RADIO SERVICING
FOR AMATEURS

by

L. G. FURLEY A.M.Brit.I.R.E

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RADIO SERVICING

Workshop Layout

Whether one is repairing Radio Receivers for pleasure or profit a well laid out workshop is of the greatest importance. It is far better to have a place for everything, and everything in its place rather than in a heap on a table.

Space of course is the limiting factor and every possible inch of it must be put to full use.

To tell one how to make use of one's own workshop, by remote control, is out of the question as every workshop presents its own problems.

Nevertheless a few suggestions might be of help to those who are first starting to make a servicing workshop for themselves. The first thing of course is a good strong work-bench. This can be made to suit requirements from ¾″ floor boards, and the supports and trestles from 2″×2″ quartering. Remember that a workbench has to carry a heavy weight at times, therefore it is not worth while trying to save a few shillings by having lighter material.

Another point worth remembering too, is that the place must be dry, as dampness can play havoc with certain components and equipment.

The top of the workbench must be at least two feet six inches wide, wider if space will allow. Shelving can be built over the workbench to carry the test equipment and so keep it clear of the actual working area.

Lighting is of great importance, which should come from overhead but just behind where the person is working, the installation of some good lighting is of great benefit as it will prevent eyestrain.

It is not always beneficial to work directly in front of a window as the bright daylight, especially on a sunny day, tends to blind one. Work to one side so that the daylight comes from the left or right-hand side.

My own favourite position for working in a room or shed is across one corner with a window on either side.

Fig. 1 shows how a neat and tidy workshop can be made, but the final result will have to be left to the reader to make full use of the space available to him.

Fig. 2 shows a side view of the bench and the method of fixing to the floor and wall.

A shelf above the actual working space can carry the lighter testing equipment, while the heavier equipment is placed either side on the main bench.

Bookshelves are a great asset as reference books and technical data can be neatly stowed away ready for instant use, and in a place where they are readily found.

Now, what about tools? Well buy the best that one can afford! There is no need to go to the extreme and spend money on very expensive tools nor to the other and buy the cheapest. Invest in some good moderate priced material and you will find that these will serve you well.

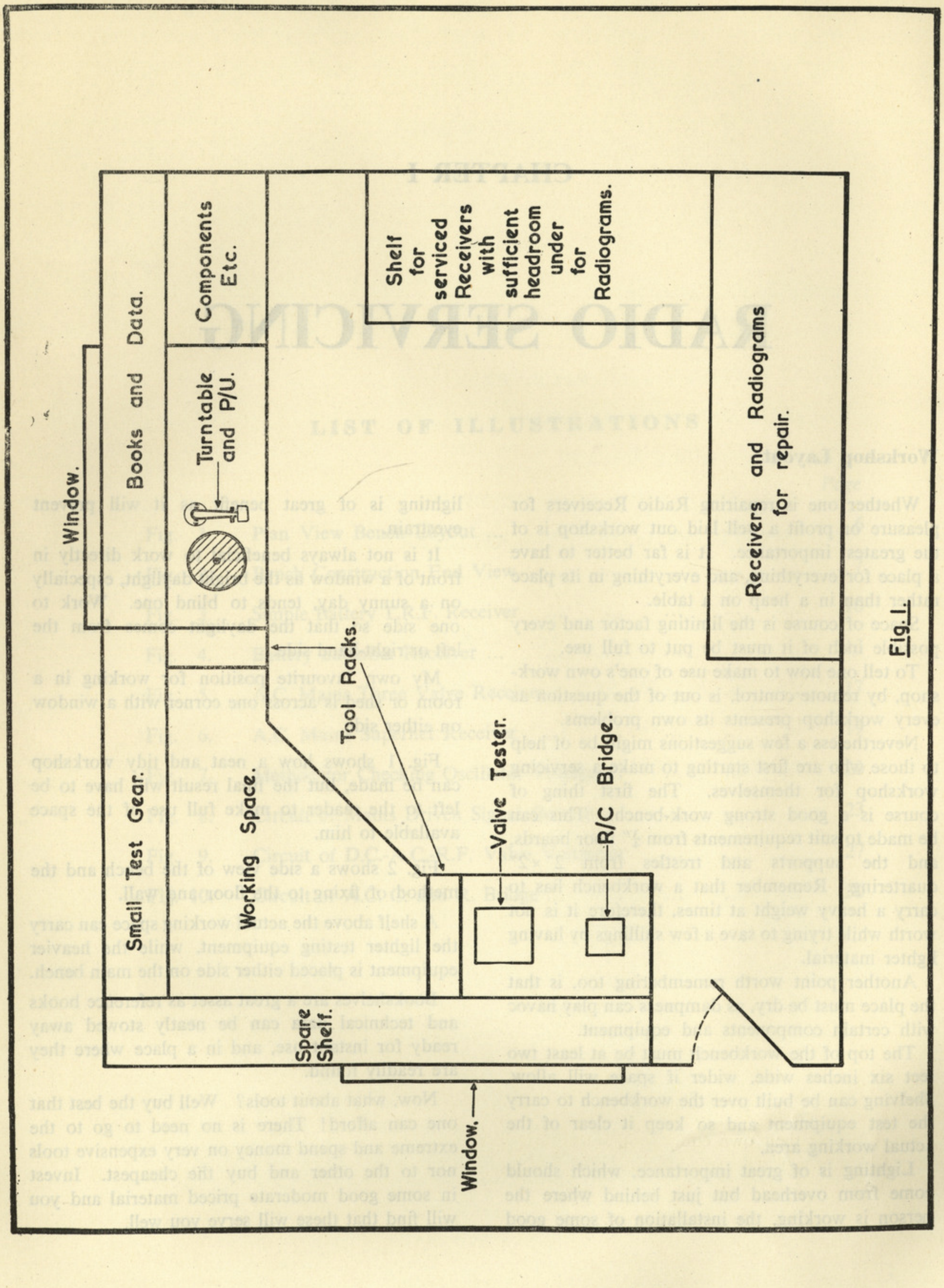


Fig. 1.

Plan View Bench Layout.

If possible provide yourself with two electric soldering irons, one a 65 watt type with an oval tapered bit, and an instrument iron. These two types will cover most of the work required by the service man. There are several good makes on the market, and it is left to the reader to make his own choice.

Pliers of course are required, here the half-round nose and the blunt nose types are the better to use, it is advisable to buy them in large and small sizes. Also buy yourself a good pair of side cutters for snipping the spare wire off components when soldered in position, making the repair neat and tidy.

Wire strippers are extremely useful and there are several good makes on the market.

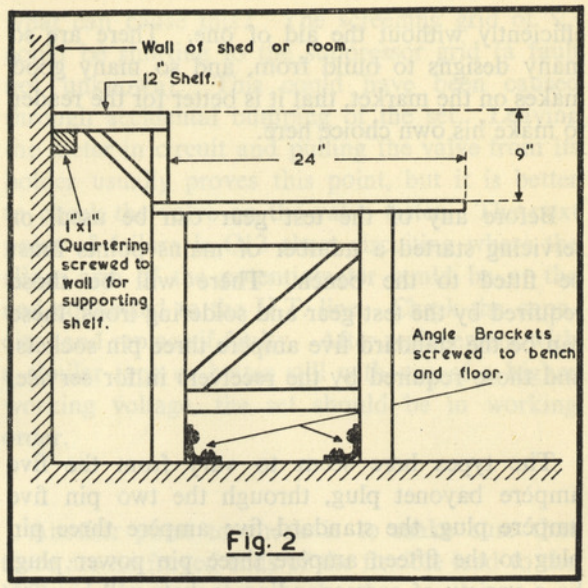
Quite often the modern type of valve is found to have some of the pins bent at the base. Invariably if one endeavours to straighten them with a pair of pliers the wire either breaks or the glass seal cracks, making the valve useless. With the help of a series of valve pin straighteners marketed by the Spear Engineering Co. Ltd., the pins can be straightened without fear of damage. This firm also produce valve wiring jigs which when fitted into the valveholders, secure the pins in the correct positions, so that when components are being wired in, no strain is imposed on the wiring when the valve is eventually plugged into the holder.

These are well worth buying and can save a number of headaches.

To complete the tool section a small second cut file will be useful for cleaning the bits of the soldering irons.

Equipment.

This is rather a difficult subject to talk about. Unless a person has the necessary money to spend on equipping a workshop with first class instruments, the only alternative is to build your own. The technical press have extremely good circuits prepared which are readily available to those who wish to make their own equipment, some circuits are also shown in the second section of this book. On the other hand there are several well known manufacturers of fine test equipment, producing relatively inexpensive meters and oscilloscopes for use by the " not so flush " service man.



Bench Construction End View.

The Universal Avominor is a very useful meter and covers the ranges of Current, Voltage and Resistance met in most commercial broadcast receivers.

If an oscilloscope is desired then the Cossor 1039 instrument is an ideal instrument, being small and compact, extremely light and therefore is easily portable. It is a very useful instrument for visual alignment and for measurements.

A commercially made valve tester can be the more expensive of the equipment necessary. Again it depends upon the depths of one's pocket. Excellent instruments for valve testing are made by the Automatic Coil Winder Co. Ltd., Taylor Instruments Ltd., and Mullard Ltd.

Another useful piece of equipment to have in the workshop is a Resistance-Capacity Bridge for checking the values of resistors and capacitors. This type of instrument proves its worth time and time again and saves quite a few minutes when tracing trouble. Several of these bridges have been described from time to time in the Technical Press.

Last but not least is the Signal Generator, a very present help in trouble. The service man would be lost without a good reliable Signal Generator, as the alignment of the various circuits in the receivers cannot be accomplished efficiently without the aid of one. There are so many designs to build from, and so many good makes on the market, that it is better for the reader to make his own choice here.

Before any of the test gear can be used, or servicing started a number of mains points must be fitted to the bench. There will be those required by the test gear and soldering irons, these can be the standard five ampère three pin sockets, and those required by the receivers in for service.

The types here seem to vary from the five ampère bayonet plug, through the two pin five ampère plug, the standard five ampère three pin plug to the fifteen ampère three pin power plug. So a variety of corresponding sockets will have to be fitted to the repair bench nicely convenient to get at easily. Nothing is more annoying than having to change plugs when receivers come in for service.

Each of these points should be separately fused and switched, otherwise if all the points are connected to one fuse only, and if it is accidently blown, annoyance is caused by the soldering iron taking time to heat up again for use.

The gramophone turntable and pick-up can be mounted within easy reach. Cupboards can be made under the bench to house components, valves, etc., and further shelving and racks made to carry the receivers for service and those serviced, making sure enough headroom is left beneath these racks to house radiograms.

It is better to cover the work-bench with a piece of stout baize to prevent the cabinets from being scratched. Nothing gives a service man a bad name than to send a cabinet home in a scratched condition.

Before attempting any service work make sure that the instruments to be used are fully understood. Voltmeters for instance have an unfortunate fault of giving a ficticious reading under certain conditions. For instance supposing a voltage reading was required across a resistor of 5000Ω in series with another resistor, to be measured with a meter whose sensitivity is 500 ohms per volt. Therefore measuring on the 100 volt range the meter resistance becomes 50,000 ohms, measurement on this range would be relatively accurate, but supposing the indication on the 100 volts range suggested a closer reading could be obtained on a lower range, the 10 volts range. The measurement of voltage here would not compare anywhere near to that of the 100 volts range, because having lowered the voltage range of the meter, the resistance of the meter has changed from 50,000 ohms to 5000 ohms.

From our knowledge of basic electricity we know that two same value resistors in parallel becomes half the value of one. Therefore as the total resistance has changed so a discrepancy of voltage reading is shown on the meter. A careful watch must be kept on the various ranges when using a meter otherwise misleading results can occur.

One word of warning to be remembered, if the value of voltage or current to be measured is in doubt, always switch the instrument to the highest range possible, and come down range by range until a sensible reading is reached. By doing this damage to the meter is prevented.

Simple Battery T.R.F. Receiver.

To enumerate all the faults possible in a receiver is virtually impossible, but some of the main ones will be described with the help of the circuit shown in Fig. 3.

Supposing the receiver was handed in for repair, with a report that it was not working.

The first thing to do, suspect the batteries. These must be tested with the set switched on and drawing current, otherwise fictitious readings would be shown, due to the meter not drawing sufficient current to represent the total current drawn by the receiver. Owing to the fact that the internal resistance of batteries increases with age, if the correct current drain is not taken from the batteries, higher voltages will be indicated by the meter and give the impression that they are still usable.

If on test a 90 volt battery shows a voltage of perhaps 65 volts or under, replace with a new one. Again if the 1.4 battery shows 1 volt or below replace that also.

On replacing the batteries the set perhaps works perfectly or again no signals. Before proceeding it is a better plan to check the H.T. line for a short circuit. To check for this, switch the meter to the ohms range, and disconnect the H.T. leads from the battery. Connect the meter between H.T. positive lead and chassis and measure for continuity. If no deflection is shown on the meter which is correct, the fault is perhaps an open circuit filament to one of the valves. Check each valve filament for continuity and replace where necessary. With reconnection of the batteries the set should work.

These two tests can be made without removing the set from the cabinet.

Instead of an open circuit on the continuity check for the H.T. line a short circuit is shown, in other words the meter needle travels the full length of the scale to the zero ohms point. Well what can cause this? The screening grid of V3 could be shorting to the suppressor grid (a fault not unknown). This could have been caused through accidental bumping of the set. Leaving the meter in circuit and pulling the valve from its holder usually proves this point, but it is better to check the valve on the valve tester. The next point of failure is C12 short circuiting where the slider arm of the potentiometer could be at the end connected to the H.T. line. Check the capacitor and replace if faulty. After replacement with a similar type or better still with one of a higher working voltage, the set should be in working order.

Another point to check is to make sure that there are no frayed ends of the flexible lead to the H.T. inside the chassis shorting across to an earth point.

No signal conditions can be caused through several faults. The primary of the output transformer might be open circuit. To prove this connect a meter, on the correct voltage range, between the anode pin of the valveholder and chassis. If no H.T. is recorded then suspect either the wiring to the valveholder, check on the ohms range for continuity between anode pin and the anode side of the output transformer. Where this is in order test across the primary tags of the output transformer. If faulty replace with the correct type of transformer.

The valveholder itself should not be overlooked as a fractured connection may be present causing trouble. It is a simple matter to push a piece of wire of the same diameter as the valve pin, into the anode pin hole, connecting the ohmmeter between the soldered tag and the wire, then gently rock the valveholder pin to check for an intermittent contact.

Any of the valves filaments open circuit cause no signal conditions, this can be due to age or accidental bumping of the set. C5 and C6 short-circuiting will by-pass the H.T. to chassis and prevent the set from working.

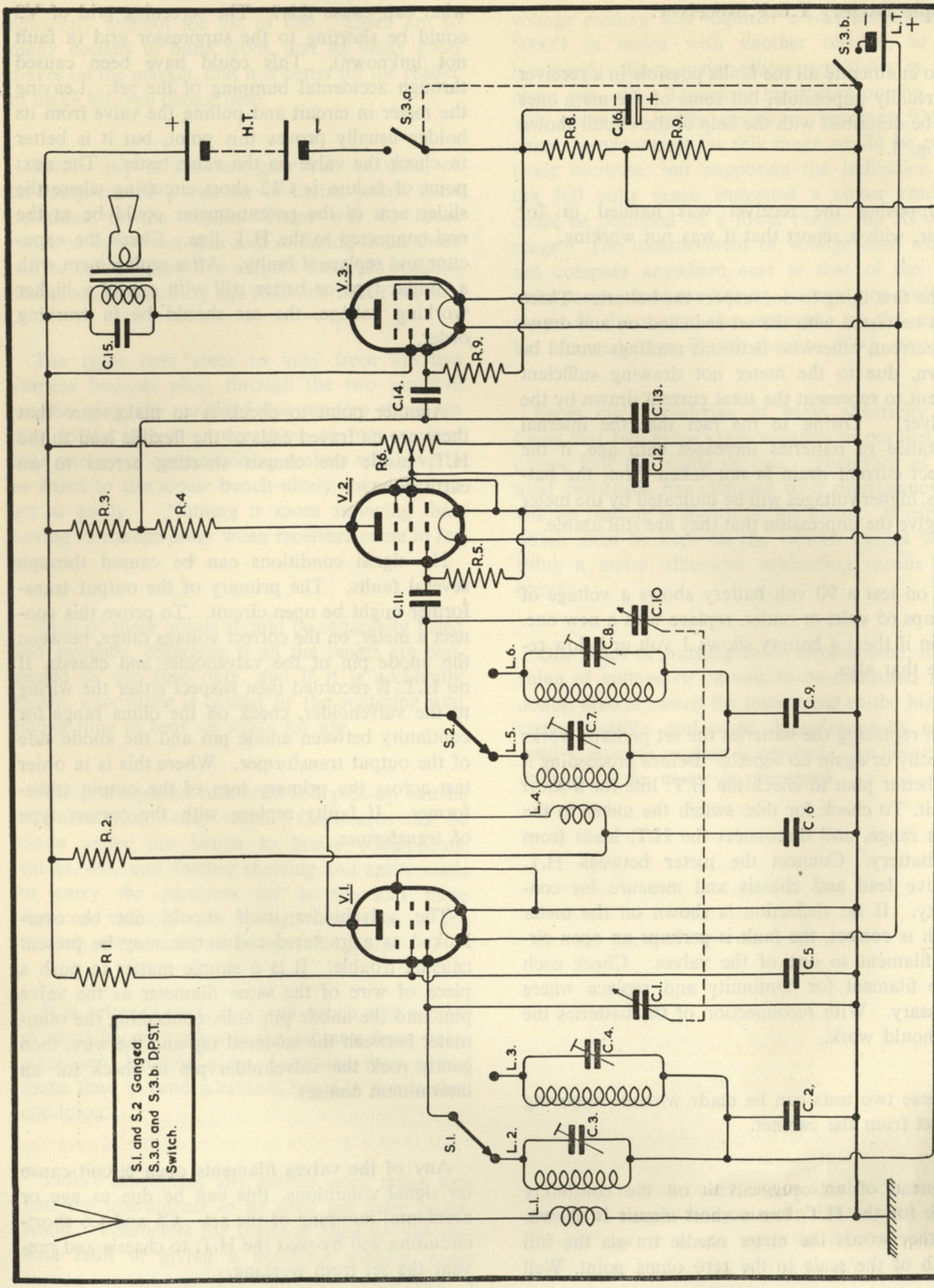


Fig. 3. *Simple Battery T.R.F. Receiver.*

Some ganged capacitors have trimmers on the top, and sometimes due to the deterioration of the valves have required adjustment. It is quite possible that in doing so the mica dielectric may have been squeezed too hard and has punctured causing a short-circuit across the gang and prevent the receiver from working. Or again the trimmers may be across the coils themselves and the same thing may have happened. This means fitting new mica and retrimming the set.

Having cleared the no signal conditions perhaps the receiver works but with a distorted output. After making sure that the H.T. and L.T. batteries are not low, test for correct bias conditions across R8 and R9. C16 might be leaking sufficiently to cause a partial short-circuit across these resistors and a too low a voltage is developed. Removing C16 and testing on the Capacity Bridge will confirm good or bad.

Again C14, the coupling condenser between the detector anode and the output grid, could be at fault. A small leakage here will develop a voltage across R7, in opposition to the bias voltage across R8 and R9 and so cause the actual grid volts to be low. By connecting a clip lead to the function of R3 and R4 and the other end of the clip lead to chassis will prove this point. If the voltage at the grid becomes normal, then remove C14 and replace with one of an equal value and higher working voltage. Connecting from the junction of R3 R4 to chassis will not cause damage as R3 is usually of a very high ohmic value, and the resulting current flow will be very small.

Instability is another fault which sometimes occurs in receivers and the decoupling capacitors to the screening grids of the valves should be checked. This fault invariably occurs if the capacitors are open circuit.

By connecting another capacitor across each of the decoupling capacitors in turn (C5, C6, C12) will usually show which capacitor is at fault.

Reaching this stage and hoping things will now be alright, the receiver now plays, but with reduced volume and lack of selectivity coupled with some intermittent crackles.

Lack of volume suggests that any or all of the valves are poor in emission and require replacing.

When a receiver lacks selectivity the fault is usually that the tuning coils have shorting turns, and can only be proved easily by substituting other coils. Noise and crackles in a receiver come from a multitude of sources. The wave-change switch may not be making proper contact on the wave-band concerned, the contact may have lost some of its pressure; this can be adjusted if one is careful by turning the switch to the next waveband, so that the rotor contract is not under stator contact of the waveband requiring adjustment. By exerting gentle pressure on this contact and pushing forward a trifle will usually suffice.

Should the contacts be dirty or oxidised a good switch cleaning fluid can be used.

If after this, the trouble still persists, and having traced it to be definitely switch fault, replacing the switch is the only alternative. Before doing so make a careful drawing showing where the wires connect including the colour code used.

A worn track on a volume control can cause noise, when the knob is rotated from minimum to maximum volume. Here it means a replacement as only that will clear the fault.

Any further crackles can only come from bad contacts on components on valveholders. The valveholders must not be excluded here, as the valveholder sockets may have expanded a little and prevent the valve pins from making good contact. A pair of pointed pliers and a gentle hand will usually exert sufficient pressure on the sockets so that the valve is seated firmly in the holder.

Intermittent electrode short circuits in the valves themselves can cause crackling and noise and the only cure is replacement.

Dirt in the ganged tuning condenser is another fault causing noise or even the vanes may be touching in places. Open the gang to minimum capacity and gently insert a feather between the vanes to clear the dust.

If the vanes are short circuiting, which can be checked by connecting an ohmmeter between the chassis and the tags on the fixed vanes, then opening or closing the moving vanes to see where the short is indicated on the meter. Careful pressure on the offending parts will usually clear the trouble.

Finally the aerial and earth connections should be carefully checked to make sure nothing is amiss here.

Battery Superhet Receiver.

The same procedure is used to trace faults in a Superhet as in the case of the T.R.F. receiver. By measuring the voltage and current at various points gives a good indication to where faults are. Experience also helps as several short cuts and time savers can be learned.

When a receiver is brought in and is reported to have "no signals" or "not working", a quick check for the audio sections is to connect a signal generator giving a 400 c.p.s. or 1000 c.p.s. note to the grid of the diode pentode valve (V3 in Fig. 4).

If the signal from a moderately low input is clear and undistorted, then obviously the fault is prior to the grid circuit of V3.

A Signal Generator which gives 400 c.p.s. audio frequency and variable Radio Frequency signals is a great asset to the service man, because by applying A.F. or R.F. to certain points quick checks may be made.

After checking the audio end with the generator. Transfer the output leads to the Anode of the I.F. amplifier and feed in the correct modulated I.F. frequency for the receiver. Here no results may appear, therefore the trouble lies between the anode of the I.F. amplifier and the grid of the succeeding valve. It can be that the primary of the I.F. transformer is open circuit, so connect a voltmeter between anode and chassis of the I.F. valve and check for anode volts. None appearing? Right replace the I.F. transformer for one with the same characteristics.

The voltage may have been correct at the anode of the I.F. valve, but still there are no signals, therefore the secondary of the I.F. transformer could have been open circuit instead of the primary or even R4 or R5 could have been at fault. Checking with the ohmmeter will quickly prove these components.

Perhaps after all this there are still no signals, now we are approaching the Frequency Changer where several faults may occur. Firstly check anode volts and then the oscillator anode volts. Next check the screen volts. If these checks are proved to be in order and the voltages appearing are correct, then the oscillator section could be at fault.

To check the oscillator section, connect a milliammeter in the Heptode anode circuit, between the I.F. primary and the anode of the valve. This will indicate a certain value of current flowing through the valve. By shorting the oscillator grid to chassis with a clip lead, the current through the valve should change if the oscillator section is working. Should there be no change of current then further searching is necessary. The trimmer C5 across the oscillator grid coil might be short circuiting, or the padding capacitor C7 could have the same fault, killing the oscillation completely.

Disconnecting the trimmer and the padder and checking with an ohmmeter will prove the position.

The remaining point where no signal conditions can occur is obviously at the aerial coil, where the trimmer C1 could be short circuiting or even the vanes if the ganged capacitor might be fouling.

To give a complete list of faults and how to deal with them is beyond the scope of this book and the following list of possible faults is given as a guide.

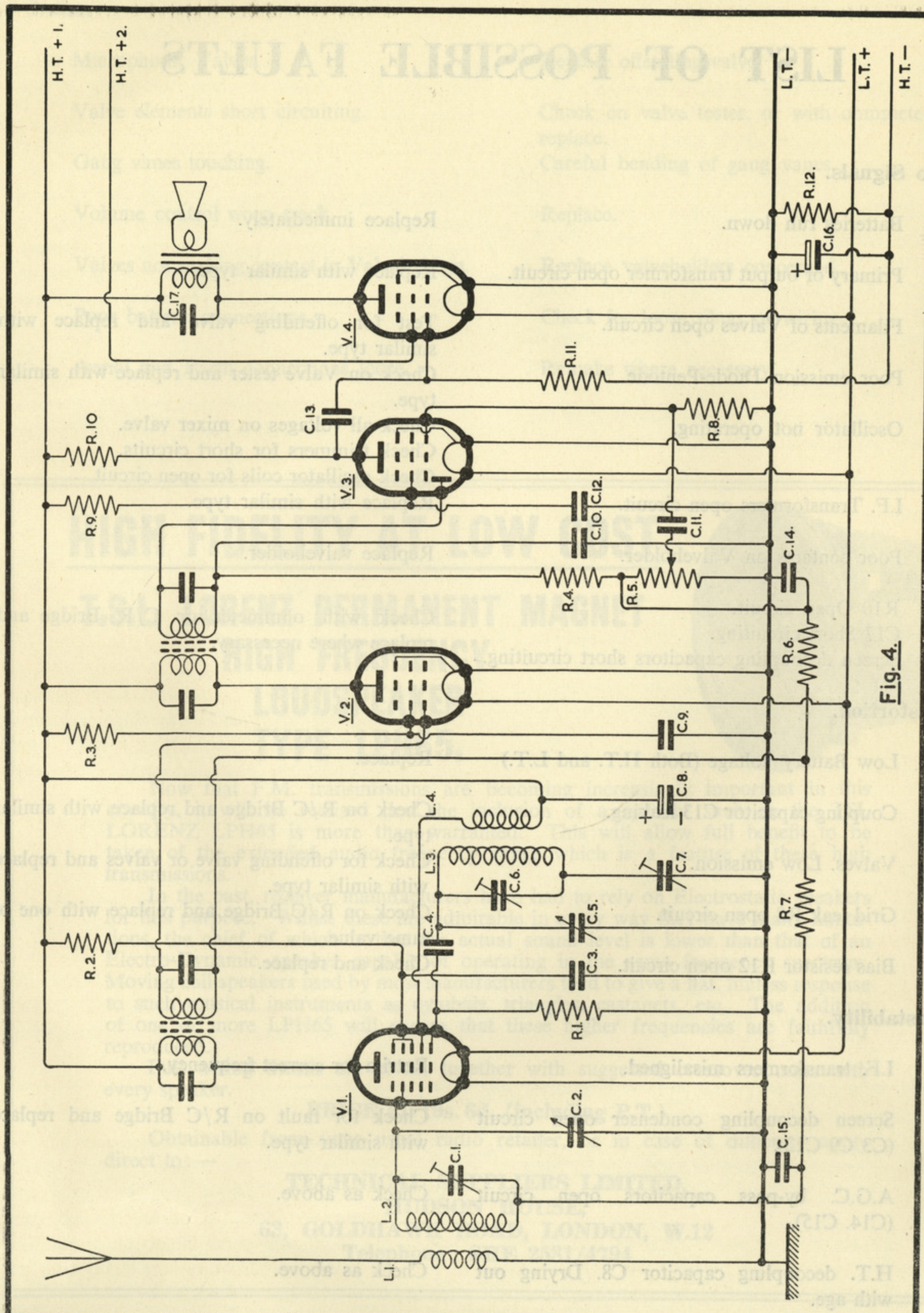


Fig. 4. *Battery Superhet Receiver.*

LIST OF POSSIBLE FAULTS

No Signals.

Batteries run down.	Replace immediately.
Primary of output transformer open circuit.	Replace with similar type.
Filaments of Valves open circuit.	Test for offending valve and replace with similar type.
Poor emission Diode-Pentode.	Check on Valve tester and replace with similar type.
Oscillator not operating.	Check all voltages on mixer valve. Check trimmers for short circuits. Check oscillator coils for open circuit.
I.F. Transformers open circuit.	Replace with similar type.
Poor contacts on Valveholder.	Replace valveholder.
R10 Open circuit. C17 Short circuiting. Screen decoupling capacitors short circuiting.	Check with ohmmeter or C/R Bridge and replace where necessary.

Distortion.

Low Battery voltage (Both H.T. and L.T.)	Replace.
Coupling capacitor C13 leaking.	Check on R/C Bridge and replace with similar type.
Valves. Low emission.	Check for offending valve or valves and replace with similar type.
Grid leak R8 open circuit.	Check on R/C Bridge and replace with one of same value.
Bias resistor R12 open circuit.	Check and replace.

Instability.

I.F. transformers misaligned.	Retrim for correct frequency.
Screen decoupling condenser open circuit (C3 C9 C12).	Check for fault on R/C Bridge and replace with similar type.
A.G.C. by-pass capacitors open circuit (C14. C15).	Check as above.
H.T. decoupling capacitor C8. Drying out with age.	Check as above.

Noise.

Microphonic Valves.	Replace offending valve.
Valve elements short circuiting.	Check on valve tester, or with ohmmeter and replace.
Gang vanes touching.	Careful bending of gang vanes.
Volume control worn track.	Replace.
Valves not making contact in Valveholders.	Replace valveholders concerned.
Poor battery connections.	Check for loose plugs or wiring.
Aerial and Earth connections loose.	Remake where necessary.

A.C. Mains Three Valve Receiver.

Exactly the same type of faults can occur in a mains driven receiver as in a battery model together with mains hum which can be prevalent in the mains model.

A rectifying system is employed to convert the alternating voltage and current to a steady direct voltage and current. This is brought about by connecting the mains supply to a suitable transformer, the secondary of which is connected to the anode or anodes of a rectifying valve. The valve, due to its peculiarity of passing current in one direction only, provides a unilateral pulsating direct current. The pulse being smoothed out by the action of the choke and capacitors immediately following the rectifier.

A circuit of an A.C. Three Valve Receiver is shown in Fig. 5, the power unit or power pack as it is called is represented by T1, V4, Ch1, and C14, C15.

Excessive hum can be produced in the receiver should C14 or C15 break down or become open circuit. To operate a receiver which is humming badly is detrimental to the rectifier.

Should C14 short circuit it is quite possible for the choke Ch1 to burn out due to excess current flowing through its windings, coupled with the possibility of destroying the rectifying valve at the same time.

A breakdown in C15 invariably causes the rectifier to pass an abnormal current and will strip the cathode of the emitting surface and so ruin the valve. As a safety measure a 500 m/a fuse could be fitted in the cathode lead of the rectifier in order to prevent damage.

The method used to test for hum in a receiver is by substitution of capacitors. In other words disconnect the positive side of the C15 and C14 in turn and connect a known good one in their place.

Hum can occur in a mains receiver due to a breakdown in cathode to heater insulation. The only check here is to substitute a new valve.

As a further precaution against hum, the top cap grid connections of the R.F. Valves should have screened top cap connectors to prevent any stray magnetic fields from reaching the grids of the valves and being amplified.

The capacitors C14 and C15 will also allow a mains ripple to pass if the capacity of either is becoming low, due to age or drying out through being placed too near the rectifier or output valve. Again substitution will prove the point for replacement if necessary.

If excessive hum persists in a receiver after all other checks and replacements made, a further refinement could be helpful by making an artificial centre tap across the heater windings x and y of the transformer T1. The potentiometer P1 is about 50 ohms in value, the two ends being connected across the L.T. windings with the slider arm taken to chassis. The slider is then adjusted with the set switch on, to give minimum hum level.

Another form of hum is a rather high pitched note characteristic of placing one's finger near the grid of an amplifying valve. The trouble here could possibly be that the electrostatic screening between the primary and secondary of the mains transformer is disconnected from the chassis.

Still a further annoying source of hum can be present in a mains operated receiver, and that is hum which is present when a station is tuned in. This is termed " modulation hum ", and can easily be cured by the connection of a 0.01μF 1000v. working capacitor from each anode of the rectifier to chassis.

Other causes of hum can be caused through insufficient screening of the volume control leads, or through a valve or valves drawing excess current, this current having to pass through the smoothing choke, will cause magnetic saturation of the iron core and so reduce the inductance of the choke.

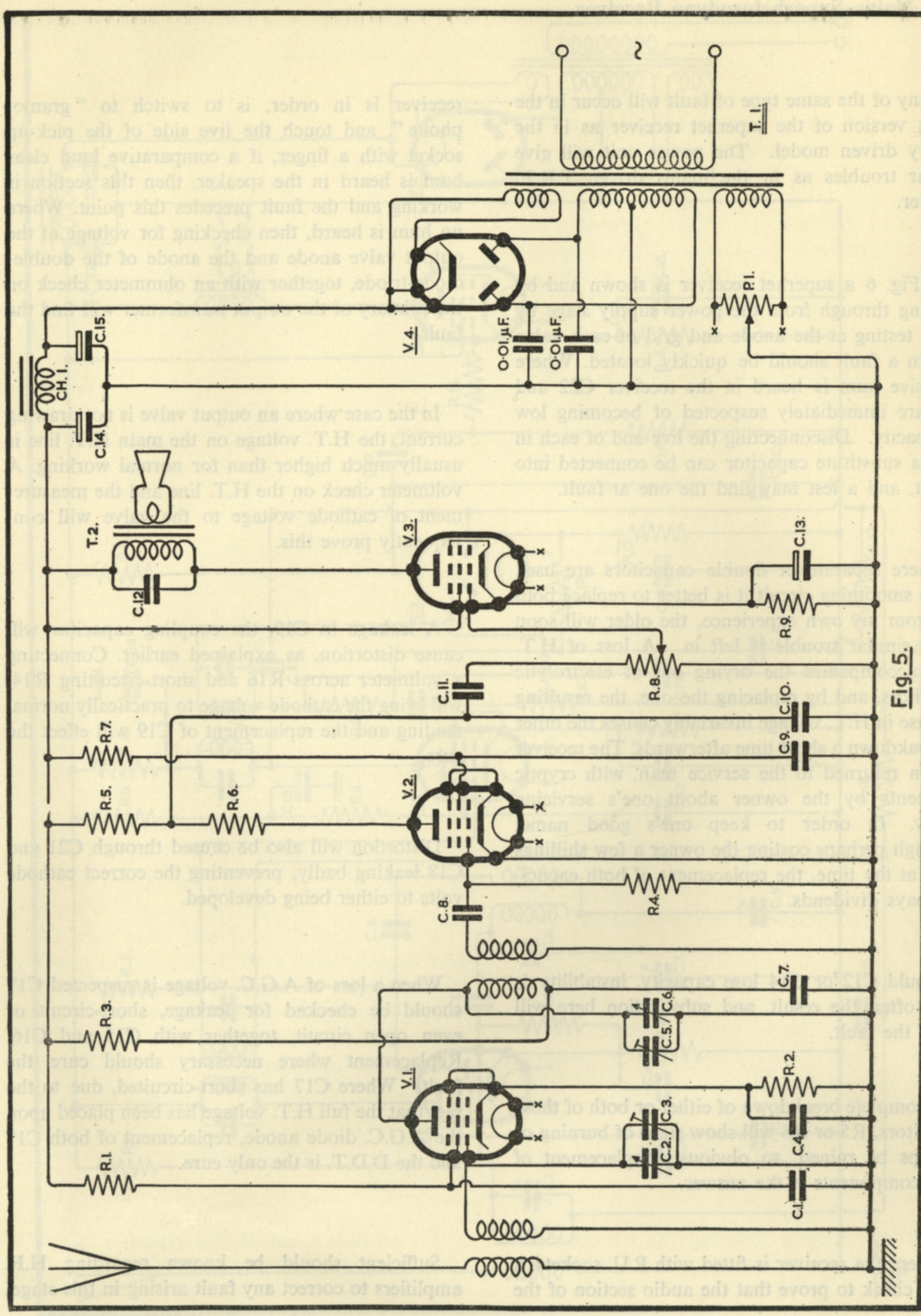


Fig. 5. A.C. Mains Three Valve Receiver.

A.C. Mains Superheterodyne Receiver.

Many of the same type of fault will occur in the mains version of the superhet receiver as in the battery driven model. The power unit will give similar troubles as in the mains driven T.R.F. receiver.

In Fig. 6 a superhet receiver is shown and by working through from the power supply stage by stage, testing at the anode and grid of each valve in turn a fault should be quickly located. Where excessive hum is heard in the receiver C22 and C23 are immediately suspected of becoming low in capacity. Disconnecting the live end of each in turn, a substitute capacitor can be connected into circuit, and a test may find the one at fault.

Where separate or double capacitors are used in the smoothing circuit it is better to replace both for, from my own experience, the older will soon cause similar trouble if left in. A loss of H.T. volts accompanies the drying out of electrolytic capacitors, and by replacing the one, the resulting increase in H.T. voltage invariably causes the other to breakdown a short time afterwards. The receiver is then returned to the service man, with cryptic comments by the owner about one's servicing ability. In order to keep one's good name, although perhaps costing the owner a few shillings more at the time, the replacement of both capacitors pays dividends.

Should C12 or C14 lose capacity, instability is quite often the result, and substitution here will prove the fault.

A complete breakdown of either or both of these capacitors, R5 or R8 will show signs of burning or perhaps be ruined, so obviously replacement of both components is the answer.

Where the receiver is fitted with P.U. sockets, a quick check to prove that the audio section of the receiver is in order, is to switch to " gramophone ", and touch the live side of the pick-up socket with a finger, if a comparative loud clear hum is heard in the speaker, then this section is working and the fault precedes this point. Where no hum is heard, then checking for voltage at the output valve anode and the anode of the double-diode-triode, together with an ohmmeter check on the primary of the output transformer will find the fault.

In the case where an output valve is not drawing current, the H.T. voltage on the main H.T. line is usually much higher than for normal working. A voltmeter check on the H.T. line and the measurement of cathode voltage to the valve will consequently prove this.

A leakage in C19, the coupling capacitor will cause distortion, as explained earlier. Connecting a voltmeter across R16 and short-circuiting R14, will bring the cathode voltage to practically normal reading and the replacement of C19 will effect the cure.

Distortion will also be caused through C21 and C18 leaking badly, preventing the correct cathode volts to either being developed.

When a loss of A.G.C. voltage is suspected C17 should be checked for leakage, short-circuit or even open circuit, together with C15 and C16. Replacement where necessary should cure the fault. Where C17 has short-circuited, due to the fact that the full H.T. voltage has been placed upon the A.G.C. diode anode, replacement of both C17 and the D.D.T. is the only cure.

Sufficient should be known regarding H.F. amplifiers to correct any fault arising in this stage.

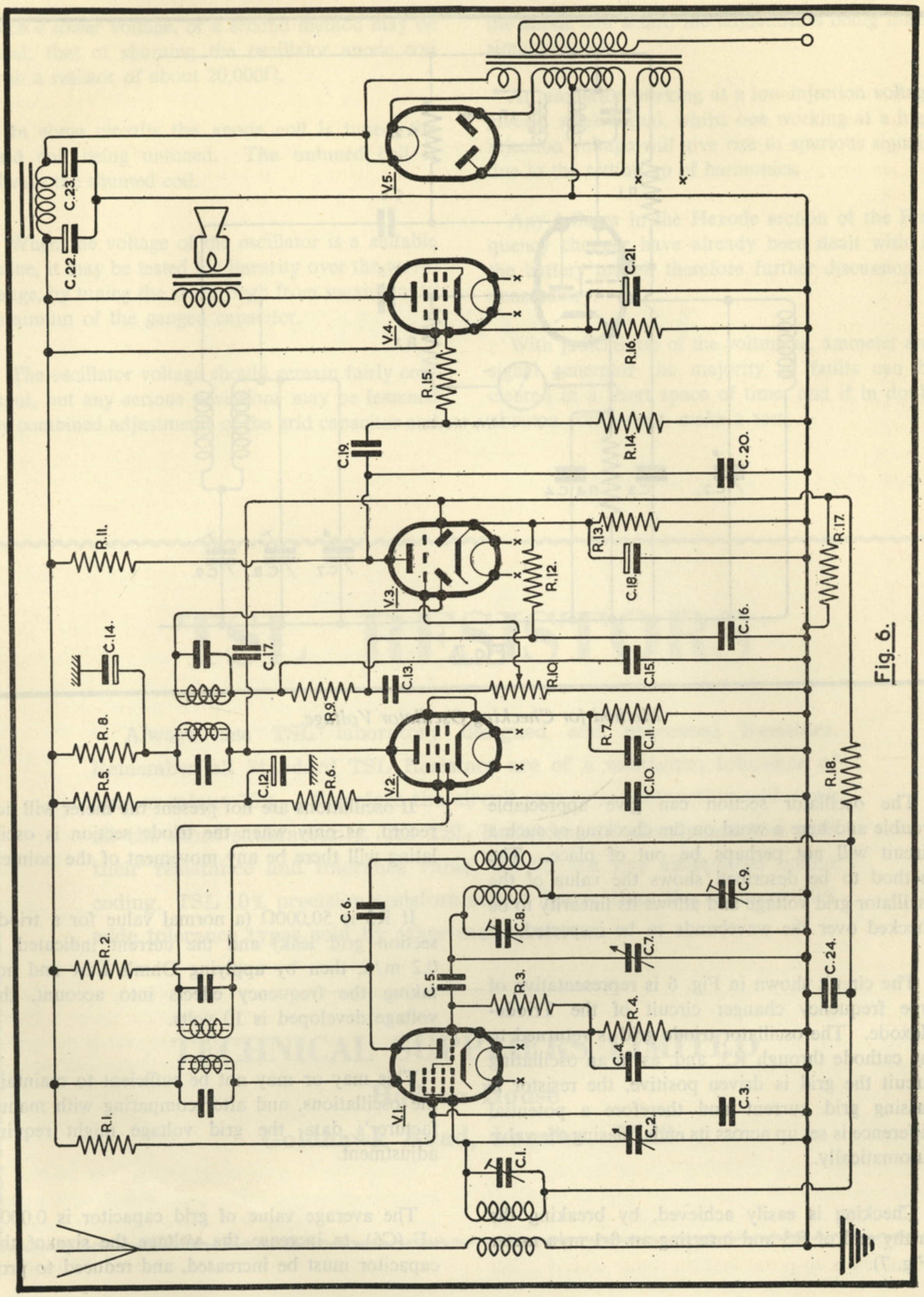
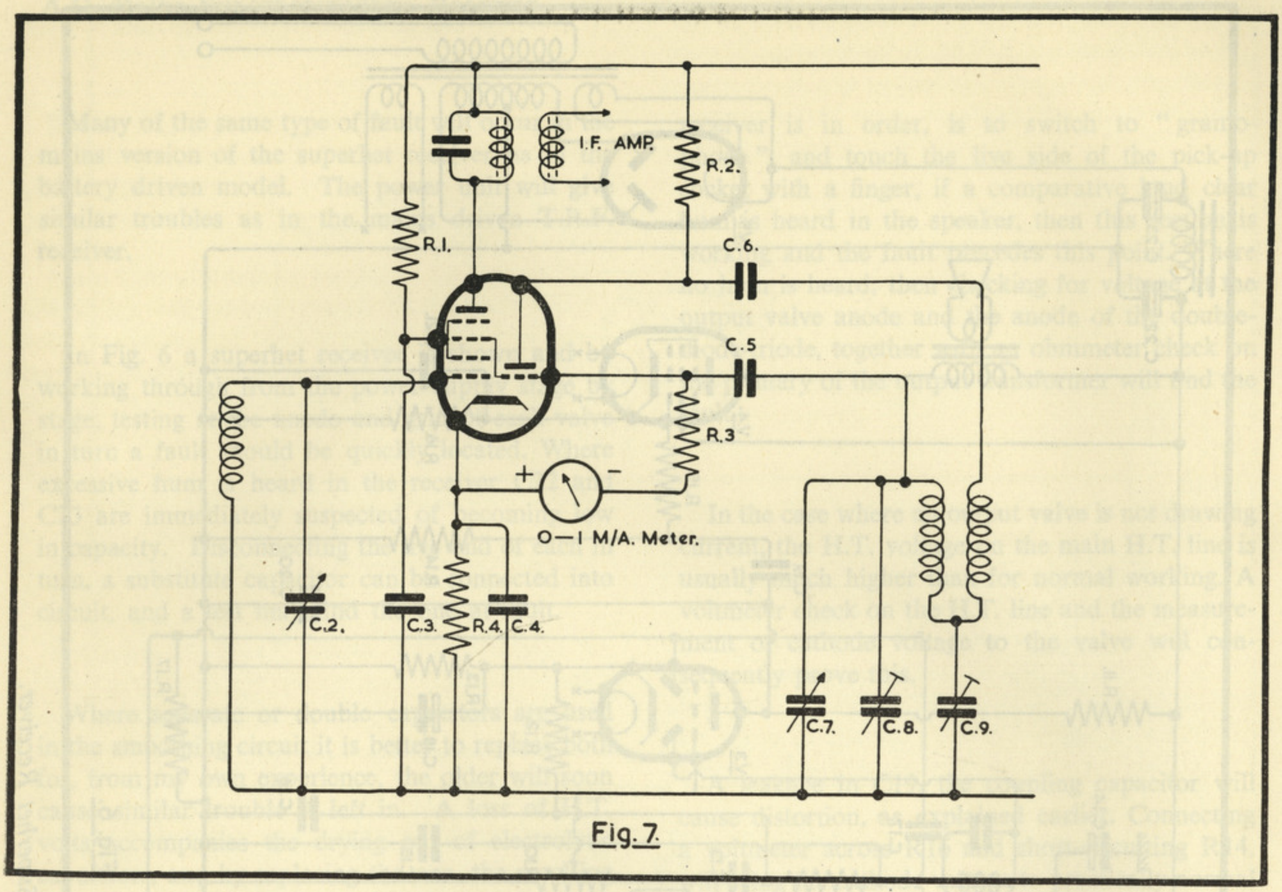


Fig. 6.

A.C. Mains Superhet Receiver.



Method for Checking Oscillator Voltage.

The oscillator section can give appreciable trouble and here a word on the checking of such a circuit will not perhaps be out of place. The method to be described shows the value of the oscillator grid voltage and allows its linearity to be checked over the wavebands to be inspected.

The circuit shown in Fig. 6 is representative of type frequency changer circuit of the Triode-Hexode. The oscillator triode grid is returned to the cathode through R3, and, as in an oscillating circuit the grid is driven positive, the resistor is passing grid current and therefore a potential difference is set up across its ends, biasing the valve automatically.

Checking is easily achieved, by breaking the earthy end of R3 and inserting an 0-1 m/a meter (Fig. 7).

If oscillations are not present the meter will not record, as only when the triode section is oscillating will there be any movement of the pointer.

If R3 is 50,000Ω (a normal value for a triode section grid leak) and the current indicated is 0.2 m/a, then by applying Ohm's Law and not taking the frequency effects into account, the voltage developed is 10 volts.

This may or may not be sufficient to maintain the oscillations, and after comparing with manufacturer's data, the grid voltage might require adjustment.

The average value of grid capacitor is 0.0001 μF (C5), to increase the voltage the size of the capacitor must be increased, and reduced to produce a lower voltage, or a second method may be used, that of shunting the oscillator anode coil with a resistor of about 20,000Ω.

In some circuits the anode coil is tuned, the grid coil being untuned. The untuned coil is always the shunted coil.

When the voltage of the oscillator is a suitable value, it may be tested for linearity over the wave-range, by tuning the set through from maximum to minimum of the ganged capacitor.

The oscillator voltage should remain fairly constant, but any serious deviations may be lessened by combined adjustments of the grid capacitor and the anode coil shunt, the adjustments being made simultaneously.

An oscillator working at a low injection voltage gives a weak signal, whilst one working at a high injection voltage will give rise to spurious signals, due to the setting up of harmonics.

Any failures in the Hexode section of the Frequency changer have already been dealt with in the battery model, therefore further discussion is unnecessary.

With judicial use of the voltmeter, ammeter and signal generator the majority of faults can be cleared in a short space of time, and if in doubt about a component, make a test.

CHAPTER II

TEST EQUIPMENT

A.C. Mains Driven Signal Generator.

For the enthusiast who likes making his own test gear the circuit of Fig. 8 shows a mains driven Signal Generator covering a range of 16 metres to 2000 metres in five steps.

A Triode-Heptode frequency changer valve is used as the combined Radio Frequency—Audio oscillator.

Modulated and unmodulated signals are available on the R.F. side, while the audio signal can also be taken out for various low frequency tests. A set of commercial coils are used, which allow the frequency bands to be covered, without being crowded as is often the case with home-made coils.

An attenuator is included in the circuit, with coarse attenuation being effected by S1, the fine control of the attenuator is governed by R12. A low impedance load appears at both the input and output sides of the attenuator.

The output from the generator may be taken directly from the attenuator or through an artificial aerial.

In the construction of the instrument the attenuator and the artificial aerial should be further shielded inside the shielding box of the generator. Attention must be paid to the lapping joints of both boxes and a good electrical contact must be maintained, whilst all earthed points and by-pass connections must be taken to one central earthing point so that no R.F. current can flow through the screening.

The Audio oscillator comprises a small intervalve transformer, the windings of which can be tuned experimentally by connecting small capacitors across either the primary or secondary until the desired note is heard. A switch (S4) allows the audio signal to be fed to the attenuator, while switch (S5) is the modulation on-off control.

The audio section is connected to the triode portion of the valve, with the R.F. oscillator connected across the grid and screen grid of the heptode. This has the advantage that the heptode anode is left free of the oscillating circuits, being readily available as the output electrode.

Tuned anode windings are used with grid reaction, so that if squegging occurs on any range a fixed resistor can be inserted in series with the grid coil and grid capacitance to reduce the amplitude of oscillation. The value of the resistor must be found experimentally but usually a value between 50 ohms and 500 ohms is sufficient to stop the squegging.

Squegging in a signal generator can be readily recognised—instead of a clear signal with a pure audio note, a band of frequencies is transmitted with a harsh hissing note being central in the band.

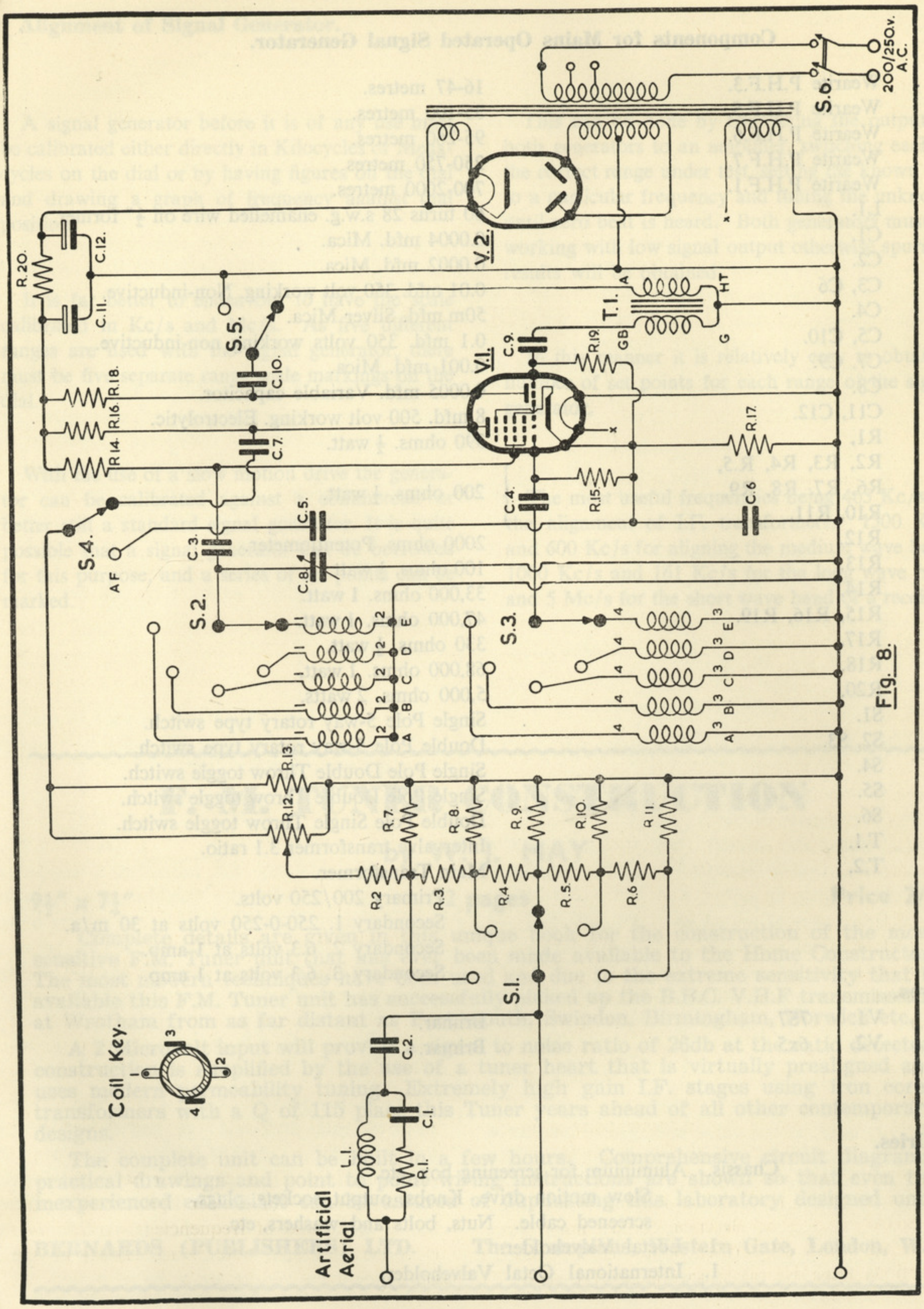


Fig. 8.

Circuit of Mains Driven Signal Generator.

Components for Mains Operated Signal Generator.

Wearite P.H.F.3.	16-47 metres.
Wearite P.H.F.5.	35-100 metres.
Wearite P.H.F.6.	95-260 metres.
Wearite P.H.F.7.	250-750 metres.
Wearite P.H.F.1.	700-2000 metres.
L1.	60 turns 28 s.w.g. enamelled wire on $\frac{1}{2}''$ former.
C1.	0.0004 mfd. Mica.
C2.	0.0002 mfd. Mica.
C3, C6	0.01 mfd. 350 volt working. Non-inductive.
C4.	50m.mfd. Silver Mica.
C5, C10.	0.1 mfd. 350 volts working non-inductive.
C7, C9.	0.001 mfd. Mica.
C8.	0.0005 mfd. Variable capacitor.
C11, C12.	8 mfd. 500 volt working. Electrolytic.
R1,	390 ohms. $\frac{1}{2}$ watt.
R2, R3, R4, R.5, R6, R7, R8, R9, R10, R11.	200 ohms. $\frac{1}{2}$ watt.
R12.	2000 ohms. Potentiometer.
R13.	100 ohms. $\frac{1}{2}$ watt.
R14.	33,000 ohms. 1 watt.
R15, R16, R19.	47,000 ohms. 1 watt.
R17.	330 ohms. $\frac{1}{2}$ watt.
R18.	68,000 ohms. 1 watt.
R20.	5,000 ohms. 2 watts.
S1.	Single Pole 5-way rotary type switch.
S2, S3.	Double Pole 5-way rotary type switch.
S4.	Single Pole Double Throw toggle switch.
S5.	Single Pole Double Throw toggle switch.
S6.	Double Pole Single Throw toggle switch.
T.1.	Intervalve transformer 3.1 ratio.
T.2.	Main Transformer.
	Primary 200/250 volts.
	Secondary 1. 250-0-250 volts at 30 m/a.
	Secondary 2. 6.3 volts at 1 amp.
	Secondary 3. 6.3 volts at 1 amp.

Valves.

V1.	7S7	Brimar.
V2.	6x5	Brimar.

Sundries.

Chassis. Aluminium for screening box, etc.
Slow motion drive, Knobs, output sockets, plugs, screened cable. Nuts, bolts and washers, etc.
1. Loctal Valveholder.
1. International Octal Valveholder.

Alignment of Signal Generator.

A signal generator before it is of any use must be calibrated either directly in Kilocycles or Megacycles on the dial or by having figures on the dial and drawing a graph of frequency against dial position.

It is far better to endeavour to have the scale calibrated in Kc/s and Mc/s. As five different ranges are used with the signal generator, there must be five separate range scale markings on the dial.

With the use of a slow motion drive the generator can be calibrated against a commercial or better still a standard signal generator. It is quite possible that a signal generator can be borrowed for this purpose, and a series of set points can be marked.

This can be done by connecting the output of both generators to an amplifier, switching each to the correct range under test, setting the known one to a particular frequency and tuning the unknown until zero beat is heard. Both generators must be working with low signal output otherwise spurious results will be obtained.

In this manner it is relatively easy to obtain a number of set points for each range of the signal generator.

The most useful frequencies being 465 Kc/s for the alignment of I.F. transformers. 1500 Kc/s and 600 Kc/s for aligning the medium wave band. 1000 Kc/s and 161 Kc/s for the long wave band and 5 Mc/s for the short wave band of a receiver.

A D.C.—A.C.—R.F. Valve Voltmeter.

The circuit shown in Fig. 9 is a main operated instrument complete with probe.

Basically a probe valve-voltmeter is a D.C. measuring instrument, the probe being plugged into circuit for measuring A.C. and R.F. The probe head contains a double diode valve, the chief purpose of which is to rectify the R.F. applied to the valve voltmeter, thus passing a D.C. potential for measurement to the main circuit of the valve voltmeter.

A double diode has been chosen (a 6AL5), because a straight diode will give a zero error, since the valve emission causes the valve voltmeter indicator to register when no A.C. or R.F. is applied to the probe.

This fault can be overcome by the use of a "backing-off" battery, or as used in the circuit a double diode is employed, connected in a self biasing circuit.

The first section of the diode rectifies the applied signal, whilst the second diode causes an emission current to flow through the variable resistance R1, thus setting up a potential across this resistance. The potential is applied to the first diode in opposition to the emission current potential generated by that section, neutralizing the zero error and enabling the signal potential to be applied to the valve voltmeter proper with no diode potential.

The probe head can be made very small if a 6AL5 is used, as the valve and control resistance can be mounted into a small cylindrical box. The assembly must be connected to the valve voltmeter through a three core shielded cable, the cable shield acting as the common lead with the three cores carrying the diode heater current and the return or positive line of the rectified signal voltage.

Diode probes give peak reading on A.C. or R.F., these readings may of course be converted to R.M.S. values. If the valve voltmeter is calibrated against a moving coil instrument the calibrations will automatically be R.M.S. values, whilst if calibrated against a standard valve voltmeter giving peak readings, the calibration will obviously be of peak values.

The D.C. voltmeter section of Fig. 9 is a bridge circuit, two valves being used with a sensitive moving coil instrument connected between the cathode loads. These loads are sufficient to give negative feedback to their respective valves, so that a reasonable linear calibration is obtained enabling the scale fitted to the instrument to be used without the need for recalibration. The calibration is originally set by R11 and periodically checked.

The probe head should not be used to measure voltages much higher than 150 volts, to avoid the risk of an overload.

Besides shielding the probe in a copper or aluminium cylinder the box housing the main valve voltmeter should also be of the same materials, and the shielding should also be taken to the D.C. sockets to prevent the chance of stray pick-up.

The grid and probe capacitors (C1 and C2) must be of the mica dielectric type, and should be built up from smaller values if the stated ones are difficult to obtain. The high resistance values for this voltmeter must also be built up from preferred values of resistors, remembering that the range resistors must have correct relationship one with the other if the ranges are to be accurate.

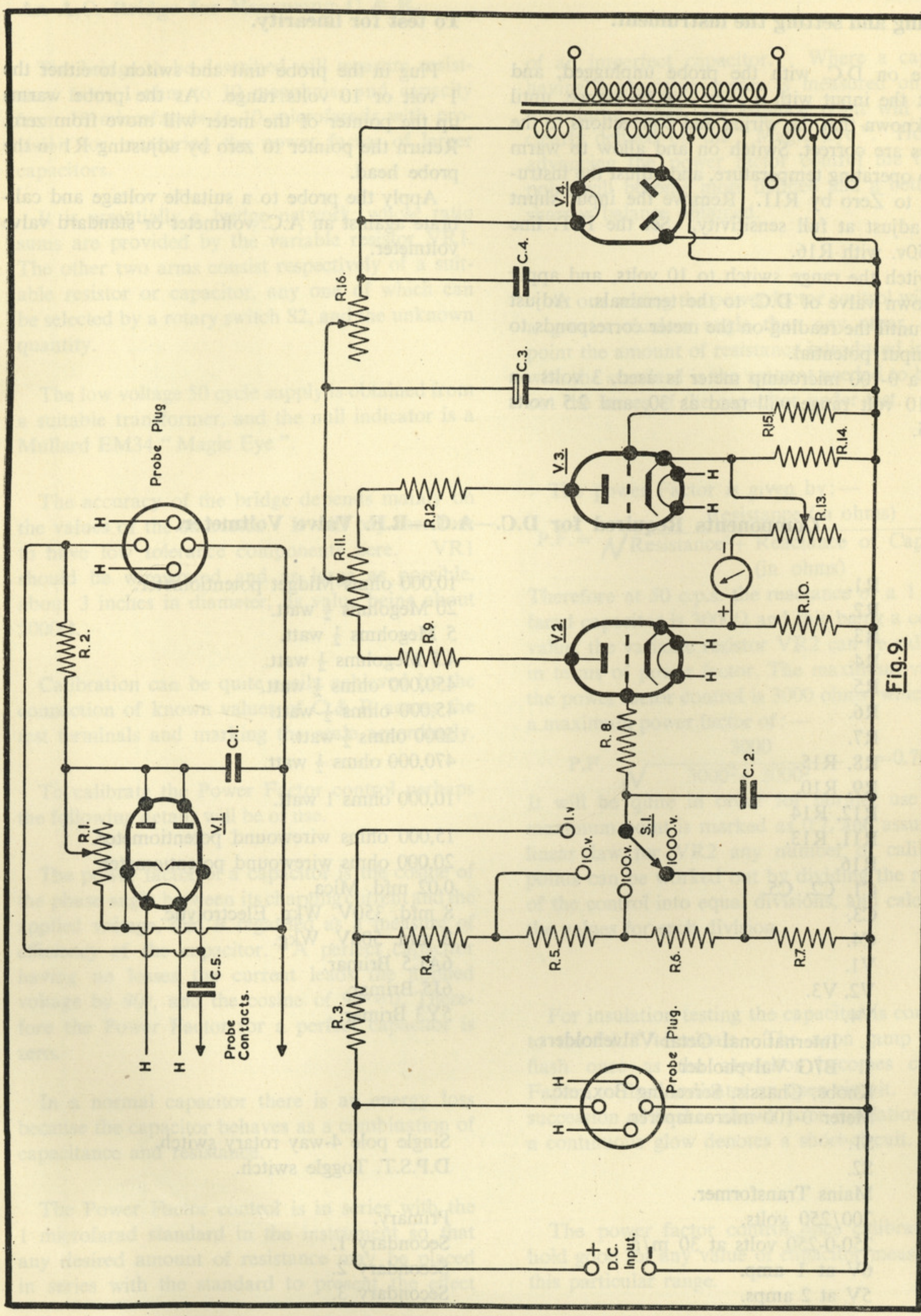


Fig.9. Circuit of Dc.—A.C.—R.F Valve Voltmeter.

Testing and setting the instrument.

Use on D.C. with the probe unplugged, and shunt the input with a very low resistance, until it is known that the wiring and connections to the valves are correct. Switch on and allow to warm up to operating temperature, and adjust the instrument to Zero by R11. Remove the input shunt and adjust at full sensitivity. Set the H.T. line to 150v. with R16.

Switch the range switch to 10 volts, and apply a known valve of D.C. to the terminals. Adjust R13 until the reading on the meter corresponds to the input potential.

If a 0-100 microamp meter is used, 3 volts on the 10 volt range will read as 30, and 2.5 volts as 25.

To test for linearity.

Plug in the probe unit and switch to either the 1 volt or 10 volts range. As the probe warms up the pointer of the meter will move from zero. Return the pointer to zero by adjusting R1 in the probe head.

Apply the probe to a suitable voltage and calibrate against an A.C. voltmeter or standard valve voltmeter.

Components Required for D.C.—A.C.—R.F. Valve Voltmeter.

R1.	10,000 ohms Midget potentiometer.
R2.	20 Megohms ½ watt.
R3.	5 Megohms ½ watt.
R4.	4.5 Megohms ½ watt.
R5.	450,000 ohms ½ watt.
R6.	45,000 ohms ½ watt.
R7.	5000 ohms ½ watt.
R8, R15.	470,000 ohms ½ watt.
R9, R10, R12, R14	10,000 ohms 1 watt.
R11, R13.	15,000 ohms wirewound potentiometer.
R16.	20,000 ohms wirewound potentiometer
C1, C2, C5.	0.02 mfd. Mica.
C3.	8 mfd. 350V. Wkg. Electrolytic.
C4.	2 mfd. 500V. Wkg.
V1.	6AL5 Brimar.
V2, V3.	6J5 Brimar.
V4.	5Y3 Brimar.
3. International Octal Valveholders.	
1. B7G Valveholder.	
Knobs, Chassis, Screening Box, etc.	
Meter 0-100 microampères.	
S1.	Single pole 4-way rotary switch.
S2.	D.P.S.T. Toggle switch.
Mains Transformer.	
200/250 volts.	Primary.
250-0-250 volts at 30 m/a.	Secondary 1.
6V at 1 amp.	Secondary 2.
5V at 2 amps.	Secondary 3.

An A.C. Bridge for Measuring C & R.

The bridge to be described will measure resistance from 1 ohm to 10 megohms, and capacity from 10 microfarads to 10 microfarads with provision for measuring the power factor of larger capacitors.

It is essentially a bridge network, whose ratio sums are provided by the variable resistor VR1. The other two arms consist respectively of a suitable resistor or capacitor, any one of which can be selected by a rotary switch S2, and the unknown quantity.

The low voltage 50 cycle supply is obtained from a suitable transformer, and the null indicator is a Mullard EM34 " Magic Eye ".

The accuracy of the bridge depends mainly on the values of the standards. It will pay therefore to have low tolerance components here. VR1 should be wirewound and as large as possible, about 3 inches in diameter, its value being about 5000Ω.

Calibration can be quite easily achieved by the connection of known values of C & R across the test terminals and marking the scale accordingly.

To calibrate the Power Factor control perhaps the following details will be of use.

The power factor of a capacitor is the cosine of the phase angle between its charging current and the applied voltage, and is regarded as a measure of efficiency of the capacitor. A perfect capacitor having no losses the current leads the applied voltage by 90°, and the cosine of 90°=0. Therefore the Power Factor for a perfect capacitor is zero.

In a normal capacitor there is an energy loss because the capacitor behaves as a combination of capacitance and resistance.

The Power Factor control is in series with the 1 microfarad standard in the instrument so that any desired amount of resistance may be placed in series with the standard to present the effect of an imperfect capacitor. Where a capacitor having appreciable losses is measured on the 1 microfarad range, the balance point will not be clearly defined on the " Magic Eye ". However, advancing the power factor control the balance point will become more defined and a better and sharper balance obtained.

At one setting the power factor control will show a greater shadow angle than any other, at this point the amount of resistance introduced in series with the standard is the amount needed to balance out the losses of the capacitor under test.

The power Factor is given by:—

$$\text{P.F.} = \frac{\text{Resistance (in ohms)}}{\sqrt{\text{Resistance}^2 + \text{Reactance of Capacitor}^2 \text{ (in ohms)}}}$$

Therefore at 50 c.p.s. the reactance of a 1 microfarad capacitor is 3000Ω and this being a constant value, the variable resistor VR2 can be calibrated in terms of power factor. The maximum value of the power factor control is 3000 ohms, which gives a maximum power factor of:—

$$\text{P.F.} \quad \frac{3000}{\sqrt{3000^2 + 3000^2}} = 0.707$$

It will be quite in order for normal use if the maximum point is marked as 0.7, and assuming a linear law for VR2 any number of calibration points can be worked out by dividing the rotation of the control into equal divisions, and calculating the values for each division.

For insulation testing the capacitor is connected to the " L " terminals. The neon lamp should flash once as the capacitor becomes charged. Failure to flash indicates an open circuit. A rapid succession of flashes shows poor insulation, while a continuous glow denotes a short-circuit.

The power factor control once calibrated will hold good for any value of capacitor measured on this particular range.

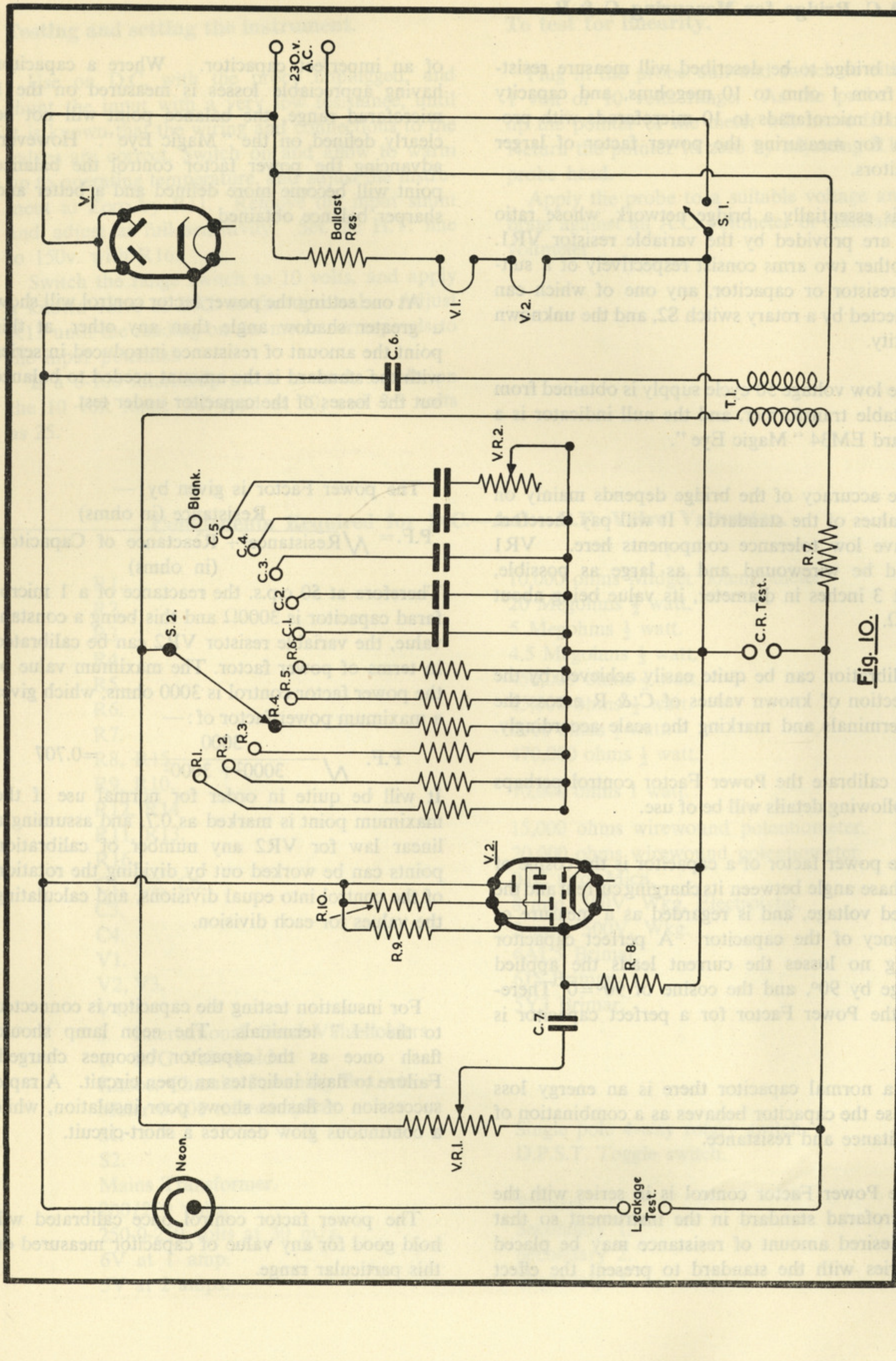


Fig. 10.

Circuit of A.C. C. and R. Bridge.

Components Required for A.C. C. and R. Bridge.

T1 Mains Transformer.
Primary 230 volts.
Secondary 30/60 volts.
S1. Single pole. Toggle switch.
S2. Single pole.
12 position Rotary switch.
VR1. 5000 ohm Wire wound.
large diameter potentiometer.
VR2. 3000 ohm wire wound
potentiometer.
R1. 1 Megohm 1 watt ± 2%.
R2. 0.1 Megohm 1 watt ± 2%.
R3. 0.01 Megohms 1 watt ± 2%.
R4. 1000 ohms 1 watt ± 2%.
R5. 100 ohms 1 watt ± 2%.
R6. 10 ohms 1 watt ± 2%.
R7. 1000 ohms 3 watts.
R8. R9. } 2.2 Megohms ½ watt.

C1. 0.001 mfd. ± 1%.
C2. 0.01 mfd. ± 1%.
C3. 0.05 mfd. ± 1%.
C4. 0.1 mfd. ± 1%.
C5. 1 mfd. ± 1%.
C6. 8 mfd. 350V. wkg. Electrolytic.
C7. 0.1 mfd. paper.
V1. CY 31.
V2. EM 34.
1 Miniature Neon Lamp
230 volts and holder.
2 International Octal Valveholders.
6 Insulated Terminals 1000Ω .2 amp.
1 Dropping Resistor

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