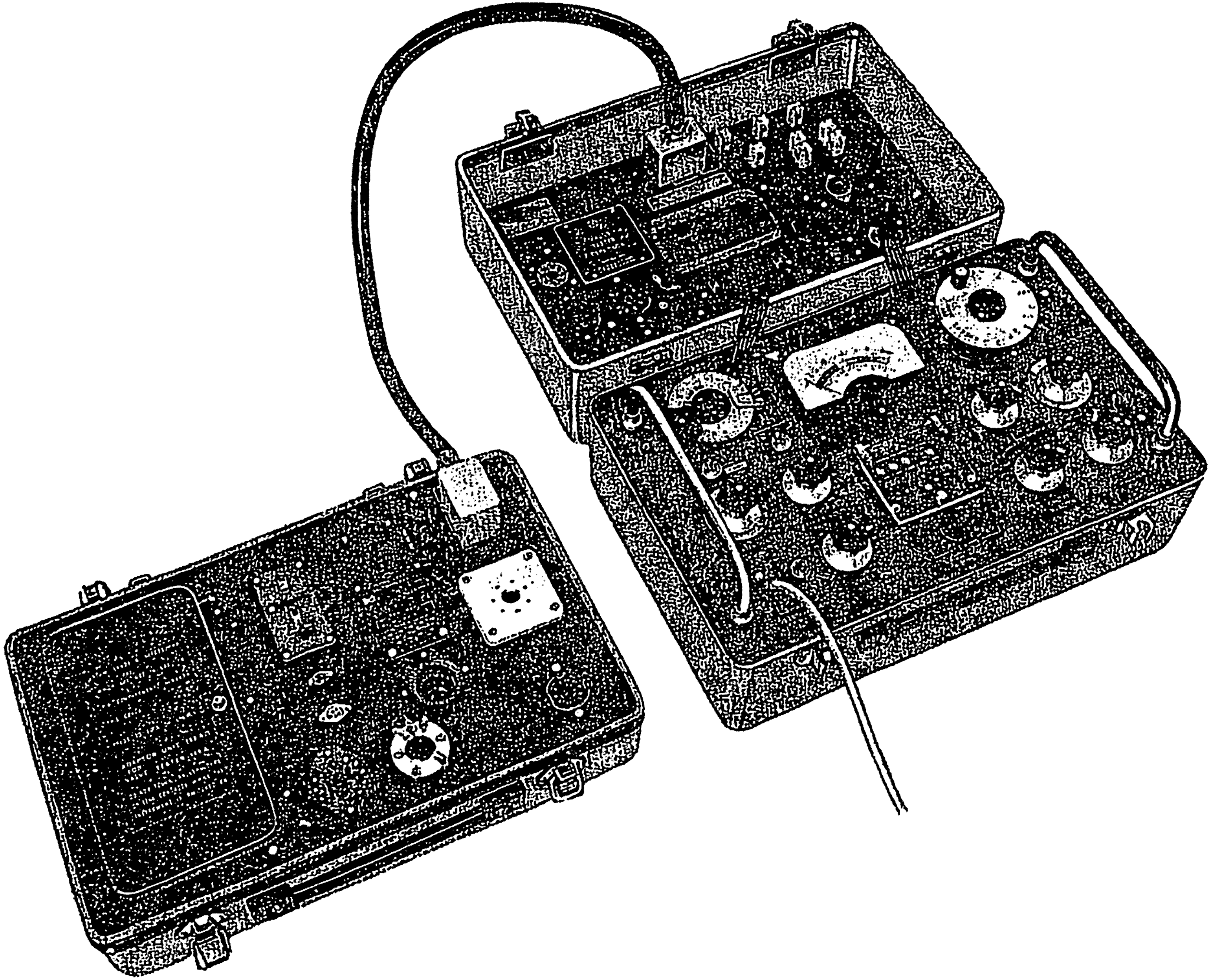
The other leg of the circuit has the mA/V control, which has a total resistance of 70Ω, in parallel with RV1, 2,500Ω; plus the 2,340Ω in series, which equal 2408.1Ω. This resistance is in parallel with the Grid volts potentiometer, RV2, which has a resistance of 10kΩ (which incidentally is a special law, not 'log'); this makes the total resistance of 1940.75 Ohm for this leg of the circuit. When you put this leg in parallel with the other leg, 1.322MΩ, you get a total resistance of 1937.9Ω, Q.E.D.

AVO
VALVE TESTER Type 160A
AND
ADAPTOR UNIT Type 160A/1

OPERATING INSTRUCTIONS, VALVE DATA AND MAINTENANCE MANUAL

AVO Ltd

AVOCET HOUSE, DOVER, KENT, ENGLAND.



THE "AVO" VALVE TESTER TYPE 160A and ADAPTOR UNIT TYPE 160A/1

THE "AVO" VALVE TESTER TYPE 160

CONTENTS

Page

CHAPTER 1. TECHNICAL DESCRIPTION

CHAPTER 2. THE VALVE PANEL AND CONTROL UNIT

CHAPTER 3. OPERATING INSTRUCTIONS AND GENERAL PROCEDURE FOR TESTING A VALVE

CHAPTER 1

TECHNICAL DESCRIPTION

Introduction

1. Whilst good/bad testing on a semi-production basis will undoubtedly be the major use for this tester, it is certain that the instrument will find considerable use in laboratories and service departments where engineers and skilled personnel will be available, and where more precise details of valve performance can be used to advantage. To this end, additional facilities on the tester, enable Ia/Va, Ia/Vs and Ia/Vg characteristics to be plotted over a wide range of voltages, these being readily available from the calibrated panel controls.

Principles of Operation

2. The tester is basically designed to check the valve according to its static characteristics which would normally require the provision of the requisite range of variable DC supplies. The difficulty lies in the regulation problems involved in the supply of the wide range of DC anode and screen voltages, on which the loading might vary from a fraction of a mA to over 100 mA, dependent on the type of valve being tested, and the nature of the test being performed. Such a requirement could of course be met by the provision of a number of regulated power supplies, which would render the instrument cumbersome and expensive, whilst a large amount of metering, would not only mean additional expense, but also make the instrument difficult to use, and would not entirely overcome the problem.

3. It can be shown, however, that if alternating electrode voltages are applied in their correct proportions, an amplifying valve can (by virtue of its property of self rectification) be caused to give DC anode and screen currents which for all practical purposes bear a constant relationship to those obtained from its DC static characteristics.

4. This immediately simplifies the problems of power supply to the valve under test. The design of transformers to give negligible regulation errors over the range of secondary currents involved is comparatively simple, whilst the range of electrode voltages may be simply provided by a predetermined secondary tappings selected by calibrated switches, thus minimising to a very large extent problems of size, weight and cost, and eliminating the necessity for separate metering.

5. A slight difficulty occurs in the supply of the variable negative grid bias voltage, which would normally consist of an alternating voltage of suitable magnitude applied in anti-phase to the anode voltage. Since rectification occurs at the anode (and screen) and the grid should pass no current it will be readily seen that during the half cycle where the anode and screen are passing no current, a positive half cycle of considerable magnitude is applied to the grid with the result that the latter can pass damaging current and in certain circuit conditions phase changes can occur that disturb the 180° relationship between the anode and grid voltages during the operative half cycle.

6. Since no current is taken from the grid voltage supply however, and the voltages involved are not very high, the inclusion of a simple half wave rectifier without smoothing between the transformer winding and the variable grid volts supply will suppress the positive half cycle whilst still maintaining the sinusoidal form of the operative negative half cycle.

7. Using the simple expression for the anode current of a triode $Ia = \frac{K}{Ra}(Ea + \mu Eg)$ and transforming this for ac operation on the positive half cycle of applied anode volts we have:—

$$Ia\ (mean) = \frac{K}{Ra} \cdot \frac{\omega}{\pi} \left\{ \int_{\omega t = 0}^{\omega t = \pi} Ea \sin \omega t + \mu \int_{\omega t = 0}^{\omega t = \pi} Eg \sin \omega t \right\}$$

8. Deriving this in terms of rms applied voltages and remembering that anode current flows only on the positive half cycle and will be read on a mean reading dc meter, we have:—

$$Ia\ (mean) = \frac{K}{2Ra} \left\{ Ea^{(RMS)} \times \frac{1}{1.1} + \mu Eg^{(DC)} \times 2 \right\}$$

Eg (dc) is the applied half sine wave dc as read on a mean reading dc voltmeter, K being a constant. The above relation holds equally well for screen grid or pentode valves which would follow the general form

$$Ia = f\left\{ Ea + \mu_1 ({}^{s}/_{g})\, Es + \mu_2 ({}^{a}/_{g})\, Ea \right\}$$

9. Thus with an applied rms anode (and or screen) voltage equal to 1·1 × Va (dc) and a mean value of half wave rectified bias voltage equal to 0·5 × Vg (dc) then the valve will read a mean dc anode current equal to one half of the dc anode current taken from the static characteristics if Va (dc) and Vg (dc) were the applied dc test volts. This relationship holds for all practical purposes over the full characteristic and is the basis of operation of the VT160 enabling accurate testing of valves, at any point on their characteristic, with simple and small apparatus. This accuracy is just as necessary on the simple " go "/" no go " type of instrument as on a complete characteristic meter, as it may be necessary to set the test point anywhere on the characteristic to correspond to required working conditions. Further in the absence of any printed or predetermined test figure, it must be possible to determine test conditions directly from manufacturers' published curves or data.

Basic Circuitry

10. The principles of operation of the main function of the tester—the comparative testing of mutual conductance—lie in the application of anode, screen, grid and heater voltages corresponding to the working point of the valve and backing off to zero the standing anode current thus obtained. A small incremental bias is applied to the valve and the change in anode current thus obtained is a measure of the mutual conductance of the valve. The figure is then compared with the correct mutual conductance to give comparative goodness on a coloured scale.

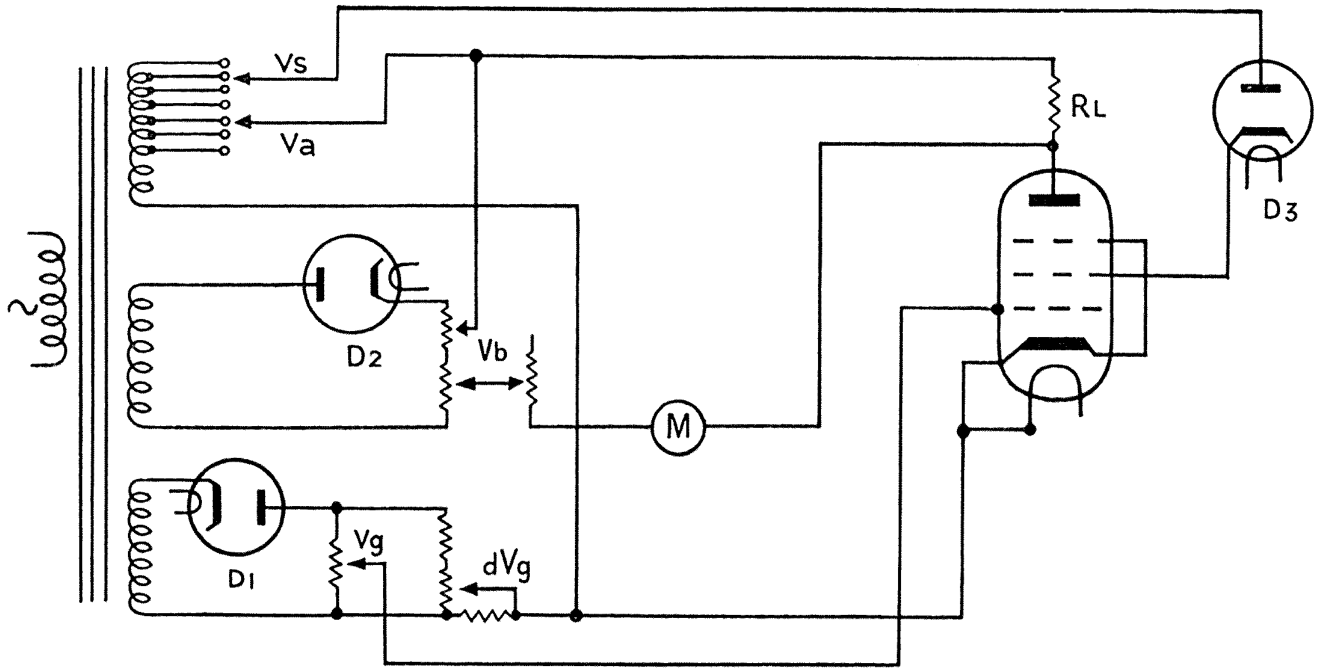


FIG. 1.

BASIC CIRCUIT FOR CHECKING OF MUTUAL CHARACTERISTICS

11. Figure 1 shows the fundamental circuit used in this measurement. With the requisite electrode voltages applied to the valve, the half wave anode current causes a voltage drop in the resistor RL, which is sufficiently low resistance not to influence the characteristics. This voltage is backed off by a voltage of similar form from the Control Vb. The voltage difference across the two arms of the bridge thus formed is shown on the DC millivoltmeter M. When this difference is zero, the voltage Vb is a measure of the anode current in RL ($Ia = \frac{V}{RL}$) and the control Vb is thus calibrated in mA anode current. A small change in bias is then applied to the valve from control dVg which causes an increased voltage drop in RL which unbalances the bridge. This unbalance is shown on M and is a measure of the mutual conductance of the valve. For a deflection on M of RL millivolts then the mutual conductance of the valve in mA/V is $\frac{1}{dVg}$ (volts). In practice the f.s.d. of M is 130% RL millivolts and the scale is zoned in three colours—green from 130% to 70% indicating a good value, white from 70% to 50% representing a failing valve, and red below 50% indicative of a reject. Thus the operating procedure after backing off the initial anode current is to set control dVg (calibrated in mA/V to a maximum of 20) to the rated mutual conductance and note the deflection on the coloured scale of M, to determine valve goodness.

12. This arrangement, which gives an incremental grid voltage inversely proportional to slope, avoids errors otherwise likely to occur on high slope valves which often exhibit marked curvature of characteristic.

13. The stopper diode D3 shown in the screen supply circuit in figure 1 is to prevent erroneous results, and possibly valve overheating and damage, that can occur when testing certain beam tetrode valves with alternating anode and screen voltages.

14. As the applied electrode voltages approach zero during a portion of the operative cycle, the focusing of the electrode beam is to some extent upset with the result that the screen current decreases, and rapidly becomes negative, with consequent rapid and continuously increasing anode current. The rectifier, whilst presenting negligibly low forward impedance to normal screen current, by virtue of its high reverse impedance successfully prevents the flow of reverse screen current.

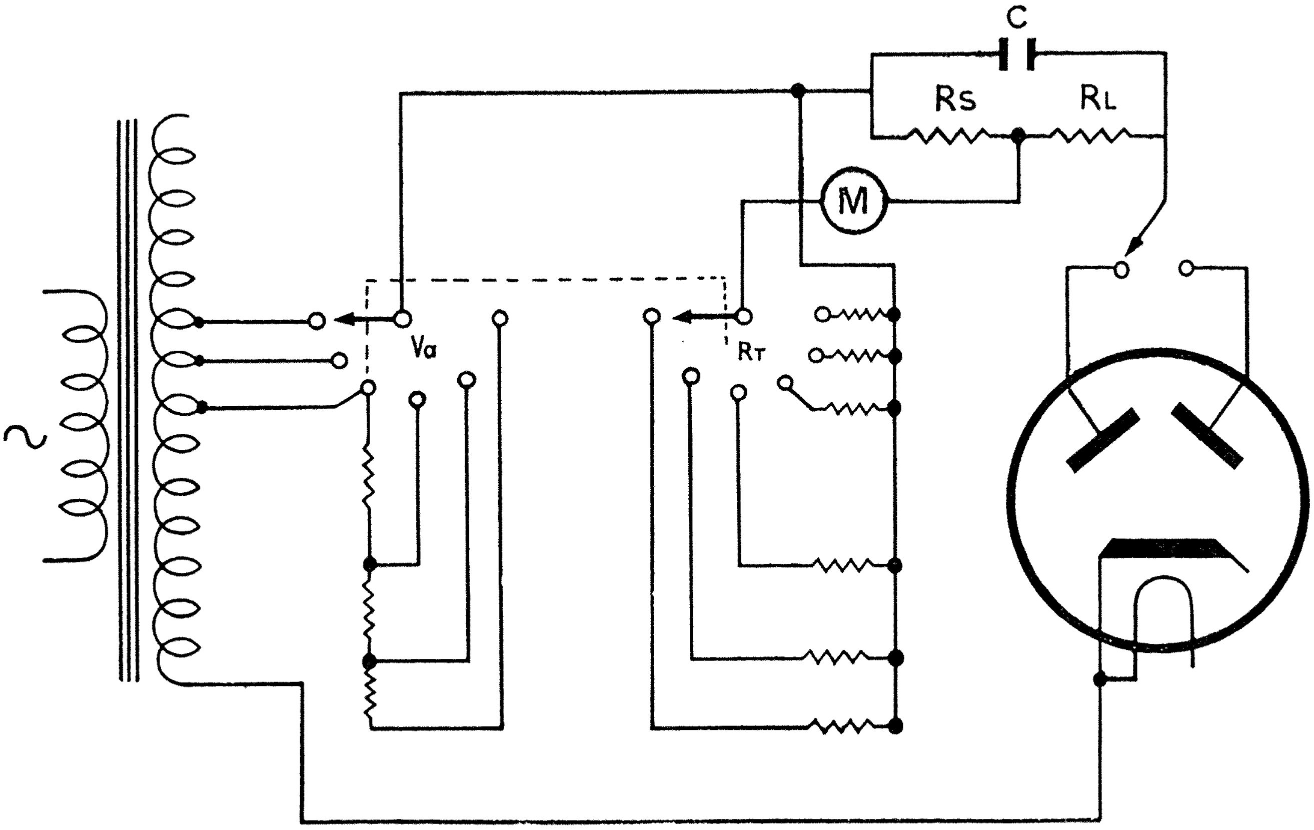


FIG. 2

BASIC CIRCUIT FOR THE TESTING OF RECTIFIERS AND SIGNAL DIODES.

15. Figure 2 shows the basic circuit of the rectifier test. The rectifier is loaded with a resistor RS + RL, and a reservoir capacitor C in parallel. Sinusoidal voltage Va is applied of sufficient magnitude to operate the rectifier on the linear portion of its characteristic, so that the combination should pass a rectified current equal to the maximum load current for the valve. The millivoltmeter M measures the voltage developed across a proportion of the load RL and is scaled by the appropriate range resistor RT so that the rated current through the load will deflect M to the middle of the " good " zone of the scale. The proportionate deflection on the coloured scale denotes the state of the valve as before. Switching of anode voltage meter range and load is ganged so that rectified currents of 1 mA, 5 mA, 15 mA, 30 mA, 60 mA, 120 mA and 180 mA per anode are available, each anode of a full wave rectifier being tested separately. The 1 mA and 5 mA ranges are suitable for signal diode testing.

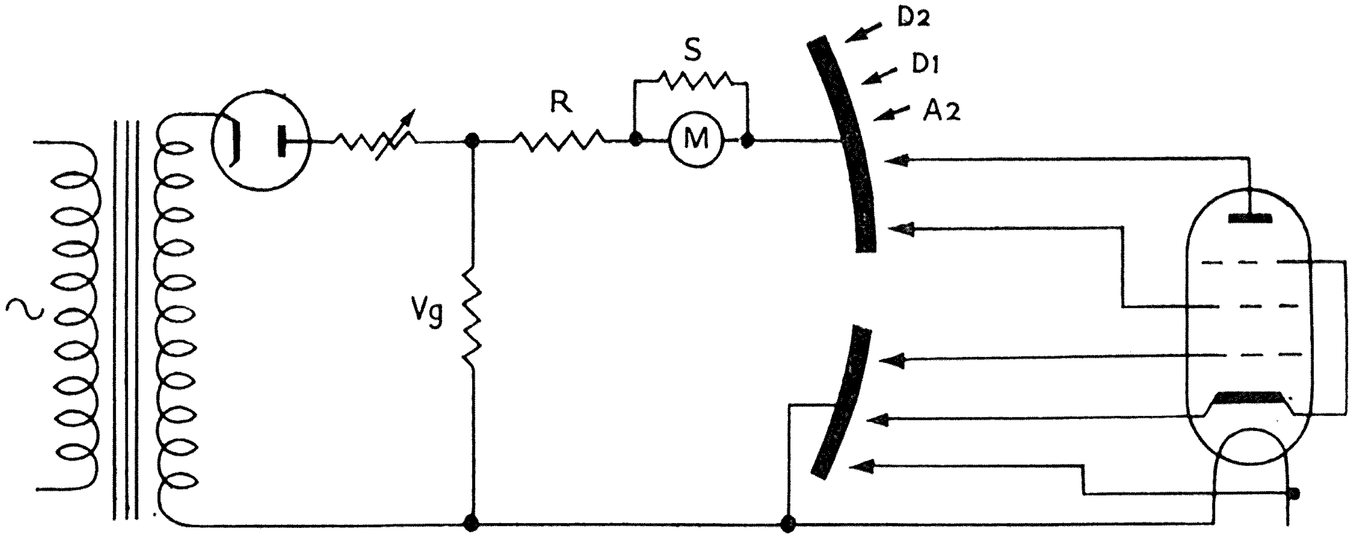


FIG. 4.

16. For the checking of inter-electrode insulation (figure 4) the unidirectional grid voltage Vg is applied through the meter M suitably loaded by a shunt(s) and high series resistor (R) across the electrode groups, between which the insulation is to be measured. Vg, S and R are such that the first meter indication is at 25 M Ω, full scale of course representing a dead short. The meter is suitably scaled for direct reading between these limits. This test serves for heater continuity and insulation measurements between anode and all other electrodes strapped, and screen and all others with the valve cold. With heater volts applied, the normal cathode/heater test is made, whilst a further test of cathode and heater strapped/rest takes care of sagging grids or filaments of directly heated valves. Since a short circuit deflection is, in fact, a measure of the grid voltage, this is used in checking the setting of the mains voltage of the instrument at position " Set ~ ". In this condition a short is put on the insulation test circuit, and the mains selector is adjusted until the meter reads full scale deflection, at which point the grid voltage and therefore all the other voltages working the instrument are correctly proportioned.

17. The full circuit (figure 3) shows how all the above combinations are incorporated in a single circuit, and selected by appropriate switch settings. Despite the full range of test voltages available and the comparative complexity of the circuit, the discreet use of ganged controls has reduced the operation to a simple and logical sequence.

18. Figure 5 shows in diagrammatic form the panel marking and it will be seen therefrom that in addition to the controls supplying the appropriate electrode voltages, only three controls are really involved in a measurement. The CIRCUIT SELECTOR rotates through the various insulation checks to position TEST, at which point the circuit is operative for mutual conductance testing by backing off with the ANODE CURRENT controls and by setting control SET mA/V, at which point the meter shows the valve goodness. Separate electrode systems of dual or multiple valves are measured by setting the ELECTRODE SELECTOR to A1 or A2. With this switch to D1 or D2 the circuit is ready for rectifier or signal diode testing, with the CIRCUIT SELECTOR at TEST. The selection of load current is made by rotating the anode current control (also separately scaled in rectifier load current) to the appropriate position, valve goodness being immediately shown on the same coloured meter scale.

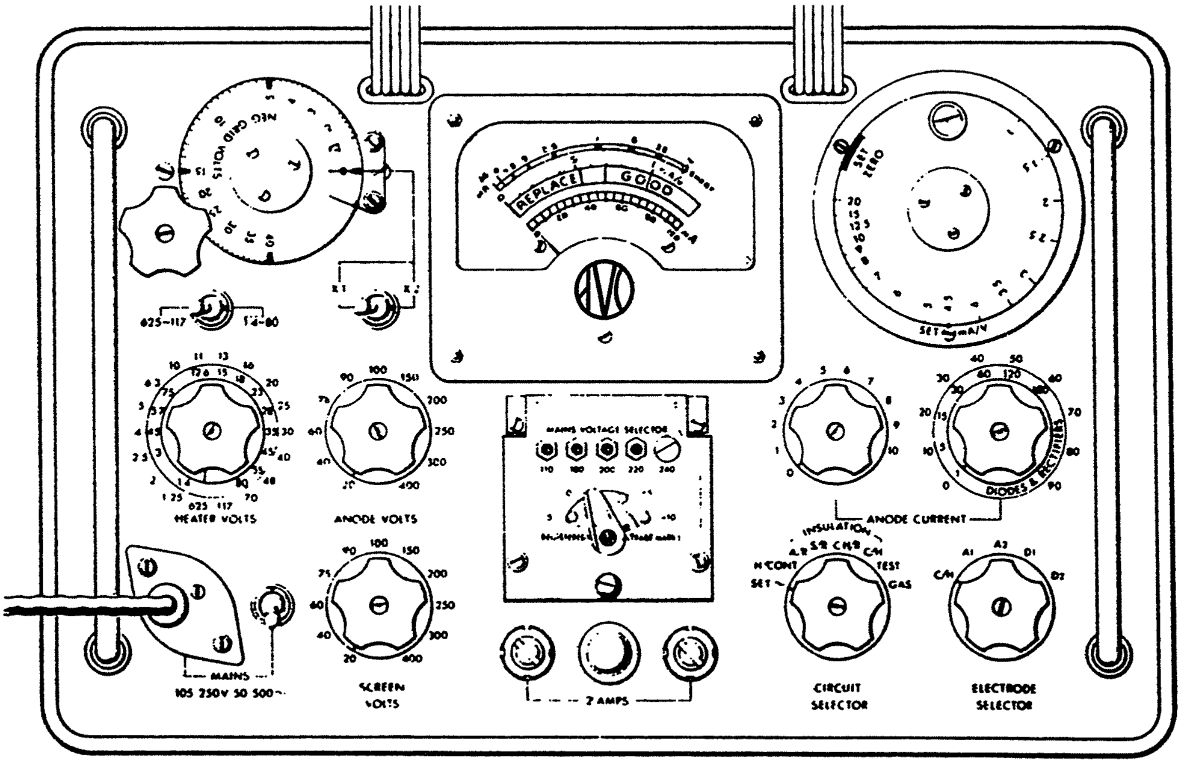


FIG. 5.

19. The rotary control SET mA/V is of the spring return type, and once a test has been made, automatically returns to its start position at which point the measuring circuit is shunted to a safety condition. Thus if a subsequent test is carelessly attempted with circuit wrongly set or if for instance a " gassy " valve is tested, this will be shown up before the circuit is put in a sensitive condition for mutual conductance testing and no damage will result to the instrument.

20. The final position of the CIRCUIT SELECTOR (marked GAS) places the meter M, shunted as a microammeter, in series with a resistor in the grid circuit of the valve being tested and allows the direct measurement of grid current in μA.

21. Further examination of the circuit diagram will show the inclusion of a safety relay with windings RL2 and RL3 in the screen and anode circuits respectively. Overloads (due to conditions of valve failure or misuse) associated with either or both of these circuits will trip the relay. This connects a high resistance lamp in series with the transformer primary windings, assisted by a hold off winding RL1 at the same time making a red warning light visible through the meter scale. This places the whole instrument in a safety condition. Normal working cannot be restored until the instrument has been switched off, the fault removed, and the instrument switched on again.

The Valve Holder Panel

22. The valve holder panel by means of which the valve is connected to the test circuit comprise a total of 32 valve bases covering all valves likely to be encountered in normal use, including disc seal and wire ended valves. The holders are wired with their corresponding sockets according to standard numbering, in parallel.

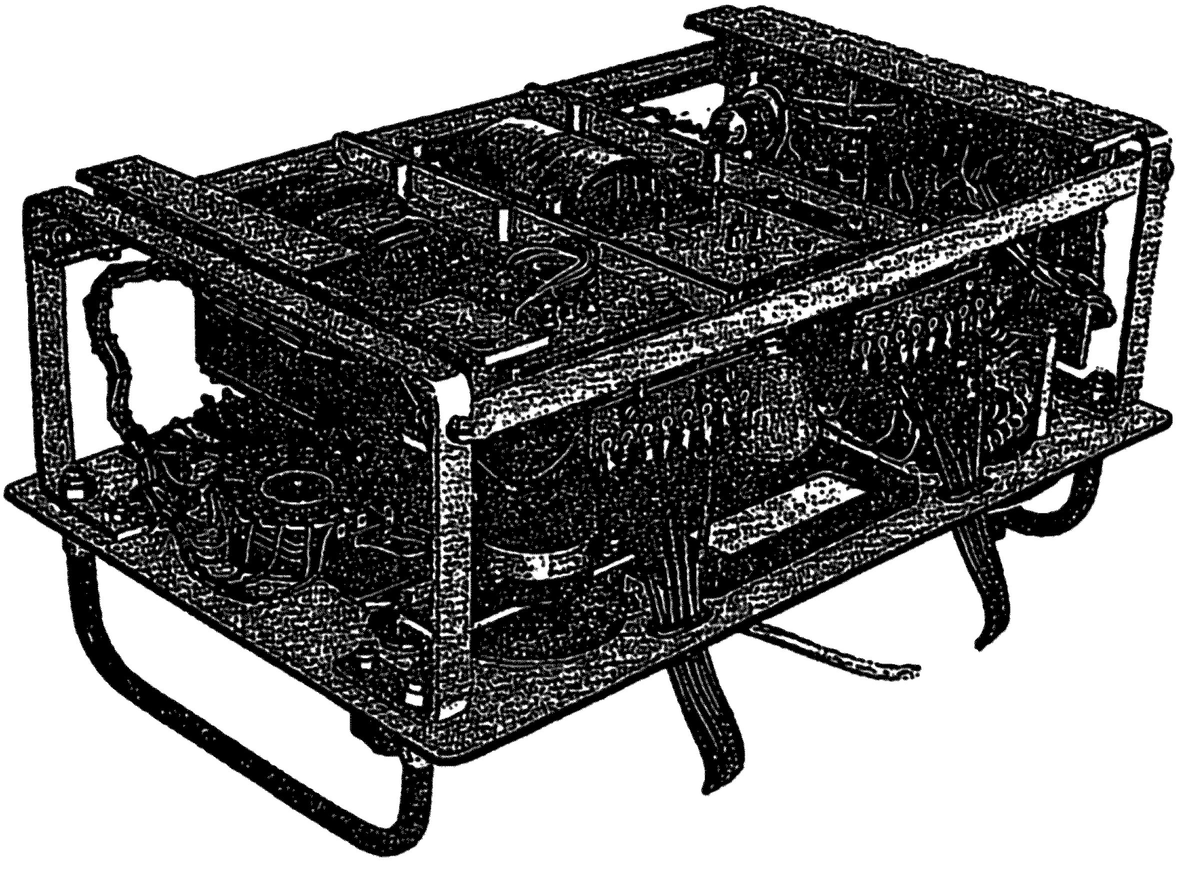


FIG. 6.
INSTRUMENT CHASSIS

23. The wire connection loops thus formed are connected to the wiper rotors of the multi-way selector switch. Associated with these rotors are ten stators; nine of which are each connected to an electrode test circuit, the tenth one being open circuited. The rotors are in the form of edge operated rollers each having the nine electrode denominations marked in symbols round their periphery, the operative selection appearing in a window. Thus any valve holder with pins up to nine, can be set up to any electrode combination, the open circuit connection serving for valves with internally connected pins.

24. The problem of self-oscillation that can occur with high slope valves at random high frequency, due to the inter-valve holder wiring, has been virtually eliminated by wiring the panel in connection loops of approximately similar length and configuration, so that a valve would tend to oscillate at a frequency dependent on the line thus formed. These wiring loops are then closed on themselves via a connector loaded to give high loss, and thus lower the Q of the line, so that oscillation is virtually impossible.

25. A manual is provided with a line of data for each valve likely to be encountered giving the mutual conductance and operating voltages. The data given comprises the pin combinations in the order of their standard numbering and in the form in which they appear in the roller selector switch window; top cap or side contact connection if any- heater volts; anode volts; screen volts; negative grid volts; operating anode current and mutual conductance (or load current in the case of a rectifier). Where multiple electrode assemblies are concerned test figures for each assembly are given. In case a valve is encountered that does not appear in the manual, the base connections and manufacturer's or other recommended test data can be directly set up on the controls without any calculation or complexity.

KEY TO FIGURE 7

1. Roller Selector Switch.
2. Disc Seal Valve Holders.
3. Top Cap Connector Panel.
4. Set mA/V Control.
5. Anode Current Controls.
6. Electrode Selector.
7. Circuit Selector.
8. Mains Voltage Selector Coarse Adjustment.
9. Mains Voltage Selector Fine Adjustment.
10. Indicator Lamp.
11. Fuses.
12. Screen Voltage Switch.
13. Mains on/off Switch.
14. AC Mains Input Socket.
15. Anode Voltage Switch.
16. Heater Voltage Switches.
17. Negative Grid Volts Control.
18. Panel Indicating Meter.
19. Anode Links.

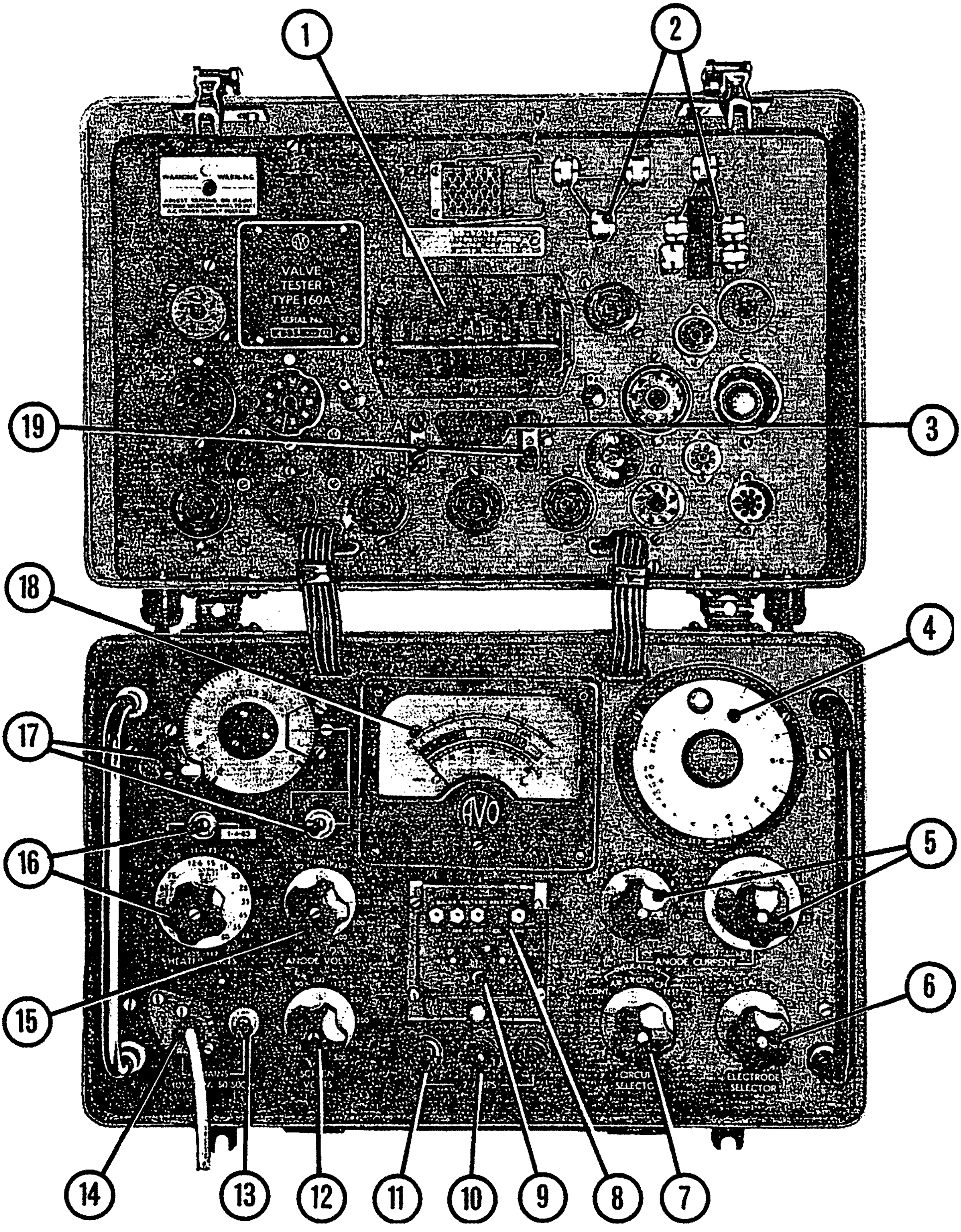
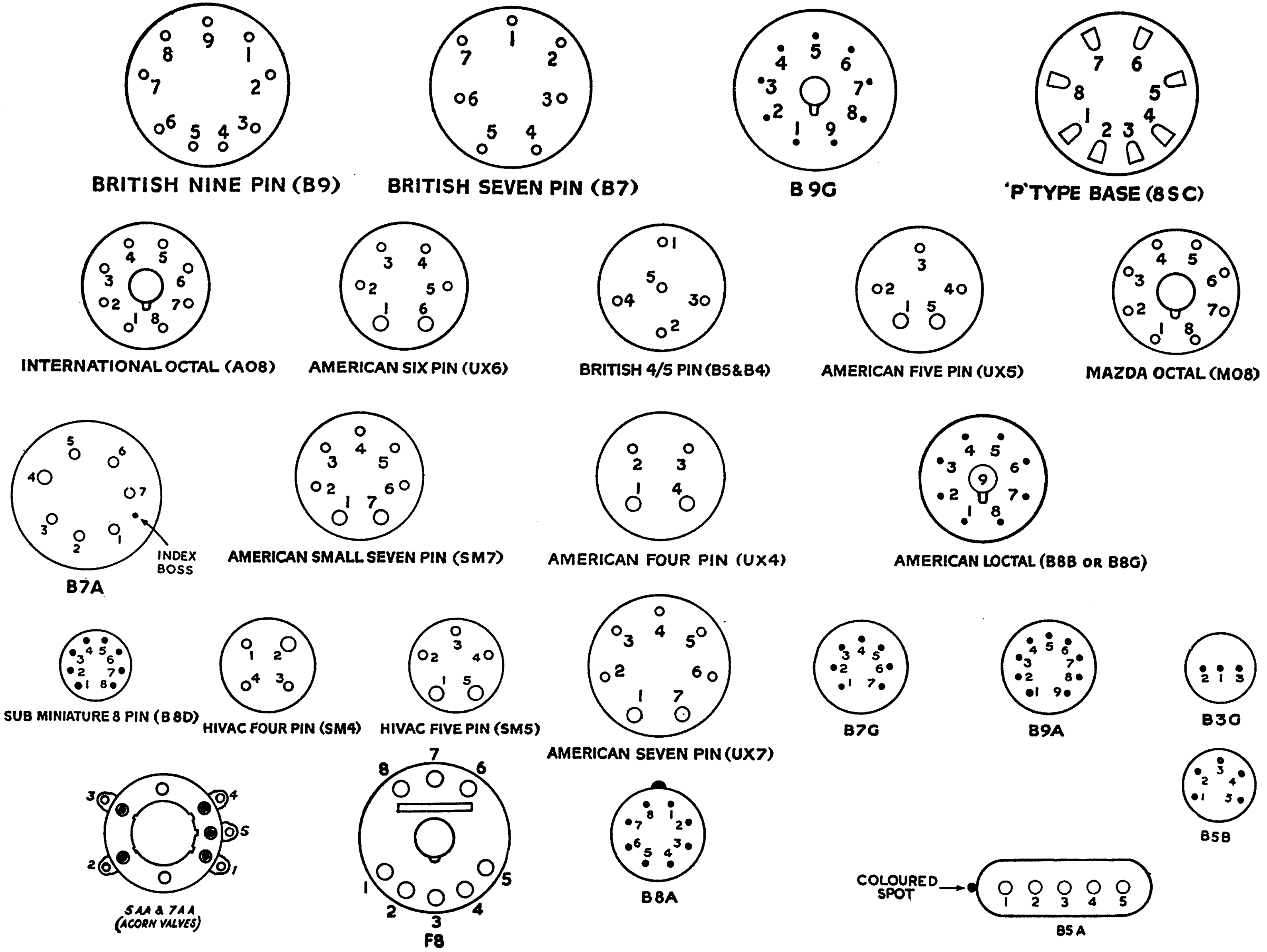


FIG. 7 THE LAYOUT OF THE INSTRUMENT

DIAGRAM OF STANDARD PIN CONNECTIONS

(viewed from underside of base)



General Construction

26. The instrument is designed in suitcase form for portability and ease of stowage It is of small size and constructed to comply with the requirements of the U.K. Government Climatic Tests Specification K.114. When closed it is completely shower-proof. All components likely to require replacement or adjustment in service are conveniently located on sub-assembly boards on the outer framework of the assembly, and are immediately to hand on removing the case, whilst the open framework construction used reduces weight to a minimum and ensures a maximum of accessibility.

Mains Supply

27. Special attention to design details has rendered an instrument suitable for operation on AC mains from 50—500 c/s±10% over the following voltage ranges:—105—120V, 175—250V.

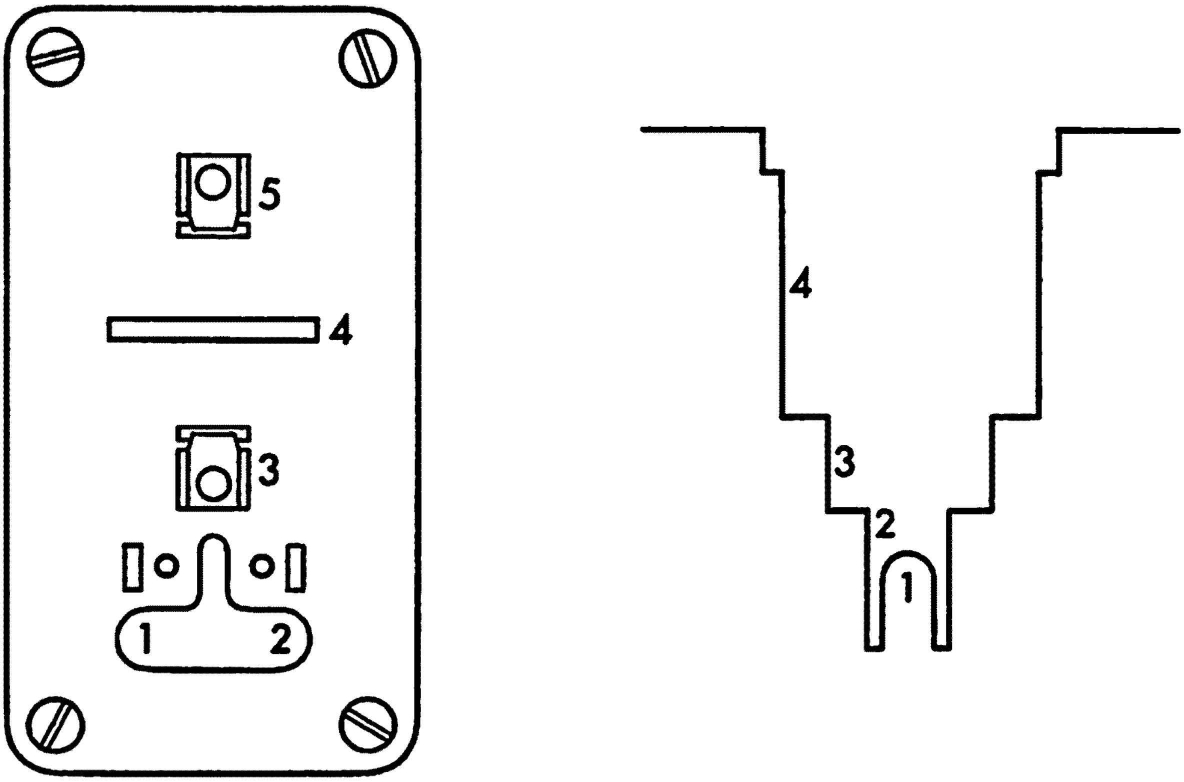
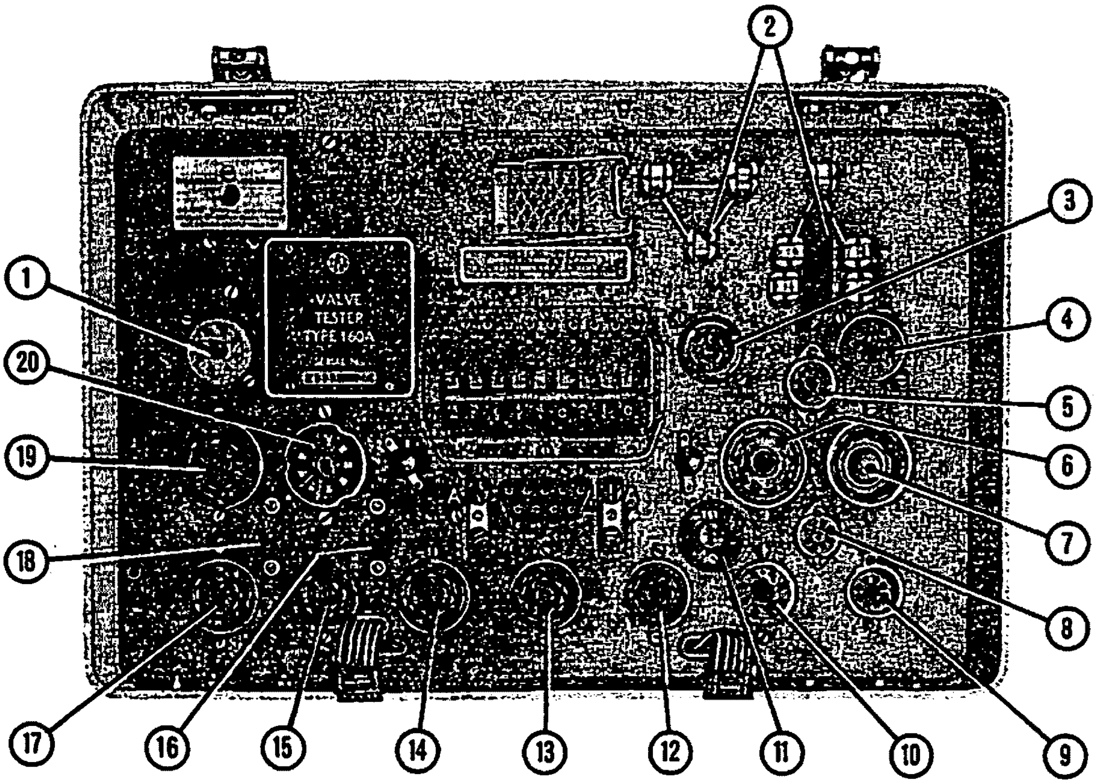


FIG. 9.

DIAGRAM OF CONNECTIONS FOR SPECIAL VALVE HOLDERS
(Showing pin connections viewed from above).


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
VALVE TESTER TYPE 160A

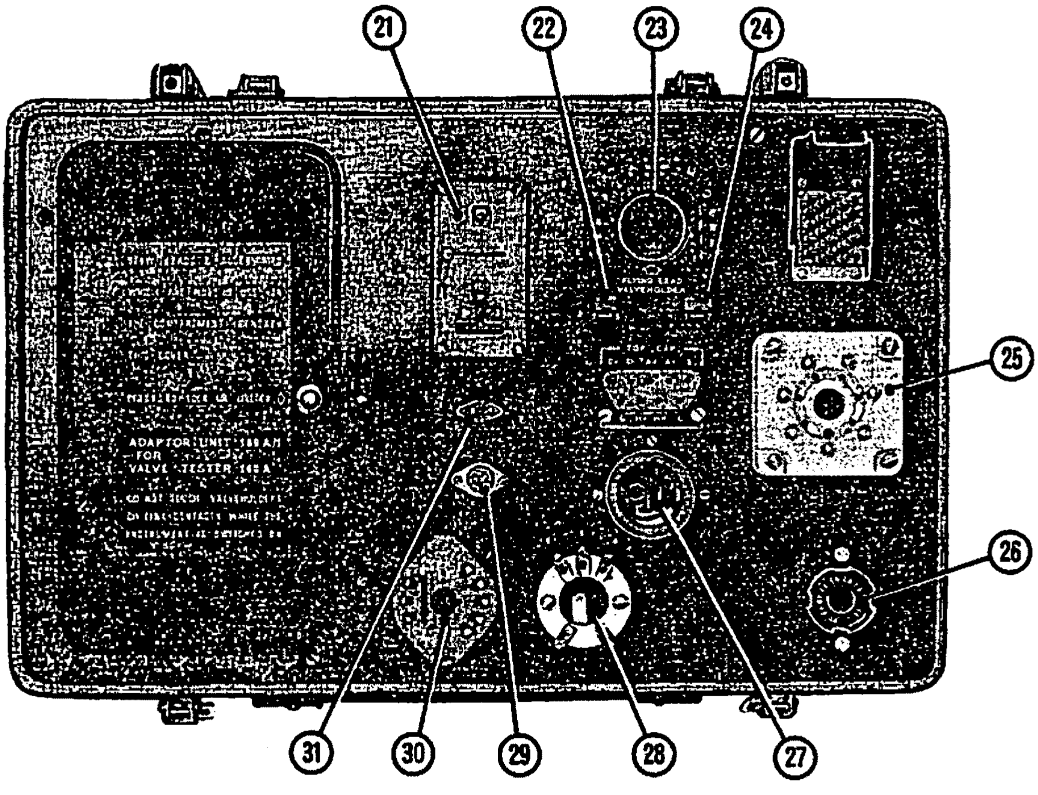
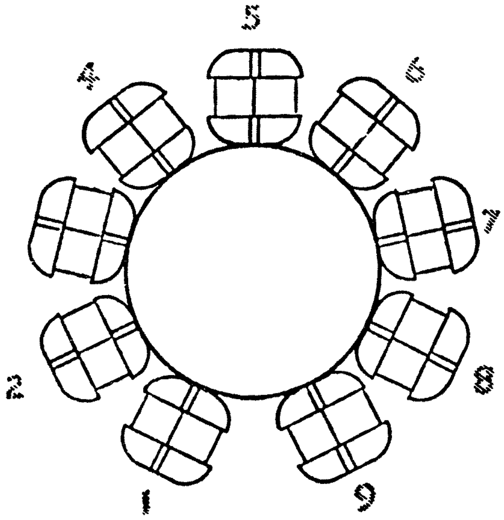
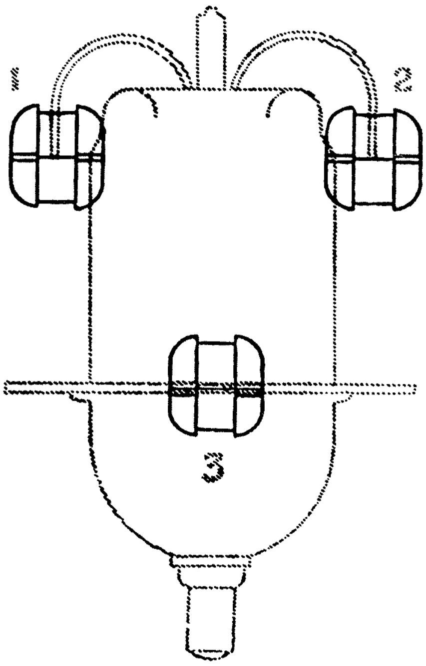
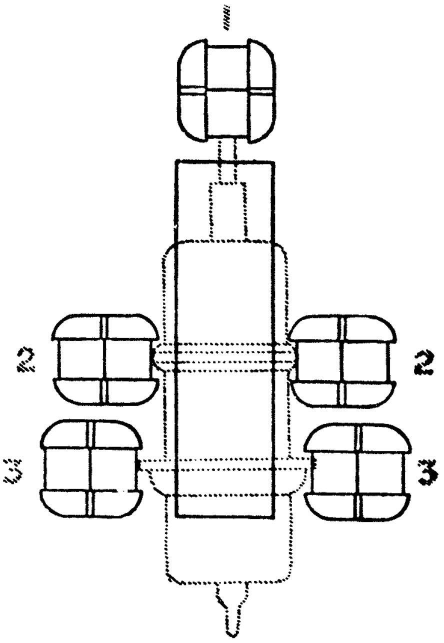

21
22
23
24
25
26
27
28
29
30
31
ADAPTOR UNIT 160AM FOR VALVE TESTER 160A

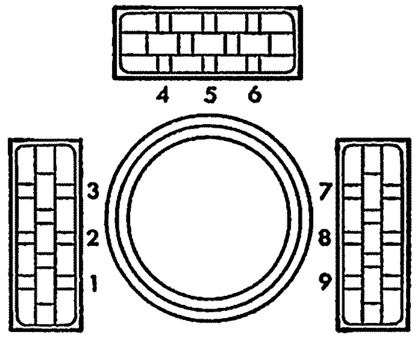
DIAGRAM OF SPECIAL VALVE HOLDERS FITTED TO THE AVO VALVE TESTER TYPE 160

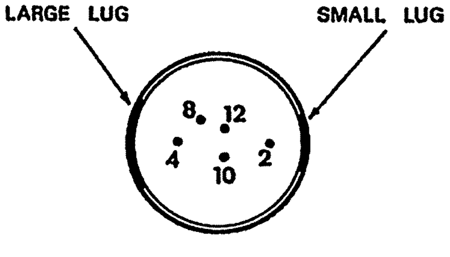
(bases are viewed from top of valve panel)











FLYING LEAD ADAPTOR

5-PIN NUVISTOR

KEY TO FIGURE 10

Valve Holders

1. International Octal (A08).
2. Disc seal.
3. British four and five pin (B4 or B5).
4. American loctal (B8B or B8G).
5. Miniature nine pin (noval or B9A).
6. British nine pin (B9).
7. Philips " P " type (8SC).
8. Miniature seven pin (B7G).
9. Philips eight pin locking (B8A).
10. Mazda Octal (M08).
11. Miniature three pin (B3G).
12. American five pin (UX5).
13. American Small seven pin (Sm7).
14. American Medium seven pin (UX7).
15. American four pin (UX4).
16. Hivac Deaf Aid four pin (Sm.4).
17. American six pin (UX.6).
18. Hivac Deaf Aid five pin (Sm.5).
19. British seven pin (B7).
20. All Glass nine pin (B9G).
21. Pencil Tubes.
22. 5 Wires in Line.
23. Flying lead.
24. 7 Wires in Line.
25. B7A.
26. B9D
27. Special base for type 2C39.
28. Acorn.
29. Nuvistor.
30. F8.
31. B8D.

CHAPTER 2

THE VALVE PANEL AND CONTROL UNIT

The Valve Panel and Selector Switch

28. The Instrument Valve Panels between them comprise 32 Valve Holders including the following types:— English 4/5 pin, English 7 pin, English 9 pin, Philips 8 pin side contact, B7G, B8A, B8G (American Loctal), B9G, B9A, Mazda Octal, International Octal, B3G, Hivac 4 pin miniature, Hivac 5 pin miniature, American 4 pin UX, American 5 pin UX, American 6 pin UX, American small 7 pin UX, American medium 7 pin UX, two disc seal and special flying lead Valve Holders. (See Figs. 8 and 9 for diagram of standard pin connections.)

29. In the case of the flying lead and disc seal valves (see Fig. 9), the pin numbering sequence corresponding to the set-up Data is printed on the panel adjacent to the appropriate socket. It is assumed that all flying lead valves will be inserted into the appropriate Valve Holder with the envelope pointing downwards, and the wire connections uppermost (corresponding to the normal method of designating valve pin numbers looking into the valve pins).

30. All Valve Holders are wired with their corresponding pins in parallel i.e., all pins numbered 1 are wired together, all pins numbered 2 and so on. This wiring combination is associated with the well-known "AVO" MULTI-WAY ROLLER SELECTOR SWITCH which enables any one of the nine standard pin numbers to be connected to any one of the electrode test circuits in the instrument, thus enabling any electrode combination to be set up for all Valve Holders.

31. It will be seen (Fig.10) that the Selector Switch comprises nine thumb rollers, numbered from left to right 1—9. This numbering appears on the moulded escutcheon immediately behind the rollers, and corresponds to the valve pins in the order of their standard pin numbering. Thus valves with any number of pin connections up to nine, can be accommodated. To cater for Top Cap and other external valve connections, a socket panel has been provided with nine sockets marked D1, D2, A2, A1, S. G., H+, H—, & C. A short lead is provided which is fitted with a plug for insertion into the panel, whilst the remote end of the lead is fitted with a universal connection clip to cater for all types of external valve connections. The socket panel is fitted with two links marked A2 and A1, to which reference is made in section 98.

32. Rotation of the rollers of the Selector Switch will reveal that each roller can be set in any one of ten positions, the appropriate setting being indicated in the window opening at the front of the escutcheon. The ten positions of each roller are marked as under:—

1	2	3	4	5	6	7	8	9	0
C	H—	H+	G	S	A	A2	D1	D2	—

33. The numbers are provided in order that the switch can be rapidly set up from the code numbers given in the Valve Data Manual, the corresponding electrode denominations being shown by the letter which appears in the escutcheon window immediately below the number thus:—

$\overset{1}{\text{C}}$ Corresponds to Cathode, or any other earthy electrode normally connected to cathode e.g. G3.

$\overset{2}{\text{H-}}$ Corresponds to Heater, normally earthy, or connected to negative L.T. in the case of a battery valve.

$\overset{3}{\text{H+}}$ Corresponds to the other Heater connections or centre tap.

$\overset{4}{\text{G}}$ Corresponds to Control Grid.

$\overset{5}{\text{S}}$ Corresponds to Screen Grid, or G2.

$\overset{6}{\text{A}}$ Corresponds to the normal Anode of single or multiple valves. In the case of an oscillator mixer valve, "A" represents the oscillator Anode.

$\overset{7}{\text{A2}}$ Corresponds to the second Anode of double valves, and in the case of oscillator mixer valves, the mixer Anode.

$\overset{8}{\text{D1}}$ Corresponds to the first Diode Anode of half and full wave Signal Diode and Rectifier valves, Diode and Rectifier/Amplifier combinations.

$\overset{9}{\text{D2}}$ Corresponds to the second Diode Anode of Signal Diode and Rectifier valves, Diode and Rectifier/Amplifier combinations.

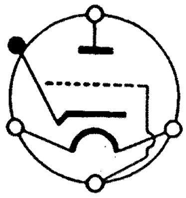
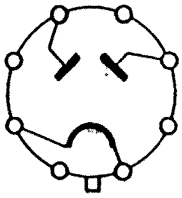
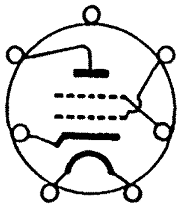
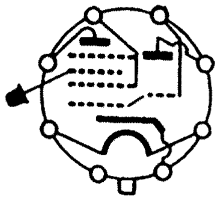
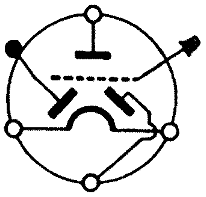
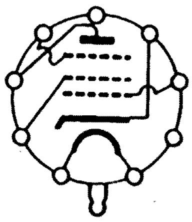
*$\overset{0}{-}$ Corresponds to a dis-connected valve pin or to a pin on which an internal electrode is anchored. Such pins are marked " I.C." in Manufacturer's literature. This switch position leaves the particular valve pin dis-connected from any circuit.

*Some instruments will be found to be fitted with rollers marked " $\overset{0}{\text{E}}$ " which can be regarded as being synonymous with $\overset{0}{-}$.

Procedure for Setting up Valve Base Connections

34. The procedure for setting up a valve ready for test is as follows:—From some suitable source, i.e. the " AVO " Valve Data Manual, Valve Manufacturer's Data Leaflet, or any other Manual of Valve Data, determine the pin basing connections for the valve. Rotate the roller of the SELECTOR SWITCH until the code number or electrode letter combination appears in the window, reading from left to right in accordance with the standard pin numbering sequence (see Fig. 8). When a valve has less than 9 pins, the free rollers on the right of the set up combination corresponds to non-existent valve electrodes, and should be set at $\overset{0}{-}$. Insert the valve into its appropriate holder (following the sequence laid down in the general procedure for testing a valve, section 55), and by means of the lead provided, connect any top cap or side connection on the valve to its appropriate socket on the socket panel. Note that the Loctal Valve Holder which has only 8 normal electrodes, has its centre spigot connected to the ninth roller (corresponding to Pin No. 9) to accommodate valves which have a connection made to this spigot.

35. The accompanying examples show how to correlate the pin basing data and the equivalent code number for various valves in common use.

Valve Type	*Roller selector Switch Code*	*Base Diagram*
Osram MH4 indirectly heated triode. British 5-pin base.	6 4 2 3 1 0 0 0 0 A G H− H+ C − − − −	
Osram U50 full wave rectifier directly heated International Octal Base.	0 2 0 8 0 9 0 3 0 − H− − D1 − D2 − H+ −	
Mullard Pen A4 indirectly heated output pentode. British 7 pin base.	0 4 5 2 3 1 6 0 0 − G S H− H+ C A − −	
Brimar 6K8 indirectly heated frequency changer. International Octal Base.	0 2 7 5 4 6 3 1 0 − H− A2 S G A H+ C − Top Cap G1.	
Mullard TDD2A battery double diode triode. British 5 pin base.	6 8 2 3 9 0 0 0 0 A D1 H− H+ D2 − − − − Top Cap G1.	
Mullard EF50 indirectly heated HF pentode. B9G base.	2 5 6 1 0 1 4 0 3 H− S A C − C G − H+	

Note

36. When the SELECTOR SWITCH setting is derived from manufacturers' Data, and a pin connection is shown as " I.C." (internally connected), the roller appertaining to this pin should be set to $\overset{0}{-}$. Where a pin connection is an electrode normally connected to cathode e.g., G3 the roller corresponding to this pin should be set to $\overset{1}{\text{C}}$.

Provision for New Valve Bases

37. Although the Valve Panel caters for all valves in common use, the possibility has not been overlooked that new valves and corresponding new bases may appear on the market from time to time. Should such a situation arise, plug-in adaptors will become available commercially which will enable the new valve to be plugged into an existing socket on the Valve Panel. Blank adaptors are already available to accommodate non-standard bases not incorporated on the existing Valve Panel.

The Control Unit and its Function

38. With the exception of the Roller Selector Switch and other features incorporated on the Valve Panel, all the controls are situated on the Main Panel of the instrument. By the manipulation of these controls, and the use of the Valve Panel, the following tests can be undertaken:—

(1) Heater continuity.
(2) The measurement of insulation resistance between electrodes with the valve cold.
(3) The measurement of insulation resistance between Heater/Cathode to all other electrodes strapped together, with the valve heater at operating temperature.
(4) The direct indication of cathode to heater insulation with the valve heater hot.
(5) The direct indication of valve " goodness " on a coloured " good/replace " scale, for a complete range of applied H.T. and bias voltages.
(6) The direct indication of anode current and mutual conductance (mA/V) at and pre-determined combination of H.T. and bias voltages.
(7) The measurement of control grid current on a scale directly calibrated in μA.
(8) The testing of half and full wave rectifiers under reservoir capacitor conditions, with a range of DC loads which can be selected by means of a switch.
(9) The testing of signal diodes with suitable DC loads which can be selected by the operator.
(10) The testing of the separate sections of multiple valves, the non-operative section of the valve under test being maintained at reasonable working electrode voltages.
(11) The ability to derive data from which the characteristic curves Ia/Vg, Ia/Va, Vg_1/Vg_2, etc., can be drawn with a range of applied electrode voltages corresponding to DC operating conditions.
(12) The testing of valves with suitable loads included in the anode circuit, together with the ability to read the required electrode current on a separate external meter. The instrument is, therefore, suitable for making tests on non-standard and specialised types of valves, not catered for in normal circuit arrangements.

The function of the various controls is as follows:—

The Mains Voltage Selector

39. The instrument has been designed to operate from supplies of 50—500c/s over the following voltage ranges:—105—120V, 175—190V, 195—210V, 215—230V, 235—250V.

40. Access to the Voltage Selector Panel can be gained by turning a thumb screw and lifting the transparent cover. The Coarse Voltage Selector is marked 110, 180, 200, 220 and 240, whilst a Fine Voltage Selector Arm is marked—5, 0, + 5, + 10. The setting on this Fine Voltage Selector must be added to the voltage marked under the socket into which the selector pin has been inserted. For example, if it is desired to operate the instrument on a 230V AC supply, the Coarse Selector Pin should be screwed into the 220V socket and the Fine Selector Arm turned to its + 10 position.

41. The Fine Voltage Selector also allows minor adjustments to be made to the input tappings on the mains transformer to compensate for voltage variations of the mains. The instrument should be switched off whilst adjustments are made to the *Coarse* MAINS VOLTAGE SELECTOR.

NOTE.—If the instrument is intended for use on 110v., the red warning lamp (LP2) should be replaced with a 110v. version.

The Circuit Selector

42. This is an eight position switch which determines the type of test to be undertaken on the instrument. All the necessary internal circuit connections are made automatically to satisfy the test conditions required, whilst internal test circuits unnecessary to the particular test in hand are removed from the valve

43. The switch position SET ~ enables final mains voltage adjustment to be made. At the H/CONT position, the meter indicates helater continuity. At the positions A/R and S/R, and used in conjunction with the ELECTRODE SELECTOR Switch, it is possible to check leakage between electrodes with the valve heater cold.

44. At the position CH/R again using the ELECTRODE SELECTOR Switch, the valve is automatically checked for electrode leakage between cathode and heater strapped, and all other electrodes with heater voltage applied.

45. At the position C/H, the valve is automatically checked for cathode to heater insulation with heater voltage applied. For this test, the ELECTRODE SELECTOR is set to C/H.

46. With the CIRCUIT SELECTOR switch set to TEST, and in conjunction with the ELECTRODE SELECTOR, ANODE CURRENT, and other relevant controls, the valve is tested for its normal characteristics the majority of the information being obtained from the setting of controls, the meter being used as a form of null indicator.

47. At the position GAS, the meter is connected in series with the control grid connection, and directly indicates gas current in μA.

The Electrode Selector

48. This switch, used in conjunction with the CIRCUIT SELECTOR, enables the meter to be associated with the anode circuit under test, with the exception of test position C/H. This latter setting is used only in conjunction with the CIRCUIT SELECTOR set to C/H for the measurement of cathode/heater insulation. Triodes, pentodes and multiple grid valves are checked with the ELECTRODE SELECTOR set to A_1 or A_2, whilst diodes and rectifiers are checked at positions D_1 and D_2.

The Heater Voltage Switches

49. Heater voltages are selected by means of two switches, the first being a simple toggle switch marked ·625—117, and 1·4—80, the second being an 18 way switch surrounded by two sets of calibration figures. The outer set of voltages on the latter can be selected when the toggle switch is in its left-hand position (·625—117), whilst the inner set of voltages can be selected when the toggle switch is in its right-hand position (1·4—80). Table 1 gives details of the 32 available heater voltages. *Note: Where given heater voltages in parenthesis should be employed.*

TABLE 1

OUTER RING On-load heater volts appearing at valve base with toggle switch set to position ·625—117	INNER RING On-load heater volts appearing at valve base with toggle switch set to position 1·4—80
·625	
1·25	1·4
2	
2·5	3
4	4·5
5	5·7
6·3	7·5
10	
11	12·6
13	15
16	18
20	23
25	28
30	35
40	45
48	55
70	80
117	

The Anode and Screen Voltage Switches

50. These switches enable the requisite electrode voltages to be applied to screen and anodes of valves for the purpose of carrying out mutual characteristic measurements. They are calibrated in the equivalent dc voltage settings and, therefore, no account need be taken of the actual value of AC voltage which appears at the electrodes of the valve, for as already explained in Chapter 1, the actual voltage will differ from the equivalent dc value marked at the switch position.

The Anode Current Controls

51. This is a dual control comprising two knobs, the first being continuously variable and calibrated from 0—10mA, the second having an inner and outer set of calibration figures. Only the outer set of figures marked in steps of 10mA from 0—90mA apply when anode current is being measured. These controls enable the expected anode current from the valve under test to be set upon the instrument and also serve as a means of final adjustment prior to making slope measurement (mA/V) tests. These controls do, in effect, back off the anode current passed by the valve, and to prevent overloading they should be set to the expected figure before the CIRCUIT SELECTOR switch is set to the position TEST.

52. When checking diodes and rectifiers, the inner range of figures around the right hand switch become operative, enabling the operator to select the required load, which is normally 1mA per anode in the case of signal diodes and from 5—120mA per anode for high vacuum power rectifiers.

The Negative Grid Volts Control

53. This is a continuously variable control calibrated 0—40 and marked NEG GRID VOLTS, which enables the initial negative bias at which a test is made to be set at any value between 0 and minus 40 volts. A times two switch enables the voltage indicated to be doubled.

The Set mA/V Control

54. The mA/V control marked 1—20mA/V enables the rapid checking of the operative " goodness " of a valve, on a " replace/good " scale on the moving coil indicator, or alternatively, the direct measurement of mutual conductance in mA/V.

CHAPTER 3

OPERATING INSTRUCTIONS
&
GENERAL PROCEDURE FOR TESTING A VALVE

The Connection of the instrument to a supply voltage

55. Remove the mains supply lead from its storage position in the lid of the instrument, and connect the cable termination to the socket provided on the control panel. Ascertain the voltage of the mains supply (which must, of course, be 50—500c/s) and set the MAINS VOLTAGE SELECTOR panel as described in Chapter 2. Connect the mains lead of the instrument to the power supply, ensuring that the red wire is connected to " line ", the black or blue wire to " neutral " and the green wire to " earth ". Set the MAINS Switch on the panel to its " ON " position, and observe that the panel indicator lamp is illuminated. The valve to be tested should *NOT* be inserted at this stage.

Final setting of Mains Voltage Selector Panel

56. Having allowed a few moments for the instrument to warm up, set the CIRCUIT SELECTOR Switch to the position SET ~. Set the fine voltage adjustment control so that the meter needle lies in the black zone. If this cannot be done, the coarse control will require adjustment, and should be moved to the next higher tapping if the needle is too far to the right of the mains adjustment zone, and in a similar manner, it should be moved to the next lower tapping if the meter needle is to the left of the mains setting zone. Once the mains voltage tapping has been correctly set, provided that extensive mains fluctuations do not occur, test voltages are automatically correct throughout the instrument.

Insulation checks with the valve cold

57. (1) The Valve Data Manual supplied with the instrument, or the Valve Manufacturer's Data, should now be consulted, and the ROLLER SELECTOR Switch set up as explained in Chapter 2, Section 35.

(2) Set the HEATER VOLTAGE Switches to the correct value for the valve under test, and insert the valve into its appropriate holder, making any necessary connection to top or side caps.

Note: Where given heater voltages in parenthesis should be employed.

(3) Set the CIRCUIT SELECTOR Switch to H/CONT, and the ELECTRODE SELECTOR Switch at C/H. The meter should now indicate a " short ", thus indicating heater continuity.

(4) Set the CIRCUIT SELECTOR Switch at A/R and S/R in turn, using each of these settings in conjunction with successive settings of the ELECTRODE SELECTOR Switch at A_1, A_2, D_1, and D_2. The meter will now indicate any insulation breakdown between electrodes.

58. (5) Table 2 sets out the manner in which insulation checks are made.

TABLE 2

Circuit Selector Switch Position.	Electrode Selector Switch Position.	Insulation Check.
A/R	A_1	Checks insulation anode 1 to screen, filament, cathode, anode 2 and grid.
A/R	A_2	Checks insulation anode 2 to screen, filament, cathode, anode 1 and grid.
A/R	D_1	Checks insulation D_1 to screen, filament, cathode, anode 1 and grid.
A/R	D_2	Checks insulation D_2 to screen, filament, cathode, anode 1 and grid.
S/R	A_1	Checks insulation screen, to filament, cathode and grid.

59. Study of the table set out above will show that all normally expected insulation breakdowns are covered with the exception of cathode to grid, which case is covered in a later check. Thus, a reading on the meter of 1 M Ω when the SELECTOR Switch is set to A/R, and the ELECTRODE SELECTOR switch is set to A_1 can only indicate a breakdown from anode 1 to grid, provided that breakdowns are not indicated in any other insulation test with heater either hot or cold. It is, therefore, apparent that it is possible to deduce between which electrodes a breakdown is occurring, although this information is normally never required, for in general, any appreciable inter-electrode breakdown will render the valve useless.

Insulation checks with the valve hot

60. All the tests referred to in section 58 were carried out with the valve heater cold. The CIRCUIT SELECTOR Switch should now be set to CH/R, and a short time allowed to elapse to enable the valve to reach working temperature. With the ELECTRODE SELECTOR Switch set to A_1, D_1 and D_2 in turn, any deflection will denote in M Ω the amount of insulation breakdown which occurs with cathode and heater strapped together to any other electrode.

61. Table 3 sets out below the manner in which these insulation checks are made.

TABLE 3

Circuit Selector Switch Position.	Electrode Selector Switch Position.	Insulation Check.
CH/R	A_1	Checks insulation cathode and heater to A_1, A_2, G_1, S.
CH/R	D_1	Checks insulation cathode and heater to D_1.
CH/R	D_2	Checks insulation cathode heater to D_2.

Cathode to Heater insulation check

62. Turn the CIRCUIT SELECTOR Switch to C/H, and the ELECTRODE SELECTOR Switch to C/H. Any insulation breakdown which occurs between heater (hot) and the cathode will be directly indicated on the insulation resistance scale of the meter. It is not possible to state a rejection figure in M Ω for a valve under test, for such a fault will be of considerable importance in some circuits, whilst in a few cases its presence has virtually no consequence at all. The instrument is capable of giving the insulation between cathode and heater, and the acceptance or rejection of the valve can only be determined when the operator has details of the circuit in which the valve is to be used. In those cases where these details are not known, it is always better to reject a valve having an insulation resistance less than 10M Ω. It will be appreciated that there are many circuits in which an appreciable potential exists between heater and cathode, DC amplifiers, etc., and the presence of heater to cathode insulation breakdown, even of the order of many M Ω, can often give rise to quite serious trouble. Heater to cathode insulation breakdown either permanent or intermittent can also give rise to noise in valve amplifier circuits.

Determination of Valve condition from Static Characteristic Data

63. Normally a valve, unless it is a diode or rectifier, is checked by a comparison of its actual mutual conductance with the rated figure. The broad procedure for obtaining this figure consists of:—

- (i) Applying to the valve the recommended electrode voltages.
- (ii) Backing off to zero the standing anode current thus produced.
- (iii) Applying a small incremental signal to the grid of the valve.
- (iv) Assessing the mutual conductance and consequently the " goodness " of the valve from the resultant rise in anode current.

64. Provision is made to test for mutual conductance under two conditions:—

- (i) Where the measurement is made at a predetermined fixed value of grid bias, the resulting anode current being balanced out.
- (ii) Where the measurement is made at the predetermined optimum value of anode current, the grid bias being adjusted to give a balance.

65. In either of these cases, the determination of " goodness " can be made by:—

- (*a*) A comparison of the mutual conductance of the valve on a percentage basis with its rated figure, the comparative " goodness " factor being indicated on a coloured " good/replace " scale.
- (*b*) A direct numerical determination of the valve's mutual conductance in mA/V which can then be compared with the rated figure.

66. In certain circumstances, where for example the valve is used as an oscillator or output valve working at peak emission, more useful information than is given by the usual mutual conductance figure can be gained from the anode current obtained for a given set of electrode voltages. Such conditions are catered for by calibrating the " backing off " controls in terms of anode current (milliamps). Thus, when the standing anode current has been " backed off " to zero as shown by the meter indication (not calibrated in anode current), the reading of the backing off controls gives the anode current for the valve under test, at a particular combination of electrode voltages. This figure can be compared with expected anode current for the conditions employed to determine the valve's suitability for the function it has to perform.

67. It is obvious that this arrangement also enables complete valve characteristics of anode current related to electrode voltages to be plotted, it merely being necessary to record the anode current obtained at a series of electrode voltage settings (either anode, screen or grid), and plotting the mutual characteristics I/aV_g, Ia/V_a etc., from the data thus obtained.

68. The detailed instructions for making the measurement outlined above, having completed the inter-electrode insulation checks, are as follows:—

69. Set ANODE VOLTS, SCREEN VOLTS, NEG GRID VOLTS, and ANODE CURRENT controls to the value indicated in Valve Data, then set CIRCUIT SELECTOR to TEST and ELECTRODE SELECTOR to A_1.

Note 1

Should the protective relay operate, switch off and check for incorrect setting of the ROLLER SELECTOR Switch or electrode voltages. If these are correct and the relay continues to " buzz " when the instrument is switched on again, the valve is probably " soft " (gassy), and the test should proceed no further. If upon removing the offending valve, the relay continues to operate, the instrument should be switched off. When switched on again, the instrument should function normally.

To check relative goodness of Valve in conjunction with Coloured Comparison Scale

70. (*a*) **Using recommended anode current**

(i) Do not alter ANODE CURRENT controls, but adjust NEG GRID VOLTS control until meter is balanced to zero.
(ii) *Slowly* rotate SET mA/V control to SET ZERO position and make any final adjustment to zero, using fine ANODE CURRENT control. (See Note 3.)
(iii) Continue rotation of SET mA/V control to expected value of mA/V (meter needle should rise).
(iv) The comparative " goodness " of the valve will now be shown by the position of meter needle on coloured scale. This scale is divided into three zones, and all valves coming within the green portion can be regarded as satisfactory. Readings in the intermediate zone between the red and green sections are not entirely satisfactory, although the valve may be capable of working in some circuits at lowered efficiency, whilst readings in the red zone indicate that the valve should be rejected or replaced.

71. (*b*) **Using recommended negative grid voltage**

(i) Do not alter NEG GRID VOLTS control, but adjust ANODE CURRENT controls until meter is balanced to zero.
(ii) *Slowly* rotate SET mA/V control to SET ZERO position and make any final adjustment to zero, using fine ANODE CURRENT control. (See Note 3.)
(iii) Continue rotation of SET mA/V control to expected value of mA/V (meter needle should rise).
(iv) The comparative " goodness " of the valve will now be shown by the position of meter needle on coloured scale. This scale is divided into three zones, and all valves coming within the green portion can be regarded as satisfactory. Readings in the intermediate zone between the red and green sections denote

that the valve is not entirely satisfactory, although it may be capable of working in some circuits at lowered efficiency, whilst readings in the red zone indicate that the valve should be rejected or replaced.

Note 2

Valves having a slope of less than 1mA/V cannot be checked on the good/replace scale, and must be checked in the manner set out in paragraph 74.

To check Valve by direct reading of Mutual Conductance (mA/V)

72. (*a*) **Using recommended anode current**

(i) Do not alter ANODE CURRENT controls, but adjust NEG GRID VOLTS control until meter is balanced to zero.
(ii) *Slowly* rotate SET mA/V control to SET ZERO position and make any final adjustment to zero, using fine ANODE CURRENT control (See Note 3.)
(iii) Continue rotation of SET mA/V control until meter needle reaches the calibration line in centre of " good " zone, marked " 1mA/V ".
(iv) Read actual value of mutual conductance from SET mA/V dial. This figure can be compared with that given in Data Manual.

73. (*b*) **Using recommended negative grid voltage**

(i) Do not alter NEG GRID VOLTS control, but adjust ANODE CURRENT controls until meter is balanced to zero.
(ii) *Slowly* rotate SET mA/V control to SET ZERO position and make any final adjustment to zero, using fine ANODE CURRENT control. (See Note 3.)
(iii) Continue rotation of SET mA/V control until meter needle reaches the calibration line in centre of " good " zone marked " 1mA/V ".
(iv) Read actual value of mutual conductance from SET mA/V dial. This figure can be compared with that given in the Data Manual.

To check Valves having a Mutual Conductance less than 1mA/V

74. Since the SET mA/V dial is not calibrated below 1mA/V, it is not possible to check on the coloured comparison scale, valves having an expected mutual conductance less than 1mA/V. Such valves are checked by direct measurement of mutual conductance using the procedure set out in paragraphs 72 or 73, with the exception that the mA/V dial is rotated to the 1mA/V position and the actual value for mutual conductance (being less than 1mA/V) is read on the meter scale calibrated 0·1—1mA/V.

75. For valves with more than one electrode assembly, having set up for any difference in electrode voltages, repeat above test with ELECTRODE SELECTOR at A_2. (See also comments under Testing of Specific Valve Types.)

Note 3

Certain valves require an exceptionally long period to reach working temperature, the symptoms being a continual rise of anode current when the SET mA/V dial is at the SET ZERO (more sensitive) position. Slope measurements should not be taken until a condition of stability has been reached.

Note 4

*When checking certain valves of the CV.*138 *type, back emission sometimes occurs between the anode and the suppressor grid which is normally connected to cathode. This condition which is caused by local overheating of the anode, would not affect the operation of the valve under normal circuit conditions, although it could give rise to doubt as to the " goodness " of the valve when checked on a valve testing instrument. The phenomenon shows itself as an apparent gradual fall in anode current as the valve heats up, and the only manner in which this effect can be overcome, is to lower the power dissipation of the valve by reducing the anode voltage. Note "E " in the "AVO " Valve Data Manual relates to the above conditions, and a note appears against those valve types concerned, together with an alternative set of test data.*

Note 5

In literature issued by American Valve Manufacturers, the term " transconductance " is used in place of mutual " conductance ". Transconductance given in micromhos, divided by 1,000 *gives mA/V.*

$$\text{mA/V} = \frac{\text{Transconductance (Micromhos)}}{1{,}000}$$

Measurement of Grid Current

76. The measurement of grid current at a desired set of electrode voltages may be made after having measured the mutual conductance of a valve. This measurement should not be made where an apparent fault in the valve has previously caused the protective relay to operate (possibly due to softness).

77. The CIRCUIT SELECTOR switch should be set to GAS, thus inserting the meter into the grid circuit of the valve, where it records grid current directly in μA. The meter is limited to read a maximum of 100μA, but it is not possible to state the value at which a valve becomes useless due to the presence of gas. The point at which gas current reaches a value great enough to affect the successful employment of the valve depends very much upon the circuitry in conjunction with which it is to be employed, e.g. it is possible for appreciable grid current to flow in the secondary of an R.F. transformer connected between grid and earth, but if resistance/capacity coupling is used in the circuit, the same magnitude of grid current may produce appreciable voltage across the bias resistor, thus completely upsetting the normal functions of the circuit.

Checking Power Rectifiers

78. The testing of rectifying valves should ideally be associated with the requirements of the circuit in which they are to operate. In most cases throughout the "AVO " Valve Data Manual, the figure quoted denotes the standard emission per anode to be expected from the type of valve under test.

79. The procedure for testing a rectifying valve is exactly the same as that for a valve with one or more grids, to the end of the insulation checks.

80. From this point onwards, before setting the CIRCUIT SELECTOR to the position TEST, the right hand ANODE CURRENT control switch reading on the inner set of figures, should be set to the load current given for the valve in the Valve Data

Manual. Set CIRCUIT SELECTOR to TEST and the ELECTRODE SELECTOR either to D_1 in the case of a half wave rectifier, or D_1 and D_2 for a full wave rectifier.

81. Having correctly set up the controls as explained above, the " goodness factor " of the valve under test will be shown on the coloured " replace/good " scale of the meter.

82. The inner ring of figures on the ANODE CURRENT Control relate to load currents and are marked " Diodes and Rectifiers ", the figures marked being the emission in mA expected per anode of the valve under test.

83. The setting of this control can either be determined from the tabulated data given, or can alternatively be related to the total current that a valve is required to deliver. Thus, on a piece of equipment where the total H.T. drain on the rectifier is 50mA, then a rectifier load setting of 60 will be an adequate test of the valve's emissive state, assuming that it is a half wave rectifier. Alternatively, if the valve is a new one, the maker's rating for maximum load current can be used as the basis for the setting of the ANODE CURRENT switch.

84. In the case of full wave rectifiers, each anode of the valve is rated independently and the setting of the ANODE CURRENT control should indicate half the total value, of the current which the valve would be expected to deliver in a full wave rectifier circuit, e.g. a valve rated at a maximum of 120mA would be tested with each anode at the 60 position on the ANODE CURRENT control. The load rating given in the Valve Data Manual is the load per anode.

Checking Signal Diodes

85. Signal Diodes are checked in exactly the same manner as rectifiers, except that the right-hand ANODE CURRENT control is always set to 1 or 5 according to the anode current figure given in the Data. (Where "AVO " Valve Data does not give a current figure for a diode, it is always checked with the right-hand ANODE CURRENT control set to its 1mA position).

INSTRUCTIONS FOR TESTING SPECIFIC VALVE TYPES

86. The functions of a valve, as distinct from the type number given to it by its manufacturer, is indicated by a symbol in the form of letters appearing at the right of the test data given in "AVO " publications, e.g. a half wave rectifier is marked " R ", whilst a full wave rectifier is designated by " RR ". In a similar manner, diode valves are shown by the letter " D ", the number of diode elements being indicated by the number of " Ds ", e.g. " DDD " refers to a triple diode.

Multiple Diodes and Rectifiers (D, DD, DDD, R, RR)

87. The testing of Multiple Diodes and Rectifiers is carried out in the manner already explained, the ELECTRODE SELECTOR being used to select the diode or rectifier element, the emission of which is indicated on the meter " replace/good " scale. When dealing with diodes or rectifiers, the D_1 and D_2 positions of the ELECTRODE SELECTOR represent diode or rectifier anodes 1 and 2 respectively, and correspond to figures 8 and 9 on the ROLLER SELECTOR SWITCH set-up number.

88. In the case of Triple Diodes, since only two anode systems are normally catered for, a special procedure is adopted in the set-up figure. At the position in the SELECTOR SWITCH number representing the third diode, the symbol † is included. The first and second diodes being indicated by 8 and 9 respectively in the normal manner. The valve should now be tested normally, with the ROLLER SELECTOR SWITCH set to " 0 " where the † appears in the set-up number. This procedure will give emission figures for diodes 1 and 2. Now rotate the ROLLER SELECTOR SWITCH rollers so that the two rollers originally set at 8 and 9 are now set to 0, and set the pin marked † in the Valve Data to 8 on the ROLLER SELECTOR SWITCH. A further test with the ELECTRODE SELECTOR Switch at D_1 will then give the emission of the third diode, e.g. EAB1 is indicated in the data as 023 1†0 890. To test diodes 1 and 2 the set-up on the ROLLER SELECTOR SWITCH will be 023 100 890, enabling these diodes to be tested in the normal manner. To obtain the emission figure for the third diode the SELECTOR Switch should be altered to read 023 180 000, and the ELECTRODE SELECTOR set to position D_1.

Diodes and Rectifiers combined with other Electrode Assemblies (DT, DDT, DP, DDP, DTP)

89. Combined diode and amplifying valves are represented in the type column of the Data by " DT " and " DDT " for diode triodes and double diode triodes, whilst " DP " and " DDP " indicate diode pentodes and double diode pentodes.

90. The testing of the separate sections of each valve is carried out in rotation, the amplifying sections being tested first, with the CIRCUIT SELECTOR at TEST, and the ELECTRODE SELECTOR at position A_1.

91. The rotation of the ELECTRODE SELECTOR to the D_1 or D_2 position will automatically set the instrument in readiness for testing one or both diodes with the right-hand ANODE CURRENT control set to 1 on the inner scale.

Double Triodes and Double Pentodes (TT, PP)

92. Double Triodes or Double Pentodes are indicated by the letters " TT " or " PP ", each section being tested in the normal manner, the selection of each assembly being made by the rotation of the ELECTRODE SELECTOR Switch to A_1 and A_2 (corresponding to the ROLLER SELECTOR SWITCH numbers 6 and 7). When double valves are used in Class B or " balanced " circuits, a close match of the characteristics of both halves is essential.

Frequency Changers (H, TH, O, TP)

93. Frequency Changers of the Heptode and Hexode classes employing the normal oscillator section as a phantom cathode for the mixer section, are not very satisfactorily tested in two sections, since the nature of the valve construction is such that each section is dependent upon the other for its correct operation. For test purposes, therefore, this valve is shown connected as a pentode or triode, for which, where possible, anode current and/or mutual conductance figures are given. Such valves are indicated by the letter " H " in the type column.

94. An exception to this type of valve is the Octode, designated by " O " in the type column, which, as will be seen from the Data, is normally tested as if it had two separate electrode assemblies, separate data being given for each. In this case, the oscillator section is tested with the ELECTRODE SELECTOR Switch at A_1, and the mixer section at A_2.

95. As a further test to ensure the probability of such a valve oscillating satisfactorily, an indication of failing emission will probably give the most useful results. When a valve is perfect, its cathode will develop its full emission at the rated heater voltage, and any change in the cathode temperature will result, at the most, in a corresponding percentage change in emission. If, however, the emission of the cathode is failing, then an increase or decrease in the cathode temperature will result in a higher percentage change in emission.

96. When a valve is oscillating, it tends to run into the positive grid region, thus making full use of the emissive capabilities of the cathode, and failing emission may well prevent oscillation taking place. As a subsequent test, therefore, it is helpful to note the anode current at the rated test figures with the normal heater voltage applied, and then to decrease the heater voltage by about 15% for a short period. (It may be necessary to operate the HEATER VOLTAGE TOGGLE SWITCH to give the necessary decrease in voltage.) In the case of a valve with failing emission, the decrease in cathode temperature will result in an excessive decrease in the anode current, considerably greater than the percentage decrease in heater voltage. Such a result would suggest that the valve will not oscillate satisfactorily. Conversely, a negligible or small decrease in anode current (or of the same order as the percentage change in heater volts) will show that the valve is developing its full emission at the rated heater voltage, and, provided that the circuit conditions are correct, it should oscillate normally.

97. Frequency Changers Employing Separate Electrode Assemblies for oscillator and mixer functions are designated by " TH " (triode hexode) and " TP " (triode pentodes). The separate sections of this type of valve are not interdependent as in the case of the phantom cathode types mentioned in the previous paragraph, and they must, therefore, be tested in two separate sections as a pentode or triode respectively.

THE USE OF THE LINKS ON THE VALVE PANEL OF THE INSTRUMENT

98. These links, in the A_1 and A_2 circuits respectively, enable a load to be inserted into the anode circuit of the valve under test. By removing the shorting links, and inserting the appropriate resistor (or other load) across the terminals which it is desired to include in the circuit, it is possible to obtain certain dynamic figures for the valve or electrode system under test.

99. The links also enable a suitable dc Moving Coil Ammeter with low millivolt drop to be inserted in series with the anode of the valve under test. Variations in the settings of the ANODE CURRENT controls will not materially affect the readings of the external meter, which will read 0·5 of the actual current flowing, i.e. the external meter reading must be multiplied by 2 for true anode current.

Note 6

Beware of high voltages on shorting links.

Checking Tuning Indicators (TI)

100. Tuning indicators (Magic Eyes) are tested with the controls set to the figures in the data table, the SCREEN SWITCH being used to obtain target volts, the appropriate anode load being inserted in accordance with the value shown in the remarks column.

At the approximate bias given in the table the triode section should be at " cut off " and the eye fully closed. Reducing the grid bias to zero, the eye should open fully and the value of anode current should be approximately that appearing in the table (where given). In the case of double sensitivity indicators giving multiple images responding to different sensitivities, two sets of data (where possible) are given, the first set referring to the more sensitive indication.

Checking Gas Filled Rectifiers (GR)

101. Gaseous rectifiers are tested in conjunction with a load resistor of suitable wattage connected across the link terminals, the value of resistance being given in K Ω in the remarks column. This type of rectifier is not tested on the rectifier or diode test circuits, but with the CIRCUIT SELECTOR set to TEST, the appropriate voltage and representative anode current figures being given in the valve data columns. Full wave examples of this class of valve are, of course, tested at the ELECTRODE SELECTOR positions A_1 and A_2, a suitable resistor being connected across each of the two anode links. The maximum loading on these rectifiers must be limited to 100mA per anode to avoid damage to the instrument.

Checking Cold Cathode Rectifiers (CCR)

102. Cold cathode rectifiers designated by the symbol " CCR " can be tested in a similar manner, the anode voltage, approximate anode current, and load resistance being given in the data columns.

SECTION 3

MAINTENANCE

INFORMATION

MAINTENANCE INFORMATION

CONTENTS

SECTION 1 - TEST EQUIPMENT REQUIRED

(A) AVO Electronic Testmeter (or equivalent dc mean valve voltmeter)
(B) Valve CV491 (Standardised for Mutual Conductance at 16mA anode current).
(C) Model 7 or Model 8 AvoMeters (3).
(D) Power Valve capable of passing 100mA anode current - CV428.
(E) Resistor 680kΩ ± 5%.

SECTION 2 - FAULT FINDING AND SERVICING NOTES (See WARNING on Page 4).

NOTE:

All measurements and tolerances stated do not include those of the testing instrument, and where necessary, these should be ascertained particularly before commencement of the calibration procedure. Where possible the recommended instruments should be employed.

1. 500c/s AC Supply Operation & its Relation to Servicing

Whilst the instrument is suitable for use on 50 to 500 c/s AC supplies, service and calibration should normally be carried out using a 220/230V 50c/s supply.

The following features play a vital part in the correct operation of the instrument on a 500 c/s supply.

(A) The two electrostatic screens (S1 and S2) on the transformers prevent spurious mA/V readings and care must be taken when replacing a transformer to ensure that these screens are connected as shown in the Circuit Diagram (See Fig. 4).

(B) The separate cable forms lying side by side across the instrument ensure that the grid circuit and its associated wiring is kept well apart from the HT wiring to prevent the transference of energy from one circuit to the other at high mains frequencies. If, at any time, it is necessary to displace wiring within the instrument, great care must be taken to ensure that it is replaced in its original position.

(C) The 0.02μF (C1) and 0.02μF (C2) capacitors prevent spurious readings on insulation ranges when the instrument is used at high mains frequencies.

2. To Check Accuracy of Instrument

Before commencing servicing the instrument should be checked as follows:-

(A) Ensure that the mains 'On/Off' switch is in the 'Off' position.

(B) Connect the instrument to an AC voltage supply of 200/250V 50 c/s of known magnitude.

(C) Set the instrument voltage adjustment to its appropriate position.

(D) Switch on, noting that the panel indicator is illuminated.

(E) Set the Mains Voltage Selector fine control such that the meter pointer lies as near as possible to the centre of the '∿' zone.

(F) Connect the AvoMeter in series with the A_1 link.

(G) Using the CV491 (standardised in accordance with Para. 3) with 200V DC anode volts, check that

(1) For 16mA anode current the negative grid volts indication is within ± 5% of the standardised value.

(11) The slope (mA/V) is within ± 7% of the standardised value.

A reading of 8mA on the external instrument will be equivalent to a DC current of 16mA through the valve (this is the value normally indicated by the anode current controls when the meter is at its null position).

(H) Remove valve and external meter.

(J) Set the Neg. Grid Volts control at '40'.

(K) Connect a resistance of 680kΩ ± 5% between grid and cathode sockets on the top cap connector panel.

(M) Set the Circuit Selector switch to position 'Gas'

The panel meter should indicate full scale deflection ± 20%.

(N) Disconnect the resistance and switch off.

3. To Obtain Standard Figures for a Valve Using DC Supplies

Using the recommended AvoMeters, the valve should be connected as shown in Fig. 1. If unable to use the recommended meters ensure that those used are of sub-standard accuracy, the current meter having a maximum voltage drop of 100mV and preferably scaled 0-25mA and the voltmeters a sensitivity of 1000 Ω/V. If rectified AC is used for the HT supply, it is essential that steps are taken to ensure that the supply circuit is adequately smoothed (the Solartron Varipack is a suitable source). The bias supply should be obtained from a suitable battery (Note polarity of connection). The heater supply for the valve may be AC or DC, but must be within ± 5% of the rated voltage.

(A) Set the Grid Bias voltmeter to read 9V.

(B) Adjust the HT supply to 200V, then by means of successive adjustments of the bias and HT controls, set the anode current at 16mA (the anode voltmeter must read 200V). Note the new grid bias reading.

(C) The standardised slope for the valve can now be obtained from:-

The difference between the two anode current readings (i.e. 1mA) over the difference between the two grid voltage readings:-

$$\frac{IA_2 - IA_1}{Vg_1 - Vg_2}$$

The result will generally be between 4 and 5mA/V (See Final Test Procedure).

For greater accuracy it is suggested that readings of grid voltage be plotted against value of anode current between 10 and 20mA and the slope taken from the curve at 16mA. The valve should now be labelled as follows:

Va = 200V DC
IA = 16mA DC
Vg = ...
Slope = ...mA/V
Date ....
CV 491

The valve should be re-standardised daily when in use.

4. Construction

The main instrument comprises two units in a hinged transit case, the lid of which is not detachable. Electrical connection between the two units is effected by means of two 5-way side by side cables. The adaptor box is connected to the main instrument by means of a 25-way connector.

5. Removal of the Instrument From its Case (See WARNING on Page 4)

To facilitate servicing or calibration of the instrument, it is necessary to remove both sections from the casing, this being accomplished by the removal of four hexagonal headed bolts, which form the feet of the control unit, from the underside of the case. The control panel will then be released. The valve panel can be withdrawn from its section of the case by the removal of eight fixing screws around its periphery.

6. Simple Faults

SYMPTOMS	POSSIBLE FAULT	ACTION
(A) No dial light indication.	No mains input. Dial light bulb burnt out.	Check mains connector. Replace ILP1.
No dial light indication or meter deflection on SET ∿ setting of Circuit Selector.	Fuse blown.	Check mains Voltage Selector setting and replace FS1 and/or FS2.
(B) No indication of meter current.	No anode volts at valve pin.	Check that Links A_1 & A_2 are tight and making firm contact.
No indication of meter current and protective relay operates when testing tetrodes or pentodes.	No anode volts at valve pin but screen volts present.	Check that Links A_1 & A_2 are tight and making firm contact.

7. Relay Operates and Fails to Clear

Should the relay operate due to a suspected faulty valve and fail to clear after switching off and on again with no valve in panel, set Roller Selector switch to read 000 000 000 and remove top cap connecting lead. Switch instrument off and on again.

If fault clears the most likely cause of the trouble is a short on the valve panel, certain pin(s) being shorted out to earth by stray wire or solder, or a breakdown in insulation.

If the fault still persists, however, check HT line for breakdown to earth between Roller Selector switch on Valve Panel and HT transformer on control unit.

8. Adjustment of Protective Relay

The relay should seldom require attention, but if for any reason parts are replaced, the adjustment is simple, it only being necessary to position two 4BA screws (see Fig.3). It should be noted that the bobbins if replaced, should be positioned such that the flux which they produce is additive.

Operational Limits are as follows:-

(A) Anode Overload - Relay should operate on 100V short circuit.

(B) Screen Overload - Relay should operate on 60V short circuit.

(C) The relay should not arc excessively on a 200V short circuit on anode or screen.

(D) The relay should not operate when checking a 180mA rectifier.

Before making any adjustments check that the lamp ILP1 is operative. When the instrument is used solely on a 110V supply, it may be preferable to replace ILP1 with a 100V, 15W Pigmy Lamp.

9. Servicing the Valve Holder Panel and Adaptor Unit

The Valve Holder Panel is connected electrically to the control panel by means of two 5-way side by side cables. One of these cables embodies two thicker sections (16/.012) for H+ and H- leads. Connections to tag boards on either unit are shown in Fig. 2.

The wiring of the valve holders on the panel is in the form of nine separate loops, all pins comprising a loop and linking in roller 1 of the Roller Selector switch. This form of loop connection is used likewise for pins 2-9, all nine circuits approximating in length and following a similar route around the panel. These loops are further loaded with beads of ferroxcube which sufficiently damp the loop to prevent the valve under test breaking into parasitic oscillation. A diagrammatic layout is shown in Fig. 2. Ferroxcube is also used on leads feeding the selector switch, as a precaution against IF oscillation.

The Adaptor Unit Type 160A/1 is similar in construction to the valveholder panel fitted to the main instrument except that it caters for the more unusual type of valves, i.e. those with B7A, B5A and Nuvistor valve bases etc.

The Unit is connected to the main instrument by means of a 25-way cable which is stored in a compartment within the Adaptor Unit when not required. When not in use, the Operating, Valve Data and Maintenance Manual is housed in the removable lid of the Adaptor Unit and is held in position by means of a retaining strip.

Where it is necessary to replace valve holders, these with the exception of the B8B are fitted to the panel with nuts and bolts, and are thus easily removable. Care should be taken to replace all wire in its original position.

10. Removal and Replacement of Knobs and Setting of Knob Skirts

To remove any knob, remove 6Ba screw and spring washer. To remove knob spindle and skirt, release locking pin. The switch nut is now accessible. To adjust skirt, slacken lock nut, rotate skirt to desired position and re-tighten lock nut. Reverse procedure to replace.

SECTION 3 - VOLTAGE CHECKS WITH NO VALVE UNDER TEST

Connect instrument to known 220/230V 50 c/s supply, ensuring that the mains 'On/Off' switch is in the 'Off' position, and adjust coarse and fine settings of the mains voltage selector panel to match the supply voltage as accurately as possible. Set the Circuit Selector to 'Test' and the Electrode Selector to 'A_1' and proceed to check the relevant electrode voltages as follows:-

1. Heater Voltages

(A) Connect the AvoMeter, switched to its AC voltage ranges, between H+ and H- sockets on top cap connector panel.

(B) Switch on and rotate the Heater Voltage switch through the full range of values, the external meter being set to the appropriate voltage range as required.

(C) The heater voltage reading on the meter should conform to the voltage limits shown in the following table.

Due allowance must be made for the limits of accuracy of the measuring instrument for each particular reading:-

Nominal Volts	Actual AC Volts	Limits Min.	Max.
2	2.34	2.2	2.5
5	5.5	5.3	5.7
10	10.4	10.2	10.8
20	21.0	20.5	22
40	42.0	41	44
117	125.0	120	130

(D) Switch off and remove the meter.

2. Anode Voltages

(A) Connect the AvoMeter, ensuring that the mains 'On/Off' switch is in the 'Off' position, and set to its AC voltage range, between A and C sockets on the top cap selector panel.

(B) Switch on and rotate the 'Anode Voltage' switch through successive positions, the meter being set to the appropriate range as required.

(C) The meter readings should be 1.1 x the voltage indicated by the 'Anode Voltage' switch -2 +6%.

Due allowance must be made for the limits of accuracy of the measuring instrument for each particular reading, e.g., with the 'Anode Voltage' switch set to 100, the actual voltage reading should be 110V -2 +6%.

(D) Switch off and remove the meter.

3. Screen Voltages

(A) Connect the AvoMeter, ensuring that the mains 'On/Off' switch is in the 'Off' position, and set to its AC voltage range between S and C on the top cap selector panel.

(B) Short circuit the diode rectifier MR1.

(C) Switch on and rotate the screen voltage switch through successive positions, the external meter being set to the appropriate range as required.

(D) The meter readings obtained should be 1.1 x the voltage indicated by the 'Screen Voltage' switch -2 +6%.

Due allowance must be made for the limits of accuracy of the measuring instrument for each particular reading.

(E) Switch off and remove the meter.

CHAPTER 2

CALIBRATION

CONTENTS

SECTION 1 - TEST EQUIPMENT REQUIRED

(A) Avo Electronic Testmeter (or equivalent DC mean valve voltmeter)

NOTE: The Electronic Testmeter should be standardised at the appropriate voltages before making any adjustment mentioned in the following paragraphs.

SECTION 2 - CHECKING THE NEGATIVE GRID VOLTS CONTROL

(A) Set the Mains 'ON/OFF' switch to 'OFF', CIRCUIT SELECTOR to TEST ELECTRODE SELECTOR to A_1 and NEG.GRID VOLTS to 40 x 1.

(B) Connect the Testmeter across RV2. Switch on, adjust RV3 for a voltage reading of 20.8V. Set NEG.GRID VOLTS to 40 x 2. Adjust RV5 for a reading of 41.6V. Remove testmeter.

(C) Connect the Testmeter between G_1 and C sockets on the top cap connector panel, or if the panel has been disconnected for servicing, to the G_1 and C positions on the tag board at the back of the Unit.

(D) Check that at the 13 and 4 marks on the dial, readings of 6.75V and 2.1V ± 5% are obtained.

If either or both readings are out of tolerance, the dial should be adjusted mechanically to split the error. If it is necessary to make an adjustment, slacken the three counter-sunk screws on the top of the dial which will then be free to move within the latitude of kidney shaped slots. After adjustment, re-tighten screws and check readings. The areas marked 0, 5, 15 and 40 should correspond within the indicated area to 0V, 2.6V, 7.8V and 20.8V ± 5% respectively.

(E) Switch off and remove the Testmeter.

SECTION 3 - CHECKING THE SET mA/V CONTROL

(A) Switch on and check that when the dial is advanced to its 10, 5 and 2mA/V positions, readings of 52.5mV, 105mV and 260mV ± 5% are obtained.

(B) If for any reason the relationship between the dial and the potentiometer has been upset, the procedure 'setting the mA/V Dial' given in Section 6 should be adopted.

(C) Switch off and remove the Testmeter.

SECTION 4 - CHECKING THE SET ∿ INDICATION

(A) Standardise the Testmeter at 47V DC. Set the panel control as follows:-

CIRCUIT SELECTOR TO 'SET ∿', and ELECTRODE SELECTOR to A_1

(B) Connect the Testmeter across RV2 and switch on.

(C) A reading of 47V should now be obtained, whilst the meter on the instrument panel should indicate within the '∿' zone.

If voltage reading is correct, but panel meter indication is outside '∿' zone, adjust RV6 as required.

(D) Switch off and remove Testmeter.

SECTION 5 - 1a CALIBRATION CHECK

(A) Open the A_1 link on the valve base panel and insert a Model 7 AvoMeter, set to a suitable DC range, into the circuit.

(B) Set up the instrument and place under test any power valve capable of passing 100mA anode current, E.G. CV428.

(C) Set the Anode Current controls to 100mA (90mA and 10mA), switch on and with the instrument set to its test position, allow the valve to warm up.

(D) Set the panel meter pointer to zero by means of the Neg. Grid Volts control.

(E) The external meter should indicate between 47.5mA and 52.5mA (0.5 x indicated value on Anode Current control ± 5%)., the panel instrument indicating zero. If required repeat this test at any other settings of Anode Current controls. Switch off and remove the meter.

SECTION 6 - SETTING THE mA/V DIAL

(A) With the link open and the 'SET' mA/V dial at rest, set RV1 at its maximum anti-clockwise position (viewed from the front panel) and adjust friction tight the locking nuts of the U-shaped stirrup.

(B) Connect the Testmeter, set to a suitable range across R5. Switch on and advance the SET mA/V dial to a reading of 5. Rotate the RV1 spindle further, by means of the stirrup, in a clock-wise direction until the Testmeter gives a reading of 105mV.

(C) If this reading is achieved without further clockwise advancement of the stirrup, or if its procurement necessitates an.anti-clockwise movement of the stirrup, then investigate the accuracy of R1, R2, R5 and RV1.

(D) The locking nuts on the stirrup should now be tightened and the reading of 105mV on the voltmeter checked. Again check that the DC millivolts developed across R5 at the 2mA/V and 10mA/V settings of the dial are 260mV and 52.5mV ± 3%.

(E) Check that the dial can now be rotated to its 1mA/V position and that the motion is eventually arrested by the stop screw on the dial and not by the stop at the end of the potentiometer track. Switch off and remove the Testmeter.

SECTION 7 - THE INDICATING METER

This is a self-contained unit which may be withdrawn from the control panel by the removal of two 2BA screws. When used in the instrument as an anode current null indicator, the meter has a full scale deflection.for approximately 10mA (not critical). When removed from the instrument, the meter has a full scale deflection of 30μA and internal resistance of 3,250Ω. When shunted by R9 only (see Circuit Diagram) the meter has a full scale deflection of 39.8μA.

CHAPTER 3

FINAL TEST PROCEDURE

CONTENTS

NOTE: When all repairs have been carried out and the instrument is re-assembled, carry out the following final test detail.

SECTION 1 - TEST EQUIPMENT REQUIRED

(A) AVO Electronic Testmeter (or equivalent mean DC Valve Voltmeter).

(B) Model 7 or Model 8 AvoMeter.

(C) Valves CV428, CV 491 and U52.

(D) Resistor 1 megohm ± 1%.

(E) Resistor 680kohm ± 5%.

SECTION 2 - FINAL TEST DETAIL (See WARNING on page 4).

(A) Apply a 500V megger test between the mains input and frame.

(B) Apply a known AC 50 c/s voltage in the range 200-250V to the instrument and with Circuit Selector at 'Set ∿', set mains voltage selector until needle on panel registers as near as possible to the centre of the '∿ mark'. Check that the selector settings show ± 5V of the actual mains voltage.

It is most important to ensure that the meter reading in the 'Set ∿' position is maintained at the centre of the '∿ mark' on the scale for all subsequent tests.

(C) Set the circuit and electrode selector switches as given in the table below and connect a 1 megohm ± 1% resistor across the electrodes on top cap board as detailed under the heading 'Condition'. Check that a leakage of 1 megohm ± 10% is indicated on the panel meter in each case:-

Circuit Selector Switch	Electrode Selector Switch	Condition
A/R	A1	Resistor connected across A1 and and of the following S, H-, C, A2 or G.
S/R	A1	Resistor connected across S and any of the following H-, C or G.
C.H/R	A1	Resistor connected across C, H- or H+ and any of the following A1, A2, S or G.
C/H	C/H	Resistor connected across C and either H+ or H-.

NOTE: In positions C.H/R and C/H check that heater volts appear across H+ and H-.

(D) Check operation of the overload cut-out with:

(1) An Anode/Cathode short at an anode voltage of 100. (Connect a short across A1 and C top cap board).

(11) A screen/cathode short at a screen voltage of 60. (Connect a short across S and C on top cap board).

(E) Check the following unloaded anode volts with the Testmeter (on appropriate AC range) connected across A1 and C on top cap board.

Nominal Volts:	60	100	150	250	400
Actual AC Volts:	66	110	165	275	440
Limits:	-2 +6%				

(F) Check the following unloaded heater volts with the Testmeter (on appropriate AC range) connected across H+ and H- on top cap board.

Nominal Volts	Actual AC Volts	Limits	
		Min.	Max.
2	2.34	2.2	2.5
5	5.5	5.3	5.7
10	10.4	10.2	10.8
20	21.0	20.5	22
40	42.0	41	44
117	125.0	120	130

(G) Insert a CV428 in the appropriate socket, set the instrument to the correct electrode selector, switch to A1 and obtain a balance, then check that:

(1) By varying the grid voltage, an anode current of 100mA is obtainable.

(11) The valve does not oscillate.

NOTE: The meter reading should not vary appreciably when the hand is placed near or on the insulated anode lead.

(111) By varying screen voltage the anode current varies accordingly.

(H) Insert a CV491 (12AU7) strapped as single triode and standardised for mutual conductance at 16mA (anode current) with 200V applied to the anode, connect the AvoMeter (on 10mA AC range) in place of the A1 link. Then check that:

SELECTOR SWITCH SET TO 641 226 413 FOR STANDARDIZATION PURPOSES

(1) For 16mA anode current on the VT160A the AvoMeter reading is 8mA.

(11) Negative grid volts is ± 5% of the standard figure.

(111) Mutual conductance is ± 7% of the standard figure.

NOTE: The mutual conductance figure for the CV491 will normally be in the order of 4mA per volt at an anode current of 16mA. The tolerance specified for measurement of mutual conductance on the instrument applies only to this point on the mutual conductance control.

Check that with the anode current set up to 8mA on the external meter the Valve Tester meter indicates a nominal figure of 16mA).

(J) Remove the CV491 and with the bias control set at 40 connect a 680kΩ ± 5% resistor between G and C connections on top cap board.

(SET - grid volts SWITCH TO X2)

Check that, with the circuit selector switch set to 'Gas' the Valve Tester meter shows f.s.d. within 20%.

(K) Insert a U52 in the appropriate socket, set the circuit selector switch to test and electrode selector switch to D1. Insert the AvoMeter (on appropriate DC current range) in series with the load from the top cap board (D1) to the rectifier anode.

Check that for all load switch positions:

(1) The Valve Tester meter reading is approximately in centre of 'good' scale.

(11) That the AvoMeter readings are within ± 10% of nominal value.

(M) Repeat test as in (J) with anode load connected to D2 on top cap board and electrode selector to D2.

APPENDIX 1

SCHEDULE OF SPARE PARTS

FOR

AVO VALVE TESTER

TYPE 160A

AND

ADAPTOR UNIT TYPE 160A/1

PROCEDURE FOR ORDERING SPARES

Throughout the past decade AVO instruments have proved themselves to be unrivalled for versatility and reliability. It is, however, inevitable that instruments will fail from time to time. We are anxious that AVO instruments are repaired to the highest possible standard and we have, therefore, produced this Schedule of Spare Parts, which will form a useful guide to the trained engineer who has the task of maintaining this instrument.

By following the procedure set out below, delays will not occur due to unnecessary correspondence.

1. State the part number of the items required, also the quantity.
2. State the serial number of the instrument. This will be found on the front panel.

Overseas users of our instruments should send their requirements to our representatives on their territory.

If parts are required in Great Britain, application should be made direct to AVO LIMITED.

VALVE TESTER TYPE 160A and ADAPTOR UNIT TYPE 160A/1

SCHEDULE OF SPARE PARTS

MAIN ASSEMBLY - 40946-A

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	40944-E	Case Assembly (for details see below)	-	1
2	40945-A	Chassis Assembly (for details see below)	-	1
3	40947-A	Valve Panel Assembly (for details see page 19).	-	1
4	14740-3	Metal Foot for Bottom Case	-	4
5	14746-7	Identity Label	-	1
6	11237-E	Top Cap Lead	-	2

CASE ASSEMBLY 40944-E

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	40944-B	Top Case Assembly	-	1
2	40944-D	Bottom Case Assembly	-	1
3	14740-4	Foot For Top Case	-	4
4	13714-3	Washer for Item 3.	-	8
5	40374-2	Gasket for Valve Panel Assembly	-	1
6	40507-1	Seal Between Case and Chassis	-	1
7	20970-A	Hinge Assembly	-	2
8	20970-B	Hinge Assembly	-	2
9	14635-3	Release Block for Hinge Assembly	-	2
10	11596-1	Rubber Foot	-	4
11	11727-A	Handle Sub-Assembly	-	1
12	11727-5	End Cap for Item 11	-	2
13	-	Negative Grid Volts Control	-	1

CHASSIS ASSEMBLY 40945-A

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	16957-2	Mains Input Cover Plate	-	1
2	11982-1	Grommet For Item 1	-	1
3	20909-1	Electrode Selector Switch	SH	1
4	14822-3	Circuit Selector Switch	SG	1
5	40471-A	Mains Adjustor Assembly	SK1 & SKT1	1
6	12049-89	Fuse Holder		2
7	12049-88	Fuse Holder Cap		2
8	12239-6	2-Amp Fuse	FS1 FS2	2
9	50010-14	Indicator Lamp (6.3V 0.3A)	ILP1	1
10	13698-1	Indicator Lamp Assembly, complete		1
11	20911-1	Screen Volts/Anode Volt Switch	SE SF	2
12	13657-1	Toggle Switch	SA SB SC SL	4
13	16961-A	Mains Input Board Assembly		1
14	40949-2	Front Panel		1
15	14822-2	Heater Volts Switch	SD	1
16	40465-A	Mutual Conductance Control Assembly (For details see page 18)		1
17	14558-2	Anode Current Potentiometer (90Ω)	RV4	1
18	40464-B	Anode Current Switch Assembly (For details see page 18)	SJ	1
19	13845-3	Handle		2
20	13846-5	Bush for Item 19		4
21	N82	Hex. Stiff Nut for Items 19/20		4
22	20888-1	End Frame		2
23	21589-8	Component Board Assembly (For details see page 17)		1
24	14274-1	'L' Shape Mounting Bracket		6
25	14627-2	Cover for Mains Voltage Panel		1
26	17087-1	Mains Lead 8' 0" (PVC 21)		1

Item No:	Part No:	Description	Cct. Ref.	Qty.
27	13701-9	Movement Mounting Pillar		2
28	PVC100	5-Way Lead (24ins per instrument)		1
29	11310-A	Tag Board Assembly		2
30	20901-B	LT Transformer Assembly	T2	1
31	20899-D	HT Transformer Assembly	T1	1
32	20908-A	Lamp Board Assembly (For details see page 19)		1
33	40466-A	Relay Assembly (For details see page 17)		1
34	14013-1	Modification Record Plate		1
35	40650-B	Movement and Case Assembly* (For details see page 19) * 30μA, 3250Ω including swamp.	M1	1

KNOB ASSEMBLY 15220-E

1	14267-1	Knob		1
2	S745	Special Screw		1
3	W39	Spring Washer		1
4	14670-2	Knob Carrier		1
5	20245-52	Spring Dowel		1

COMPONENT BOARD ASSEMBLY 21589-B

1	21589-A	Component Board Tagged		1
2	12049-385	Resistor 10kΩ ± 2% HSC	R8	1
3	12049-403	Capacitor 0.02μF 200V working	C2	1
4	12049-384	Resistor 330kΩ ± 2% HSC	R7	1
5	12049-402	Capacitor 0.04μF (2 in series)	C1	2
6	12049-1042	Resistor 910Ω ± 1% HSC	R6	1
7	12049-237	Resistor 10kΩ ± 10%	R36	1
8	12049-400	Resistor 8kΩ ± 5%	R11	1
9	12049-404	Capacitor 8μF 450V working Electrolytic	C3	1
10	12049-	Resistor 1kΩ ± 2.5%	R12,13	2
11	14709-B	Resistor 200Ω ± 2.5%	R10	1
12	15581-60	Silicon Diode Type 10DE8	MR1-4	4
13	12049-876	Resistor 82kΩ ± 10%	R41	1
14	10770-9	Potentiometer 500Ω	RV3,5	2
15	15832-9	Potentiometer 20kΩ ± 10%	RV6	1
16	12049-244	Resistor 100kΩ ± 10%	R38	1
17	12049-432	Resistor 1.22MΩ ± 2%	R3	1
18	12049-1043	Resistor 2.41kΩ ± 1% HSC	R39	1
19	12049-380	Resistor 2.34kΩ ± 1% HSC	R1	1
20	12049-	Resistor 220Ω ± 10%	R4	1

RELAY ASSEMBLY 40446-A

1	40466-24	Relay Board (Tagged)		1
2	14655-2	Nylock Anchor Plate 4BA		1
3	14548-4	Contact		1
4	14650-A	Contact Screw		1
5	10466-2	Contact		1
6	14647-2	Armature Spring		1
7	11832-5	Split Pin		2
8	14648-2	Spring		1
9	14644-2	Spring Retainer		2
10	14643-2	Armature		1
11	14642-2	Pole Piece		1
12	14646-2	Contact Spring		1
13	20885-A	Wound Bobbin	RL3	1
14	14645-2	Armature Retainer		1
15	20885-B	Wound Bobbin	RL1,2	2
16	13658-2	Anchor Plate		1

NEGATIVE GRID VOLTAGE CONTROL

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	14267-1	Knob		1
2	S.745	Screw 6BA Tin-plated		1
3	W.39	Coiled Washer 6BA		1
4	14670-2	Knob Carrier		1
5	20245-52	Spring Dowel		1
6	14711-2	Spindle		1
7	14275-2	Bush		1
8	13908-2	Hexagonal Locknut		1
9	14681-3	Friction Washer		2
10	W.3	Washer 4BA		1
11	14669-2	Collar		1
12	N.77	Hexagonal Locknut 4BA Tinplated		2
13	14630-1	Cover		1
14	S.867	Instrument Head Screw 8BA		3
15	14559-2	Negative Grid Volts Dial		1
16	13920-2	Dial Flange		1
17	A.1510	Cheesehead Screw 4BA Tinplated		5
18	14632-4	Friction Disc		1
19	S.869	Countersunk Screw 8BA Tinplated		3
20	13917-1	Clamp Plate		1
21	14560-1	Cursor		1
22	S.740	Cheesehead Screw 6BA Tinplated		2
23	14710-2	Pillar		2
24	13843-10	Pillar		2
25	14557-1	Potentiometer Strap		1
26	14558-1	Potentiometer 10kΩ	RV2	1

MUTUAL CONDUCTANCE CONTROL ASSEMBLY
40465-A

1	14666-2	Dial Support		1
2	14630-1	Cover		1
3	20969-1	Slope Dial		1
4	20902-1	Dial Housing		1
5	20897-1	Cover Plate (engraved)		1
6	14662-1	Potentiometer 2.5kΩ	RV1	1
7	14659-2	Drive Pin		1
8	14660-2	Drive Bracket		1
9		Telephone Dial Assembly		1
10	12049-387	Resistor 22kΩ ± 2% HSC	R14	1
11	12049-382	Resistor 500Ω ± 1% HSC	R5	1
12	12049-381	Resistor 70Ω ± 1% HSC	R2	1
13	40465-34	Component Board		1

ANODE CURRENT SWITCH ASSEMBLY 40464-B

1	40464-2	Anode Current Switch	SJ	1
2	12049-29	Resistor 80Ω ± 2% HSC	R15-R23	9
3	12049-388	Resistor 240Ω ± 2% HSC	R24-R26	3
4	12049-389	Resistor 600Ω ± 2% HSC	R27	1
5	12049-390	Resistor 3kΩ ± 2% HSC	R28	1
6	12049-391	Resistor 15kΩ ± 2% HSC	R29	1
7	12049-392	Resistor 814kΩ ± 2% HSC	R30	1
8	12049-393	Resistor 406kΩ ± 2% HSC	R31	1
9	12049-394	Resistor 202kΩ ± 2% HSC	R32	1
10	12049-395	Resistor 100kΩ ± 2% HSC	R33	1
11	12049-396	Resistor 31.5kΩ ± 2% HSC	R34	1
12	12049-397	Resistor 4.35kΩ ± 2% HSC	R35	1
13	12049-432	Resistor 1.22MΩ ± 2% HSC	R40	1
14	12049-911	Resistor 13Ω ± 10% (2 in Parallel Selected)	R37	2

KNOB ASSEMBLY 15220-A

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	S745	Special Screw		1
2	W39	Spring Washer		1
3	14266-6	Knob Carrier		1
4	14268-4	Knob Skirt		1
5	15066-2	Knob Washer		1
6	14269-4	Retaining Nut		1
7	20245-52	Spring Dowel		1
8	14267-1	Knob		1

LAMP BOARD ASSEMBLY 20908-A

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	40653-1	Lamp 200V 15W RED	ILP2	1
2	12049-386	Resistor 10kΩ ± 1% HSC	R9	1
3	20908-11	Lamp Board (Tagged)		1

MOVEMENT ASSEMBLY 40650-B

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	40537-2	Moulded Front Cover		1
2	40538-A	Moulded Case Rear		1
3	12730-2	Window Glass		1
4	30006-W	Swamp Bobbin		1
5	14384-3	Scale Plate		1
6	21124-D	Moving Coil Assembly		1
7	10194-B	Fixed Jewel Assembly		1
8	10184-B	Sprung Jewel Assembly		1
9	10191-4	Zero Adjuster		1
10	10158-4	Pivot		2
11	10075-16	Hair-Spring		2

MAIN INSTRUMENT VALVE PANEL ASSEMBLY 40947-A

Item No:	Part No:	Description	Cct. Ref.	Qty.
1	40140-9	Valve Holder UX6		1
2	40140-13	Valve Holder Hivac 5-pin		1
3	40140-3	Valve Holder American UX7 (Large)		1
4	40140-4	Valve Holder American IX4		1
5	40140-20	Valve Holder American UX7 (Small)		1
6	40140-12	Valve Holder Hivac 4-pin		1
7	40140-6	Valve Holder American UX5		1
8	40140-7	Valve Holder Mazda Octal		1
9	40140-1	Valve Holder British 9-pin		1
10	40140-14	Valve Holder B7G		1
11	40140-11	Valve Holder B8A		1
12	40140-10	Valve Holder 8-pin side contact		1
13	40140-19	Valve Holder B9A		1
14	40140-16	Valve Holder B8G		1
15	40140-5	Valve Holder British 4/5-Pin		1
16	40140-8	Valve Holder International Octal		1
17	40140-2	Valve Holder British 7-pin		1
18	10281-1	Valve Holder B9G		1
19	10509-1	Valve Holder B3G		1
20	40166-3	Escutcheon		1
21	14651-1	Grommet		2
22	40157-C	Roller Selector Switch		1
23	20903-A	Top Cap Escutcheon Assembly		1
24	20968-1	Valve Holder Segment (Ceramic)		8
25	14714-A	Valve Holder Spring Assembly for Item 24		8
26	14264-2	Collar for Item 24		8
27	40948-2	Valve Holder Panel		1
28	14745-1	Warning Label		1
29	11310-B	Tag Board Assembly		2
30	14732-2	Plug Block		1

Item No:	Part No:	Description	Cct. Ref.	Qty.
31	14746-6	Identity Label		1
32	11673-3	Pillar for Item 29		4
33	14747-1	Ferroxcube Bead		38
34	13561-1	Insulating Plug		2
35	14739-2	Special Screw		2
36	14745-2	Warning Label		1
37	30008-63	Washer for Item 24		8
38	15639-5	Socket (25-way)		1
39	10511-6	Cap for Item 38		1
40	16995-1	Connector Retainer for Item 39		1
41	16973-1	Socket		2

ADAPTOR UNIT TYPE 160A/1 - Part No: 40953-A.

1	40703-Q	Case Assembly		1
2	40952-B	Valve Panel Assembly (for Details see Below)		1
3	21562-A	Valve Panel Lead (for Details see Below)		1
4	11237-E	Top Cap Lead		2

ADAPTOR UNIT VALVE PANEL ASSEMBLY 40952-B

1	40952-A	Valve Panel Assembly		1
2	17008-2	Hinge Pin		2
3	40140-23	Valve Holder Acorn 5-pin		1
4	40140-21	Valve Holder Continental F8		1
5	40140-15	Valve Holder B7A		1
6	40140-22	Valve Holder B8D		1
7	40140-25	Valve Holder B9D		1
8	40140-26	Valve Holder 5-pin in line		1
9	40140-27	Valve Holder 7-pin in line		1
10	40140-28	Valve Holder Nuvistor 5-pin		1
11	21564-A	Special Valve Holder Assembly		1
12	21199-A	Holder Assembly for Flying Lead/Valve		3
13	15626-2	Tab		6
14	14555-1	Socket		1
15	20903-D	Top Cap Escutcheon Assembly		1
16	15639-6	Plug 25-way		1
17	16981-1	Support Plate		1
18	16971-A	Contact Board Assembly		1
19	21561-C	Cover Assembly		1
20	15627-1	Plug		1
21	16911-1	Receptical		1
22	14269-4	Retaining Nut		1
23	21563-A	Partition Assembly		1
24	16995-1	Connector Retainer		1
25	21585-A	Valve Holder Assembly (Lighthouse)		1
26	15367-32	Label		1
27	14747-1	Ferroxcube Bead		34

VALVE PANEL LEAD 21562-A

1	15639-5	Socket 25-way		1
2	15639-6	Plug 25-way		1
3	15639-7	Cover		1
4	15639-8	Cover		1

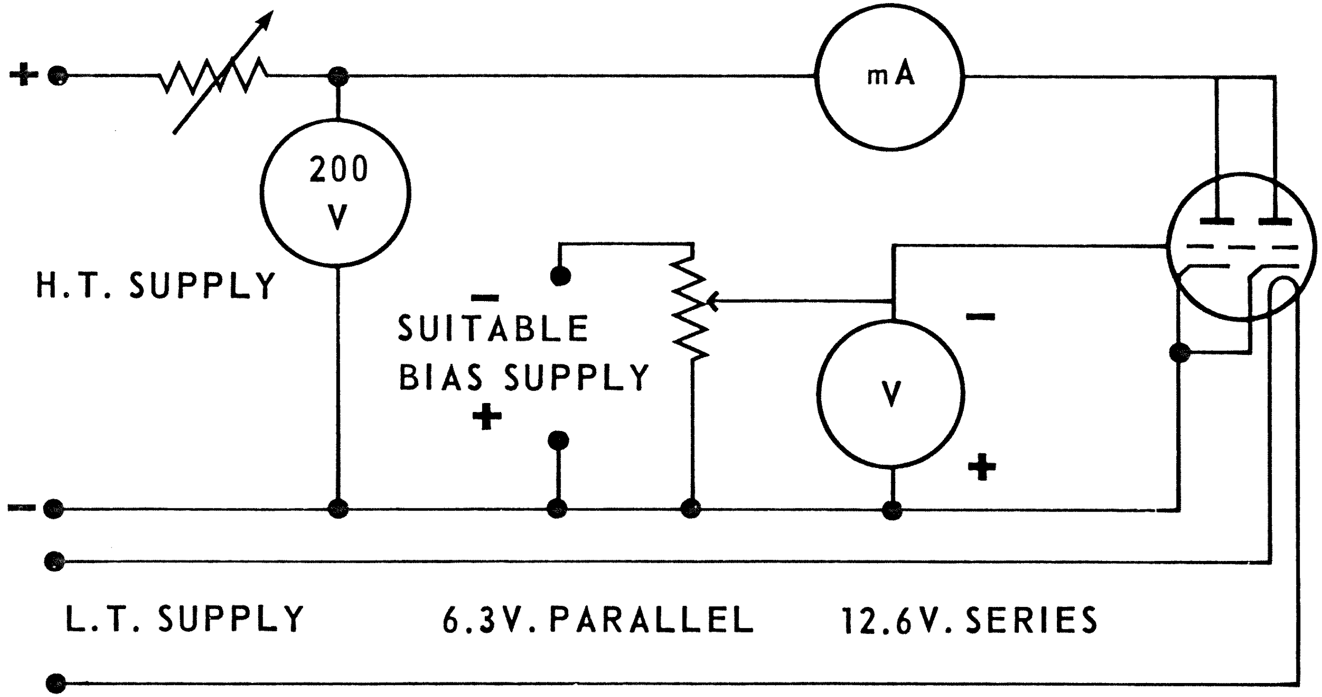


FIG 1 — VALVE STANDARDISING CIRCUIT

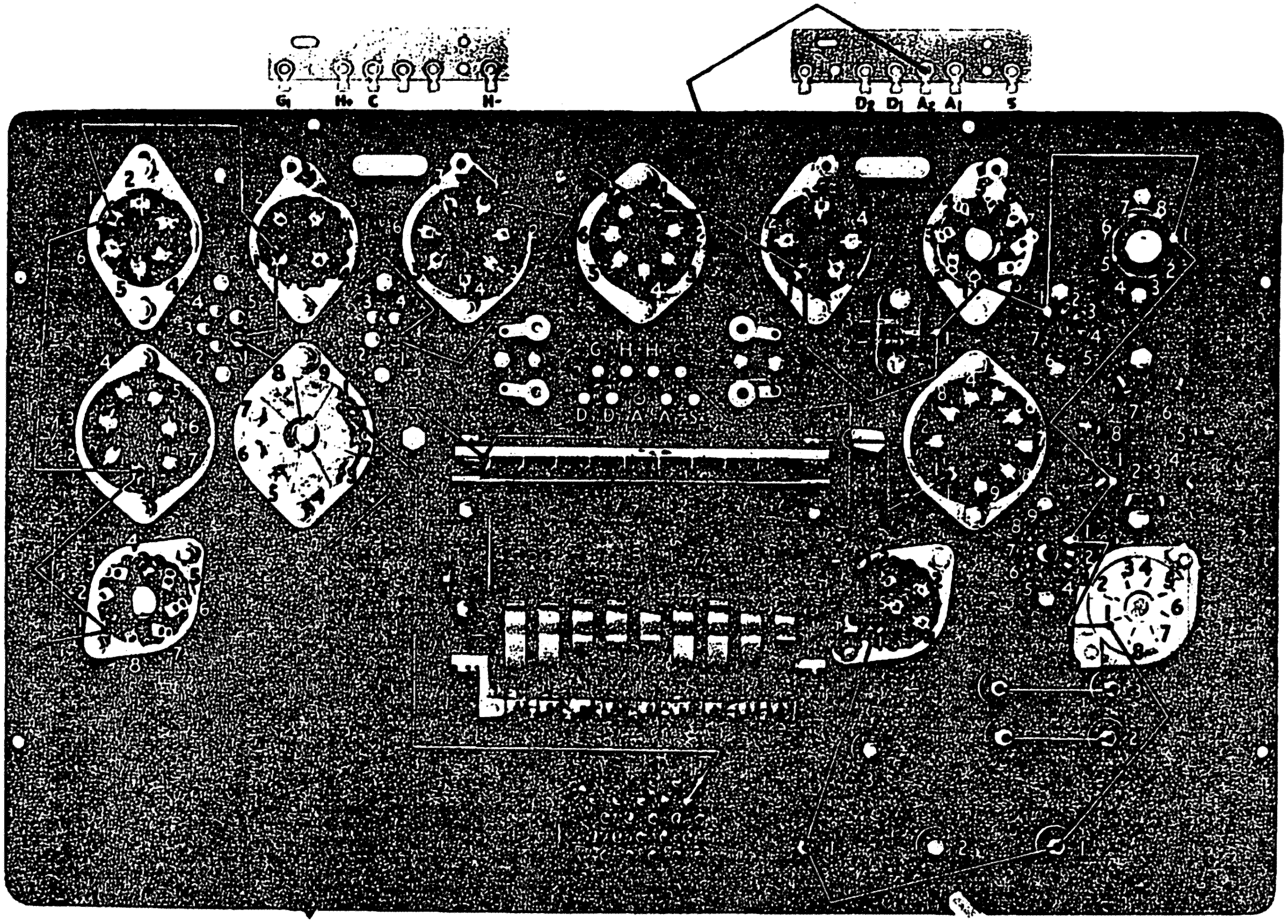


Fig 2.Underside of Instrument Valve Panel

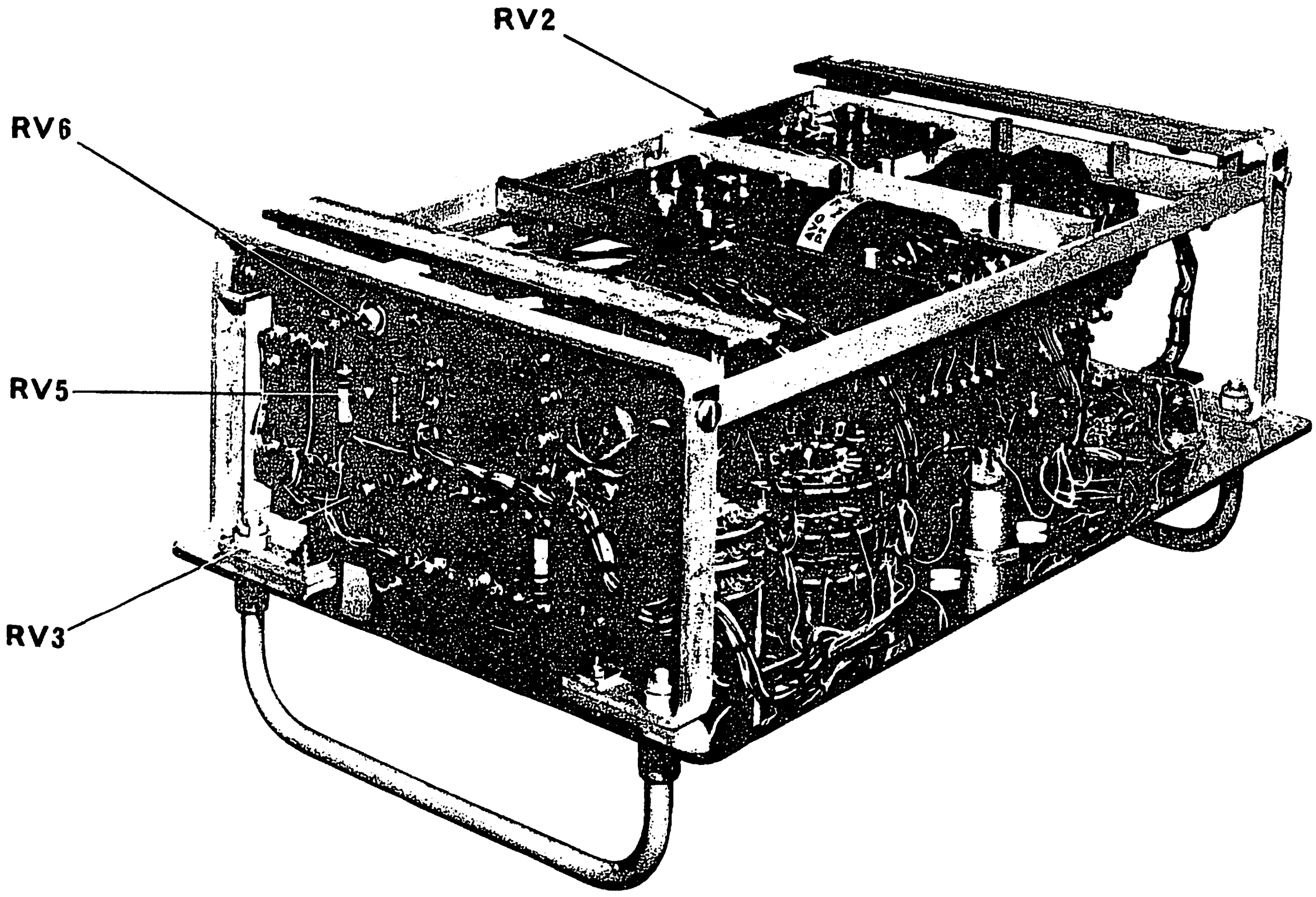


Fig 3. Instrument Chassis

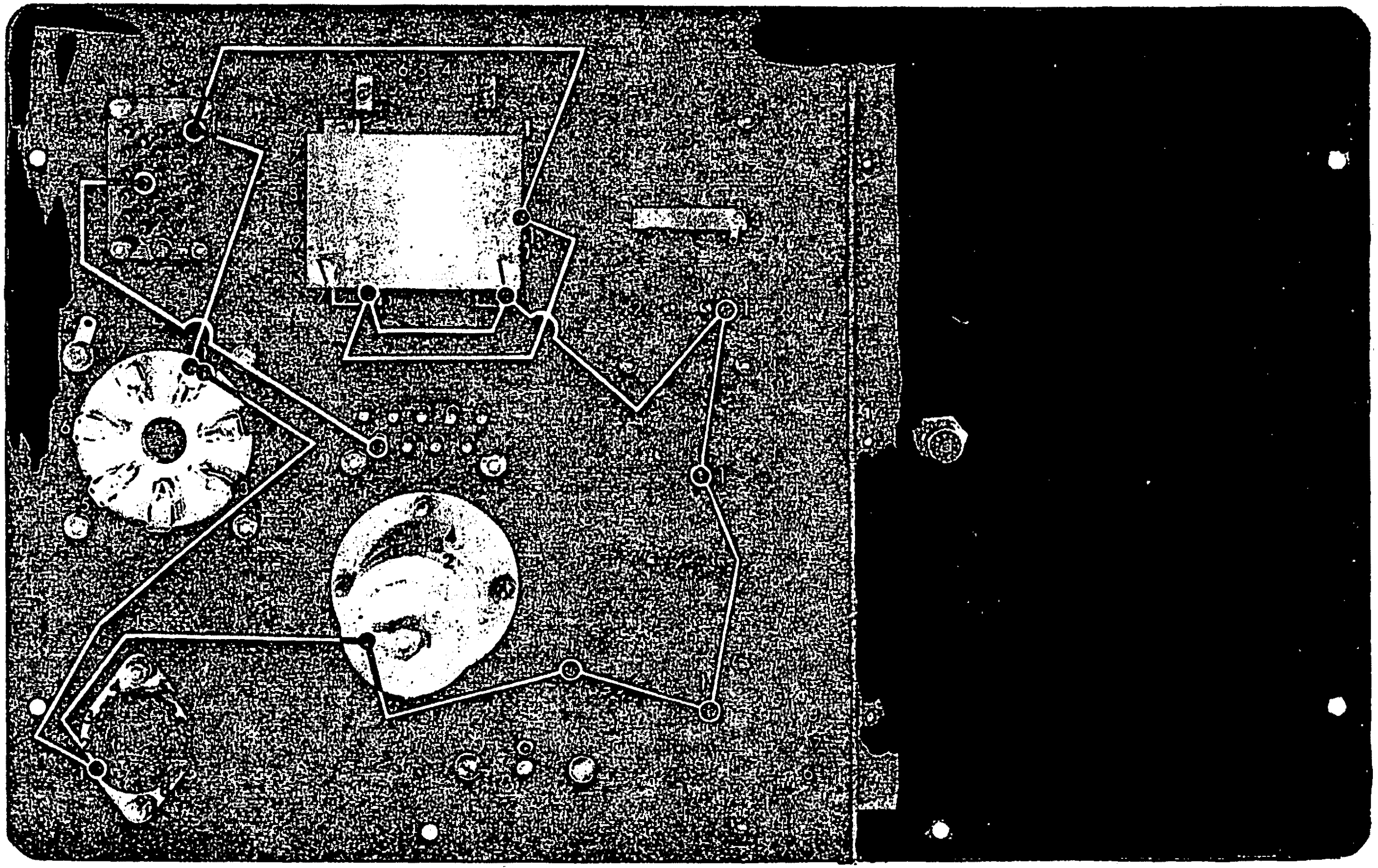
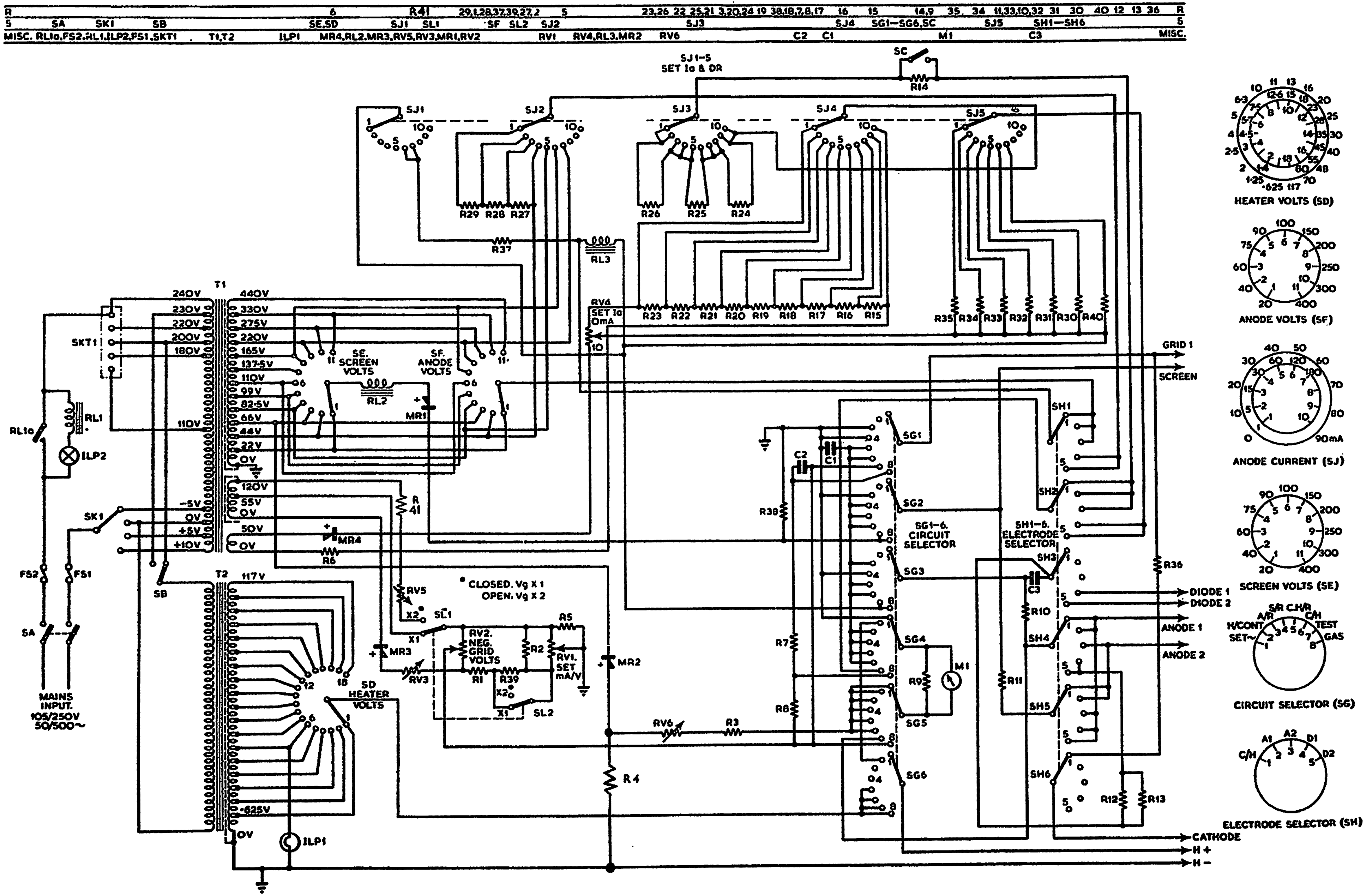


Fig. 4 Underside of Adaptor Unit Valve Panel

COMPONENT LIST

Cct. Ref:	Value	Remarks
R1	2.34kΩ	± 1%
R2	70Ω	± 1%
R3	1.22MΩ	± 2%
R4	220Ω	± 10%
R5	500Ω	± 1%
R6	910Ω	± 1%
R7	330kΩ	± 2%
R8	10kΩ	± 2%
R9	10kΩ	± 1%
R10	200Ω	± 2.5%
R11	8kΩ	± 5%
R12	1kΩ	± 2.5%
R13	1kΩ	± 2.5%
R14	22kΩ	± 2%
R15	80Ω	± 2%
R16	80Ω	± 2%
R17	80Ω	± 2%
R18	80Ω	± 2%
R19	80Ω	± 2%
R20	80Ω	± 2%
R21	80Ω	± 2%
R22	80Ω	± 2%
R23	80Ω	± 2%
R24	240Ω	± 2%
R25	240Ω	± 2%
R26	240Ω	± 2%
R27	600Ω	± 2%
R28	3kΩ	± 2%
R29	15kΩ	± 2%
R30	814kΩ	± 2%
R31	406kΩ	± 2%
R32	202kΩ	± 2%
R33	100kΩ	± 2%
R34	31.5kΩ	± 2%
R35	4.35kΩ	± 2%
R36	10kΩ	± 10%
R37	13Ω	± 10%
R38	100kΩ	± 10%
R39	2.41kΩ	± 1%
R40	1.22MΩ	± 2%
R41	82kΩ	± 10%

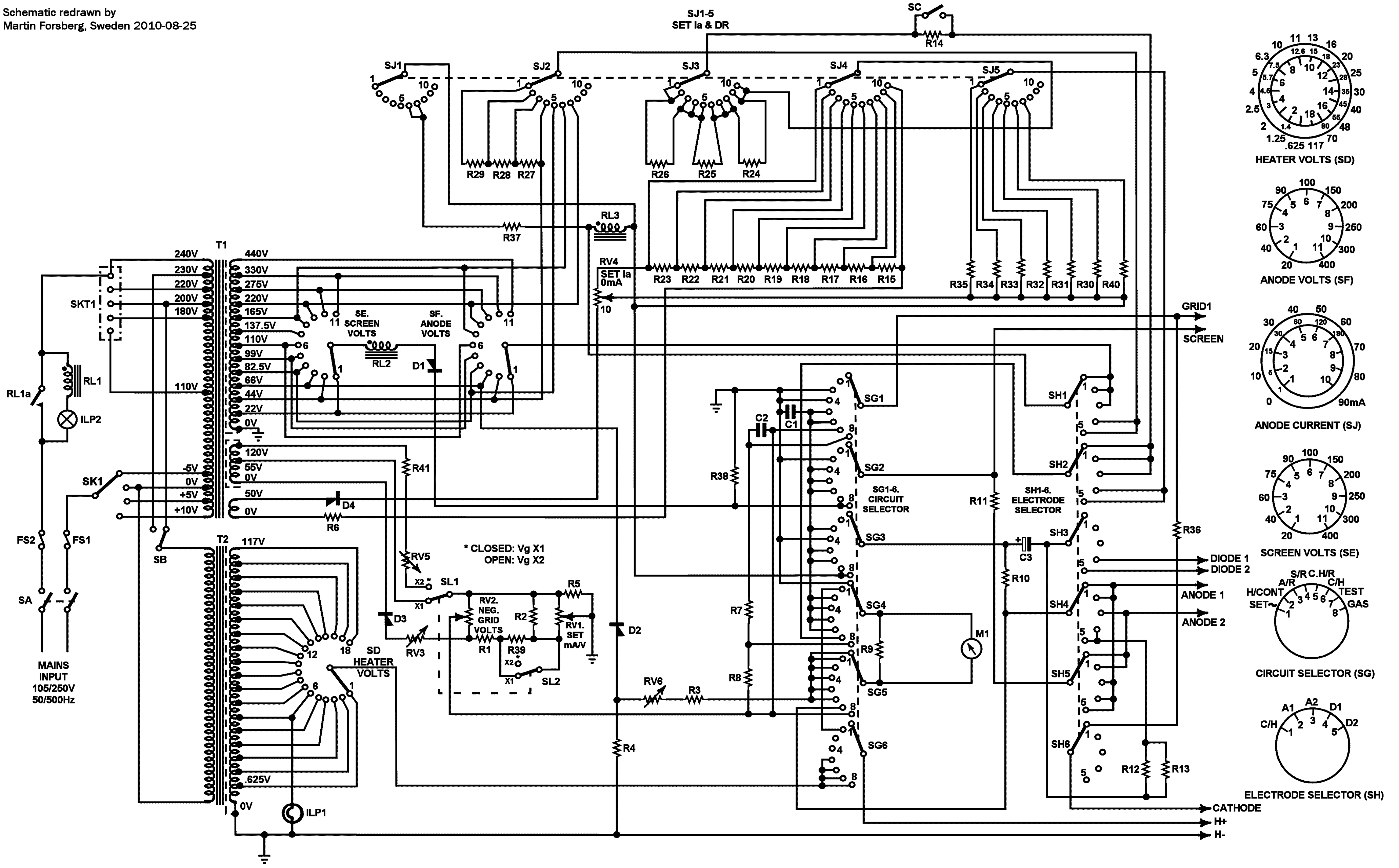
Cct. Ref:	Value	Remarks
RV1	2.5kΩ	
RV2	10kΩ	
RV3	500Ω	
RV4	90Ω	
RV5	500Ω	
RV6	20kΩ	
C1	0.04µF	2 in series
C2	0.02µF	200V wkg.
C3	8µF	450V wkg.
FS1	2A	
FS2	2A	
ILP1	6.3V	0.3A
ILP2	200V	15W RED
SA	On/Off	
SB	Heater Volts	
SC	Slope Switch	
SD	Heater Volts	
SE	Screen Volts	
SF	Anode Volts	
SG	Circuit Selector	
SH	Electrode Selector	
SJ	Anode Current	
SK	Mains Adjuster	
SL	Grid Volts	
MR1	10DE8	Silicon Diode
MR2	10DE8	Silicon Diode
MR3	10DE8	Silicon Diode
MR4	10DE8	Silicon Diode
M1	30µA 3250Ω including swamp.	
T1	HT Transformer	
T2	LT Transformer	



Valve Tester type 160A - Circuit Diagram

R						6	41		29,1,28,37,39,27,2			5	4	23,26	22,3	25,21	38,20,24,7,8	19	18,17	16	15,9	14		35	34	11,33,10,32	31	30	40	12,13	36	R
S	SA	SK1	SB			SE,SD	SJ1	SL1	SF	SL2		SJ2				SJ3				SJ4	SG1-SG6, SC					SJ5	SH1-SH6					S
MISC.	RI1a,FS2,RL1,ILP2,FS1,SKT1			T1,T2	ILP1	D4, RL2, D3, RV5, RV3, D1			RV2		RV1		RV4,RL3,D2	RV6				C2	C1				M1			C3						MISC.

Schematic redrawn by
Martin Forsberg, Sweden 2010-08-25

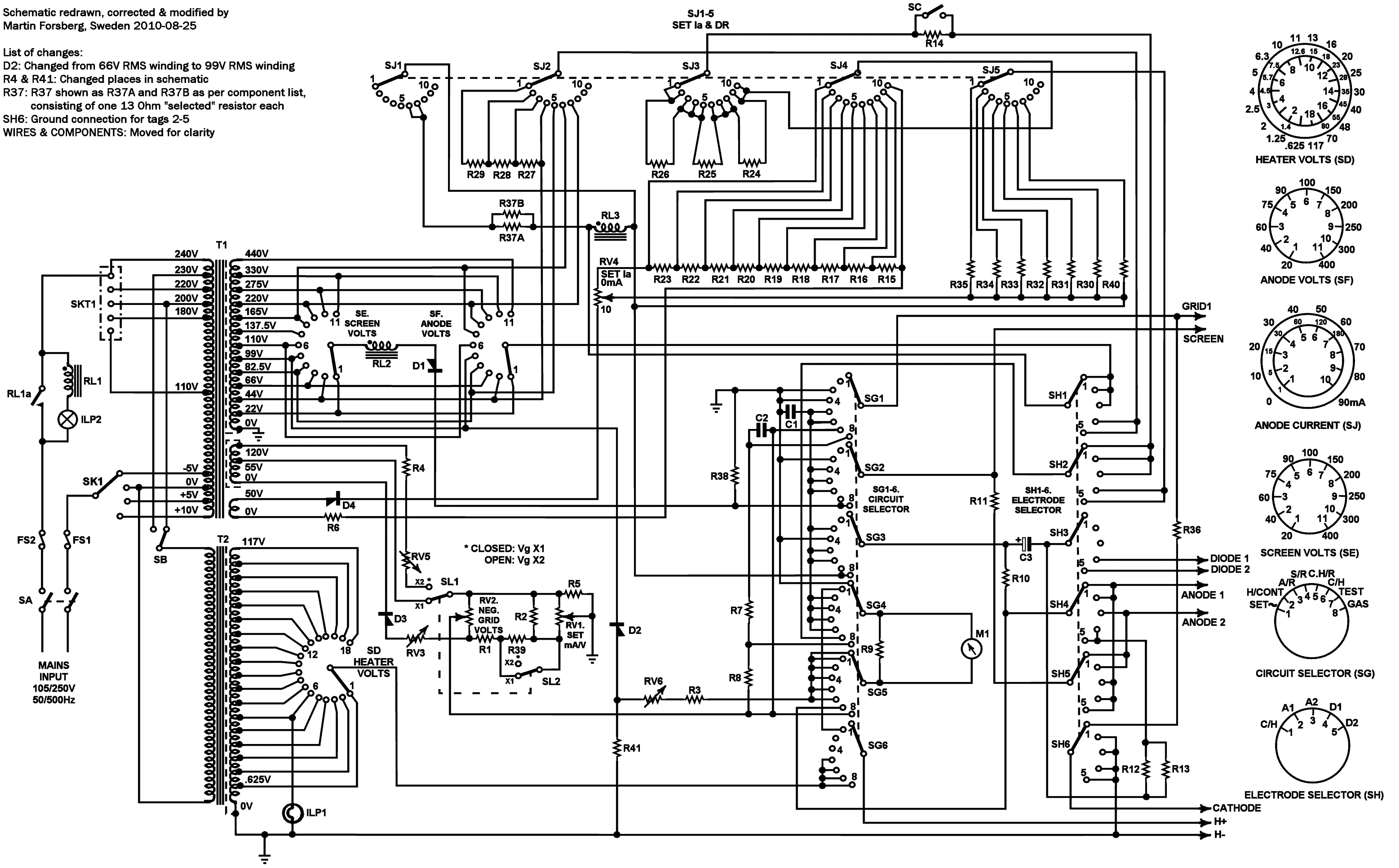


Valve Tester type 160A - Circuit Diagram ** Redrawn!

R						6		4			29,1,28,37,39,27,2			5	41	23,26		22,3	25,21		38,20,24,7,8	19		18,17	16	15,9	14		35	34	11,33,10,32	31	30	40	12,13	36	R
S	SA	SK1	SB			SE,SD		SJ1	SL1		SF	SL2		SJ2						SJ3					SJ4		SG1-SG6, SC				SJ5	SH1-SH6					S
MISC.		Rl1a,FS2,RL1,ILP2,FS1,SKT1		T1,T2	ILP1		D4, RL2, D3, RV5, RV3, D1			RV2			RV1		RV4,RL3,D2		RV6					C2	C1					M1			C3						MISC.

Schematic redrawn, corrected & modified by
Martin Forsberg, Sweden 2010-08-25

List of changes:
D2: Changed from 66V RMS winding to 99V RMS winding
R4 & R41: Changed places in schematic
R37: R37 shown as R37A and R37B as per component list,
consisting of one 13 0hm "selected" resistor each
SH6: Ground connection for tags 2-5
WIRES & COMPONENTS: Moved for clarity



Valve Tester type 160A - Circuit Diagram ** Redrawn & Corrected!

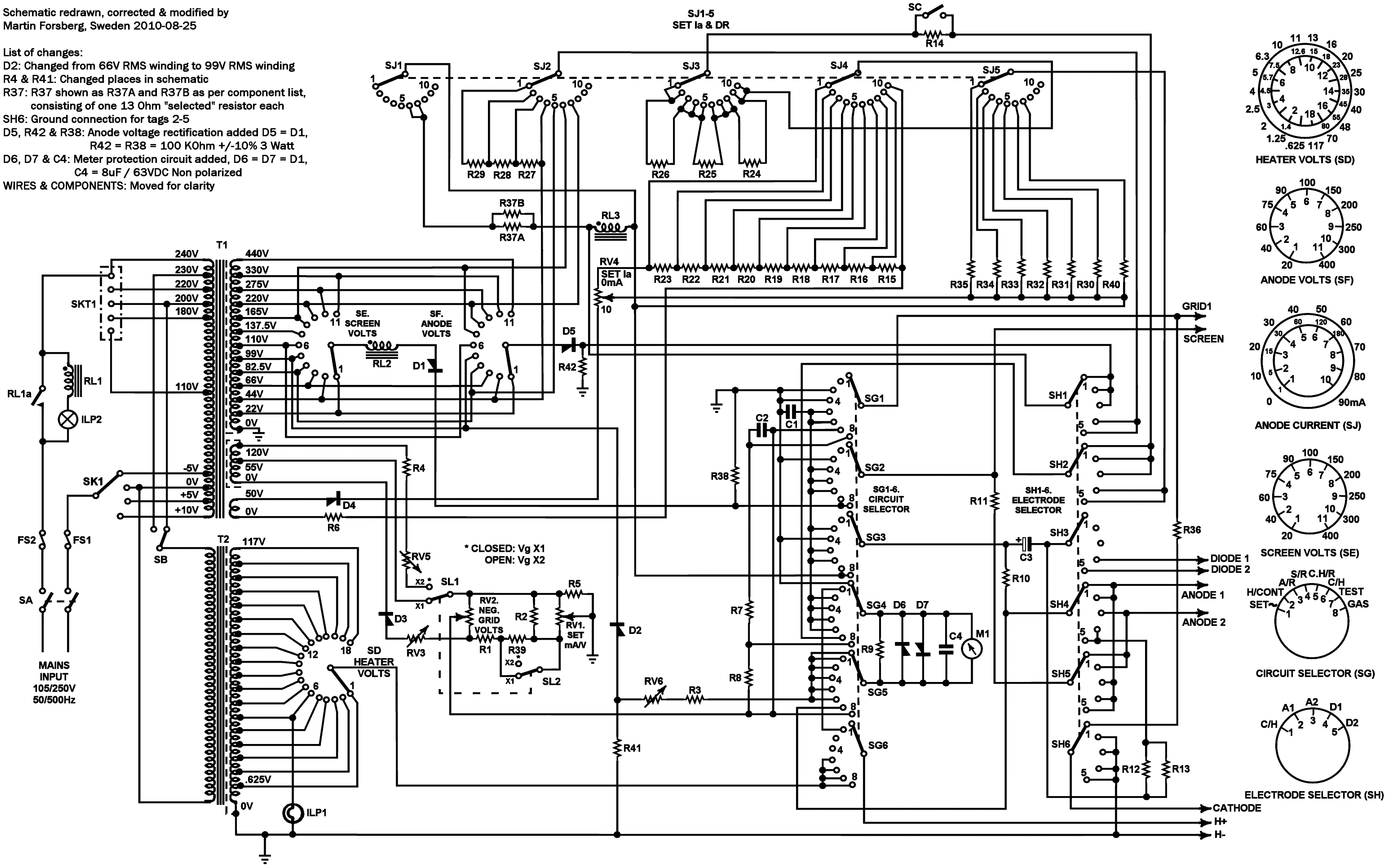
R 6 4 29,1,28,37,39,27,2 5,42 41 23,26 22,3 25,21 38,20,24,7,8 19 18,17 16 15,9 14 35 34 11,33,10,32 31 30 40 12,13 36 R

S SA SK1 SB SE,SD SJ1 SL1 SF SL2 SJ2 SJ3 SJ4 SG1-SG6, SC SJ5 SH1-SH6 S

MISC. Rl1a,FS2,RL1,ILP2,FS1,SKT1 T1,T2 ILP1 D4, RL2, D3, RV5, RV3, D1 RV2 RV1 D5 RV4,RL3,D2 RV6 C2 C1 D6,D7,C4,M1 C3 MISC.

Schematic redrawn, corrected & modified by
Martin Forsberg, Sweden 2010-08-25

List of changes:
D2: Changed from 66V RMS winding to 99V RMS winding
R4 & R41: Changed places in schematic
R37: R37 shown as R37A and R37B as per component list,
consisting of one 13 0hm "selected" resistor each
SH6: Ground connection for tags 2-5
D5, R42 & R38: Anode voltage rectification added D5 = D1,
R42 = R38 = 100 KOhm +/-10% 3 Watt
D6, D7 & C4: Meter protection circuit added, D6 = D7 = D1,
C4 = 8uF / 63VDC Non polarized
WIRES & COMPONENTS: Moved for clarity



Valve Tester type 160A - Circuit Diagram ** Redrawn, Corrected & Modified!