THE "AVO"

VALVE CHARACTERISTIC METER
Mk. III

WORKING INSTRUCTIONS

SECOND EDITION

PUBLISHED BY

AVO LIMITED,

AVOCET HOUSE, 92-96 VAUXHALL BRIDGE ROAD, LONDON, S.W.1

Telephone: VICtoria 3404 (12 lines)

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FOREWORD

FOR more than a quarter of a century we have been engaged in the design and manufacture of "AVO" Electrical Measuring instruments. Throughout that time we have consistently pioneered the design of modern multi-range instruments and have kept abreast of and catered for the requirements of the epoch-making developments in the fields of radio and electronics.

The success of our steadfast policy of maintaining high standards of performance in instruments of unexcelled accuracy, and making such instruments available at reasonable cost, is reflected in the great respect and genuine goodwill which "AVO" products enjoy in every part of the World.

It has been gratifying to note the very large number of instances where the satisfaction obtained from the performance of one of our instruments has led to the automatic choice of other instruments from the "AVO" range. This process, having continued over a long period of years, has resulted in virtual standardisation on our products by numerous Public Bodies, The Services, Railway Systems, and Post Office and Telegraph Undertakings throughout the world.

Our designers have thereby been encouraged to ensure that new instruments or accessories for inclusion in the "AVO" range fit in with existing "AVO" apparatus and serve to extend the usefulness of instruments already in use. Thus, the user who standardises on "AVO" products will seldom find himself short of essential measuring equipment; for, by means of suitable accessories, his existing equipment can often be adapted to meet unusual demands.

It is with pleasure that we acknowledge that the unique position attained by "AVO" is due in no small measure to the co-operation of so many users who stimulate our Research and Development staffs from time to time with suggestions, criticisms, and even requests for the production of entirely new instruments or accessories. It is our desire to encourage and preserve this relationship between those who use "AVO" Instruments and those who are responsible for their design and manufacture, and correspondence is therefore welcomed, whilst suggestions will receive prompt and sympathetic consideration.

INDEX

The "AVO" Valve Data Manual and Handbook

This instrument will produce maximum information when used in conjunction with the Valve Manufacturer's Graphs and Technical Data, but to enable rapid checks to be made relative to a valve's general efficiency, the "AVO" Valve Data Manual (civilian valve types) and the " AVO" Valve Data Handbook (service valve types) have been produced.

This instruction book refers throughout to the "AVO" Valve Data Manual, a copy of which should always be kept with the instrument. New editions of this data manual will be published from time to time. Watch our advertisements in the technical press for further announcements,

Introduction

To

THE “AVO” VALVE CHARACTERISTIC METER Mk. III

The problem of designing a Valve Testing Instrument capable of giving a true and comprehensive picture of the state of any valve has always been one of considerable magnitude, increasing in complexity as new valve types are brought into general use.

For a quick general purpose test necessitating a minimum of time and technical effort a mutual conductance figure will give an adequate idea of a valve’s usefulness, and the original “AVO” Valve Tester was designed to test the efficiency of valves on this basis.

Whilst a Valve Tester must, of necessity, be accompanied by a data book correlating the results of the Tester with the condition of the valve in question, a purely empirical figure, if used as a standard, will always give rise to doubts in the mind of the operator.

The instrument should therefore, produce a figure which can be compared with some standard quoted by the valve manufacturer, if the operator is to use his instrument with confidence. For this reason the “AVO” Valve Tester used the static zero bias mutual conductance figure as a basis of comparison, this figure being at that time almost universally quoted by the valve manufacturer.

In order to reproduce this standard correctly, it was also necessary to reproduce the stated values of DC anode and screen voltage, a matter of some considerable difficulty when it is realised that for any stated condition of anode and/or screen volts the corresponding electrode currents can vary over very wide limits, and in the case of valves of low initial anode current and high slope, the actuation of the control which produces the milliamp-per-volt reading might easily double the anode current flowing. With DC methods of testing the inherent internal resistance of the rectifying circuits used could be such as to give regulation errors which could cause results to be meaningless unless complicated thermionic stabilising circuits and a vast array of monitoring meters were used in all voltage supply circuits, Such complications would not only render the Tester of prohibitive price and size, but would considerably increase the complication of operation for the non-technical user.

The problem was overcome by the introduction of the AC method of operation (Patent No. 480752) by which means the necessary DC test conditions were correctly simulated and a true mutual conductance figure produced by the application of AC voltages of suitable amplitude to all electrodes. This enormously simplified the power supply problem, rendered regulation errors negligible, and obviated the necessity for voltage circuit monitoring. The “AVO” Valve Tester thus fulfilled normal testing needs for a long period.

During recent years, however, electronic techniques have become much more precise and the nature and multiplicity of valve types have continuously increased. The zero bias mutual conductance figure is seldom quoted by the valve manufacturers, who, usually now publish the optimum working point mutual conductance and voltage figures, and in a large number of cases give full families of curves, from which, precise operation, under a variety of working conditions, can be judged. To cater for present day requirements therefore, a valve testing device should not only be capable of producing a working point mutual conductance figure at any reasonable value of anode, screen or grid voltage recommended by the manufacturers, but should also be capable, if necessary, or reproducing any one of the mutual characteristics associated with the valve in question. The instrument thus has

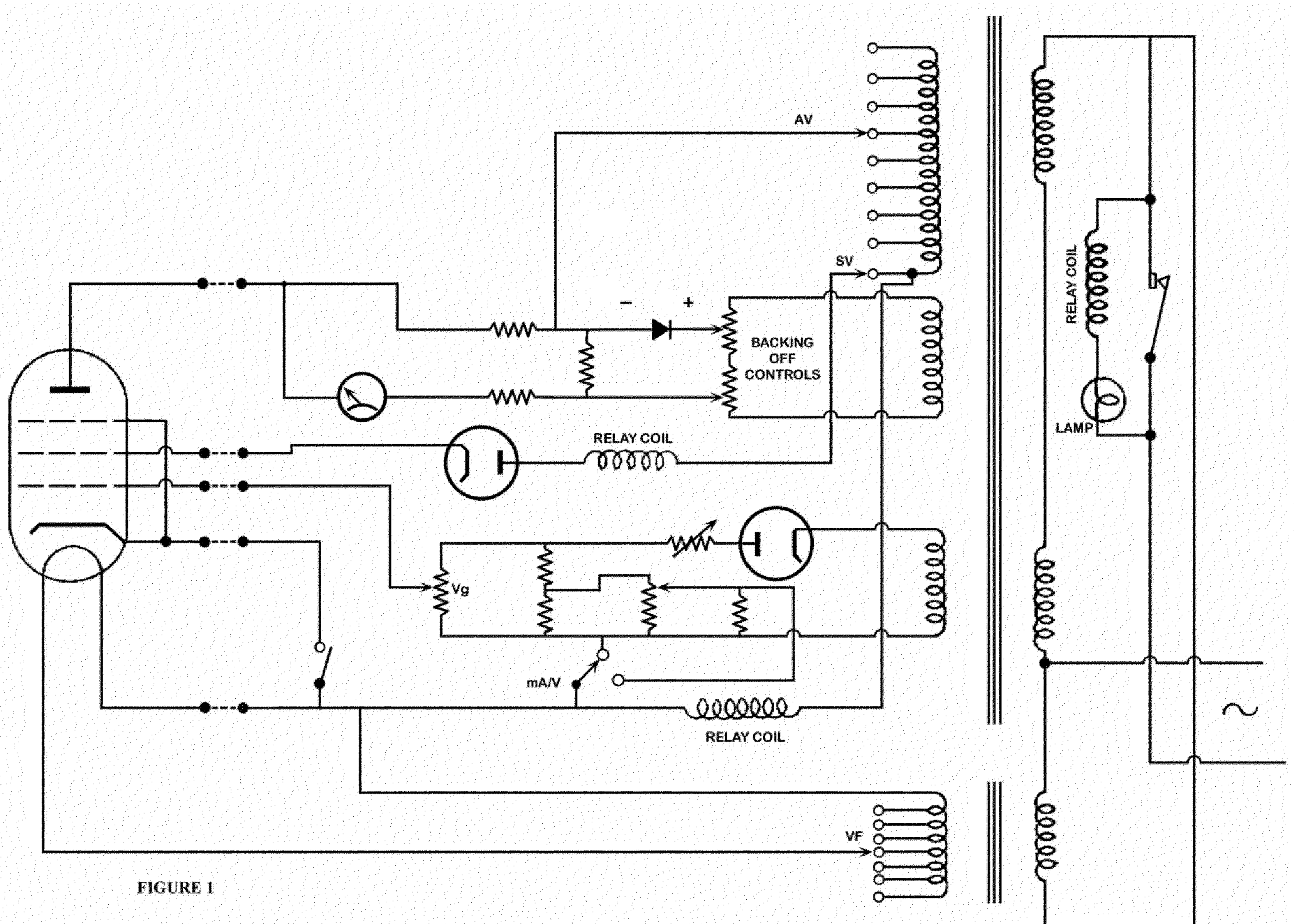
AV
SV
–
+
BACKING
OFF
CONTROLS
RELAY COIL
Vg
mA/V
RELAY COIL
VF
RELAY COIL
LAMP

FIGURE 1

to simulate the performance of a comprehensive valve measuring set-up of laboratory type and yet, at the same time, be sufficiently cheap and simple to cater for the needs of the comparatively inexperienced radio test assistant. It is obvious that the very much wider application of an instrument of this class would render the regulation difficulties, already referred to, much more critical.

Investigations were, therefore, put in hand to see whether the AC test method would reproduce DC conditions not only in respect of the mutual conductance figure taken at a single discrete point, but at all points on all characteristics from zero bias to cut off. In other words, it was necessary to determine whether the general function for a DC static valve characteristic

$$Ia = f\frac{(Va + \mu_1 Vg_1 + \mu_2 Vg_2}{Ra}$$

would hold when Ia was measured in terms of DC current, but when Va, Vg_2 and, if necessary, Vg_1, were replaced by 50 cycle AC voltages of suitable magnitude and phase. It was eventually found that a complete co-relation between these two sets of conditions was held when the grid voltage took the form of a sinusoidal wave form with the positive half cycle suppressed (in other words, rectified but completely unsmoothed AC), and the following relationships were maintained:-

Va RMS = 1.1 Va indicated DC
Vg_2 RMS = 1.1 Vg_2 indicated DC
Vg_1 (mean unsmoothed) = 0.52 Vg_1 indicated DC
Ia (mean *DC*) = 0.5 indicated Ia

From the above conditions, therefore, the required relationships were obtained which formed the basis of operation of the Valve Characteristic Meter (Patent No. 606707).

Such an instrument, whilst retaining the advantages of simplicity, size and reasonable price, resultant upon the elimination of complicated regulated DC supply systems and universal monitoring, would have the inherent regulation easily obtained from a well designed AC transformer. It would enable a valve to be checked at any point on any one of its many mutual characteristics and if necessary would allow a full family of characteristics to be drawn.

The basic method of characteristic checking

The fundamental circuit of operation of the instrument is shown in Figure 1. As in the original Valve Tester, the process of obtaining a direct reading mutual conductance figure is simplified by the introduction of a backing off circuit, which balances out the deflection due to the standing anode current at the desired test conditions prior to the measurement of mutual conductance. It will be noticed that the current flowing in this backing off circuit is similar in wave form, but precisely opposite in phase to the anode current, this eliminating any indesirable ripple that could otherwise become apparent when the meter, after backing off, was set to a sensitive range. To facilitate the measurement of mutual conductance of high slope/short grid base valves and valves requiring a long heater stabilising period, two distinct methods of measurement have been incorporated.

The basic method of checking diodes and rectifiers

Any simple emission test at low applied voltage must necessarily give rise to a purely empirical figure for the valve in question, which cannot necessarily be correlated with any one of the maker's characteristics and which, owing to the fact that it relates to the lower bend portion of the rectifier characteristic may vary very widely for any given type of valve.

The important function of a rectifying valve is that it will, under suitable reservoir load conditions, produce sufficient current to operate the apparatus which it is intended to supply. This fundamental requirement, therefore, is the basis of rectifier testing in the Valve Characteristic Meter. A sufficiently high AC voltage is applied to operate the valve above the bend in its characteristic, and to ensure that its internal voltage drop is negligible. With a suitable reservoir condenser in circuit, the DC load is adjusted to correspond to a number of DC current conditions, i.e. 1mA, 5mA, 15mA, 30mA, 60mA, 120mA and 180mA. The actual current flowing in the load circuit is then indicated on a meter shunted to correspond with the DC load required. The meter reading will then indicate the comparative efficiency of the valve on the basis of the required DC load. Each half of a full wave rectifying valve is tested separately thus enabling the two halves to be checked for matching and any tendency to produce hum by partial half waving to be indicated.
The pre-determined load figures are chosen so that they not only give a sufficiently wide range of currents to cater for the normal requirements of electronic apparatus, but also correspond to the DC maximum emission figures usually quoted by manufacturers in their rectifying valve data.
Signal diode valves are similarly tested, but usually these loads at the 1 mA or 5 mA load positions, being normally more than sufficient to cover the rectified signal current that would be obtained. The basic operating circuit of the diode and rectifier system is shown in Figure 2.

Insulation Testing
To cover all eventualities, three distinct forms of insulation measurement are catered for in the Valve Characteristic Meter. Measurements are taken with DC applied voltages, and direct indication of the insulation value in megohms is shown on the meter scale. As an initial test, prior to the application of operating voltages to the valve, the rotation of a switch enables the insulation figure to be shown, which occurs between each of the valve

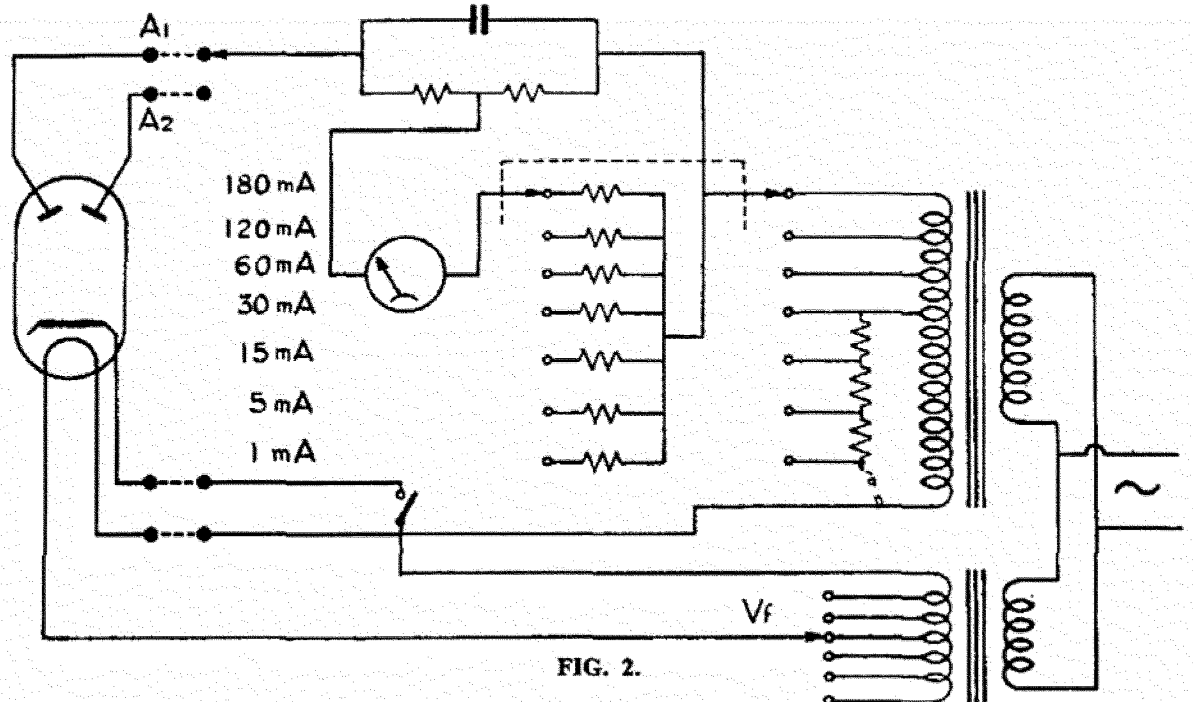

FIG. 2.

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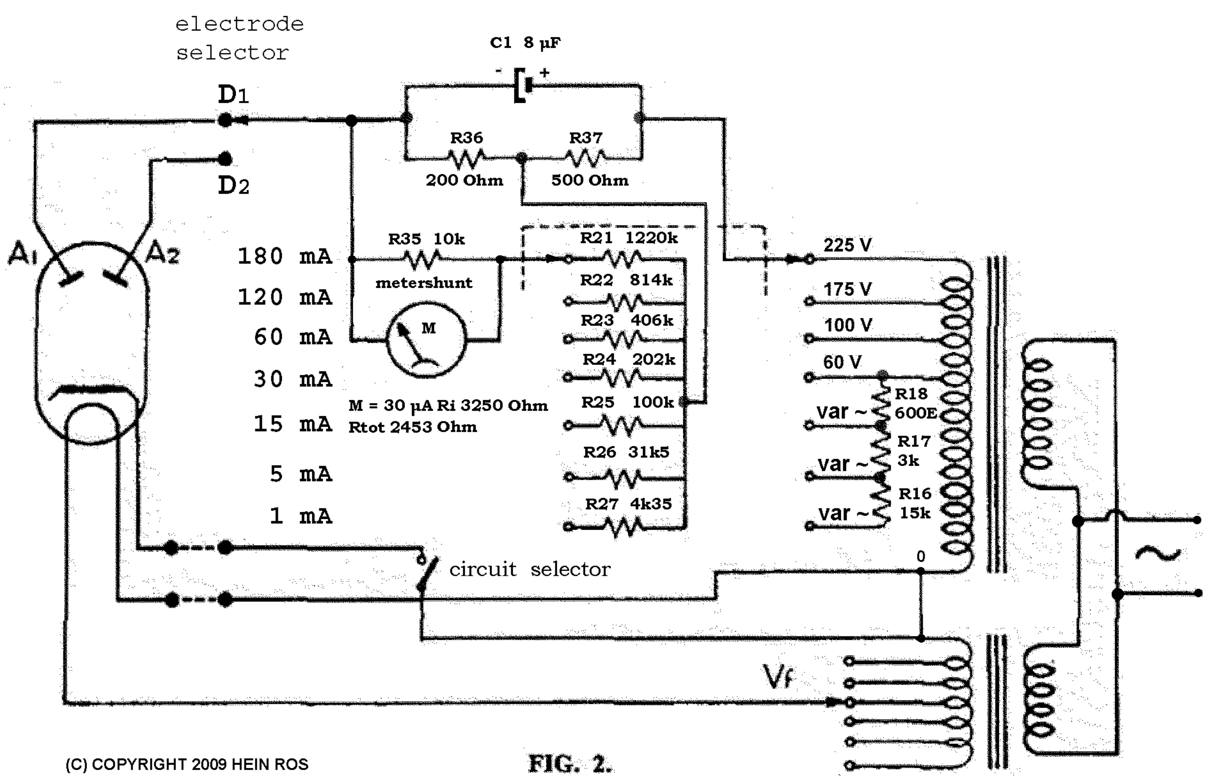


FIG. 2.

electrodes taken in order and all the others strapped together. The denomination of the electrodes between which any breakdown exists will thus be automatically indicated and further, the continuity of the heater circuit is shown as a zero resistance at the heater **(H)** position of the switch.

With the application of heater voltage to directly heated valves, electrode expansion may be sufficient to cause a breakdown between the heater and an adjacent electrode. In the same manner cathode distortion may occur in indirectly heated valves causing similar breakdowns. To show up this condition a test circuit is provided indicating the insulation resistance between the heater and cathode of a valve and all other electrodes strapped when heater voltage has been applied.

Finally the very important factor of heater to cathode insulation when the heater is hot can be tested, the insulation again being shown directly in megohms, the usual cathode to heater connection being opened for this purpose and the applied voltage being in such a direction as to make the cathode negative with respect to the heater, thus avoiding false indications of insulation resistance due to electrode emission.

Protective relay

To prevent damage to the internal components of the valve characteristic meter due to inadvertent or deliberate shorting of the electrode voltages, a protective relay is incorporated which operates when damaging overloads of alternating current are taken from either the anode or screen voltage sources. The relay carries three windings, one in each of the two high tension supplies, the remaining winding being a "hold-off" coil. Operation of the relay connects a high resistance lamp in series with the transformer primary winding whilst simultaneously a red warning indicator is illuminated behind the transparent meter scale and aural warning given. This operation places the instrument in a safety condition and normal working cannot be restored until the instrument has been switched off, the fault removed and the instrument switched on again. The relay is entirely self-setting and in consequence no reset mechanism has been incorporated.

NOTE: The relay does not protect the valve when incorrect heater voltages are applied. It must also be stressed that the relay will not operate on the passage of normal heavy current of a DC nature occurring in a valve anode circuit, and it will not protect the movement if the latter is wrongly set on a range too to low to accommodate the current passing. This problem can only be dealt with by ensuring that the movement is always set to its maximum current range when the magnitude of the expected current is unknown.

THE VALVE PANEL AND SELECTOR SWITCH

The Valve Panel comprises 19 valve holders of the following types:—English 4/5 pin, 7 and 9 pin, 8 pin side contact. B7G, B8A, B8B, (or B8G) (American Loctal), B9A, B9G, Mazda Octal, B3G, 4 and 5 pin Hivac: American-4, 5. 6 and small 7 pin UX, medium 7 pin UX, and Octal. Provision is made by means of plug-in adaptors to cater for newly introduced valve bases. The valve holders are all wired with their corresponding pins, according to the standard pin numbering, in parallel, i.e., all pins number one are wired together, all pins number, two, and so on. This wiring combination is associated with the well-known "AVO" Multi-Way 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 Valve Characteristic Meter, thus enabling any electrode combination to be set up for any normal valve holder.

It will be seen that the Selector Switch comprises nine thumb control 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 base connections up to nine can be accommodated. Further, to accommodate top cap and other external valve connections a socket panel is provided with nine sockets marked G1, S, Al, A2, Dl, D2, C, H-, H+, the markings corresponding to the valve electrode connections which are made externally to the valve.

Rotation of the rollers by the finger rim provided will reveal that each roller can be set in any one of ten positions, the setting in question being indicated in the window opening at the front of the escutcheon. The ten positions on the roller are marked as under: —

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

The numbers are provided for ease of memorising and noting base combinations, but the corresponding electrode denominations are shown by the letter appearing in the escutcheon window immediately is underneath the number, thus:—

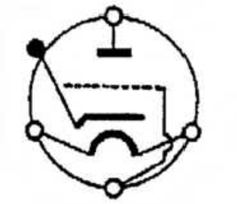
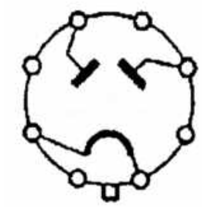
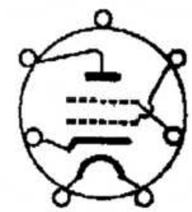
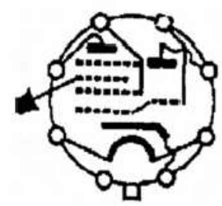
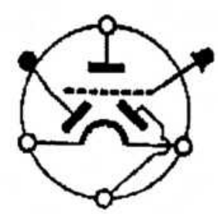
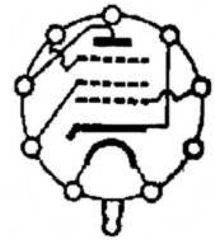
(1)	C	corresponds	to	Cathode, or to an electrode normally connected to cathode e.g., G3.
(2)	H-	"	"	Heater normally Earthy or connected to negative L.T. in the case of a battery valve,
(3)	H+	"	"	the other Heater connection or centre tap.
(4)	G	"	"	Control Grid
(5)	S	"	"	Screen Grid or g_2
(6)	A	"	"	Normal anode of single or multiple valves. In the case of an Oscillator mixer valve, A represents the Oscillator anode.
(7)	A2	"	"	second anode of double valves, and in the case of Oscillator mixer valves, the mixer anode.
(8)	D1	"	"	the first diode anode of half and full wave signal diode and rectifier valves, diode and rectifier/amplifier combinations.
(9)	D2	"	"	the second diode anode of signal diode and rectifier valves, diode and rectifier/amplifier combinations
(0)	—	"	"	disconnected valve pin or to a pin upon which an internal electrode is anchored. Such pins are marked "I.C." in manufacturers' literature, or by an asterisk (*) in the "AVO" valve data manual This switch position leaves the particular valve pin completely disconnected.

NOTE: *Some instruments are fitted with this roller position marked* 0/E
This marking is synonymous with 0̲

Procedure for setting up valve base connections

The standard procedure for setting up a valve ready for test is as follows. From some suitable source i.e. "AVO" Valve Data Manual or Handbook, Valve Manufacturer's Data Leaflet or published manual of Valve Data, determine, the pin basing connections for the valve, in order of their standard pin numbering. Rotate the rollers of the Selector Switch until the set up number or electrode letter combination appears in the window reading from left to right in order of the standard pin numbering. In the case of valves having less than nine pins, the free rollers on the right of the set up combinations corresponding to non-existent valve electrodes should be set at 0̲. When the valve is inserted in the appropriate valve holder, use the universal top cap lead to connect any top cap or side connection on the valve to its appropriately marked socket, on the Socket Panel immediately behind the Selector Switch. Note that the loctal valve holder having only eight normal pins, has its centre lug connected to the ninth roller (corresponding to pin No. 9) to accommodate valves which have a cathode connection made to this lug.

The accompanying examples show how to correlate the pin basing data and the equivalent set-up combination for a number of valves in common use.

	Valve Type	*Set up Number*									*Base Diagram*
1.	Osram MH4 indirectly heated triode British 5-pin base.	6 A	4 G	2 H-	3 H+	1 C	0 -	0 -	0 -	0 -	
2.	Osram U50 full wave Rectifier directly heated Octal base	0 -	2 H-	0 -	8 D1	0 -	9 D2	0 -	3 H+	0 -	
3.	Mullard PenA4 indirectly heated output pentode. British 7 pin base.	0 -	4 G	5 S	2 H-	3 H+	1 C	6 A	0 -	0 -	
4.	American 6K8 indirectly heated frequency changer. Octal base. Top Cap G1	0 -	2 H-	7 A2	5 S	4 G	6 A	3 H+	1 C	0 -	
5.	Mullard TDD2A battery double diode triode. British 5-pin base. Top Cap G1	6 A	8 D1	2 H-	3 H+	9 D2	0 -	0 -	0 -	0 -	
6.	Mullard EF50 indirectly heated HF pentode. B9G base.	2 H-	5 S	6 A	1 G3	0 -	1 C	4 G	0 -	3 H+	

Provision for New Valve Bases

To cover the possibility of the introduction of new valve bases not provided for on the standard panel and also the introduction of valves which may necessitate special conditions associated with standard valve holders, a plug-in adaptor is available which enables many non-standard valve holders to be combined in this adaptor and plugged into the octal or other suitable base on the Valve Characteristic Panel. These adaptors are available for bases not included on the Valve Panel, and also with a blank valve holder mounting panel in which can be mounted the user's own valve holder if he requires any special arrangement for which we have not catered.

The Prevention of Self Oscillation of valves under test

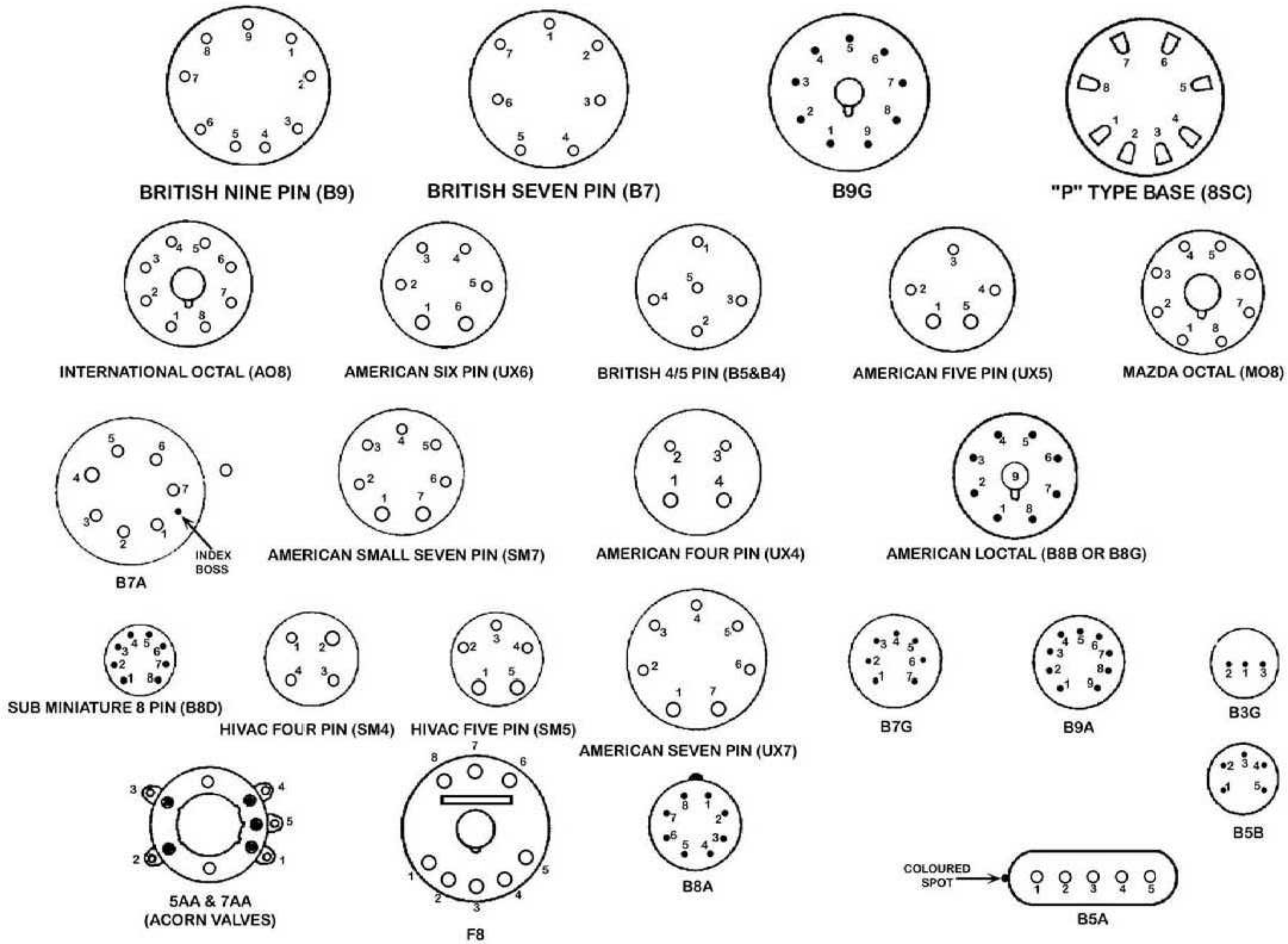
It will be realised that the length of wiring and its associated capacity, connected to the grid and anode pins of any one of the valve holders, can constitute a tuned line corresponding to a high resonant frequency often of' the order of 100 megacycles per second or higher. A number of modern valves have sufficiently high slope to overcome the inherent losses associated with such a tuned line, and are, therefore, capable of bursting into oscillation at a frequency determined by the constants of their associated valve holder wiring when being tested at or near their maximum working slope. It is quite obvious that in order to test a valve some wiring must exist between the valve holder and test circuit. Further, since a multiple test panel is desirable to obviate the necessity of a vast number of separate plug-in units, the total amount of wiring associated with any one valve holder must be a considerable number of inches in length. It is almost impossible to increase the effective resonant frequency of the lines thus produced to such a high value that no normal valve will oscillate therewith. The only alternative is to render the line of comparatively high loss and in extreme cases to stopper the valve in question right on top of its anode and/or grid connection. Unfortunately, however, since a very large number of pin combinations have to be accommodated in any one valve holder the presence of such a resistance in say a heater or cathode circuit could give completely erroneous results, and this stoppering system could therefore only be very sparsely used.

The problem of self oscillation has been almost completely eliminated in the "AVO" Valve Characteristic Meter Mark III, by wiring the Valve Holder Panel in connection loops of' predetermined lengths, so that any valve inserted would tend to oscillate at a definite frequency dependent on the loop lengths. These separate inter-connection loops are then loaded with ferrox cube beads so that oscillation cannot occur when testing valves with conventional characteristics, irrespective of the Valve Holder and pin combination used.

In certain circumstances where a newly introduced valve of high efficiency is likely to be tested in any quantity and shows signs of oscillation, the separate valve holder adaptor can be employed with considerable advantage. By this means a valve holder can be stoppered to the maximum extent necessary for the valve in question without references to any other valves that may be incorporated therein, for when other types of valve are likely to be used, the adaptor can be set aside and the valve panel used normally. It must be stressed that this oscillation is unlikely to occur where the valve is tested at anode currents lower than normal, or at a point on its curve which renders its mutual conductance low. Were a purely empirical method of testing employed in the Valve Characteristic Meter, therefore, the problem would in all probability not arise, but since every effort has been made to actually test the valve under its correct operating conditions of current and voltage, then it is on this account working at its normal efficiency and can, unless special precautions are taken give rise to the oscillation troubles to which we have referred.

DIAGRAM OF STANDARD PIN CONNECTIONS

(viewed from underside of base)



Whilst discussing the problem of oscillation, mention should be made of the rectifier (which will be seen in the circuit diagram) included in the screen circuit of pentode and tetrode valves. This rectifier has been incorporated to obviate a difficulty which can arise in certain circumstances when testing valves of the beam tetrode type with alternating current applied to their electrodes. As the applied electrode voltages approach zero during a portion of their operative cycle, the focusing of the beam of such valves is to some extent upset and the result can be that the screen circuit begins to show an emission in a reverse direction to normal screen current, with the result that the anode current rises and the current taken by the screen decreases rapidly and becomes negative. This can cause screen overheating and besides giving an unstable and erroneous impression of the condition of the valve, can, if allowed to continue, damage the valve. To obviate this condition, therefore, the rectifier is included in such a manner that only its low forward resistance is presented to the screen passing current in the normal direction, thus causing a negligible variation to standard conditions, but the reverse resistance of the rectifier is operative to limit screen current of the opposite direction to negligible proportions and thus prevent the conditions stated above, from coming into effect.

Procedure for Valves having Internally Connected Pins

On certain valves of recent manufacture, particularly the miniature glass type employing B7G, B8A, B9A, etc. bases, it has become the practice of manufacturers to connect internally, certain of the valve electrodes to pins which would otherwise be blank and free from any connection. Although the manufacturers specify the pins on which this is likely to occur they reserve the right to vary the nature of the internal connections from time to time as prevailing conditions might demand. This in itself prevents the inclusion of the electrode thus internally connected, in the normal selector switch set-up of the valve.

Valves with internally connected pins present no difficulty when tested on the valve characteristic meter Mk. III but because the valve data manual is used with earlier instruments, internally connected valve pins are marked (*) in the **Roller Selector Switch** number column. When using the valve characteristic meter Mk. III, where the asterisk appears in the **Roller Selector Switch** number denoting an internal connection, the appropriate roller should be set 0, e.g. U81, where the roller selector switch number reads **9 **8 230, set roller selector switch to read 009 008 230 and follow the normal procedure.

THE CONTROLS ON THE FRONT PANEL THEIR FUNCTIONS AND OPERATIONS

All the controls necessary for carrying out the essential valve testing functions are situated on the front panel of the instrument, and by the manipulation of these controls and the use of the valve panel already described, the following tests can be undertaken.

1. The direct indication of insulation resistance between specific electrodes with the valve cold. This test will also indicate heater continuity.
2. The direct indication of insulation resistance between electrodes with the valve filament hot, including a separate test for the important function of cathode to heater insulation.
3. The measurement of mutual conductance directly in milliamps/volt over a full range of applied high tension and bias voltages.
4. The comparative indication of valve goodness on a coloured scale on the basis of mutual conductance reading.

5. The ability to plot complete sets of mutual characteristics Ia/Vg_1, Ia/Va, Is/Vg_1, Is/Vs etc., with a complete range of applied electrode voltages corresponding to D.C. operating conditions.

6. The testing of rectifiers under reservoir condenser conditions with a full range of D.C. loading.

7. 'The testing of signal diodes under suitable D.C. load.

8. The testing of the separate sections of multiple valves, the non-operative section of the valve being maintained at reasonable working electrode voltages.

9. The indication of grid current and valve softness, directly on meter scale.

10. The anode current can, if desired, be read on an external meter of greater sensitivity and tests carried out on valves which require an anode load.

The separate functions of the controls available are as follows:—

The Set ~ Control

This control enables minor adjustments to be made to the input tappings on the mains transformer after the coarse mains tapping has been set.

The Leakage Switch

This switch serves the dual purpose of putting the instrument in a condition for the initial setting of the Set ~ control and also indicates the electrodes, if any, between which leakage occurs with the valve in a cold condition. It also serves to indicate heater continuity.

The Circuit Selector Switch

This is a five position switch enabling the instrument to be set up in readiness for the type of test to be undertaken. All the necessary internal circuit connections are made to satisfy the test conditions required, whilst internal test circuits, not required, are automatically removed from the valve.

On position **Check (C)** the instrument is set up for the initial mains voltage adjustment, and is suitably connected for the cold electrode leakage test.

At the **Check (H)** position of the switch, the valve is automatically tested for electrode leakage, with the heater hot, between the cathode and heater, and all other electrodes strapped.

At position **C/H.INS** the valve is automatically tested for cathode to heater insulation with the valve hot.

With the circuit selector turned to **Test** all normal mutual characteristics are measured in conjunction with the electrode voltage switches and other relevant controls. It will be noted that in the case of the insulation tests the meter is automatically shunted to the appropriate sensitivity and the insulation scale can be read directly. On the **Test** position of the **Circuit Selector** switch, however, the **Meter Switch** is brought into circuit, thus enabling the meter range to be suited to the current measurement to be undertaken.

Also at this setting in conjunction with the D_1 and D_2 positions of the **Electrode Selector** switch and the appropriate scale of the **Meter Switch**, signal diodes and rectifying valves can be checked. At the position **gas**, the meter is connected in series with the grid, and gives direct indication of any gas current flowing.

The Anode and Screen Voltage Switches

As their names imply these switches enable the requisite electrode voltages to be applied to screens 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, which, as already explained, will differ from the equivalent DC value marked at the switch position.

The Heater Voltage Switches

This dual switch combination is for adjustment of the heater voltage applied to the valve under test. To enable a very wide range of heater voltages to be obtained the settings of the two switches are arranged to be additive. Thus, with the left hand switch set at 0 all useful voltages between 0.625 and 7.5 can be applied to the valve by the right hand switch, whilst with the left hand switch at any figure above 0 the value indicated on the left hand switch should be added to the indication of the right hand switch. For example, with the right hand switch set at 5 and the left hand switch at 80, the heater voltage applied to the valve will be 85.

The Negative Grid Voltage Controls

The negative grid volts supply comprises two sections: (*a*) a continuously variable control calibrated 0—20 and (*b*) a five-way switch giving four increments each of 20 volts. This arrangement enables any bias voltage down to -100 volts to applied to the valve, the incremental steps being additive to the setting of the variable control.

The Backing Off Controls enables the initial anode current reading for the valve to be neutralised prior to the taking of mutual conductance readings. Two variable controls are used for this purpose, one fine and one coarse, which provide smooth backing off control to a maximum of 100 mA. The rotation of the controls in a clockwise direction will cause the meter needle to approach zero. For normal characteristic tests, both controls should initially be set fully anti-clockwise.

The Meter Switch is a combination switch to shunt the meter suitably to the current measurement to be undertaken and also to insert the right value of load when making tests on rectifiers and diodes. It has two calibration scales. The left hand scale marked Ia, with switch positions **2.5**, **10**, **25** and **100**, is used with the **Circuit Selector** at position " test" and the **Electrode Selector** at the position **A1**, **A2** or **S** to indicate the full scale deflection of the meter in mA when measuring anode or screen current. The position mA/V after having the "backed off" standing anode current is used in conjunction with the **Set mA/V Control** for the measurement of mutual conductance either direct or by the comparison method using the coloured scale on the meter.

The right hand scale marked **D/R** with switch positions **1**, **5**, **15**, **30**, **60**, **120** and **180** represents the load current when making diode or rectifier tests with the **Electrode Selector** at **Dl** or **D2**. Thus if the valve is rated at say 60 mA per anode, the **Meter Selector Switch** should be turned to "60" on the **D/R** scale and the comparative goodness of the valve with reference to this basic figure will be shown on the coloured scale.

The Set mA/V Control. This control has two scales 1—10 and 3—30 selected by means of an associated toggle switch. When the control is set to the expected mutual conductance figure for the valve under test, the standing anode current backed-off to zero and the **Meter Switch** set to **mA/V**, the meter shows the relative goodness of the valve under test.

If required the actual mutual conductance of the valve can now be obtained by rotating the **set mA/V Control** until the meter needle covers the calibration point at the centre of the "good" portion of the scale (marked **1 mA/V**) the mutual conductance of the valve can now be read directly from the **Set mA/V Control.**

The Electrode Selector Switch marked A1, A2, S, D1 and D2 enables separate tests to be made on multiple valves, and also makes possible the taking of Screen (or g_2) characteristics. With this switch turned to "A1" the figures of anode current and mutual conductance shown on the meter are relevant to the anode designated on the set-up roller by ${}^{6}_{A}$. As such the switch is in position for measurements on all single electrode system valves (triodes, pentodes, etc.). This position also serves for the first half of double valves (double triodes etc.) and for the triode or pentode section of multiple diode valves (double diode-triode, etc.) The same setting of this switch serves for the triode or oscillator section of frequency changers.

With the **Electrode Selector Switch** at position "A2", the indicator meter will show anode current and mutual conductance associated with the second anode of double valves, the mixer anode of frequency changers and all anode systems associated with the set up figure ${}^{7}_{A2}$. In this condition the first anode is not left floating, but has the normal screen volts supplied to it via a. limiting resistance.

With the **Electrode Selector** set to "S", the current meter is inserted in the screen (g_2) circuit of valves and screen current will thus be indicated. When making this test, anode voltage is automatically applied to all anodes in the valve. Note that in the case of a double pentode valve, the current indicated will be the combined current of both screens.

With the **Electrode Selector** at position D1, the indicating meter is associated with the diode anode of a signal diode or rectifying valve (and the first anode of double diode and full wave rectifiers). This switch position is directly associated with the anode designated on the selector switch roller by ${}^{8}_{D1}$.

With the **Electrode Selector** at position D2 the indicating meter is associated with the second anode of double diodes and full-wave rectifiers. In this case the switch position is associated with the roller switch setting ${}^{9}_{D2}$

The Mains Adjustment Panel at the rear of Instrument

This will be uncovered by the removable plate at the back of the instrument and the following will be exposed to view,

(*a*) The coarse setting for the applied 50/60 mains voltage marked 100/115, 200/215, 220/230, 240/250, the setting being made by means of the plug on this small sub-board, to the tapping most nearly corresponding to the nominal mains voltage.

(*b*) The fuse holder cap which when unscrewed reveals a small cartridge fuse which may be thus easily replaced if blown. The correct value for this fuse is 3 amp.

GENERAL PROCEDURE FOR TESTING A VALVE

1. After having set the coarse mains voltage plug at the rear of the instrument to suit the supply voltage, connect mains lead to supply noting that red and black leads are live and neutral. The green or yellow lead is the Earth connection. Switch on and the indicator lamp should light up. The valve to be tested should ***not*** be inserted at this stage. Allow a few moments for the instrument to warm up.

2.Turn the **Circuit Selector** switch to position **Check (C)** and **Leakage** switch to position "~". The instrument needle should now rise and assume a position near the black region of the insulation scale denoting zero ohms. Rotate the Set ~ control until the meter needle assumes its nearest point to the red line in the middle of this black scale marking. With a correct setting of the initial mains voltage adjustment rotation of the Set control should enable the needle to be moved on either side of the red line. If this is not the case and rotation of the Set ~ control does not enable the needle to reach its setting mark from either direction, then the initial mains setting should be moved to the next appropriate tapping. This tapping should be higher than the one chosen if the needle always appears to the right of the red mark and lower if to the left.

3. Having set up the accuracy of the instrument to conform to the applied mains voltage, refer to the "AVO" Valve Data Manual, or alternatively to the maker's characteristic data for the valve and set up the appropriate valve holder connections on the Valve Panel selector switch as already explained.

Set the Heater Voltage Switches to their correct value for the valve and insert it in the appropriate valve holder (NOTE: Heater voltages in parenthesis should be ignored as they relate to valve tester Type 160 ONLY), without moving the **Circuit Selector** switch from its position **Check (C)**. Rotate the **Leakage** switch through its various electrode positions starting with the extreme counter clockwise position marked "H". At position "H" the meter should show a short, thus indicating heater continuity. Thereafter any reading obtained on the insulation scale of the meter will show an electrode insulation breakdown corresponding to the electrode indicated by the **Leakage switch** setting. (Thus a reading on the meter of 1 megohm when the **Leakage switch** is set to position "G1" and position "S" will indicate that a cold insulation breakdown of 1 megohm is occurring between the grid and screen electrodes of the valve). It will be noted that wherever electrode leakage occurs, indication of this will be shown at two positions of the **Leakage switch**, because, obviously, leakage must occur between two points. In the case of breakdown to heater from any other electrode, such leakage indication will only occur at one switch setting subsequent to the initial selector setting, which should automatically show zero ohms to denote heater continuity.

4.Having ensured that no cold leakage path of any magnitude is present in the valve to be tested turn the **Circuit Selector** switch to **Check (H)**. Allow a few moments for the valve heater to warm up and note whether any meter deflection occurs. Such a deflection would denote in megohms the amount of insulation breakdown that occurs between cathode and heater strapped and all other electrodes of the valve when heater voltage is applied. Note that if for any reason, the Circuit Selector switch is turned back to **Check (C)** there will, in all probability, be an indication of an apparent cold electrode insulation breakdown between a number of the valve electrodes. This need not be the cause and the reading will be found generally to disappear after a few moments. The reason for such an indication is obvious when it is realised that the valve cathode has been heated during the **Check (H)** test. When returning to the **Check (C)** position, therefore, the cathode is hot and still emitting. What appears to be a temporary electrode breakdown, therefore, is in fact the indication of emission which disappears as the heater or cathode cools.

5. Turn Circuit Selector switch to **C/H. INS** when any cathode to heater insulation breakdown which occurs with the heater hot will be shown on the insulation resistance scale of the meter. No set rule for the rejection of a valve on this score can be laid down, but it will be realised that in many circuits where an appreciable potential exists between heater and cathode such as, for instance, in cathode follower circuits or DC valve amplifiers, the presence of a heater to cathode breakdown of the order of megohms can often give

rise to quite serious trouble. Heater to cathode insulation breakdown, either permanent or variable, can also give rise to noise in valve amplifier circuits. If, on the other hand, the value of cathode to heater circuit resistance is only of the order of a few hundred ohms, as for instance where cathode biasing is used with high slope valves, then a cathode to heater insulation breakdown of the order of fractions of a megohm need not give rise to any serious trouble.

6. The next test normally to be made upon the valves is the measurement of some or all of its mutual characteristics. This may take the form of the complete plotting of one or all of its characteristics, or the measurement of its mutual conductance, or the comparative testing of the valve on the basis of its mutual conductance. All these require the manipulation of the main voltage and meter controls and, before such a test is undertaken and the **Circuit Selector** switch turned to position **Test**, one should be assured that all the requisite controls are correctly set. This applies to the setting of the anode, screen and grid voltage controls, the **Meter Switch** and the **Electrode Selector** switch. *In particular, where the probable anode current of the valve is unknown, the* **Meter Switch** *should be set to* 100*mA to avoid damage to the movement if the current flowing is such as to be considerably higher than that catered for by the lower meter range positions.* It is always perfectly simple and safe to set the **Meter Switch** at successively lower full scale current deflections to cater for a valve, the anode current of which is less than that which can be appropriately read on a higher range. If the reverse procedure is adopted, however, then it is quite possible that a damaging current may have passed through the meter circuit before the latter is set to a suitable high range. The procedure for taking the necessary valve measurements is then almost self explanatory.

Where only a measurement of mutual conductance is required then, the data for this can be taken from the AVO" Valve Data Manual or Handbook. The electrode voltage settings should be made as indicated and consequent upon such settings an initial anode current will be shown on the meter which has been finally set to a suitable range. This anode current reading should normally be compared with the anode current reading shown in the tables, as it will give an initial indication of the valve's "goodness"**.** Quite obviously if a valve shows an anode current reading considerably below that which is appropriate for the applied electrode voltages, then its emission is much lower than would normally be expected and in normal circumstances the valve will not function at full efficiency. More particularly does this apply in the case of valves used either as oscillators or output valves, for in both conditions the valve has to deliver an appreciable power which cannot obviously be up to standard if the emission is low. At the same time care should be taken not to jump to false conclusions on this basis when testing valves of very high slope and short grid base, where it may be possible to double the valve anode current for a change in bias of some ·25V, and a very slight variation in the valve characteristics may give rise to an erroneous impression of the valve's "goodness" on the score of anode current.

7. After having observed the initial anode current reading and obtained therefrom such information as is desirable, this anode current indication may now be backed off to zero by the **Backing Off** controls and the **Meter Switch** Set to its 2·5 position, any further adjustment to zero being made by the **Fine Backing off Control**.

The Set mA/V Control should already have been set to the value given in the valve data and it would be as well to explain here how the two scales on this control should be employed. The outer scale marked 1 —10 applies a potential to the grid such, that at the slope indicated the rise in anode current is 1mA. Thus when the **Set mA/V** dial indicates 1 mA per volt, the bias change is equivalent to 1V, but when the control is set at 10 mA per volt the bias change is only 1/10th of a volt.

The inner scale marked 3—30 applies a potential to the grid such that at the slope indicated the rise in anode current is 3mA. It therefore follows that for a slope of 10mA/V on this scale the voltage change at the grid will be 0.3V.

For general purpose use, the inner scale should be employed, but when checking (*a*) a valve with slope less than 3mA/V or *(b)* a valve with a high slope/short grid base, the outer scale should be used.

Whilst in *(b)* above, there is no necessity to use the outer scale, a more accurate result should be obtained by its employment due to the smaller decremental voltage used to produce the mutual conductance reading. To measure the comparative "goodness" of a valve in terms of mA/V, with the anode current backed off to zero as already explained, any final zero adjustment having been made with the **Meter Switch** at its 2.5 mA position, set **Meter Switch** to position **mA/V**. The comparative "goodness" of the valve will now be given on the **Replace/Good** scale.

All valves coming within the green portion can be taken as satisfactory. Valves in the red portion are suitable for rejection, whilst the small intermediate band between the green and red portions denotes a valve which, whilst not entirely unsatisfactory, is not by any means working at its full rated efficiency. Subsequent action on the valves whose test figures come within this band will obviously have to be related to the particular requirement of the moment.

Alternatively, where it is required to obtain a reading of mutual conductance, and not merely a gauge of the valve's "goodness" factor on the basis of mutual conductance, then after backing off to zero, the **Meter Switch** should be set to position **mA/V** and the **Set mA/V** control rotated until the meter needle covers the calibration line at the centre of the good scale (marked mA/V). The mutual conductance of the valve may now be read from the **Set mA/V Control**.

Valves having a slope of less than 1mA/V cannot be checked by the comparative "goodness" method (using replace/good scale). In such instances, the set mA/V control should be set to position 1, the standing anode current backed off, and the **Meter Switch** set to position **mA/V**. The mutual conductance (slope) of the valve will now be directly indicated on the meter (using scale marked 0.1—1 mA/V).

Where more comprehensive tests of the valve are required, to assist in the solution of development or more intricate test problems, the plotting of one or a family of mutual characteristics can often give a much move complete answer. This may readily be undertaken with the **Valve Characteristic Meter** and is performed with the **Circuit Selector** in its position **Test.** The manipulation of the controls subsequent to the obtaining of the initial anode current readings is not of course required, it being merely necessary to plot the value of the appropriate electrode currents as read from the meter, against the settings of the associated electrode voltage switches. Ia/Vg_1 curves will be taken at a pre-determined setting of anode and/or screen volts, the reading of the anode current obtained being plotted against the settings on the variable grid bias controls. Similarly Ia/Va curves will require a fixed setting of grid bias, anode current being plotted against the settings of the anode voltage switch.

Where either mutual conductance characteristic curves are required for the screen or g_2 of the valve in question, then the **Electrode Selector** switch should be set to position

“S” the meter current shown will be an indication of the screen (or g_2) current and all the above instructions can be related thereto.

Remarks in relation to the tests described above as applied to multiple or special types of valve, will be found in subsequent test notes.

8. Where a valve is suspected of passing too much grid current; a measure of the magnitude of grid current at the desired conditions of applied electrode voltage may be made after having measured the mutual conductance of the valve in question. With the Meter Switch set to 100 mA on the Ia scale and the **Circuit Selector** turned to position **Gas** the meter is now directly connected in the grid circuit of the valve under test and gives a direct indication of grid current flowing. (To prevent damage to the instrument, a limiting resistance is incorporated which affects the accuracy of readings at the upper end of the scale).
The scale is calibrated 0—100 µA.

9. The testing of rectifying valves should really be associated with the requirements of the circuit in which these valves are to work, although in most cases, in the data for the valve in question a figure is quoted denoting the standard emission to be expected for a valve of the type under test.

The procedure for carrying out the test is again straightforward. All initial tests should have been carried out as for amplifying valves, but before setting the **Circuit Selector** to **Test**, the suggested load current figure for the valve given in the Data Manual should be set on the **D/R** scale of the **Meter Switch**. This load current, it will be realised, applies to one anode only. The setting of load current can either be determined from the tabulated data as already mentioned, or alternatively can be related to the total current that the valve is required to deliver. Thus in a piece of apparatus where the total HT current drawn is say 50mA, then a rectifier load current setting of “60” will be an adequate test for the valve emission (assuming half wave rectification). 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 **Meter Switch**. It will be realised that since each half of a full wave rectifier is tested independently, then the setting of the range switch should indicate half the total value of current that the valve would be expected to deliver in a full wave circuit. For instance a valve rated at a maximum current of 120 mA would be tested with each anode at the “60” position on the **Meter Switch**.

No further manipulation of the electrode voltage controls is required. The heater voltage is already set whilst anode, grid and screen voltage controls are completely disassociated from the test circuit by the setting of the **Electrode Selector** switch to **Dl** or **D2**, all appropriate voltage and circuit connections also being automatically made, Having, therefore, correctly set up the valve as explained, the indication of the meter needle on the coloured scale will show the operative goodness of the valve in relation to the standard load current chosen.

Similar remarks apply to the testing of signal diode valves, with the exception that these are always tested with the **Meter Switch** at “1” unless otherwise specified.

INSTRUCTIONS FOR TESTING SPECIFIC VALVE TYPES

The function of a valve, as distinct from its manufacturer’s type number is indicated by a symbol in the form of letters appearing at the extreme right of the test data; thus a half wave rectifier would have the letter R in the function column, whilst a full wave rectifier would be designated by “RR”. Similarly, diode valves will be shown by the letter “D” the number of diode elements being indicated by the number of “Ds”, thus “DDD” refer to a triple diode.

The testing of *multiple diodes or rectifiers* is carried out in the manner already explained, the **Electrode Selector** switch being used to select the diode or rectifier element, the comparative emission for which, being indicated on the meter. It will be realised that when dealing with diodes or rectifiers **D1** and **D2** positions of the selector switch represent diode or rectifier anodes 1 and 2 respectively and correspond to figures 8 and 9 in the set up figure.

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 set up number representing the third diode the symbol † is included, the first and second diodes being indicated by 8 and 9 respectively in the normal way. The valve should now be tested normally with the selector switch set to 0 where the †appears in the set up number. This will give emission figures for diodes 1 and 2. Now rotate the **Selector Switch** rollers so that the two rollers originally set at 8 and 9 are now set to 0 and set up the position †as 8 on the **selector switch**. A further test with the **Electrode Selector** switch at **Dl** will thus give the emission of the third diode. e.g., AAB1 will be indicated in the data as 0231†0980. To test diodes 1 and 2 the set up on the roller switch will be 023100980 and diodes 1 and 2 will be tested in the normal manner. For obtaining the emission figure for the third diode the **Selector Switch** will be altered to 023180000 and the **Electrode Selector** to position **Dl**.

Combined Diode and Amplifying Valves will be represented in the type columns by “DT” and “DDT” for diode triodes and double diode triodes, whilst “DP” and “DDP” indicate diode pentodes and double diode pentodes. The testing of such valves is automatic, the amplifying section being tested first with the **Circuit Selector** switch at position **Test** and the **Anode Selector** at position “**A1**” whilst the rotation of the **Meter Switch** to the appropriate load setting and the **Electrode Selector** to “**Dl**” and, or “D2” would cause the meter to indicate the comparative goodness of the valve. (Unless otherwise stated the load setting will be position 1 on the **D/R** scale of the **Meter Switch**.)

Double Triodes, Double Pentodes or Double Tetrodes will be indicated by the letters “TT” or “PP” in the type column and will be tested in the normal way for each half of the valve, selection being made by the rotation of the **Electrode Selector** switch to A1 or A2 corresponding to set up figures 6 and 7. Note that screen current readings obtained whilst checking double tetrodes or double pentodes will be a combined value for both halves of the valve.

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

Frequency changers of the Octode class designated by “0” in the type column are, as will be seen from the data, tested as if they had two separate electrode assemblies, separate data being given for each. In this case the oscillator section is tested with the **Electrode Selector** at A1 and the mixer section at A2.

As a further test to ensure the probability of such a valve oscillating satisfactorily, an indication of failing emission will possibly give the most useful results. It will be realised that when a valve is up to standard its cathode will develop its full emission at the rated heater voltage for the valve, and any slight change in the cathode temperature will not result in a corresponding change in the emission. If, however, the cathode's emission is failing, then an increase or decrease in the cathode temperature will result in a noticeable change in the emission for the valve. When a valve is oscillating it tends to run into the positive grid region, and thus makes use of the full emission capabilities of the cathode. Any failing emission will limit its utility in this respect. As a subsequent test, therefore, on a valve designed to be used as an oscillator, it is helpful to note the anode current at the rated test figures with the normal heater voltage applied and then decrease the heater voltage by about 10 to 15% (the next tapping on the heater switch) for a short period. In the case of a valve with failing emission this will result in a decrease in the anode current considerably greater than the percentage decrease in heater volts. Such a result would suggest that the valve will not oscillate very satisfactorily. A negligible or small percentage decrease in anode current (or of the same order as the heater volts change) 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.

Frequency Changers employing separate electrodes assemblies for oscillator and mixer functions are designated by "TH" (Triode Hexode) "TP" (Triode Pentode). The separate sections of this type of valve are not interdependent, as in the case of the phantom cathode types, and they can thus be tested in two separate sections as triode and pentode respectively. This arrangement is catered for in the set up figures given, 6 corresponding to the triode section and tested with the **Electrode Selector** at A_1 whilst. 7 in the set up figure corresponds to the mixer section which is tested with the **Electrode Selector** at A_2. The figures to be expected from both halves of the valves are given in the tables where available, but it is often informative to apply a test for failing cathode emission to the triode or oscillator section in the manner already described.

In the case of normal triodes and pentodes (including beam tetrodes) the test procedure for which has already been fully outlined, the type column will show the symbol "T" and "P" respectively.

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

These links enable a load to be inserted into either anode circuit of the valve under test when an anode current or mutual conductance test is being undertaken on the electrode circuit in question. They therefore enable dynamic figures for the valve or electrode system concerned to be obtained, the Procedure being to disconnect the shorting link and to connect across the terminals a resistance or other load which it is desired to include in circuit.

Tuning indicators (Magic Eyes) are tested with the controls set according to the figures given in the separate data table, using the screen switch for obtaining target voltage and inserting the anode load, shown in column marked "Ra" by means of the link on the valve panel of the instrument. At the approximate bias given in the table the triode section should be at cut-off and the "eye" fully closed. On varying the grid bias to zero the "eye" should open fully and the value of anode current should be approximately that appearing in the table. 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.

Gaseous Rectifiers

These also necessitate the use of the link, as such valves would normally pass a damaging current if tested without suitable limiting load in the anode circuit. They are tested with the **Circuit Selector** switch turned to **Test**, anode voltage and representative anode current figures being given in the Valve Data columns. The value of load resistance (of suitable wattage) which must be included across the link, before the valve is tested, is shown in KΩ in the "mA/V" column (which would not normally apply to a rectifier valve).

Full wave examples of this class of valve are of course tested at **Electrode Selector** switch positions A_1 and A_2 and the appropriate load connected across each link on the top panel of the instrument.

Cold Cathode Rectifiers designated by the symbol "CCR" can be tested in a similar manner to Gaseous Rectifiers, the anode voltage, approximate anode current, and load resistance being given in the data columns.

Thyratrons can be checked by comparison if set up as a normal triode, with a limiting resistance included in the link, the control ratio being indicated by a comparison between the peak value of the applied anode voltage, and the setting of the grid bias control which will prevent the valve striking and passing anode current. It must be emphasised, however, that the main value of such a test is in comparison only, as the hold off grid bias value shown on the grid bias control is only approximately half that of the bias which would normally be required to hold off the anode current of the valve at the peak anode voltage in question.

In the data columns where information is given on common thyratrons, it will be seen that this comprises a Roller Selector Switch No., Heater Voltage, Anode Voltage, expected Anode Current, and the value of the limiting resistor required. The resistor should be of suitable wattage and connected across the link terminals before the valve is inserted in its holder. Grid volts should be at their maximum setting. With the **Meter Switch** set to "100" on the Ia scale, the **Electrode Selector** at "**A1**", and the **Circuit Selector** at **Test**, the bias on the valve should be reduced until the valve strikes and anode current flows. A good valve will pass approximately the anode current given in the Data. (If necessary, reduce setting of **Meter Switch**.) This test is suitable as an emission check on thyratrons used in television and commercial radio equipment.

Neon Indicators may be tested for striking, by setting up the roller switch so that anode and cathode pins of the tube are set to 6 and 1 respectively, all other rollers being connected to 0. A suitable load resistance (normally between 5,000 and 15,000 ohms) should be included in the anode circuit link and the anode voltage switch should be set to a peak value as near as possible to (and in no cases lower than) the striking voltage of the neon in question. The striking of the neon will, of course, be indicated by a passage of anode current shown on the **Meter Switch** being set to "100" on the Ia scale. It should be noted that where the anode voltage refers to the peak applied voltage, as in the case of thyratrons and neons, the actual peak voltage applied to the valve is higher than the indication on the anode voltage switch. To obtain the peak voltage equivalent to a given setting of the anode voltage switch the figure shown on the switch should be multiplied by approximately 1·5; thus with the anode voltage switch set to represent a DC voltage of 100V the peak applied voltage is approximately 150V.

GENERAL PRECAUTIONS TO BE OBSERVED WHEN USING THE VALVE CHARACTERISTIC METER

It will be realised that when dealing with an instrument such as the Valve Characteristic Meter with such flexibility of control, it is almost impossible to protect the instrument to such an extent that the operator cannot cause damage to either the valve or the instrument by some combination or wrong setting of the controls or incorrect use of the meter. It is, therefore, important that the correct procedure, as previously outlined should be used in the sequence of the tests applied. Valves should be tested for insulation or breakdown before full voltages are applied for characteristic tests. Where any doubt whatever exists as to the probable electrode current likely to be passed, the **Meter Switch** should always be turned to its highest current range and then gradually reduced in order to facilitate reading of the electrode current.

In experimental work where a variable voltage is required to be supplied to the anode or screen electrodes of the valve, always start with the lower voltage tappings and increase only after correct adjustments have been made to the **Meter Switch** to ensure that the meter circuit is not overloaded by an unknown current. Always make sure that the selector voltage switches have been correctly set for the valve before the instrument is switched on. In this respect it is a good practice to return the selector voltage switches to zero (particularly Heater Voltage switches) after a test has been applied and before a new valve is inserted.

Take care in setting the **Roller Selector Switch** to avoid wrongly connecting the electrodes of the valve under test. In this respect the automatic cut-out is advantageous in that it will usually save a valve if high tension voltage is inadvertently applied to the heater by incorrect setting of the switch, but it must be pointed out that after the switch is correctly set *nothing can save the heater from being burnt out if an overload heater voltage is applied by wrong setting of the heater voltage switches.*

Do not apply test voltages to the valve without ensuring that where necessary top cap connections have been correctly made, as a valve can often be irreparably damaged by running it with its grid or its anode wrongly connected

Where a valve appears to be performing abnormally, as indicated for instance by a continuously rising or falling anode current which does not attain a condition of stability, do not leave the valve "cooking" for a long period to see what will ultimately happen, as this will in all probability result in the damaging of the valve due to excessive currents in the anode or screen circuits. In general, it is not necessary or helpful to leave a valve on test for a considerably longer period than is necessary to complete the test in question.

Finally, it must be stressed that whilst every care has been taken in the compilation of this publication, the "AVO" Valve Data Manual and the "AVO" Valve Data Handbook to ensure that all data given is correct as far as is known at the time of going to press, it is not impossible that with the many thousands of figures involved, errors will have crept in. The manufacturers cannot hold themselves responsible for any damage that might occur to a valve or to the instrument from such a cause.

ABBREVIATED WORKING INSTRUCTIONS FOR THE "AVO" VALVE CHARACTERISTIC METER MARK III

Before switching "ON" the full instruction Book should be read and always used for reference when testing unusual types of valves.

1. Check mains adjustment tap and connect mains lead to the supply, red and black leads are line and neutral, green or yellow being the earth connection.

2. Set “Circuit Selector” to “Check C” and “Electrode Selector” to “A”.

3. Set “Meter Switch” to 100 on the Ia scale.

4. Turn “Backing Off” controls fully anti-clockwise.

5. Set “Heater Volts” switches to value indicated in Valve Data. (Heater volts in parenthesis should be ignored.)

6. Set “Anode Volts”, “Screen Volts” and “Grid Volts” to values indicated in Valve Data.

7. Rotate the “Set Ma/V” control to figure given in Valve Data using (where possible) the inner scale and appropriate setting of associated switch.

8 Set “Roller Selector” switch as indicated in Valve Data and ensure that A_1 and A_2 links are tight. (For “*” in data read “0”).

9. With leakage switch at “~” switch on, and allow instrument to warm up. Adjust pointer to position “~.” by means of “Set ~” switch.

ALL VALVES

1. Insert valve, and make any top cap connections if required.

2. Fully rotate Leakage” switch. Check heater continuity at “H and insulation on all other positions.

3. Set “Circuit Selector to “Check H” to measure leakage from Heater/Cathode to all other electrodes strapped together with valve hot.

4. Turn “Circuit Selector” to “C/H” to measure leakage between heater and cathode with valve hot (if valve is indirectly heated.).

TRIODES, DOUBLE TRIODES, DIODE TRIODES PENTODES, DOUBLE PENTODES, DIODE PENTODES AND TETRODES IN SIMILAR COMBINATION

ANODE CURRENT. With “Electrode Selector” at “A_1” set “Circuit Selector” to “Test”. Meter should then indicate anode current. Reduce Meter Switch setting if required. *If protective relay operates, switch* off *and check for incorrect setting of “Roller Selector” switch or panel controls. if all controls are correct and relay continues to operate when instrument is switched on again, the valve is probably soft and the test should be dis-continued.*

MUTUAL CONDUCTANCE. Reduce meter reading to zero by means of “Backing Off” controls. Set “Meter Switch” to “2·5” position and re-adjust zero if necessary. Turn “Meter Switch” to “mA/V” position, when a good valve will give an indication in the green band on the meter scale. To obtain actual mA/V reading, adjust “Set mA/V” control until needle reads on calibration point 1 mA/V, in centre of green band. The “Set mA/V” control will now indicate the mutual conductance of the valve under test. To obtain a reading for valves with mutual conductance below 3mA/V, use outer scale setting on “Set mA/V” control and follow the procedure outlined above.

For double valves, check data for difference in electrode voltages and repeat above operations with the “Electrode Selector” set to “A2”

GAS TEST. To measure grid current, set “Circuit Selector” to position “Gas” and the Meter Switch” to its 100 mA position. Meter will now indicate gas current, full-scale indication being 100 µA.

DIODES. To check diodes turn “Electrode Selector” to “D1”and “Meter Switch” to “1 mA” on D/R scale (unless otherwise indicated in Valve Data). Turn “Circuit Selector” to “Test”. The condition of the valve will now be given on the “Replace/Good” scale, Check double diodes at D1 and D2 position of the “Electrode Selector”.

RECTIFIERS. To check rectifiers, set “Electrode Selector” to “D1” and set anode loading given in Valve Data. on D/R scale of “Meter Switch”. Turn “Circuit Selector” to “Test”. The condition of the valve will now be indicated on “Replace/Good” scale. Load reading is per anode. Check full-wave rectifiers at position ‘‘D1” and “D2” of “Electrode Selector” switch.

On completion of tests return controls to their fully anti-clockwise position.

CHECKING DETAILS FOR CORRECT SET UP

VALVE CHARACTERISTIC METER MARK III

1. Connect instrument to suitable 50 Hz supply of good waveform and with coarse mains tapping appropriately set, adjust set-control until meter needle reads in the set-zone, with the valve characteristic meter switched to the check mains condition.

2. The unloaded R.M.S. heater volts are not critical and arranged to approximately compensate for the voltage drop due to the heater current likely to flow and will normally be between + 3% and + 10% up on the reading of the heater voltage switch. For example a nominal 6v. heater voltage would read between say 6.2 and 6.6 volts on open current.

3. The unloaded anode volts measured with a standardised Model 8 or Model 7 Avometer should be such that the R.M.S. reading on the meter equals 1.1 times the calibration on the panel of the instrument +5 - 3%.

4. The screen voltage should bear a similar proportion to the anode voltages, provided that the internal screen stopped rectifier is shorted out.

5. The grid voltage should be such that when measured with a standardised Electronic Testmeter, or other standard D.C. mean Valve Voltmeter, the Voltage measured between grid and cathode (this measurement must be made with the link open) should be such that the mean D.C. voltage equals the calibrated voltage on the panel of the instrument x 0.52, i.e. 100v negative bias should read, with the link open, 52.0v mean D.C.

5a With fixed grid voltage control set to zero and the incremental grid voltage control to -1V with the mA/V control set to 1mA/V, switch the meter selector switch to the 2.5 mA position. The voltage measured between grid and cathode should be 0.52V ± 2%. On switching the meter selector switch to the mA/V position, this reading should reduce to zero ± 2%.

6. With the instrument working under the above normal tolerances with the grid link closed and presuming that a valve has been standardised on D.C., then with the anode and/or screen and negative grid voltages set to be equivalent to any one setting of the equivalent D.C. voltages, the anode current of the valve should correspond to within ± 10% of the absolute anode current measured with Battery D.C. H.T., screen and grid voltages and A.C. heater voltage.

7. The mutual conductance of the valve should also compare with the mutual conductance obtained from the curve of a valve suitably standardised, as mentioned in 5, such that if anode and/or screen voltages are set to correspond to this under D.C. conditons, and the grid current for any given point on the D.C. Characteristic, then at these two like anode currents the mutual conductance should compare within ± 5%. This tolerance may widen slightly on very high slope short grid base valves.

8. For an additional check on anode current, the anode current as read on the meter of the V.C.M. may be compared with the D.C. current read on a standardised Avometer on suitable D.C. range inserted in series in the anode link. The anode current read on the panel of the V.C.M. should then be equal to within ± 3% of twice the anode current read on the external D.C. Avometer.

9. With the instrument set for test of a pentode and a suitable output pentode (KT.33C etc.) inserted, and voltage controls adjusted for an indicative anode current of 80mA, the valve should not show any signs of oscillation or running off of anode current.

10. With the instrument set up for electrode insulation and a valve inserted into an adaptor with a 1 megohm resistor connected across H/C and A/G, then with the requisite settings for H/C insulation (hot) and A/G insulation (cold) the meter should indicate 1 megohm ± 10%.

SETTING UP DETAILS FOR VALVE CHARACTERISTIC METER MARK III

WHICH IS PRESUMED TO BE IN WORKING ORDER

1. With suitable mains voltage applied, carry out preliminary check for the presence of Anode, Screen, Grid and Heater voltages, ensure that they are of the right order of magnitude and follow the switch settings.

2. Open anode current link, insert moving coil D.C. milliammeter in link. Obtain anode current from suitable valve in the tester and, checking on each V.C.M. anode current range in turn ensure that the reading on the external milliammeter is 0.5X the anode current read on the V.C.M. meter ± 2%. (Ia ranges 100-25-10-2.5 mA DC)

3. Then with RMS (not greater than 200Ω/V) A.C. Voltmeter standardised at 220v, and coarse mains tapping on V.C.M. set to approximate mains input volts, vary set ~ switch with A.C. Voltmeter between anode and cathode of a valveholder, and with AV switch set to 200v, until reading on A.C. meter is 220v RMS ± 2%.

4. Set the additive grid volt selector to 80 and the variable grid control to maximum. Then, with the grid circuit link open, and a standardised D.C. Valve Voltmeter between grid and cathode, adjust the grid voltage pre-set until the reading on the meter equals 52.0v (100 x .52). Loosen skirt on grid voltage control, and with incremental grid switch set at 0, rotate variable grid control until meter reads 2.6v (5 x .52). Tighten grid control skirt, so that with this effective grid voltage, the skirt reads 5v on the perspex scale. Increase grid voltage control to read 15v. Note reading on Valve voltmeter; this should read between 7.8 and 7.6v (15 x .52 ± 1%). If this reading is in error, it will almost invariably be found to be high and corrections can be made by connecting a fixed resistance between zero and the slider of the grid voltage pot. as follows:

    a. Reading between 7.7 and 7.8v connect approx 350K between slider and zero.
    b. Reading between 7.8 and 7.9v connect approx 250K between slider and zero.
    c. Reading between 7.9 and 8v connect approx 150-175K between slider and zero.

   This should average out law of potentiometer to be within required limits between 0.5v and 21v.

   Note that correction is quite flat and above suggested values may vary quite widely.

5. With V.C.M. circuit selector and leakage switches set at the Set Mains condition, adjust if necessary, meter load resistance until needle reads in the middle of the set ~ zone.

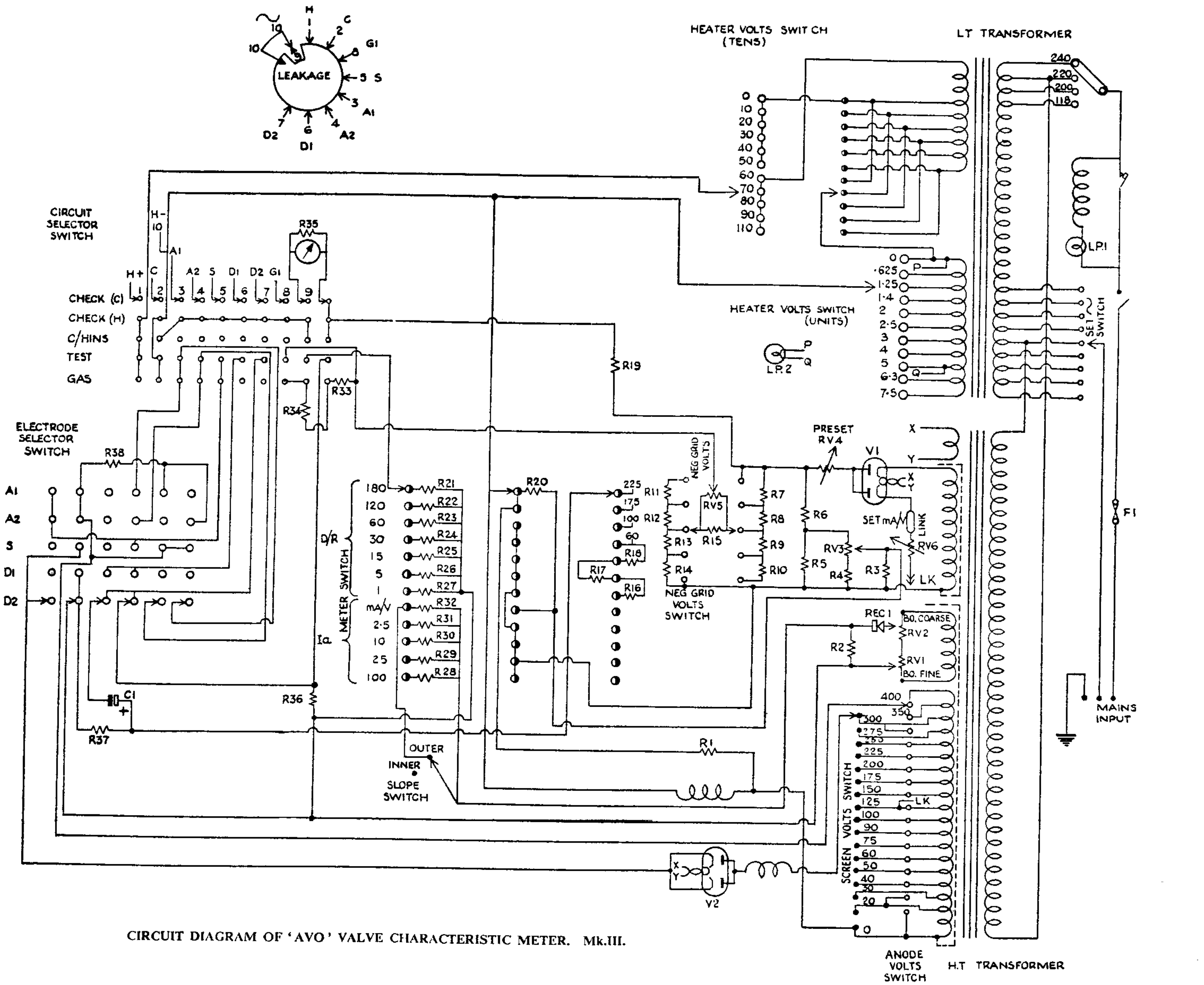
6. It is wise to monitor the 200v anode volts tapping during 2, 3 and 4 to ensure that the mains have not shifted. A stablised supply is not generally suitable because of wave form errors.

7. Set relay:

   With Electrode Switch Set to A1, and the anode voltage switch set to 100V the relay should operate when A1 is shorted to cathode. Repeat with the anode switch to 200V. The above procedure should be repeated with the Electrode Selector set to A2. With the Electrode Selector set to 'S' and the screen voltage set to 100V the relay should break when the screen is shorted to cathode. The relay contacts should break cleanly and stay open until the instrument is switched off and then switched on again. Faulty action of the relay is generally due to soft springs and usually results in the relay buzzing.

   WARNING

   Do not prolong this test or the load resistors may be damaged.



CIRCUIT DIAGRAM OF 'AVO' VALVE CHARACTERISTIC METER. Mk.III.

REF.	TOL.	VALUE
R1	± 20%	3·9 Ω
R2	± 2%	760 Ω
R3	± 1%	2 K Ω
R4	± 1%	1860 Ω
R5	± 1%	300 Ω
R6	± 1%	25·6 K Ω
R7	± 1%	2·5 K Ω
R8	± 1%	"
R9	± 1%	"
R10	± 1%	"
R11	± 1%	"
R12	± 1%	"
R13	± 1%	"
R14	± 1%	"
R15	± 1%	3·54 K Ω
R16	± 2%	15 K Ω
R17	± 2%	3 K Ω
R18	± 2%	600 Ω
R19	± 1%	2·96 M Ω MATCHED PAIR
R20	± 2%	10 K Ω
R21	± 2%	1·22 M Ω
R22	± 2%	814 K Ω
R23	± 2%	406 K Ω
R24	± 2%	202 K Ω
R25	± 2%	100 K Ω
R26	± 2%	31·5 K Ω
R27	± 2%	4·35 K Ω
R28	± 1%	249 K Ω
R29	± 1%	59·6 K Ω
R30	± 1%	21·8 K Ω
R31	± 1%	2·9 K Ω
R32	± 1%	6·8 K Ω
R33	± 2%	330 K Ω
R34	± 2%	10 K Ω
R35	± 1%	10 K Ω
R36	+ 5 % − 0 %	190 Ω {OVERWOUND TO 200Ω ± ·5%
R37	± 2½%	500 Ω
R38	± 5%	8 K Ω
L.P.1.		200 V 15 W SMALL EDISON SCREW
L.P.2.		6·3 V 0·3A M.E.S.
RV1		25 Ω
RV2		250 Ω
RV3		10 K Ω
RV4		5 K Ω
RV5		10 K Ω
RV6		5 K Ω
F1		2-3 AMP
C1		8 ufd ELECTROLYTIC
V1		D77
V2		D77
REC.1		1/6A

AVO

VALVE CHARATERISTIC METER

MARK III

SERVICE MANUAL

AVO

VALVE CHARATERISTIC METER

MARK III

SERVICE MANUAL

AVO LTD
AVOCET HOUSE 92/96 VAUXHALL BRIDGE ROAD LONDON S.W.1
Telephone VICtoria 3404 (12 lines)

WARNING

CARE SHOULD BE EXERCISED WHEN SERVICING DUE TO THE PRESENCE OF UP TO 480V rms WITHIN THE INTERIOR OF THE INSTRUMENT

CONTENTS

CHAPTER 1

MAINTENANCE INFORMATION

CONTENTS

NOTE: On receipt of an instrument for repair, the setting of the Coarse Mains Voltage Control should be noted and set to the same position prior to return to the customer.

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.
(e) Resistor 700kΩ ± 5%.

SECTION 2 - FAULT FINDING AND SERVICING NOTES

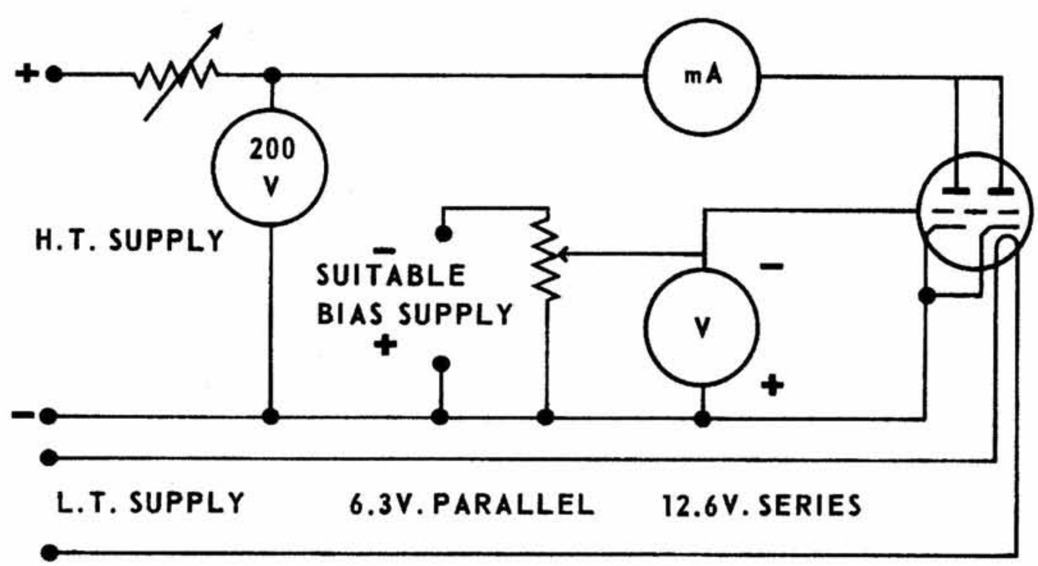
(See WARNING on page 2)

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.

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.

To Obtain Standard Figures for a Valve Using dc Supplies

Using the recommended AvoMeters, the valve should be connected as shown below:—



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 1000Ω/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 until voltmeter reads 9V and note anode current.

(b) Adjust the ht supply to 200V, then by means of successive adjustments of the bias and ht voltage 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. For greater accuracy it is suggested that readings of grid voltage be plotted against values of anode current between 10 and 20mA and the slope taken from the curve at 16mA.

The valve should now be labeled as follows:—

Va	=	200V dc
Ia	=	16mA dc
Vg	=	…………..
Slope	=	mA/V
Date	=	…………..
		CV491

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

To Check the Accuracy of Instrument

(a) With Circuit Selector switch set to check Cold, Leakage switch to ~ position, and Meter switch to a current range (Ia)*, connect instrument to suitable 50 c/s supply of good wave form and with coarse mains tapping appropriately set, adjust Set ~ control until meter needle reads in the Set ~ zone.

(b) The unloaded rms heater volts are not critical and are arranged to approximately compensate for the voltage drop due to the heater current likely to flow and will normally be between +3% and +10% up on the reading of the heater voltage switch. For example a nominal 6V heater voltage would read between say 6.2 and 6.6 volts on open current.

**WARNING:-. If Meter Switch is set to mA/V positions or D/R positions 180 or 120mA a false setting of all instrument voltages will result.*

(c) The unloaded anode volts measured with a standardised Model 8 or Model 7 AvoMeter should be such that the r.m.s. reading on the Meter equals 1.1 times the calibration on the panel of the Instrument +6 -2%.

(d) The screen voltage should bear a similar proportion to the anode voltages, provided that the internal screen stopper rectifier is shorted out.

(e) The grid voltage should be such that when measured with a standardised Electronic Test-meter, or other standard d.c. mean Valve Voltmeter, the voltage measured between grid and cathode (this measurement must be made with the link open) should be such that the mean d.c. voltage equals the calibrated voltage on the panel of the instrument x 0.52 i.e. 100V negative bias should read, with the link open, 52.0V mean d.c. With fixed grid voltage set to zero, measure incremental grid voltage with the mA/V control set to 1 mA/V. The incremental voltage thus shown should be 0.52 d.c. (0.52 x 1v) ±2%

(f) With the Instrument working under the above normal tolerances with the grid link closed, and presuming that a valve has been standardised on d.c., then with the anode and/or screen and negative grid voltages set to be equivalent to any one setting of the equivalent d.c. voltages, the anode current of the valve should correspond to within ± 10% of the absolute anode current measured with d.c. anode, screen and grid voltages and a.c. for the heater voltage.

(g) The mutual conductance of the valve should also compare with the mutual conductance obtained from the curve of a valve suitably standardised, such that if anode and/or screen voltages are set to correspond to this under d.c. conditions, and the grid voltage is so set that the anode current is the same as the anode current for any given point on the d.c. characteristic, then at these two like anode currents, the mutual conductance should compare within ± 5%. This tolerance may widen slightly on very high slope short grid base valves.

(h) For an additional check on anode current, the anode current as read on the meter of the instrument may be compared with the d.c. current indicated on a standardised AvoMeter set to a suitable d.c. range inserted in a series in the anode link. The anode current read on the panel of the instrument should then be equal to twice the anode current ±5% read on the external d.c. AvoMeter.

(j) With the instrument set for testing a pentode and a suitable output pentode (KT.33C) inserted and controls adjusted for an anode current of 80mA, the valve should not show any signs of oscillation.

(k) With the instrument set up for electrode insulation and a 1 megohm resistor connected across H/C and A/C, then with the requisite settings for H/C insulation (hot) and A/G insulation (cold), the meter should indicate 1 megohm ± 10%.

Removal of the Instrument from its Case (See WARNING on page 2)

To facilitate servicing or calibration of the instrument, it is necessary to remove the back and side plates from the instrument case. This is accomplished by the removal of four instrument headed screws from the side plates and six round-headed screws from the back plate. The valve panel is then readily accessible.

Simple Faults

SYMPTOMS	POSSIBLE FAULT	ACTION
(a) No dial light indication.	No mains input. Dial light bulb burnt out.	Check mains connector. Replace LP2
(b) No dial light indication or meter deflection on set '~' setting of Circuit Selector	Fuse blown	Check mains voltage selector and replace fuse
(c) No indication of meter current	No anode volts at valve pin.	Check that links A_1, and A_2, are tight and making firm contact.
(d) 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, and A_2, are tight and making firm contact.

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. 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 LP1 is operative. When the instrument is used solely on a 110V supply, it may be preferable to replace LP1 with a 100V, 15W pigmy lamp.

Servicing the Valve Holder Panel

The Valve Holder Panel is connected electrically to the control panel by means of a 10-way tagboard.

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. Ferroxcube is also used on leads feeding the selector switch as a precaution against oscillation.

Where it is necessary to replace valve holders, those fitted to the panel with nuts and bolts are easily removable. When removing riveted valve holders, care should be taken to ensure that rivets are drilled out from the underside of the panel. All wire must be replaced in its original position.

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. Reverse procedure to replace. To adjust skirt, slacken lock nut, rotate skirt to desired position and re-tighten lock nut.

SECTION 3 — MOVEMENT SERVICING

The Valve Characteristic Meter Mk III is fitted with one of three different types of meter movement. Externally these movements fall into two categories:—

(a) The original meter movement assembly manufactured between approximately 1955 and 1956. This movement has three vertical lines in the centre of the moulding and also incorporates a large white AVO monogram approximately $1^3/_8$ in dia. (34.925mm).
This type of movement is now obsolete but can be replaced by meter movement assembly Part No. 40650-C.

(b) The new type meter movement assembly has a plain moulding with a black AVO monogram approximately $^3/_4$ in dia. (19.05mm).

Two types of movement have been supplied with the range described in (b) above:—

(1) Early versions of this type which were manufactured approximately between 1956 and 1958 had a moving coil whose dimensions were $^{11}/_{32}$ *x* $^{13}/_{32}$ in approximately (8.734 x 10.322mm).
This moving coil is now obsolete and the complete movement assembly Part No. 40650-C should be fitted.

(11) This movement manufactured since 1958 uses the same moulding but has a different basic movement assembly, in which the moving coil assembly has a dimension of $^{17}/_{32}$ x $^7/_{16}$ in approximately (13.498 x 11.11mm) overall. Replacements are available for this movement as detailed in Plate 5.

If in doubt as to the type of movement in the instrument, it should be returned to AVO LIMITED who will examine it and overhaul it, if of the later manufacture, or will advise replacement of an obsolete type.

NOTE: — The latest movement Part No. 40650-C is directly interchangeable with all movements used on the Valve Characteristic Meter MK. III

Moving Coil Will Not Move

If the instrument is subjected to the most severe shock, it sometimes happens that the moving coil is thrown completely out of its jewels. When this happens, the instrument must be opened, the movement removed, and the pivots and jewels examined for possible damage.

The Movement Needle Tends to Stick at One Point on the Scale

This symptom usually indicates that a small piece of iron or some other foreign body has found its way into the magnetic gap, and is fouling the moving coil former. The movement should be withdrawn from the meter, examined in a good light against a white background, and any nonmetallic bodies removed with a small, non-magnetic pin, or iron dust carefully drawn out by means of a thin steel needle. Iron dust in the gap will adhere to the needle, and with a little patient effort, an iron particle can usually be withdrawn.

This ‘stick’ can also be due to the pointer fouling the scale plate. In such instances, the scale plate should be bent away from the pointer to give it adequate clearance.

The Movement Needle Tends to Stick at All Points Across the Scale

However well an instrument is constructed, there will always be some measure of friction between its pivots and jewels. If this friction is increased by damage due to impact, it may assume noticeable proportions, and it sometimes happens that an instrument will give slightly different consecutive readings upon the same test, although tapping the glass makes all readings more or less agree. Such a suspected fault can be found by carrying out the following procedure:—

(a) Pass a known current through the instrument, and note its reading.

(b) Reduce the current considerably, and then bring it slowly back to its original value and take a second reading.

(c) Increase the current well beyond its original value, and then slowly reduce it to the value fixed under (a).

If the differences between the readings are too great to be ignored, the movement will require attention. The trouble is usually due to increased friction in the movement bearings caused by dirt, a blunted pivot or a damaged jewel. Dirt can be removed by cleaning the pivots with pith, and gently inserting the sharp point of a small stick of orange wood into jewel recesses, or by washing the jewel screws in Trichloroethylene. A damaged jewel or pivot must always be replaced.

NOTE: The two connections to the meter movement should always be shorted out when the movement is removed from the instrument for repair or return to the manufacturer. This damps the movement and reduces the risk of further damage.

SECTION 4 - VOLTAGE CHECKS WITH NO VALVE UNDER TEST

Connect the instrument, correctly * set up as detailed in Chapter 2 to a known 220/230V 50 c/s supply, ensuring that the mains ‘ON/OFF’ switch is in the ‘OFF’ position. Switch on

**See warning on Page 5*

and adjust coarse mains tapping and/or 'SET~ switch until meter reads in the centre of the ~ zone. Set the Circuit Selector to 'A_1' and proceed to check the relevant electrode voltages as follows:—

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	2.3	2.2	2.4
5	5.5	5.3	5.7
10	10.3	10.0	10.6
20	20.6	20.0	21.1
40	41.2	40.4	42
117.5	121.4	118.7	124.1

(d) Switch off and remove meter.

Anode Voltages

(a) Set the mains 'ON/OFF' switch to the 'OFF' position and connect the AvoMeter, set to its ac voltage range, between A_1 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.

Screen Voltages

(a) Connect the AvoMeter set to its ac voltage range, between S and C on the top cap selector panel ensuring that the mains 'ON/OFF' switch is in the 'OFF' position.

(b) Short the anode of V_1 (a) to cathode (pins 2 and 5).

(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.

Modification Kit

Using the Avo Modification Kit the ht transformer may be modified to provide a 12.6V anode supply. Fitting instructions for this kit are given in the diagrams overleaf.

The Appearance of the Repaired Instrument

Having ensured that the instrument is perfect electrically and mechanically, do not be content to return it to the customer in a dirty condition. Thoroughly clean the components and wipe out the inside of the case, taking particular care that no small particles of iron or other foreign substances are left within the instrument

MODIFICATION TO PROVIDE A 12·6 V ANODE SUPPLY

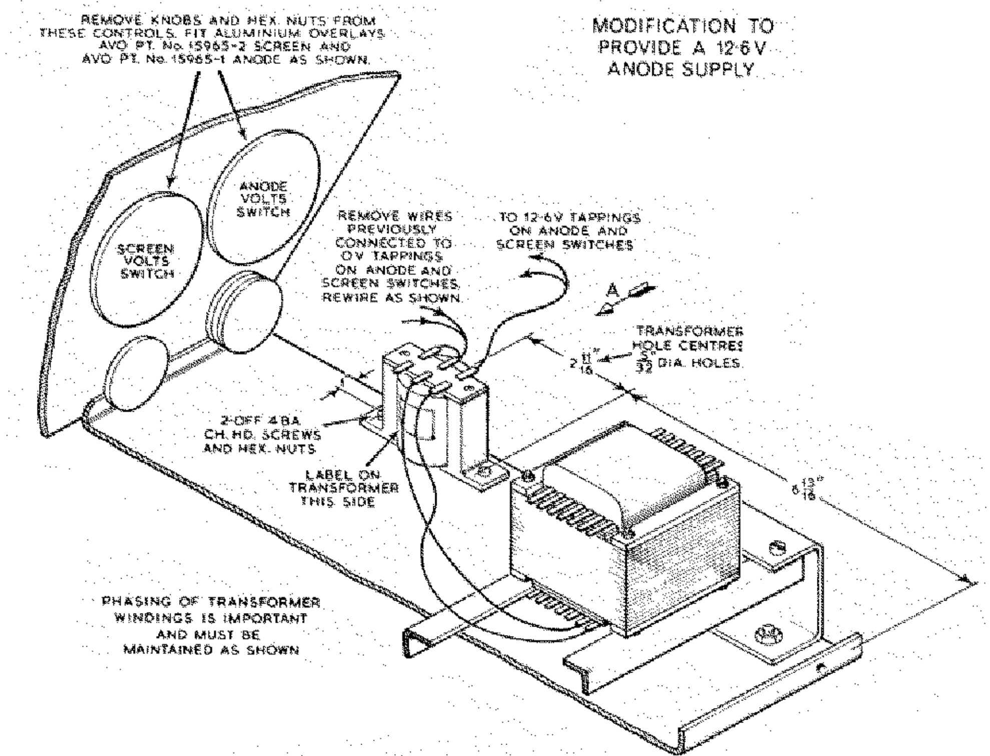


FIG. 1. ISOMETRIC VIEW

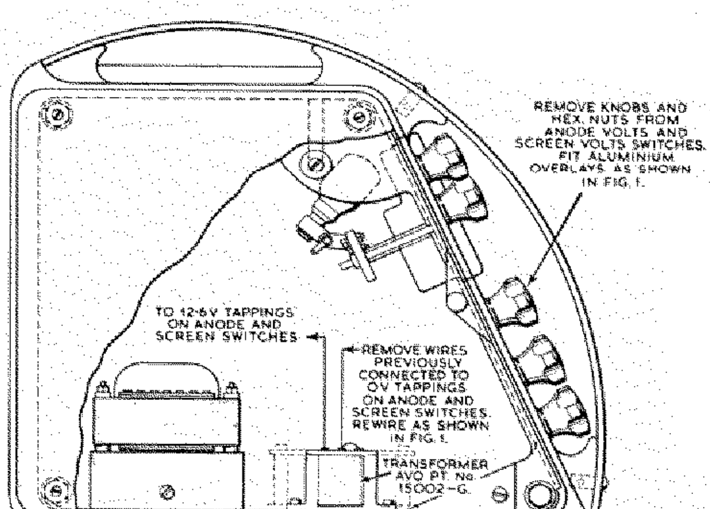


FIG. 2 SIDE VIEW ON ARROW A

CHAPTER 2

SETTING-UP PROCEDURE

CONTENTS

SECTION 1 — TEST EQUIPMENT REQUIRED

(a) Avo Electronic Testmeter (or equivalent dc mean Valve Voltmeter).

(b) AC Voltmeter (not greater than 200Ω/V) standardised at 220V.

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

WARNING

It is wise to ensure that the mains voltage does not change during the following test. A stabilised supply is not recommended due to 3rd and 5th harmonic waveform distortion.

SECTION 2 — SETTING-UP DETAILS

(a) With suitable mains voltage applied, carry out preliminary check for the presence of Anode, Screen, Grid and Heater voltages, ensure that they are of the right order of magnitude and follow the switch settings.

(b) Open anode current link, insert moving coil dc milliameter in link. Obtain anode current from suitable valve in the tester and, checking on each anode current range in turn ensure, that the reading on the external milliameter is 0.5 x the anode current indicated by the panel meter ±5%. Remove Valve and Close Link.

(c) Set the coarse mains tapping on the instrument to approximate mains input voltage. Connect the ac Voltmeter between anode and cathode of a valveholder. Set anode voltage switch to 200V and vary Set ~ switch until a reading of 220V r.m.s. ±2% is obtained.

(d) Set the additive grid volt selector control to 80 and the variable grid potentiometer to maximum. Then, with the grid circuit link open, and the dc Valve Voltmeter between grid and cathode, adjust the grid voltage pre-set potentiometer (RV4) until the reading on the Valve Voltmeter equals 52.5V (101 x 0.52). Loosen skirt on grid voltage control, and with incremental grid switch set at 0 rotate variable grid control until meter reads 2.6V (5 x 0.52). Tighten grid control skirt so that, with this effective grid voltage 5V is indicated on the perspex scale. Increase grid voltage control to read 15V. Note reading on Valve Voltmeter; this should read between 7.8 and 7.9V (15 x 0.52 ±1%). If this reading is in error it will almost invariably be found to be high and corrections can be made by connecting a fixed resistance between zero end of the slider and the grid voltage potentiometer.

Note the correction is quite flat and the value of resistance required may vary quite widely but a value between 150kΩ and 350kΩ is suggested.

(e) Check law of mA/V potentiometer as follows: —
Set Meter switch to 2·5mA position and adjust Vg. potentiometer until a reading of 105mV is

obtained on the Valve Voltmeter.

Set Meter switch to mA/V and mA/V control to 5 on the outer scale. The valve voltmeter reading should now fall to zero.

The above procedure should be repeated with grid voltage adjusted to 52.5V and the mA/V control set to 10.

Repeat again with grid voltage adjusted to 0.52V and the mA/V control set to 1.
Adjust dial as necessary for best overall characteristic.

Close link.

(f) With circuit selector and leakage switches set at the Set Mains condition and anode current switch set to 100mA, adjust RV6 until pointer reads on the Set ~ mark.

(g) Set Relay:

With Electrode Selector set to A1, and the anode voltage switch set to 100V the relay should operate when Al is shorted to cathode. Repeat with the anode switch set to 200V under which conditions there should not be excessive arcing at the contacts.
The above procedure should be repeated with the Electrode Selector set to A2. The relay should operate when A2 is shorted to cathode. With the Electrode Selector set to 'S' and the screen voltage set to 60V the relay should break when the cathode is shorted to screen. Using the normal test procedure for checking a valve type U52 except that the roller switch should be set to read 020 808 030 and the meter selector switch set to 180mA. Reduce the meter selector switch reading to 60mA and check that the relay has not operated.

WARNING

Do not prolong this test or the load resistors may be damaged.

CHAPTER 3

FINAL TEST PROCEDURE

CONTENTS

SECTION 1 — TEST EQUIPMENT REQUIRED

(a) Avo Electronic Testmeter (or equivalent mean dc Valve Voltmeter).

(b) Model 7 or Model 8 AvoMeter.

(c) Valves CV491 — KT33C — HL2.

(d) Resistance 1 megohm ±1%.

(e) Resistor 700Ω ±5%.

SECTION 2 — FINAL TEST DETAIL — INSTRUMENT

(a) Apply 500V megger tester between mains leads and frame.

(b) Check that the earth lead is connected to frame.

(c) Switch on—adjust 'Set Mains' control so that the meter pointer is as near as possible to the ~ mark on the scale plate.

(d) Check the Check (C), Check (H) and C/H INS, positions of the Circuit Selector Switch using a 1 megohm resistance. Indication on the meter should be 1 megohm ±10%.

(e) With the anode and screen voltages set to 100 and 60 respectively, check the operation of the overload cut-out by applying first an anode/Cathode short, and then an anode/Screen short.

(f) Check grid volts.

(g) Check the following unloaded H.T. voltages:

Nominal	60	100	150	250	400
Actual	66	110	165	275	440
Limits	+6% -2% of nominal				

(h) Check voltage sequence of anode and screen. (Screen volts are derived from the same tappings of the transformer).

(j) Check the following unloaded l.t. voltages:

NOMINAL VOLTS	ACTUAL AC VOLTS	LIMITS	
		MIN.	MAX.
2	2.3	2.2	2.4
5	5.5	5.3	5.7
10	10.3	10.0	10.6
20	20.6	20.0	21.1
40	41.2	40.4	42
117.5	121.4	118.7	124.1

(k) Insert a KT 33c valve and set up the instrument to obtain the following condition:

Va = 200, Vg2 = 150, Ia = 100mA.*
*Adjust grid voltage until this is obtained

Check that the valve does not oscillate. With the Circuit Selector Switch in the 'Gas' position, check that there is no indication on the meter.

(m) Using the KT 33c as a source of current, check the accuracy of the meter on the anode current ranges, i.e. 2·5mA, 10mA, 25mA and 100mA ranges against an external standard. The external standard should read half of the indication of the V.C.M. meter ±5%.

(n) Using standardised valves check that for given anode currents a 'Slope' reading is obtained within ±5% of nominal.

Check Ia is ±5% nominal at a given -Vg.

Carry out these tests using valves to give approximate slope readings of 3 and 7 (to be read on outer scale) and of approximately 11 (to be read on inner scale).

(p) Check the 'Gas' position of the circuit Selector Switch with the bias control set at 40 and 700kΩ resistance inserted between grid and cathode connections. The meter should read full scale ±20%.

(q) With the instrument set up to check rectifiers and diodes use an external meter to check that when nominal current is flowing the V.C.M. movement pointer is approximately in the centre of the 'Good' scale. Check on all diode and rectifier ranges.

Check an H.L2 valve to ensure the correct phasing of the h.t. and l.t. transformers.

(s) Check that all valve pins of the same number are connected together.

(t) Check there is no negative reading in the 'Gas' position with a valve whose grid voltage is 1V or below.

SECTION 3 - FINAL TEST DETAIL — MOVEMENT

(a) Ensure that the zero adjuster gives an approximately equal swing on either side of the zero ±2% f.s.d. Check that the panel adjuster and movement adjuster are correctly meshed. Set the adjuster such that a clockwise rotation causes a positive or forward movement of the pointer. The instrument zero should be within one width of the pointer at the end of the arc line.

(b) Check that the balance is within ±1% in the vertical plane. Balance should be within ± one width of the pointer from its zero position over 180^0 arc in the vertical plane.

THE FOLLOWING TESTS SHOULD BE CARRIED OUT WITH THE INSTRUMENT AT AN ANGLE OF 60^0 TO THE HORIZONTAL.

(c) The Sensitivity of the movement should be 30µA ±1% and 26.5µA ±2.6µA at the set ~ mark on the scale plate.

(d) The movement resistance should be 3250 ohms ±5%. Total resistance of the moving coil should not exceed 1600 ohms. Current at 1mA/V position to be 22.2mA.

The positive connection to the coil must be well clear of the pole-piece and any flying leads to the movement must be clear of the case edges.

(e) The scale shape linearity should be within ±1% of full scale current at all cardinal points.

(f) The top cover should not bear on the end stops.

(g) Check for sticks in all positions over the whole scale length.

(h) Flash test complete assembly at 1000V dc to exposed metal parts. (Terminal Studs shorted).

APPENDIX 1

SCHEDULE OF SPARE PARTS

FOR

AVO VALVE CHARACTERISTIC METER

MARK III

PROCEDURE FOR ORDERING SPARES

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 rear panel.

3. When ordering spare parts for the movement assembly, the serial number on the scale plate should also be quoted.

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

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

PLATE 1 FRONT PANEL

Item No.	*Description*	*Circuit Ref*	*Part No*
1	Knob Assembly Complete With Skirt		15220-A
2	Valve Data Manual		----------
3	Handle		40533-2
4	End Frame		40530-3
5	Indicating lamp holder		14812-1
	Bulb 6.5V 0.3A	LP2	50010-14
6	Knob Assembly Complete With Dial		15220-C
7	End Plate		40529-3
8	Knob (Screw AS23)		12840-A
9	Meter Movement Complete		40650-C
10	Roller Selector Switch Escutcheon		40166-2
11	Top Cap Lead		11237-C
12	Valve Board Lid Assembly		40137-B
13	Anode Link Terminals		13834-A
14	Front Panel		40525-1
15	Toggle Switch		13657-1
† 16	Knob For Item 1		14267-1
† 17	Transparent Cursor For Item 6		14806-1

†Not Illustrated.

PLATE 1 **FRONT PANEL**

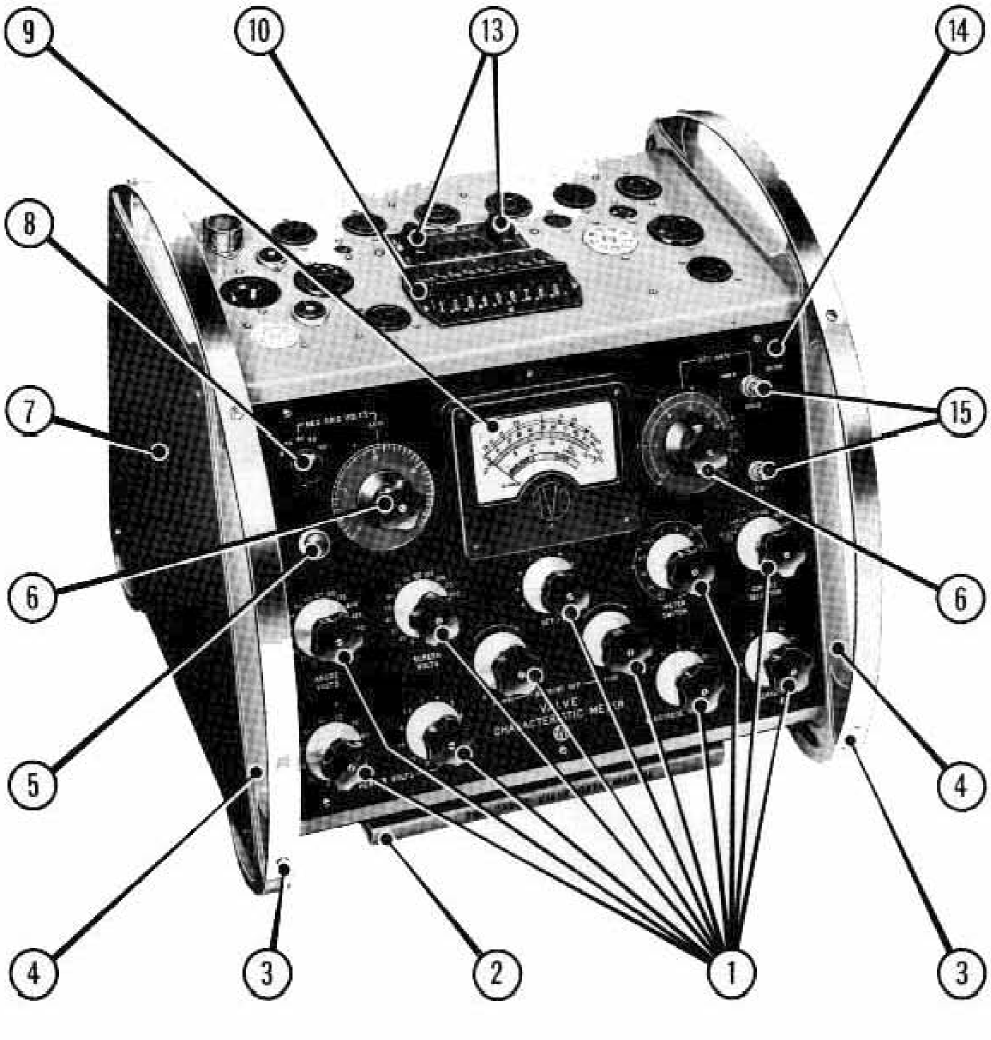


PLATE 2 POWER SUPPLY PANEL

Item No.	*Description*	*Circuit Ref*	*Part No*
1	Fuse	F1	12239-3
2	Mains Selector Panel Assembly		11966-C
3	LT Transformer Assembly	LT1	21005-B
4	Resistor 200Ω	R36	14709-B
5	Resistor 8kΩ ±5% Vitreous	R38	12049-400
6	Capacitor 8µF Electrolytic	C1	12049-404
7	Capacitor Clip		13699-1
	Capacitor Clip Rubber Strip		14772-1
8	Resistor 500Ω ±2% Vitreous	R37	12049-401
9	Rectifier 1/6 A	REC 1.	12049-704
10	Resistor 3.9Ω ±20%	R1	12049-434
11	Resistor 760Ω ±2%	R2	12049-422
12	Potentiometer 5kΩ Set Grid Volts	RV4	10770-5
13	Tag Board (Tagged)		21004-25
14	Resistor 25.6kΩ ±1%	R6	12049420
15	Potentiometer 5kΩ Cal. Set ~	RV6	10770-5
16	Link		13062-2
	Self Tapping Screw		PKS4
17	Valve Holder With Skirt B7G		13738-2
18	Valve Holder Can B7G		13819-1
19	Valve Type D77	V1/V2	12241-S
20	HT & Grid Transformer Assembly	HT1	21002-B
21	Relay Assembly Complete		40466-A

PLATE 2 POWER SUPPLY PANEL

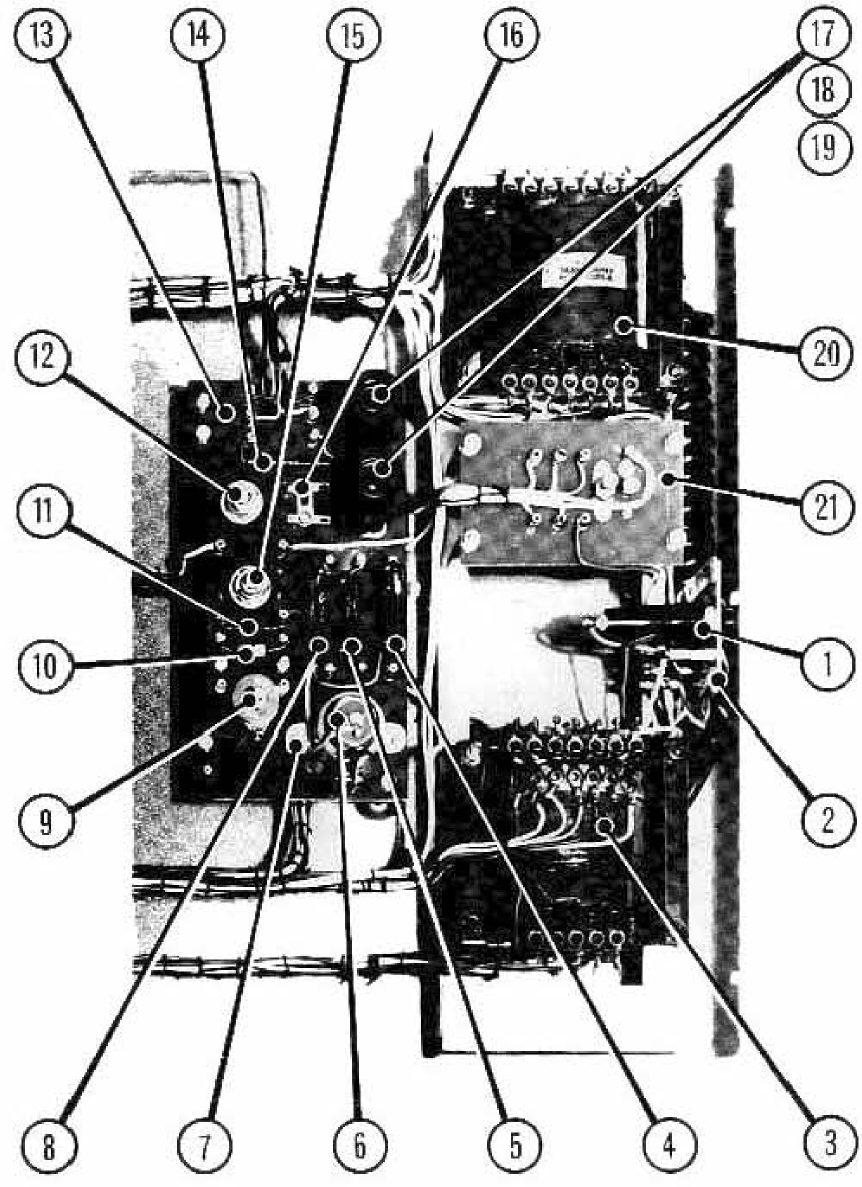


PLATE 3 CONTROL PANEL

Item No	*Description*	*Circuit Ref*	*Part No*
1	Leakage Switch		20992-1
2	Electrode Selector Switch		20996-1
3	Fine Backing Off Control 250Ω	RV1	14558-4
4	Circuit Selector Switch		20991-1
	Resistor 15kΩ ±2%	R16	12049-391
	Resistor 2.96MΩ ±1% (Matched Pair)	R19	12049-433
	Resistor 10kΩ ±1%	R35	12049-386
	Resistor 10kΩ ±2%	R34/R20	12049-385
	Resistor 330kΩ ±2%	R33	12049-384
	Resistor 2kΩ ±1%	R3	12049-424
	Resistor 1860Ω ±1%	R4	12049-423
	Resistor 300Ω ±1%	R5	12049-421
	Resistor 600Ω ±2%	R18	12049-389
	Resistor 3kΩ ±2%	R17	12049-390
5	Meter Switch		20997-1
	Resistor 6.8kΩ ±1%	R32	12049-428
	Resistor 2.9kΩ ±1%	R31	12049-426
	Resistor 21.8kΩ ±1%	R30	12049-429
	Resistor 59.6Ω ±1%	R29	12049-430
	Resistor 249kΩ ±1%	R28	12049-431
	Resistor 1.22MΩ ±2%	R21	12049-432
	Resistor 814kΩ ±2%	R22	12049-392
	Resistor 406kΩ ±2%	R23	12049-393
	Resistor 202kΩ ±2%	R24	12049-394
	Resistor 100kΩ ±2%	R25	12049-395
	Resistor 315kΩ ±2%	R26	12049-396
	Resistor 4.35kΩ ±2%	R27	12049-397
6	Toggle Switch		13657-1
7	Potentiometer 10kΩ Set mA/V	RV5	14558-3
8	Tag Board Assembly		11996-A
9	Movement Board Assembly		14810-2
10	Lamp	LP1	14653-1
11	Meter Movement Complete		40650-C
12	Set ~ Switch		20994-1
13	Potentiometer 10kΩ Neg. Grid Volts	RV3	14558-3
14	Negative Grid Volts Switch		20995-1
	Resistor 2.5kΩ ±1%	R7/R14	12049425
	Resistor 3.54kΩ ±1%	R15	12049-427
15	Indicating lamp holder		14812-1
	Bulb 6.5V 0.3A	LP2	50010-14
16	Anode Volts Selector Switch		14822-1
17	Screen Volts Selector Switch		14822-1
18	Coarse Backing Off Control 250Ω	RV2	14558-5
19	Heater Volts Switch Coarse		20993-1
20	Heater Volts Switch Fine		20994-1

PLATE 3 **CONTROL PANEL**

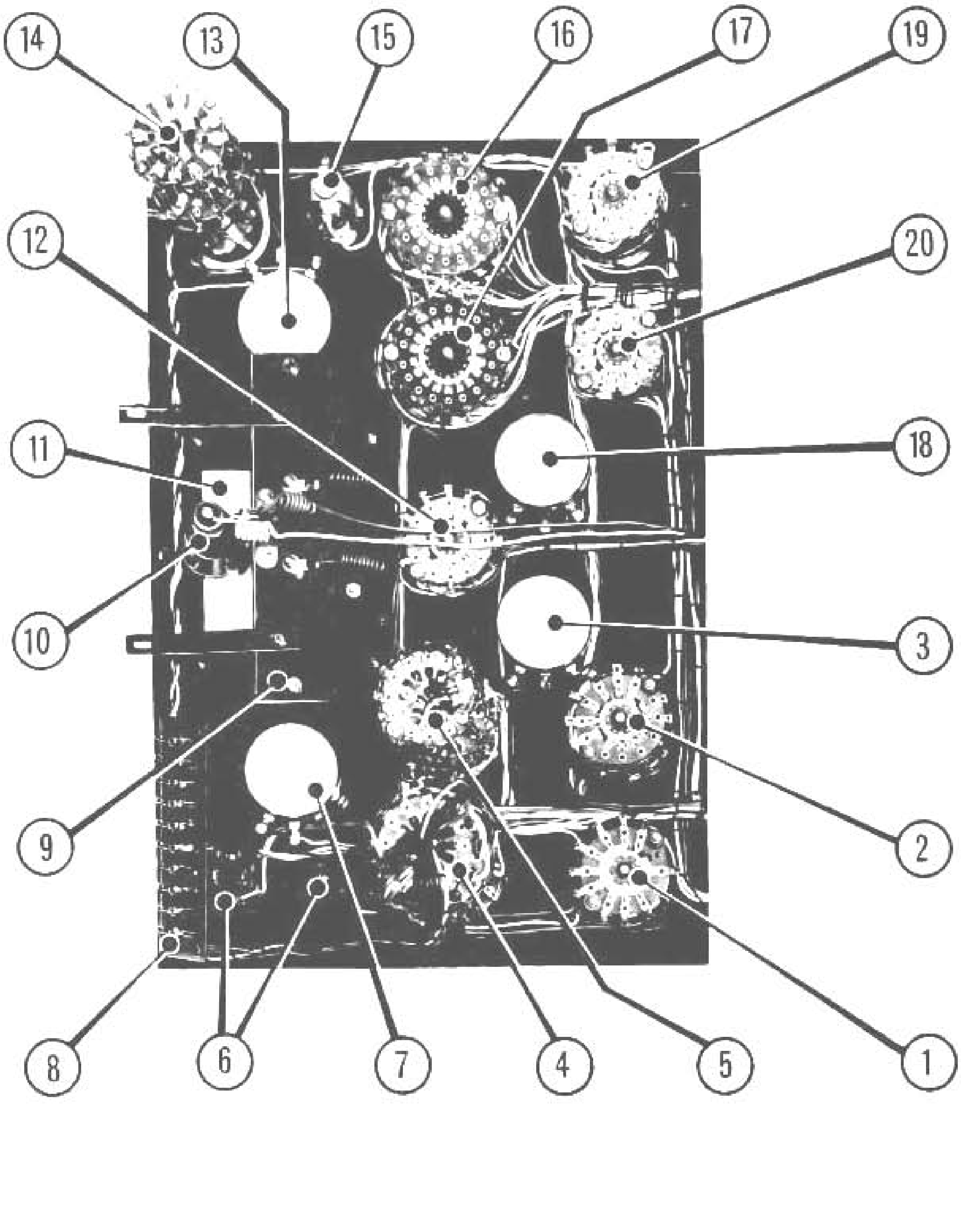


PLATE 4 VALVE HOLDER PANEL

Item No	*Circuit Part No* *Description*	*Circuit Ref*	*Part No*
.			
1	Roller Selector Switch Assembly		40157-B
2	Ferroxcube Bead		14747-1
3	Valve Holder B9G		10281-1
4	Valve Holder IO8 International Octal		40140-8
5	Valve Holder B7 English 7 Pin		40140-2
6	Valve Holder SM5 Hivac 5 Pin		40140-13
7	Valve Holder UX6 American 6 Pin		40140-9
8	Valve Holder UX4 American 4 Pin		40140-4
9	Valve Holder SM4 Hivac 4 Pin		40140-12
10	Valve Holder UX7 American 7 Pin (Large)		49140-3
11	Valve Holder SM7 American 7 Pin (Small)		40140-20
12	Top Cap Escutcheon Assembly		20903-A
13	Tag Board Assembly		11996-A
14	Valve Holder UX5 American 5 Pin		40140-6
15	Valve Holder B3G		10509-1
16	Valve Holder MO8 Mazda Octal		40140-7
17	Valve Holder B8A		40140-11
18	Valve Holder B7G		40140-14
19	Valve Holder 8SC (P Type Base)		40140-10
20	Valve Holder B8G		40140-16
21	Valve Holder B9A		40140-19
22	Valve Holder B9 English 9 Pin		40140-1
23	Valve Holder B4/5 English 4/5 Pin		40140-5

PLATE 4 **VALVE HOLDER PANEL**

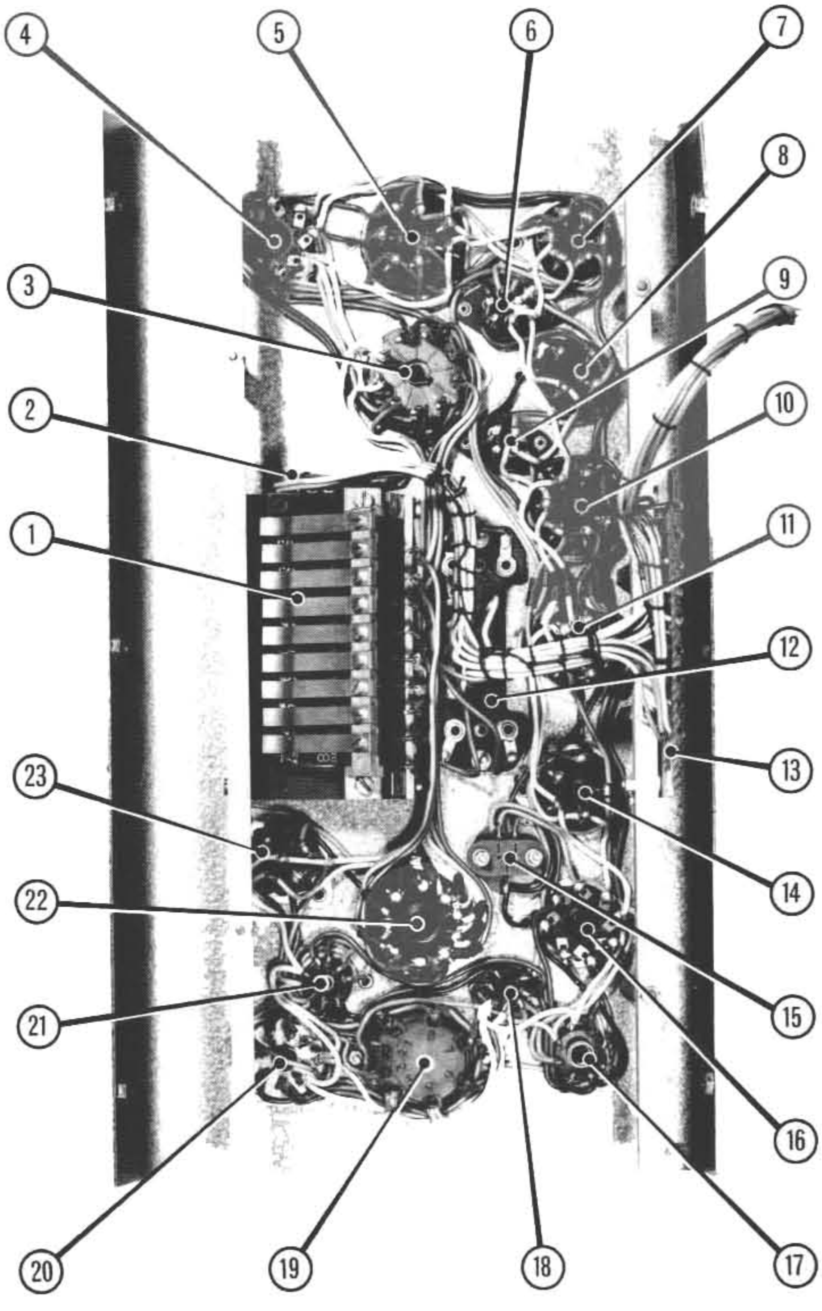


PLATE 5 MOVEMENT ASSEMBLY

Item No	*Description*	*Part No.*
1	Scale plate	(14824-4)
		(14824-10)
2	Moving coil assembly	21124-D
3	Zero Adjustor	15436-1
4	Hairsprings	10075-16
5	Sprung Jewel Assembly	10184-8
6	Pivots	10158-4
7	Movement Case Front	40537-2
8	Movement Case Rear	40538-A
†9	Rear Case Glass	10059-B

† Not illustrated

PLATE 5 MOVEMENT ASSEMBLY

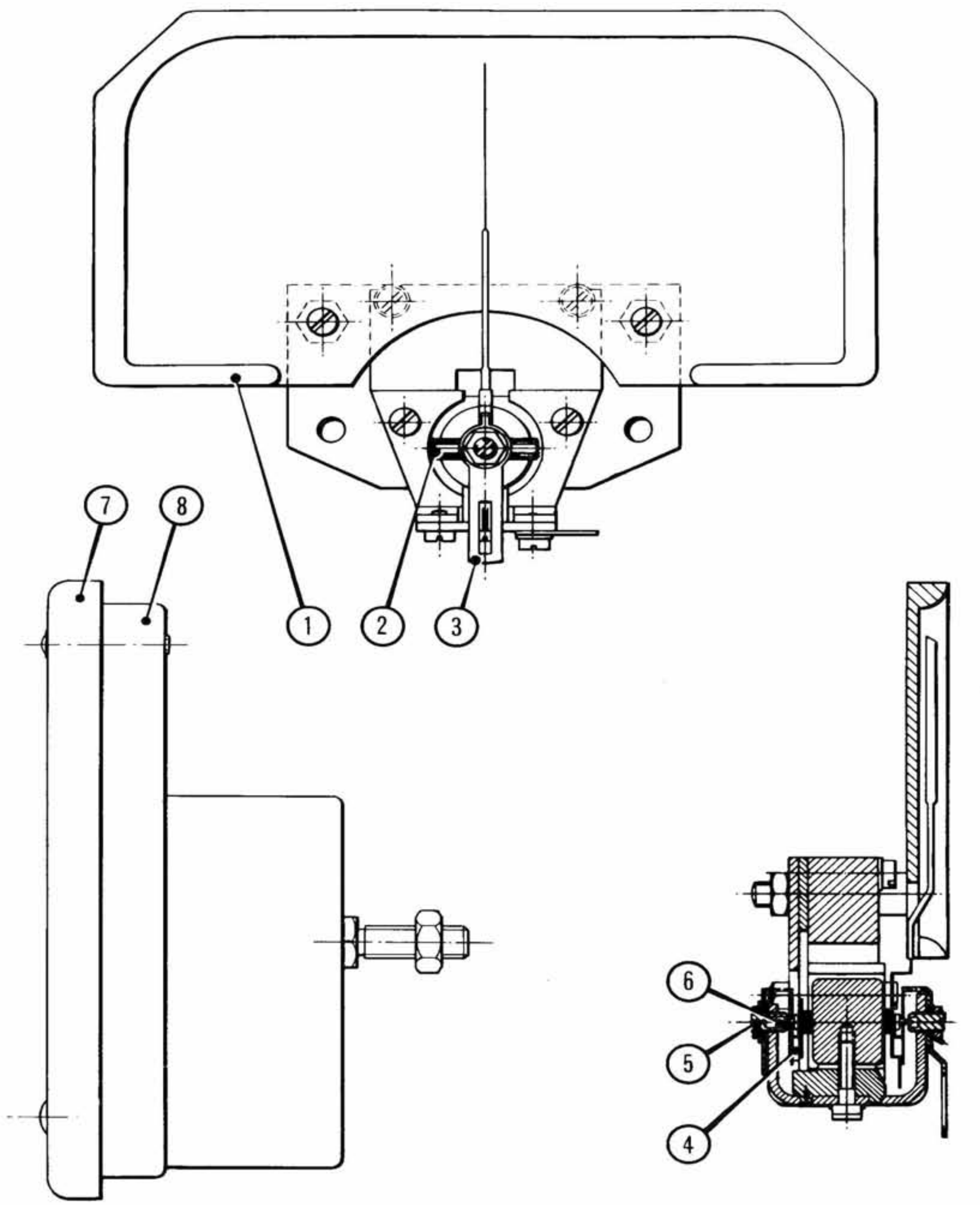


PLATE 6 CIRCUIT DIAGRAM OF VALVE CHARACTERISTIC METER MK. III

MODIFICATION TO H.T. SUPPLIES

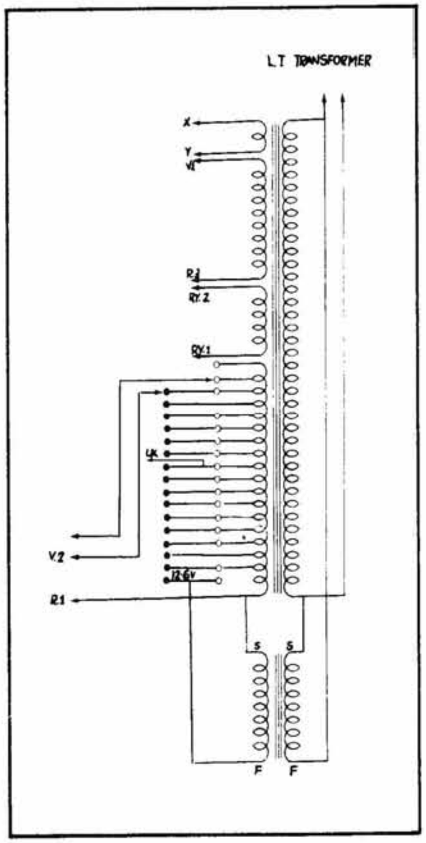
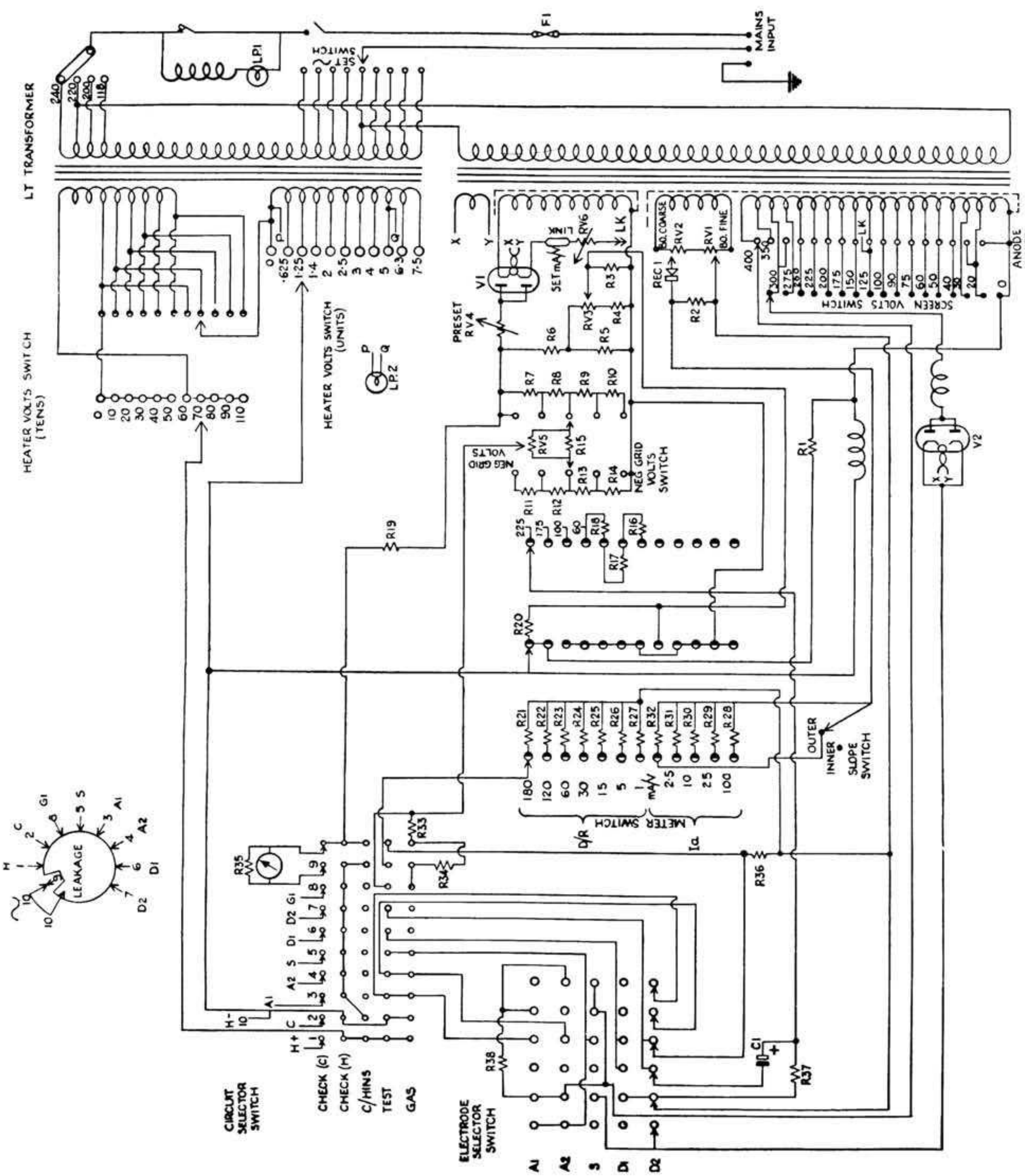


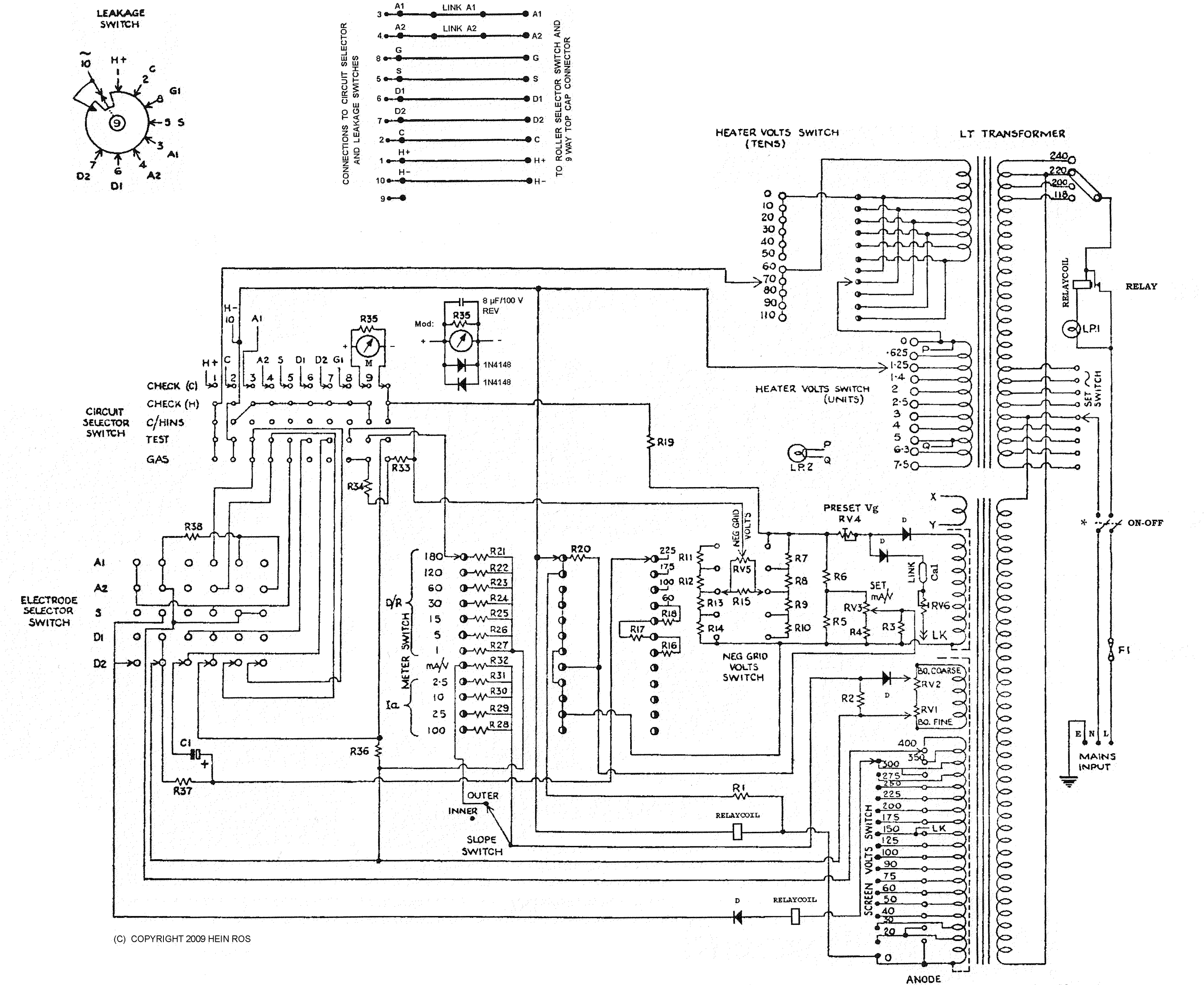
TABLE OF COMPONENTS FOR PLATE 6

REF.	VALUE	TOL.
R1	3·9 Ω	±20%
R2	760 Ω	± 2%
R3	2 K Ω	± 1%
R4	1860 Ω	± 1%
R5	300 Ω	± 1%
R6	25·6 K Ω	± 1%
R7	2·5 K Ω	± 1%
R8	▪	± 1%
R9	▪	± 1%
R10	▪	± 1%
R11	▪	± 1%
R12	▪	± 1%
R13	▪	± 1%
R14	▪	± 1%
R15	3·54 K Ω	± 1%
R16	15 K Ω	± 2%
R17	3 K Ω	± 2%
R18	600 Ω	± 2%
R19	2·96 M Ω MATCHED PAIR	± 1%
R20	10 K Ω	± 2%
R21	1·22 M Ω	± 2%
R22	814 K Ω	± 2%
R23	406 K Ω	± 2%
R24	202 K Ω	± 2%
R25	100 K Ω	± 2%
R26	31·5 K Ω	± 2%
R27	4·35 K Ω	± 2%
R28	249 K Ω	± 1%
R29	59·6 K Ω	± 1%
R30	21·8 K Ω	± 1%
R31	2·9 K Ω	± 1%
R32	6·8 K Ω	± 1%

REF.	VALUE	TOL.
R33	330 K Ω	± 2%
R34	10 K Ω	± 2%
R35	10 K Ω	± 1%
R36	190 Ω { OVERWOUND TO 200 Ω ± ·5%	+ 5 % − 0 %
R37	500 Ω	± 2½ %
R38	8 K Ω	± 5 %
L.P.1.	200V 15 W SMALL EDISON SCREW	
L.P.2.	6·3V 0·3A M.E.S.	
RV1	25 Ω	
RV2	250 Ω	
RV3	10 K Ω	
RV4	5 K Ω	
RV5	10 K Ω	
RV6	5 K Ω	
F1	2-3 AMP	
C1	8 ufd ELECTROLYTIC	
V1	D77	
V2	D77	
REC. 1	1/6A	



CIRCUIT DIAGRAM 'AVO' VALVE CHARACTERISTIC METER Mk.III



CIRCUIT DIAGRAM OF 'AVO' VALVE CHARACTERISTIC METER Mk.III modification

	REF.	TOL.	VALUE
	R1	±20%	3·9 Ω
	R2	± 2%	760 Ω
	R3	± 1%	2 K Ω
	R4	± 1%	1860 Ω
	R5	± 1%	300 Ω
	R6	± 1%	25·6 K Ω
	R7	± 1%	2·5 K Ω
	R8	± 1%	"
	R9	± 1%	"
	R10	± 1%	"
	R11	± 1%	"
	R12	± 1%	"
	R13	± 1%	"
	R14	± 1%	"
	R15	± 1%	3·54 K Ω
	R16	± 2%	15 K Ω
	R17	± 2%	3 K Ω
	R18	± 2%	600 Ω
	R19	± 1%	2·96 M Ω MATCHED PAIR
	R20	± 2%	10 K Ω
	R21	± 2%	1·22 M Ω
	R22	± 2%	814 K Ω
	R23	± 2%	406 K Ω
	R24	± 2%	202 K Ω
	R25	± 2%	100 K Ω
	R26	± 2%	31·5 K Ω
	R27	± 2%	4·35 K Ω
	R28	± 1%	249 K Ω
	R29	± 1%	59·6 K Ω
	R30	± 1%	21·8 K Ω
	R31	± 1%	2·9 K Ω
	R32	± 1%	6·8 K Ω
	R33	± 2%	330 K Ω
	R34	± 2%	10 K Ω
	R35	± 1%	10 K Ω
	R36	+ 5% − 0%	190 Ω {OVERWOUND TO 200 Ω ± ·5%
	R37	±2½%	500 Ω
	R38	± 5%	8 K Ω
	M		30 µA Ri = 3250 Ω
*	L.P.1.		230V 15W RED E14
	L.P.2.		6·3V 0·3A M.E.S.
	RV1		25 Ω
	RV2		250 Ω
	RV3		10 K Ω
	RV4		5 K Ω
	RV5		10 K Ω
	RV6		5 K Ω
	F1		3 AMP
	C1		8 µfd 350V
			ELECTROLYTIC
*	D		1N4007

* modification