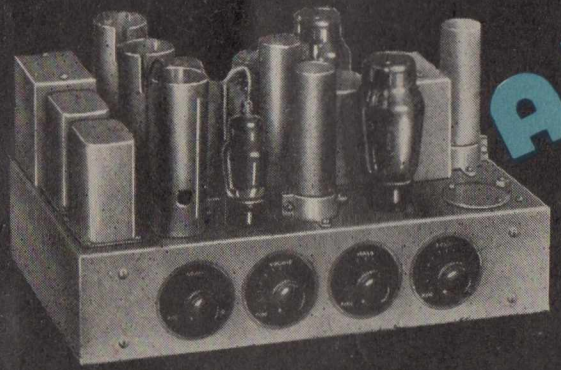
WIRELESS AMPLIFIER MANUAL



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No. 41

NOTES ON AMPLIFIERS

Special attention must be paid to the working conditions of circuits in sections 2, 3 and 4. On D.C. mains polarized (electrolytic) condensers must be connected with their polarities correct. In A.C./D.C. amplifiers the chassis and any apparatus in electrical connection with it may, under certain unavoidable conditions of supply, be " live " to earth.

Due care must be taken.

The circuits in this book are designed to give as great a range of capabilities as possible, and for that reason features shown in one diagram may not appear in another.

Input grid leads are shown shielded in high sensitivity circuits, for example, but any amplifier will be improved by extensive shielding. G. I. Turner advises that the amplifier shown in Fig. 23 should have each stage in separate iron boxes, all earthed, with the first valve leads screened with mumetal and the output valve leads with iron.

Grid stoppers, as shown in Fig. 11, may be included in any circuit. They must not be wirewound but of the composition type.

Circuits are to some extent interchangeable. Different types of phase splitters are shown. all performing much the same operation, while some A.C. circuits might be used on D.C. with the correct re-arrangement of heater wiring together with a dropping resistor and any change in biasing caused by a drop in the voltage supply.

Construction

The circuits shown all have the input grid shunted to earth by a volume control or fixed resistor. The values shown are arbitrary, and in practice must be matched with the apparatus whose loads they are to form. An example is given in Section 11 on Crystal Microphones.

Heater leads should be twisted together to minimize hum pick up. Grid leads should be short and direct, spaced from other leads.

Condensers, especially grid coupling condensers, must be in perfect condition, otherwise damage to valves may result. Their working voltage values must be adequate.

The working voltages of biasing condensers is not shown except in a few specialised cases as it falls well within the commercial range of 25 mfd-12 volt, 50 mfd-50 volt.

Output valves in Push Pull circuits must be matched—that is, they must both draw the same anode current within 1-2 m.a.s. The circuits show no matching devices as it is presumed that matched valves will be obtained, but if matching is necessary it may be performed by separating the biasing circuits in the cathode leads and adjusting the bias on each valve until the anode currents are identically similar.

Small resistors of 100 ohms may be included in the anode leads, if desired, so that the voltage drop may be measured across them instead of breaking the circuit for the inclusion of a milliameter.

One valve of a Push Pull pair must not be removed to leave the other working. Serious voltage surges will occur, damaging the emission and unbalancing the biasing circuits.

In some circuits of Sections 3, 4 and 5 the smoothing choke is indicated by its resistance only. It was felt that speaker fields could not be used in these positions as they would neither give sufficient smoothing nor be suitably energised, so that the use of permanent magnet speakers is recommended. The choke used should have the highest inductance obtainable for the resistance shown. The current rarely exceeds 60 m.a.s., except in Figs. 12, 14 and 16, where the capacity of the choke should be 100 m.a.s.

In circuits where a 35 RE rectifier is used one cathode may be made to energise a suitable loudspeaker.

Unless otherwise stated, these circuits have sufficient gain to enable them to be driven by any ordinary pickup.

The valve outputs in watts shown correspond with makers' tables and information.

The Amplifier photograph appearing on the front cover of this Manual is reproduced by courtesy of The General Electric Co., Ltd., London.

SECTION I—Battery Amplifiers

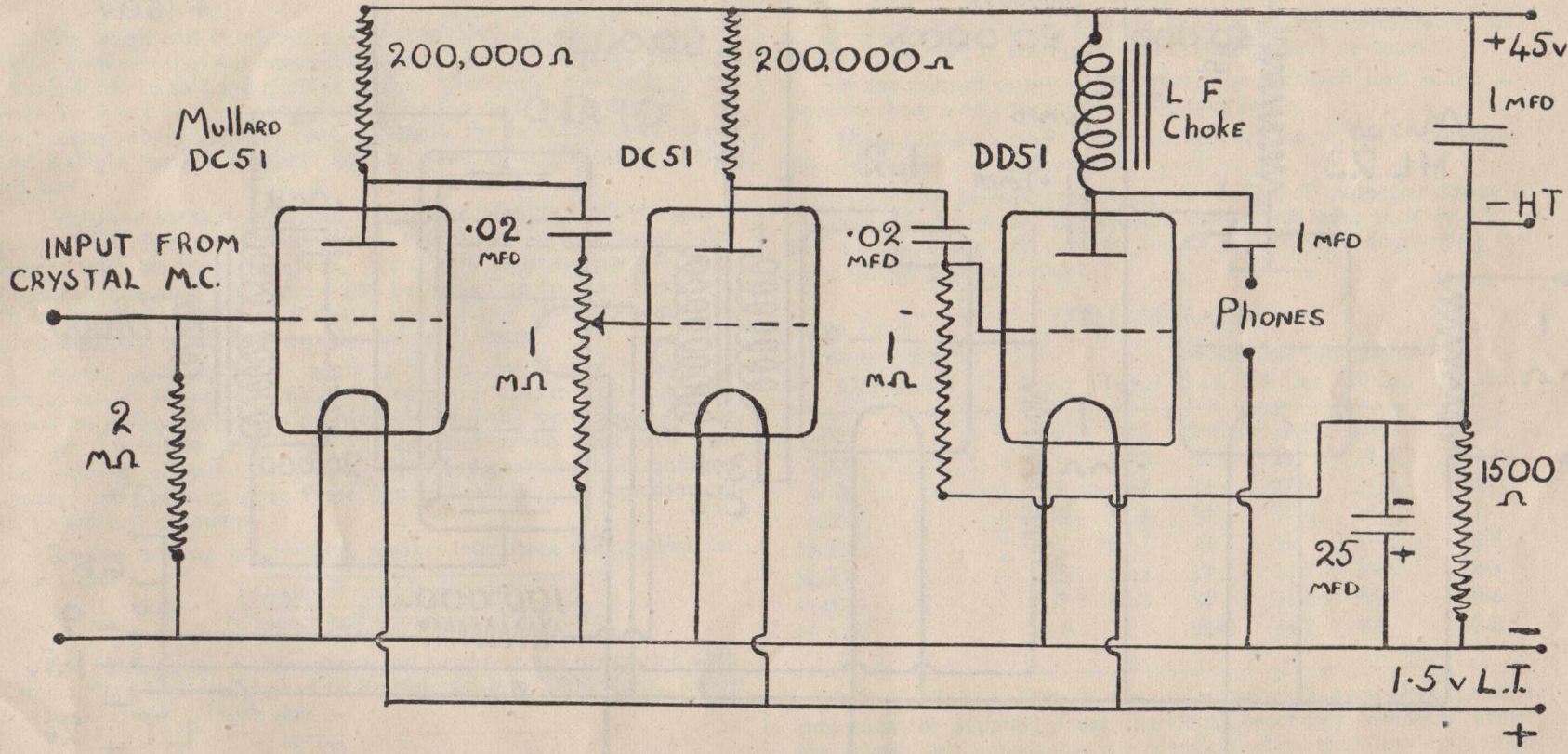
(Figs. 1—6)

Battery amplifiers are unable to give anything in the nature of a large output due to the necessity for economising in current, but when fed by a pickup or small radio set they will give adequate volume for the average living-room.

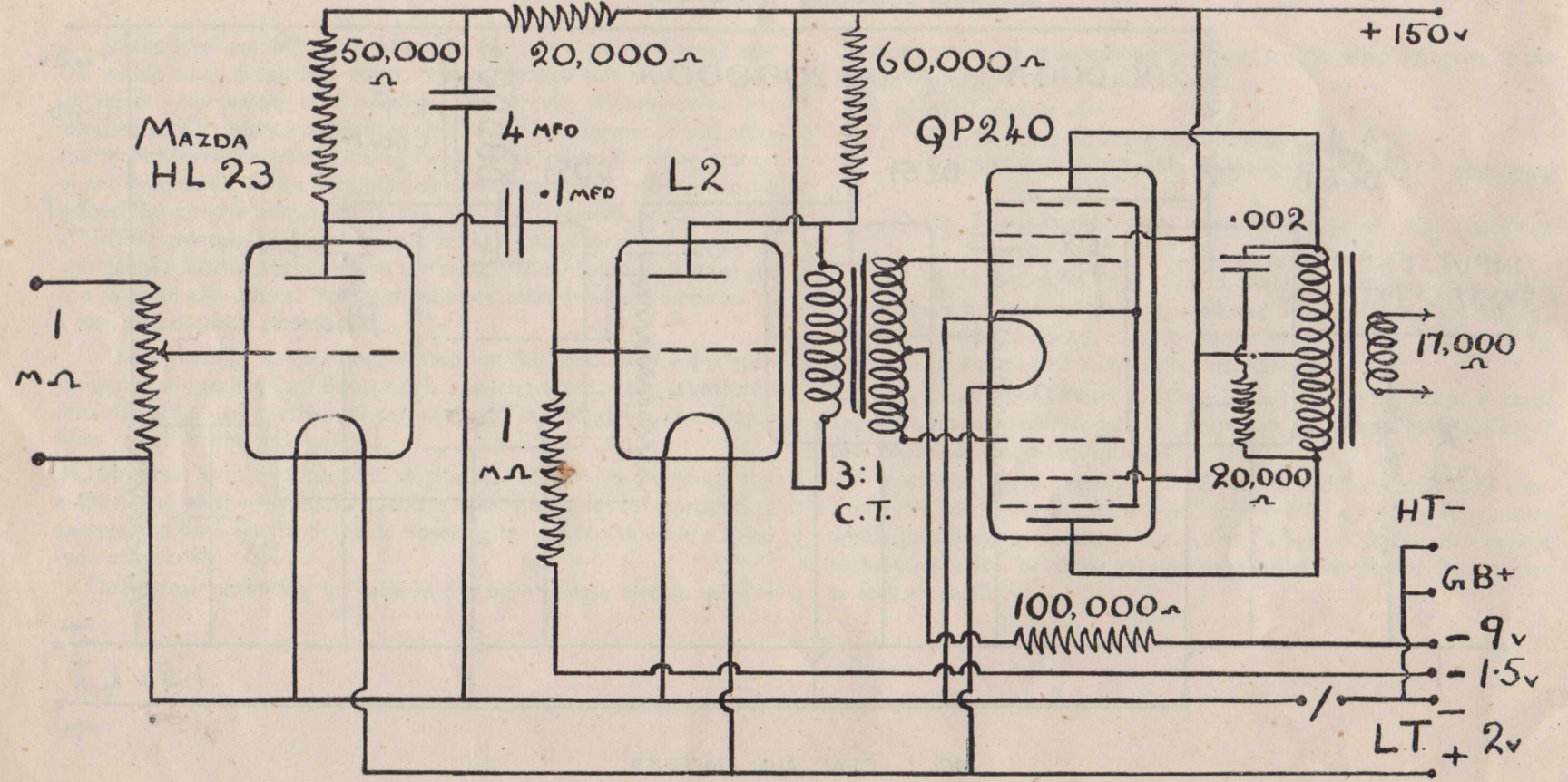
As gramophone amplifiers, for example, the volume obtainable may not be greater than that given by mechanical reproduction, but to offset this electrical playing of records means that volume and tone are controllable while the playing can be a more faithful reproduction.

As pre-amplifiers for microphones or photo-electric-cells battery circuits are excellent. There is no chance of hum arising from the circuit itself and external interference may be prevented by totally enclosing the valve and allied apparatus in a screen.

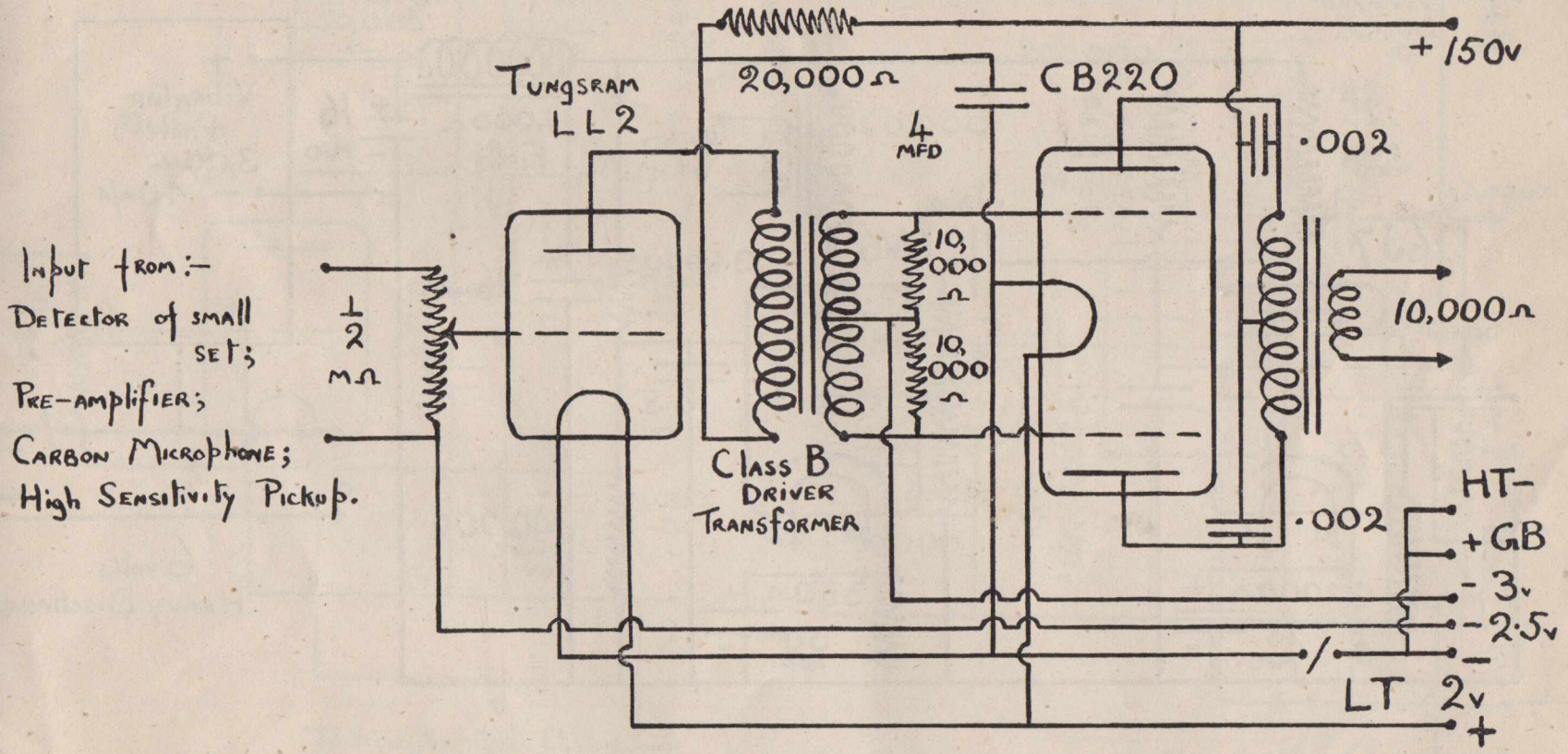
In Figs. 2 and 6 the input valve is shown unbiased. Overloading is unlikely but should it occur the grid circuits may be isolated and biased as desired.



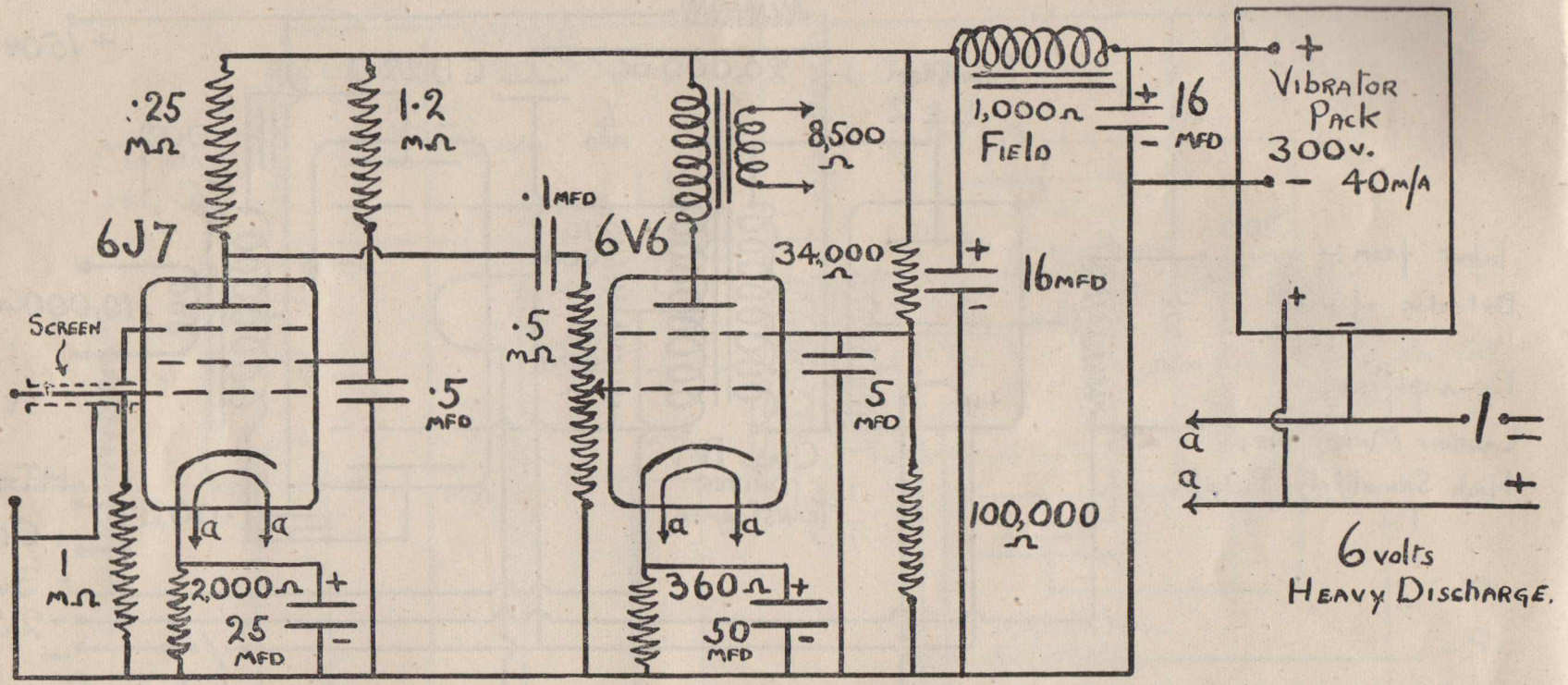
NO. 1. DEAF AID AMPLIFIER



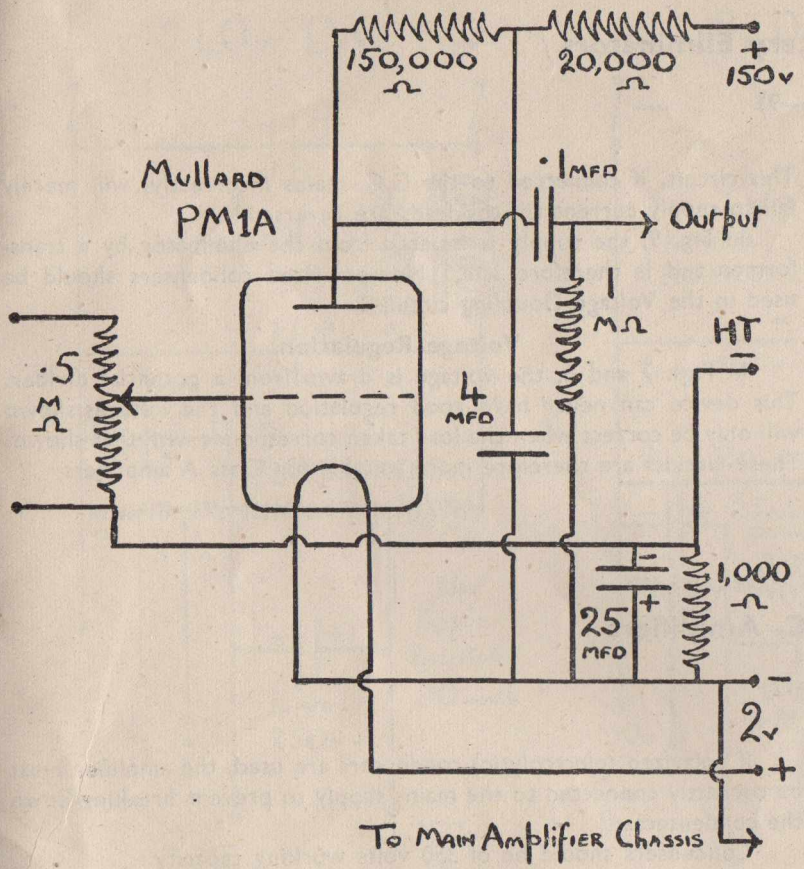
NO. 2. 1 WATT Q.P.P. BATTERY AMPLIFIER



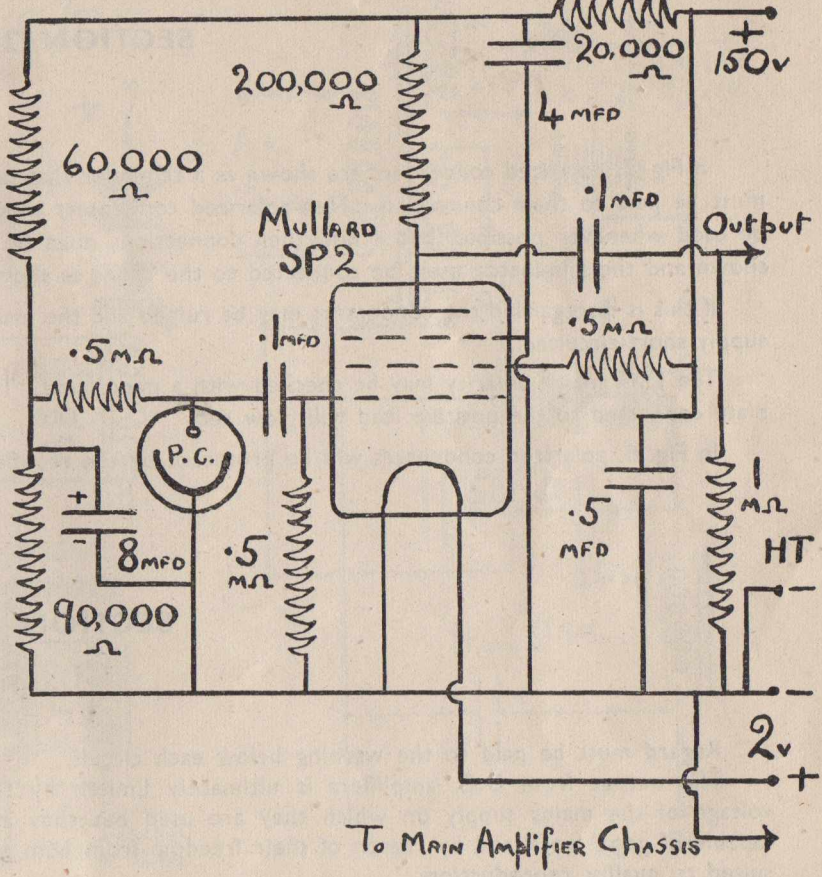
NO. 3. 2 WATT CLASS B BATTERY AMPLIFIER



NO. 4. 4 WATT BATTERY (VIBRATOR) AMPLIFIER



NO. 5. BATTERY PRE-AMPLIFIER



NO. 6. PHOTO-CELL AMPLIFIER HEAD

SECTION 2—Battery Eliminators

(Figs. 7—9)

In Fig. 7, polarized condensers are shown as a reminder that care must be paid to their connection. Non-polarized condensers should be used whenever possible, but if not, then connections must be as shown and the eliminator must be connected to the mains as shown.

If this is disregarded the condensers may be ruined and the mains supply short-circuited.

The D.C. mains polarity may be checked with a neon lamp. The plate connected to the positive lead will glow red.

In Fig. 8, polarized condensers will be protected by the rectifier. This circuit, if connected to the D.C. mains incorrectly, will merely fail to supply current till the leads are reversed.

In Fig. 9, the supply is isolated from the eliminator by a transformer and is therefore safe. Non-polarized condensers should be used in the Voltage Doubling circuit.

Voltage Regulation

In Figs. 7 and 8, the voltage is drawn from a potential divider. This device can never have good regulation and the voltages shown will only be correct when the load taken corresponds with that shown. These circuits are therefore more suitable for Class A amplifiers.

SECTION 3—D.C. Amplifiers

(Figs. 10—12)

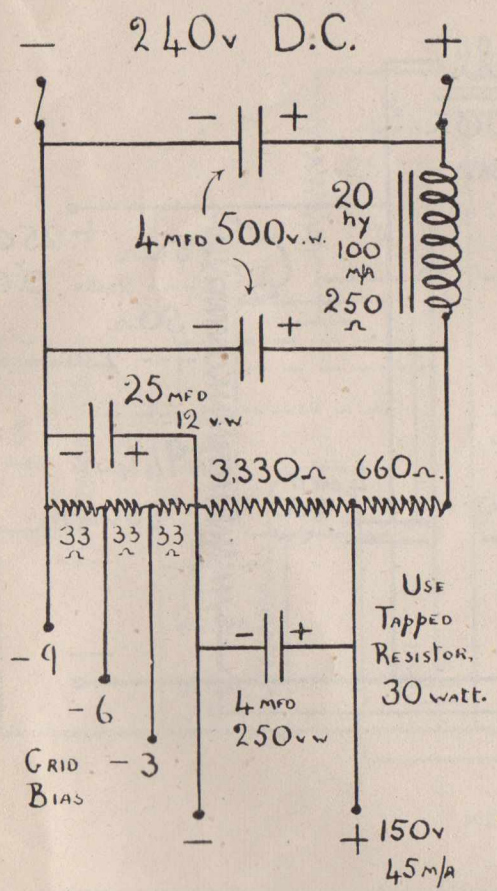
Regard must be paid to the warning below each circuit.

The output from D.C. amplifiers is ultimately limited by the voltage of the mains supply on which they are used but they are capable of good work and by reason of their freedom from hum are suited to quality reproduction.

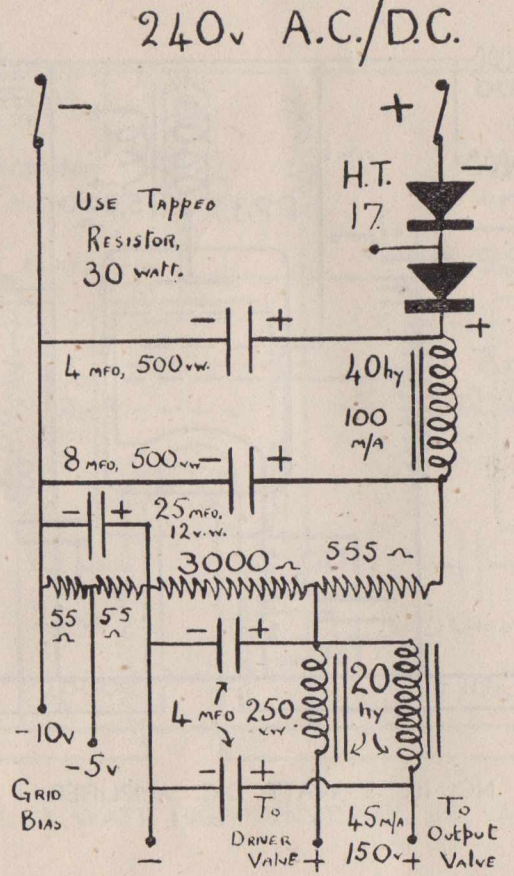
If polarized (electrolytic) condensers are used, the amplifier must be correctly connected to the mains supply to prevent breaking down the condensers.

Condensers should be of 350 volts working capacity.

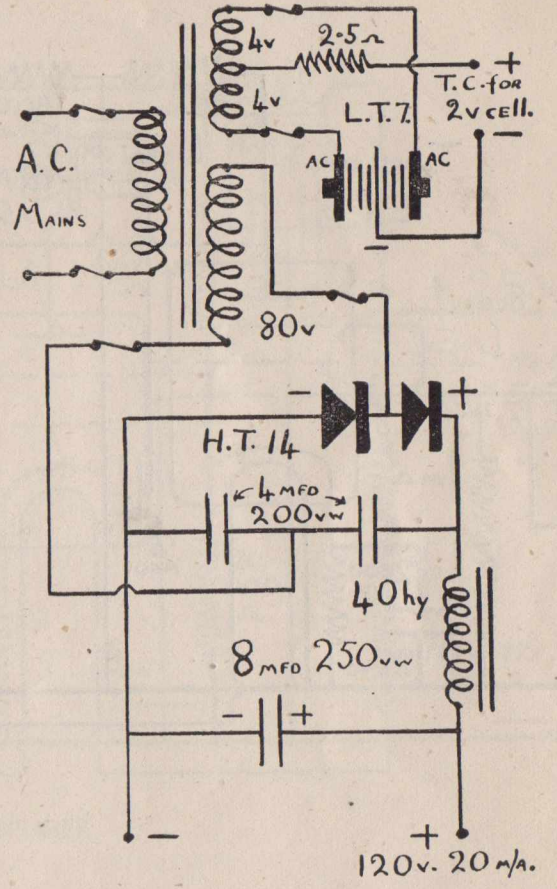
Mains polarity may be checked with a neon lamp.



NO. 7. D.C. ELIMINATOR

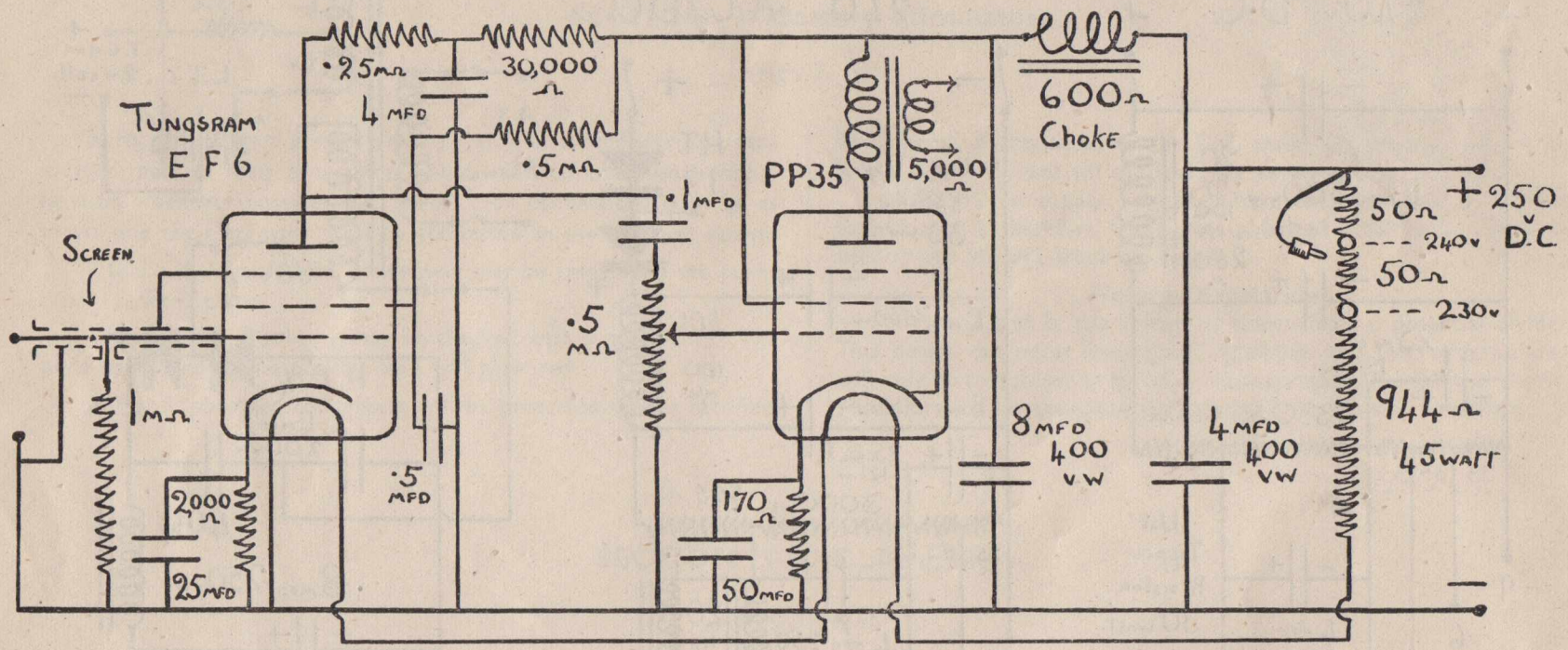


NO. 8. A.C./D.C. ELIMINATOR



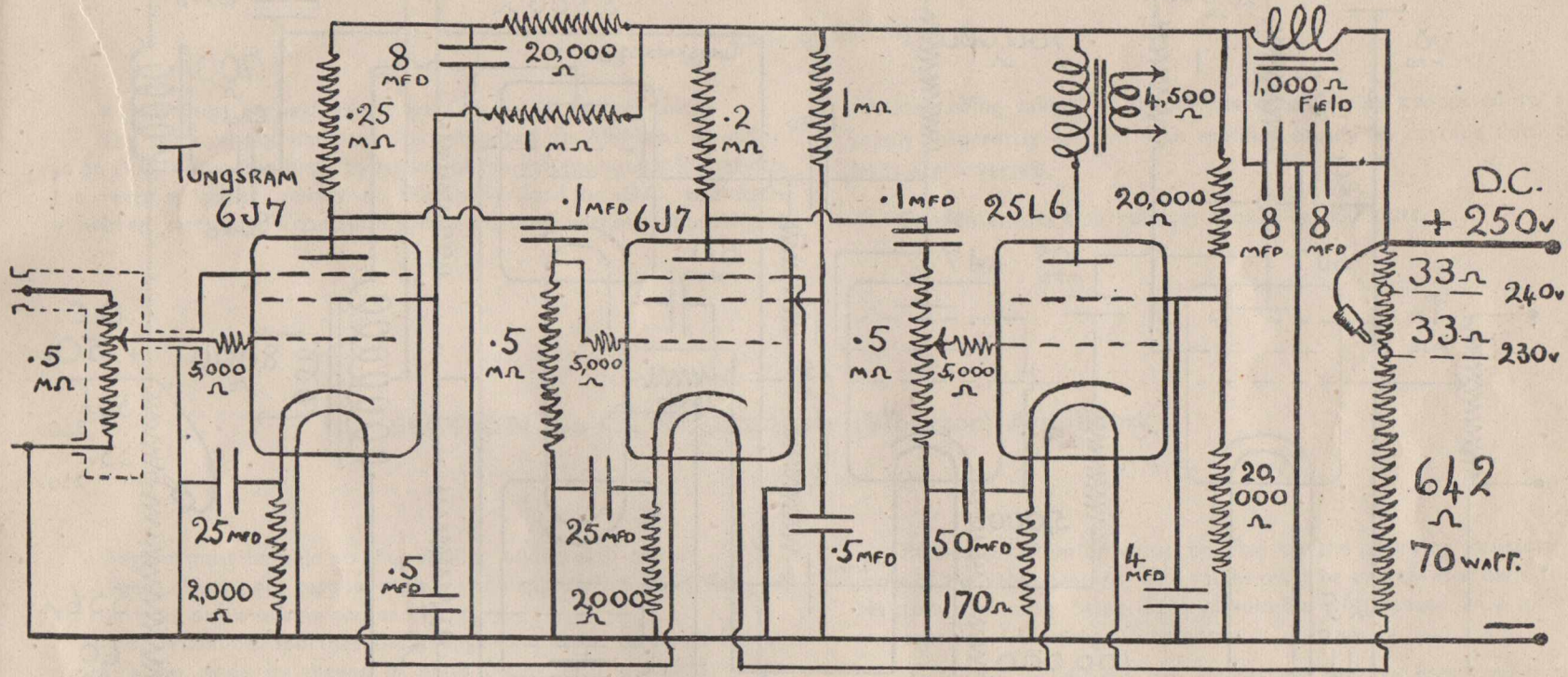
NO. 9. A.C. ELIMINATOR WITH TRICKLE CHARGER

WARNING! Under certain circumstances the circuits of Figs. 7 and 8 may be "live" to earth, together with apparatus connected to them. If earthing is necessary the negative lead must be earthed through a condenser of .1 mfd. 400 volt working capacity.



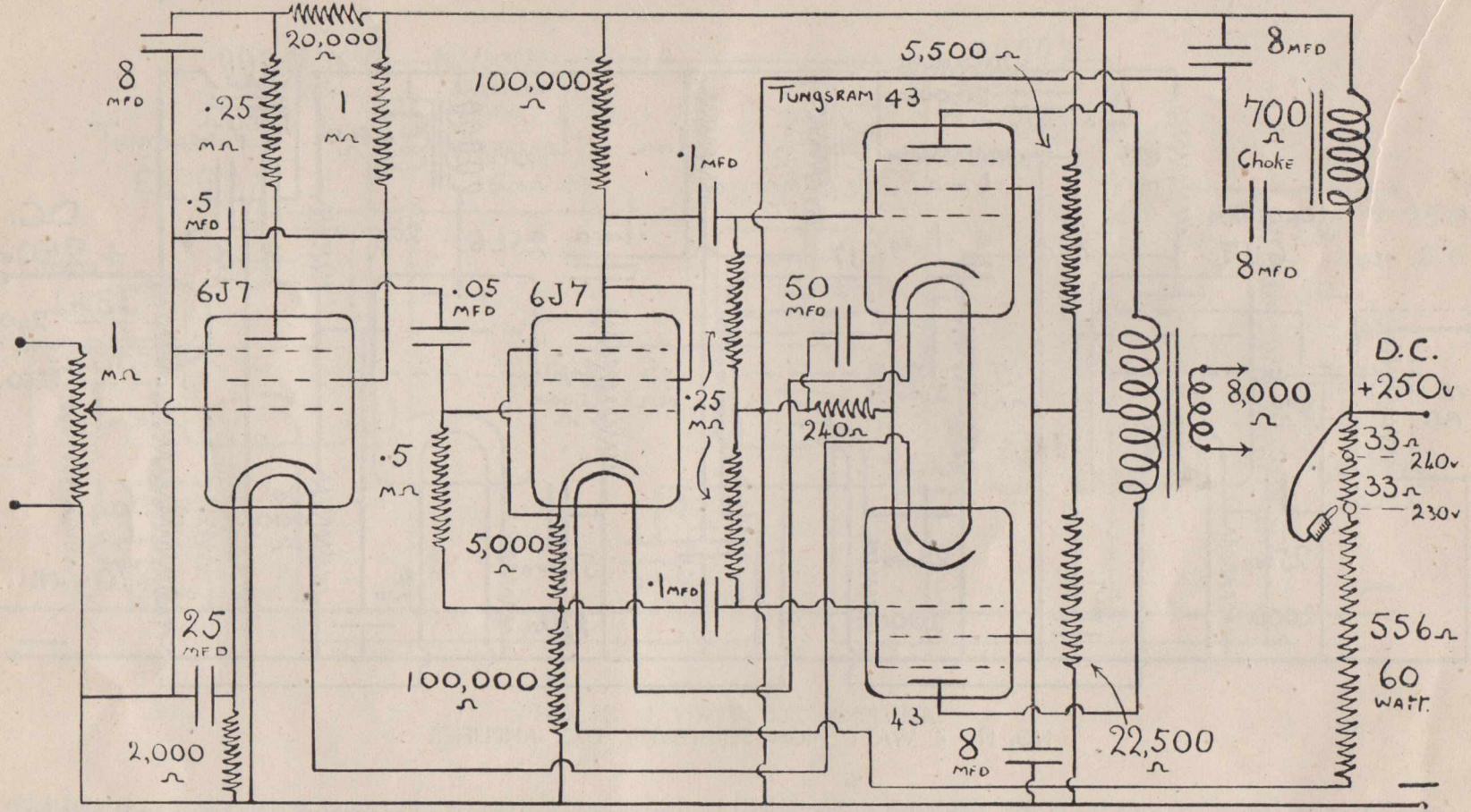
NO. 10. 3 WATT D.C. AMPLIFIER

WARNING ! If the mains supply has an earthed positive the chassis of this amplifier and apparatus connected to it will be "live." Earth chassis only through a .1 mfd. 400 v.w. condenser.



NO. 11. 4 WATT HIGH SENSITIVITY D.C. AMPLIFIER

WARNING ! If the mains supply has an earthed positive the chassis of this amplifier and apparatus connected to it will be "live." Earth chassis only through a .1 mfd. 400 v.w. condenser.



NO. 12. 6 WATT PUSH-PULL D.C. AMPLIFIER

WARNING ! If the mains supply has an earthed positive the chassis of this amplifier and apparatus connected to it will be "live." Earth chassis only through a .1 mfd. 400 v.w. condenser.

SECTION 4—A.C./D.C. Amplifiers

(Figs. 13 and 14)

Regard must be paid to the warning below each circuit.

The same output limitations are imposed on All-Mains amplifiers as on D.C. mains amplifiers by reason of the voltage supply limitations, the rectifier acting merely as a resistive load on D.C. operation. However, electrolytic condensers may be used without unusual precautions being taken, as should the amplifier be connected to the supply incorrectly on D.C. the rectifier passes no current until the leads are reversed.

Condenser working voltages should be 400 volts.

SECTION 5—A.C./D.C./Battery (Vibrator) Amplifiers

(Figs. 15 and 16)

Regard must be paid to the warning under each circuit.

These circuits are capable of very wide application, being designed to run from any available source of supply.

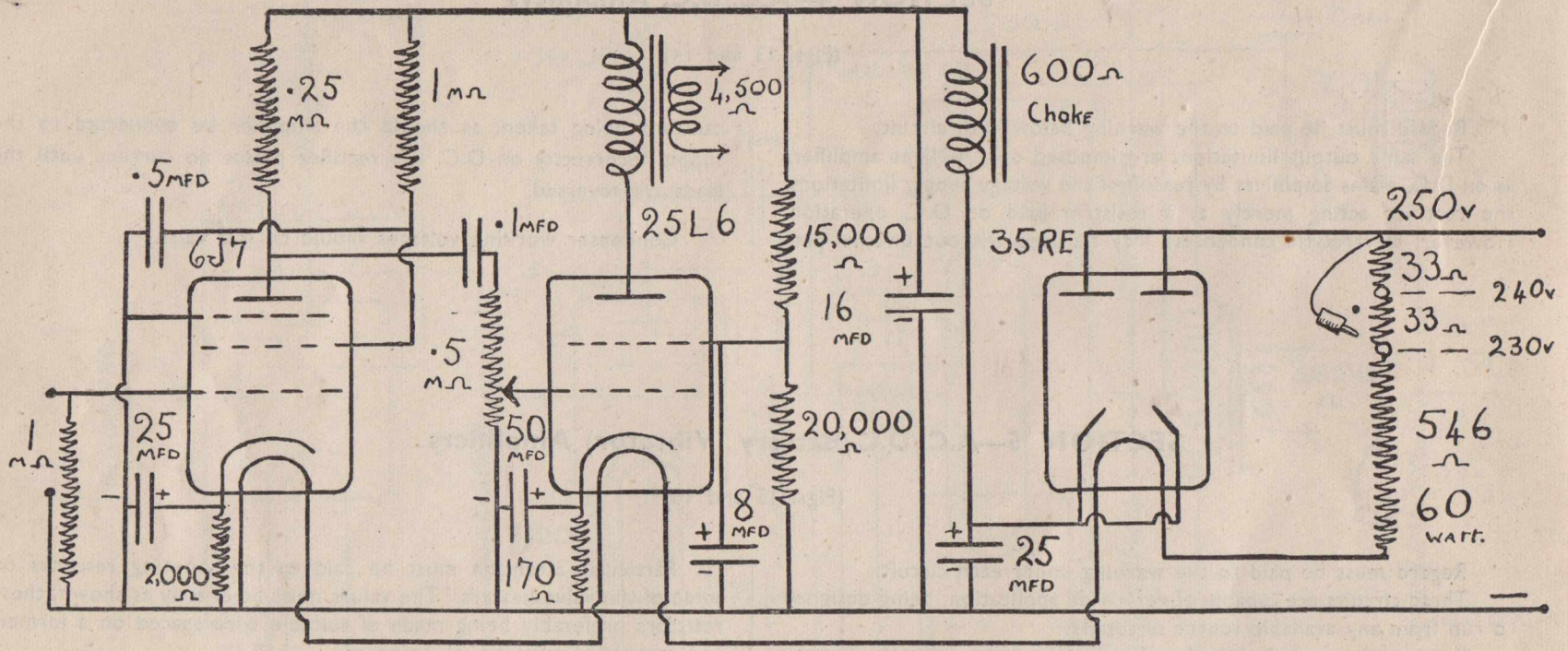
It is recommended that the change-over from mains to battery working be made by means of plugs fitting into a socket on the amplifier chassis, such plugs and sockets easily being made from valve bases and valve holders.

The Vibrator packs must be of good design and make, and treated with due care, while the battery should be of the heavy discharge type.

Particular attention must be paid to the shunting resistors on some of the valve heaters. The values must be exactly as shown, these resistors preferably being made of suitable wire spaced on a former, and capable of carrying .15 amperes.

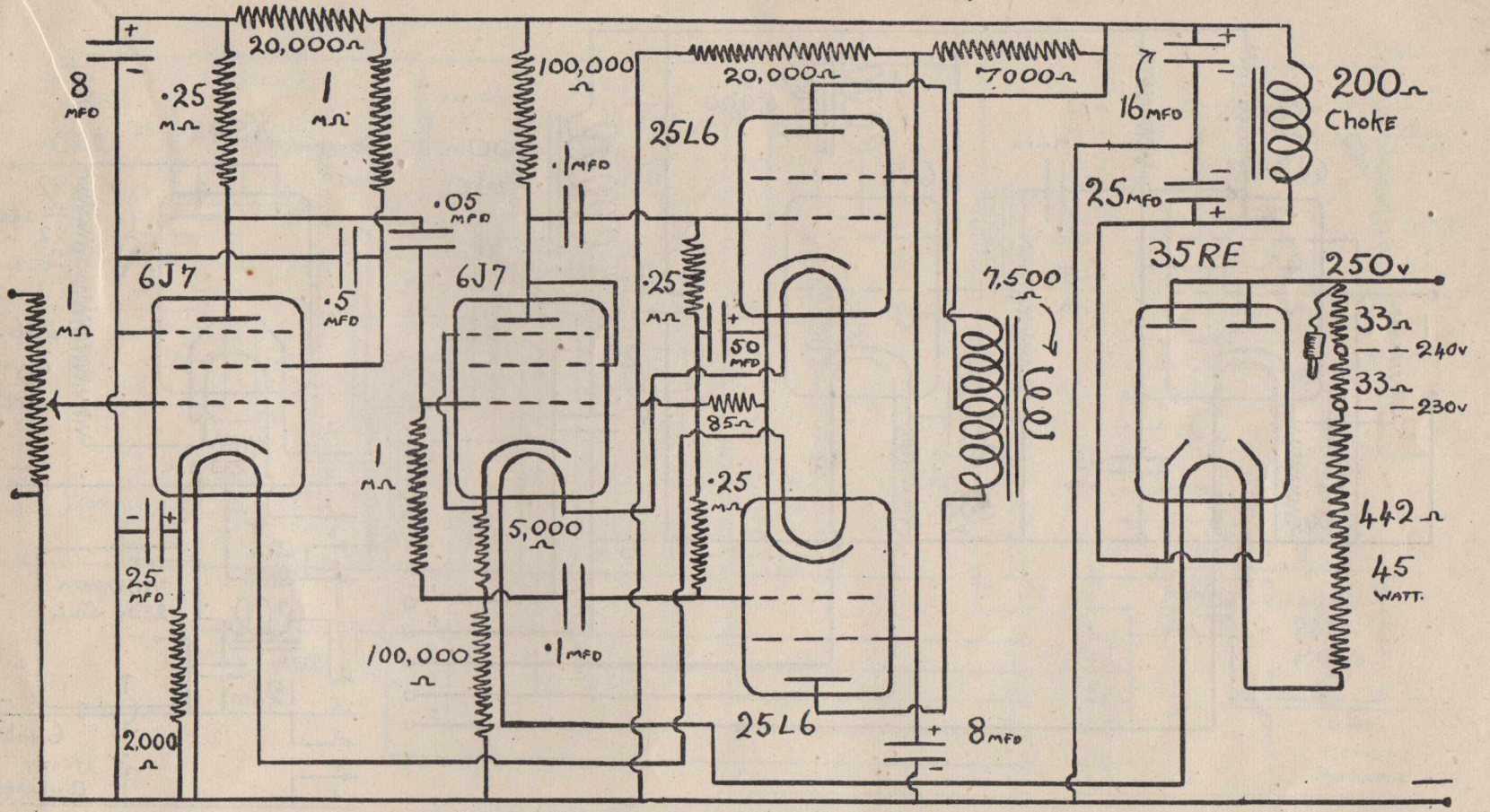
As before, condensers are electrolytic and are protected by the rectifying devices.

The circuits shown are still in the experimental stage, and in view of their possibilities good work might be done in developing them.



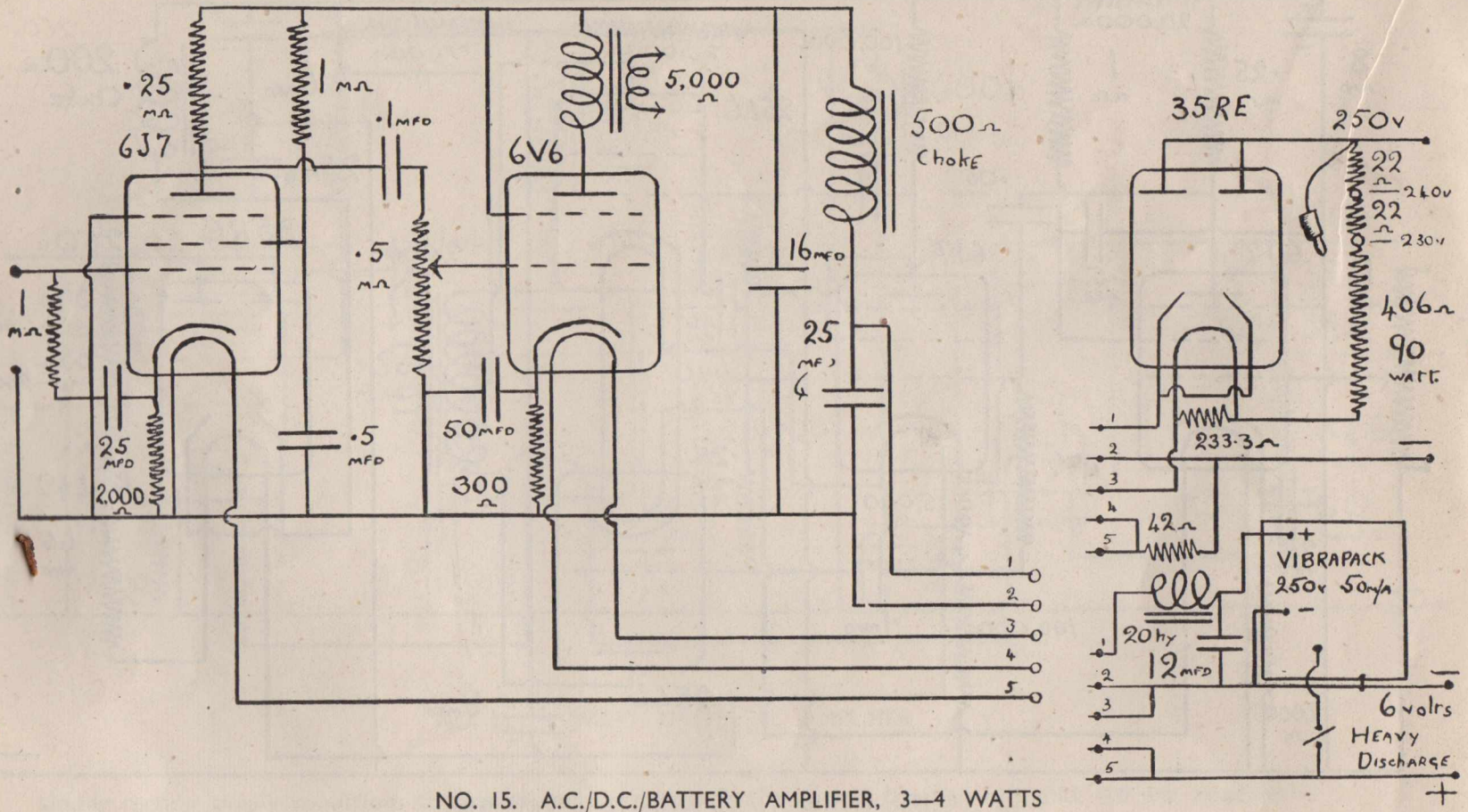
NO. 13. 4 WATT UNIVERSAL AMPLIFIER

Under certain supply conditions the chassis may be "live." Earth only through a .1 mfd. 400 v.w. condenser.



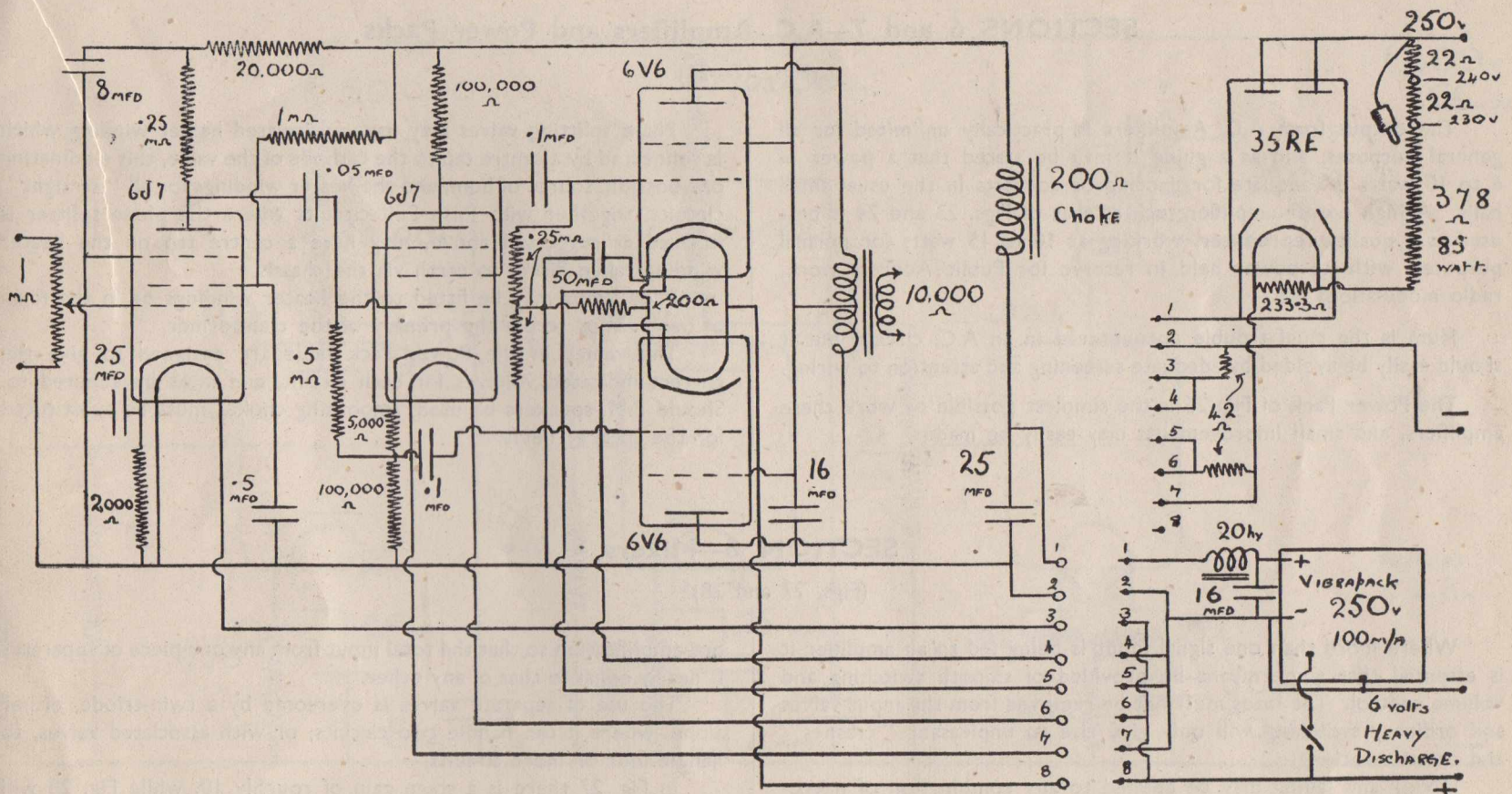
NO. 14. 10 WATT UNIVERSAL AMPLIFIER

Under certain supply conditions the chassis may be "live." Earth only through a .1 mfd. 400 v.w. condenser.



NO. 15. A.C./D.C./BATTERY AMPLIFIER, 3—4 WATTS

Under certain supply conditions the chassis may be " live." Earth only through a .1 mfd. 400 v.w. condenser.



No. 16. A.C./D.C./BATTERY AMPLIFIER, 8 WATTS

Under certain supply conditions the chassis may be " live." Earth only through a .1 mfd. 400 v.w. condenser.

SECTIONS 6 and 7—A.C. Amplifiers and Power Packs

(Figs. 17—26)

The output from A.C. Amplifiers is practically unlimited for all general purposes, and as a guide it may be stated that a power of 6 to 10 watts is adequate for dancing or concerts in the usual small halls. A high power amplifier such as that of Figs. 23 and 24 is best used as a quality reproducer, working at 10 to 15 watts for normal purposes, with its power held in reserve for Public Address work, radio modulation, etc.

Hum is the chief trouble encountered in an A.C. circuit, but it should easily be avoided by adequate screening and attention to wiring.

The Power Pack of Fig. 26 is the simplest possible to work these amplifiers, and small improvements may easily be made.

Phase splitting valves may have an isolated heater winding which is connected by a centre tap to the cathode of the valve, this eliminating one possible source of hum, and the heater windings for all " straight " circuits, together with Push Pull circuits where the phase splitter is isolated as suggested above, may have a centre tap on the heater winding taken direct to earth via the chassis.

Pilot lamps may be fitted to the heater windings or in the form of neon lamps across the primary of the transformer.

The values in the Power Pack table are designed to give the correct indicated voltages for each circuit, and must be adhered to. Should P.M. speakers be used, smoothing chokes must be substituted for the speaker fields.

SECTION 8—Mixers

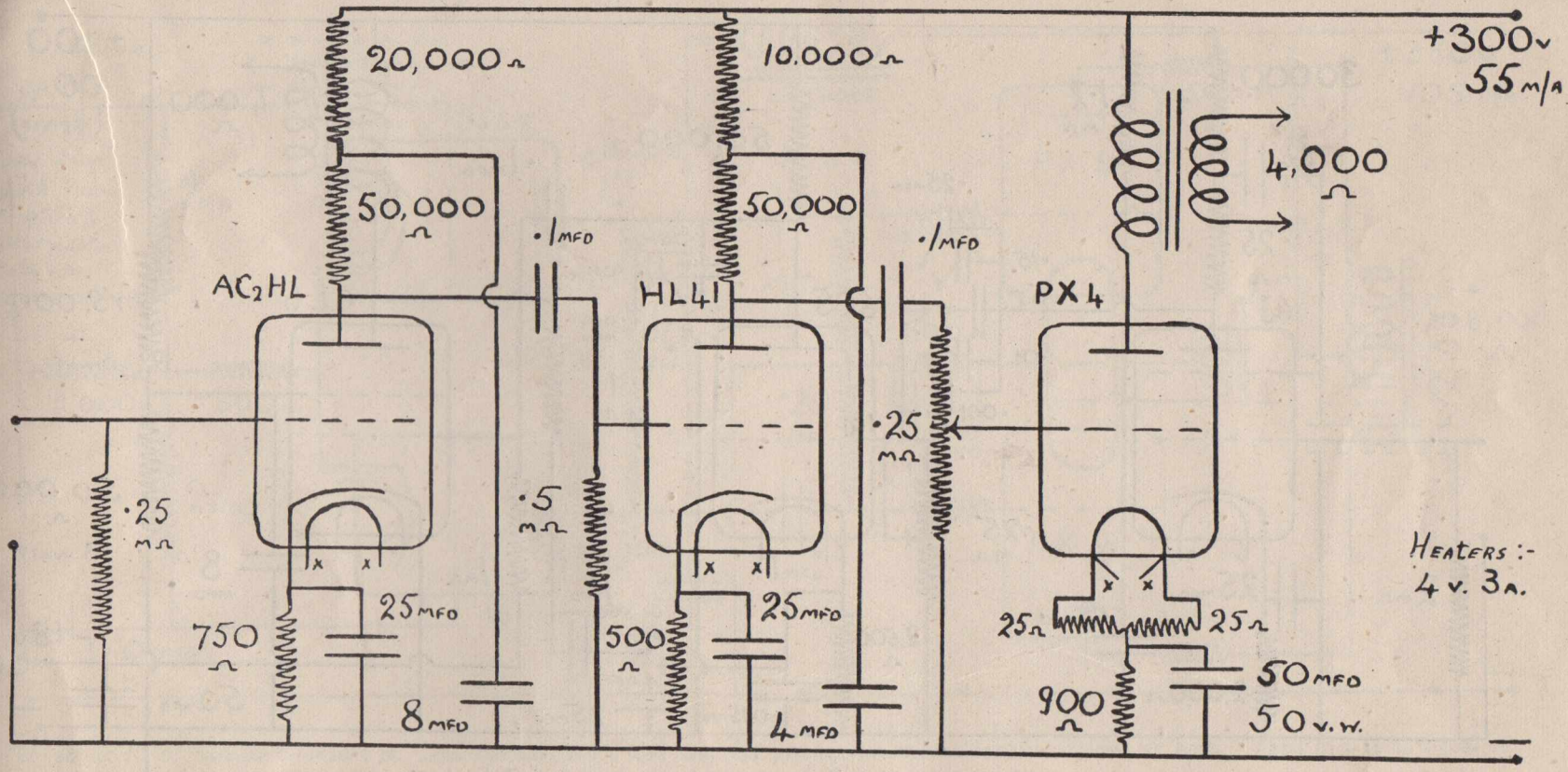
(Figs. 27 and 28)

Where more than one signal input is being fed to an amplifier it is essential that some means be provided of smooth switching and volume control. The loads must not be removed from the input valves and ordinary switching will only give rise to unpleasant " crashes " and erratic working.

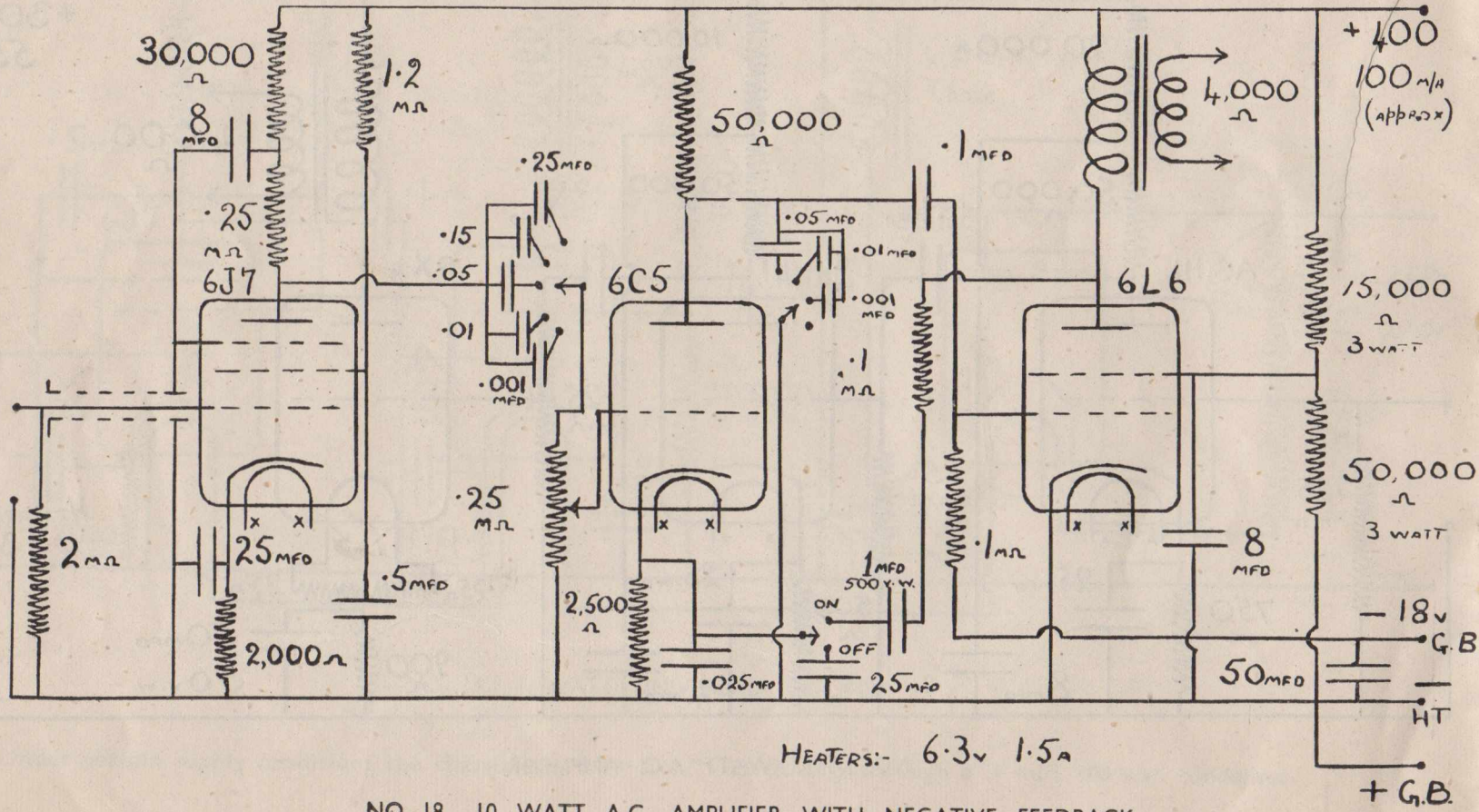
Mixing and fading may be applied to any combination of microphones and pickups, but as the output from a microphone is so much smaller than that of a pickup it is usual to provide some degree of pre-amplification so that the total input from any one piece of apparatus is nearly equal to that of any other.

The use of separate valves is overcome by a twin-triode, either alone, where it can handle two circuits, or with associated valves, to handle four or more circuits.

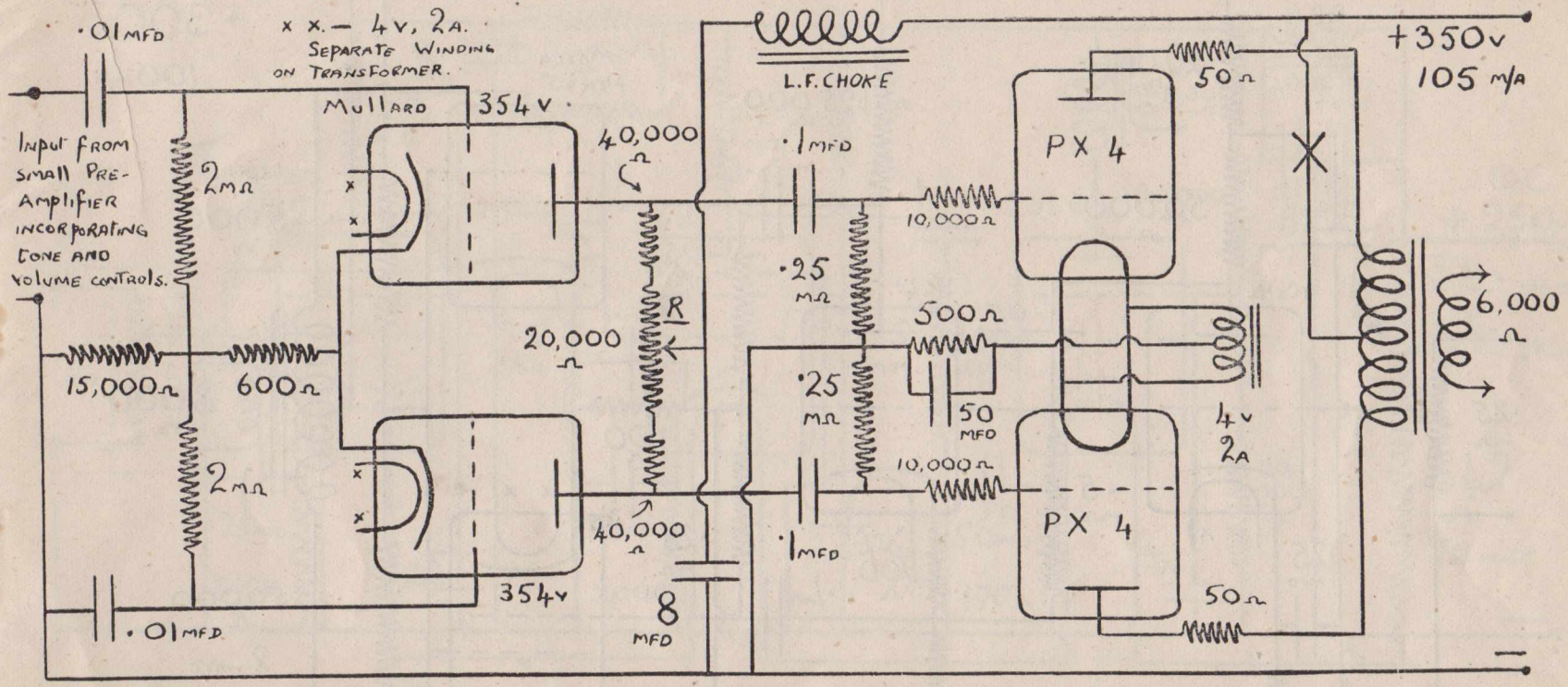
In Fig. 27 there is a stage gain of roughly 10, while Fig. 28 will give sufficient gain to be fed directly into a phase splitter and Push Pull stage.



NO. 17. 3 WATT A.C. AMPLIFIER



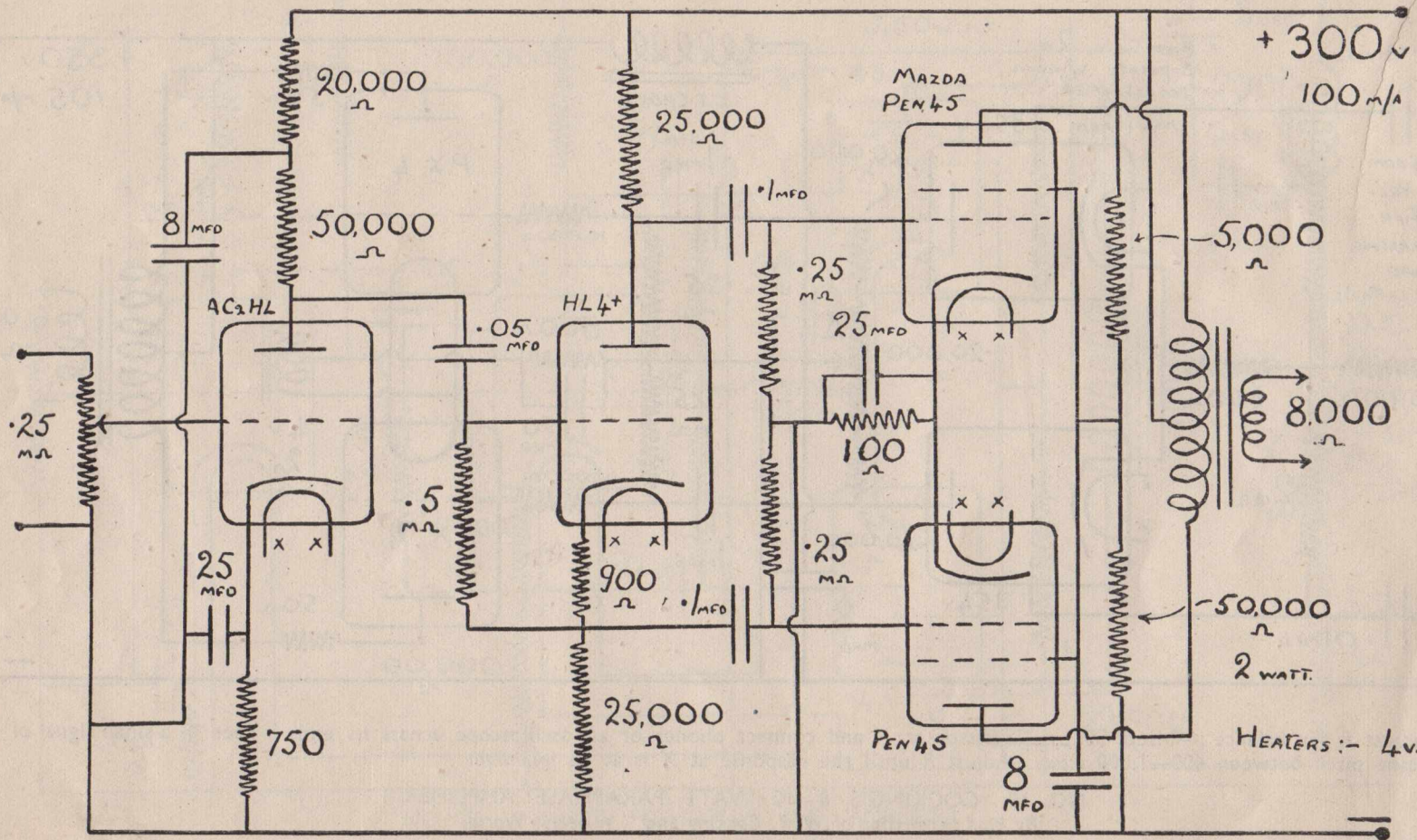
NO. 18. 10 WATT A.C. AMPLIFIER WITH NEGATIVE FEEDBACK



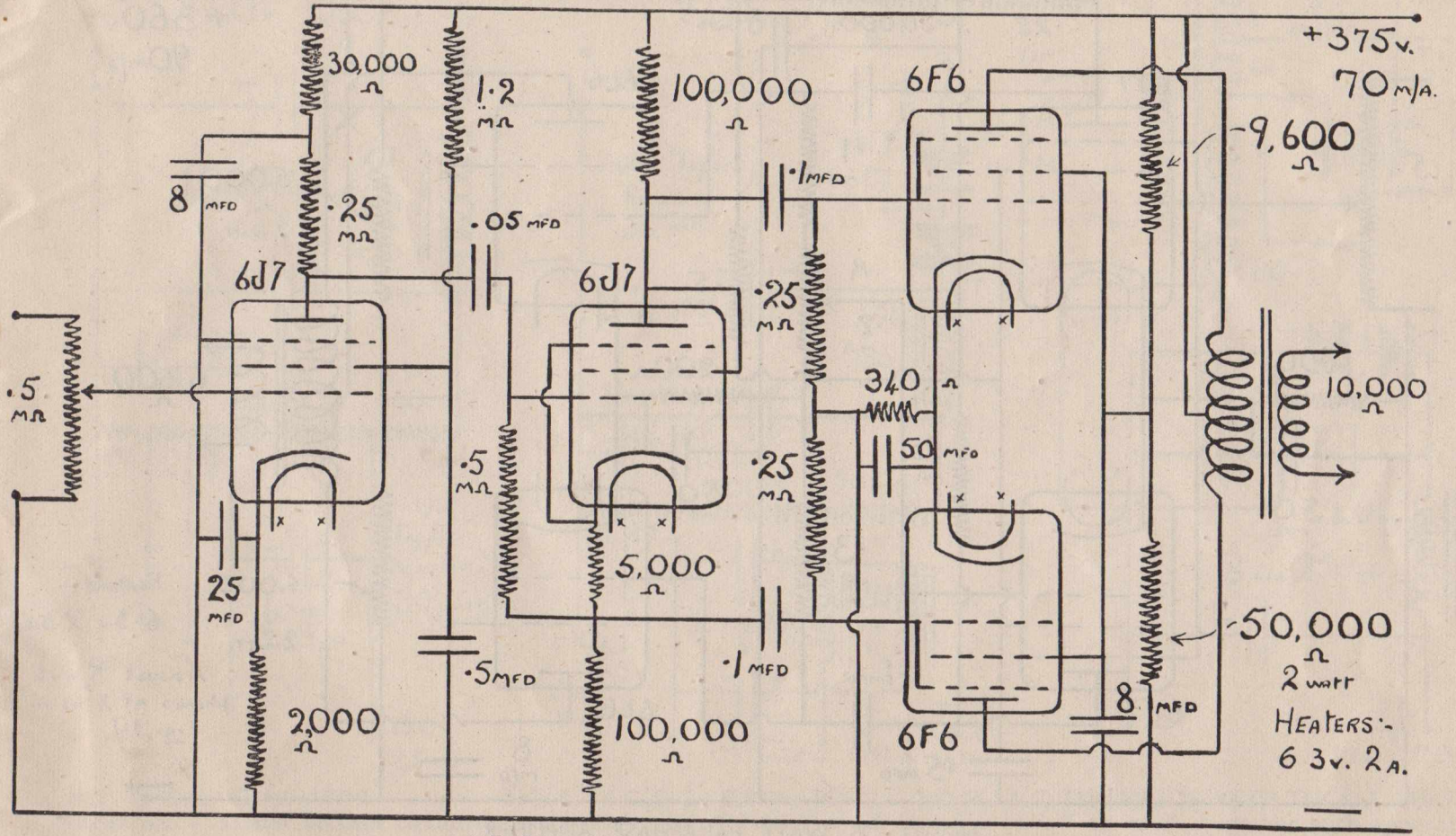
To adjust *R* for balance :—Insert 50 _Ω_ resistor at *X* and connect phones or an oscilloscope across its ends. Feed in a small signal of constant pitch between 400—1,000 c.p.s. Adjust *R* until the response at *X* is at its *minimum*.

NO. 19. COCKING'S 8—10 WATT PARAPHASE AMPLIFIER

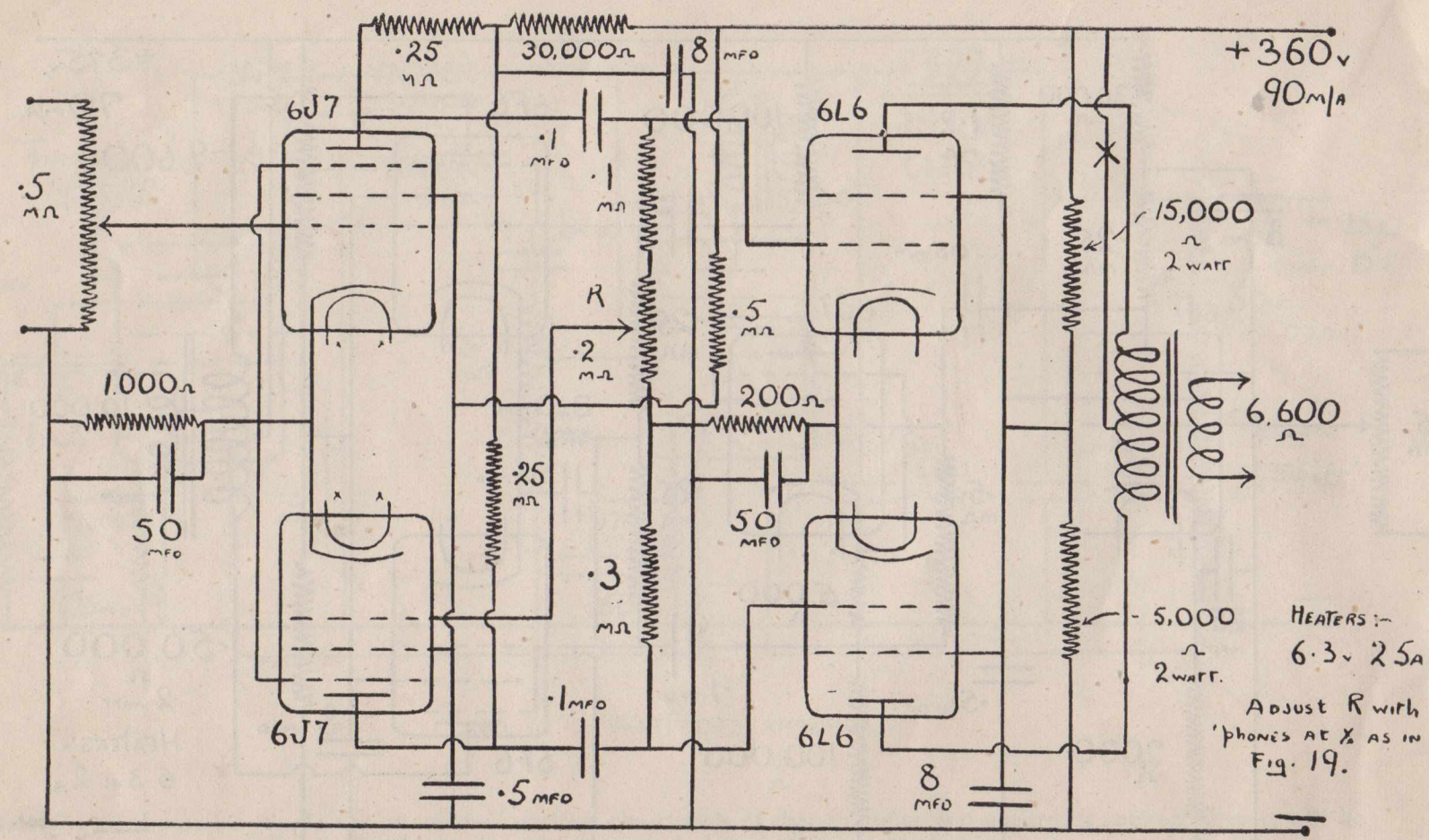
By kind permission of W. T. Cocking and "Wireless World."



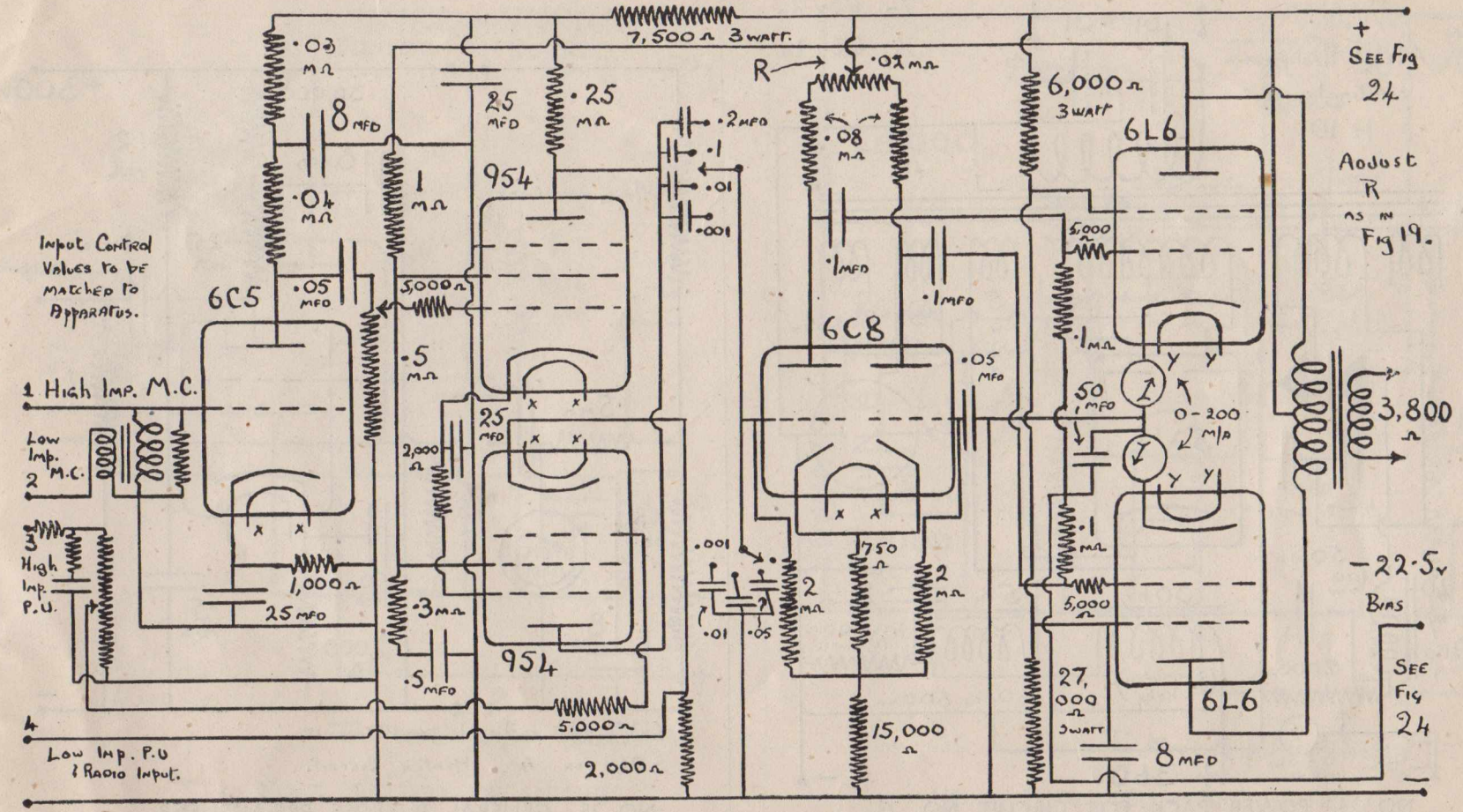
NO. 20. 12 WATT PARAPHASE AMPLIFIER



NO. 21. 15 WATT PARAPHASE AMPLIFIER

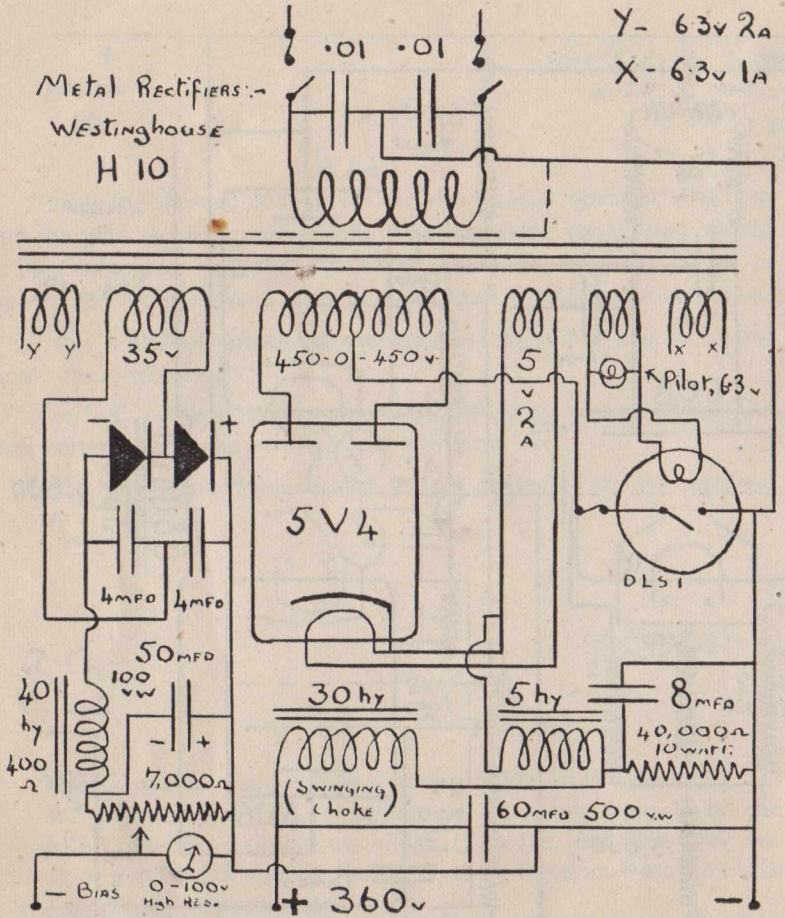


NO. 22. 25 WATT PARAPHASE AMPLIFIER

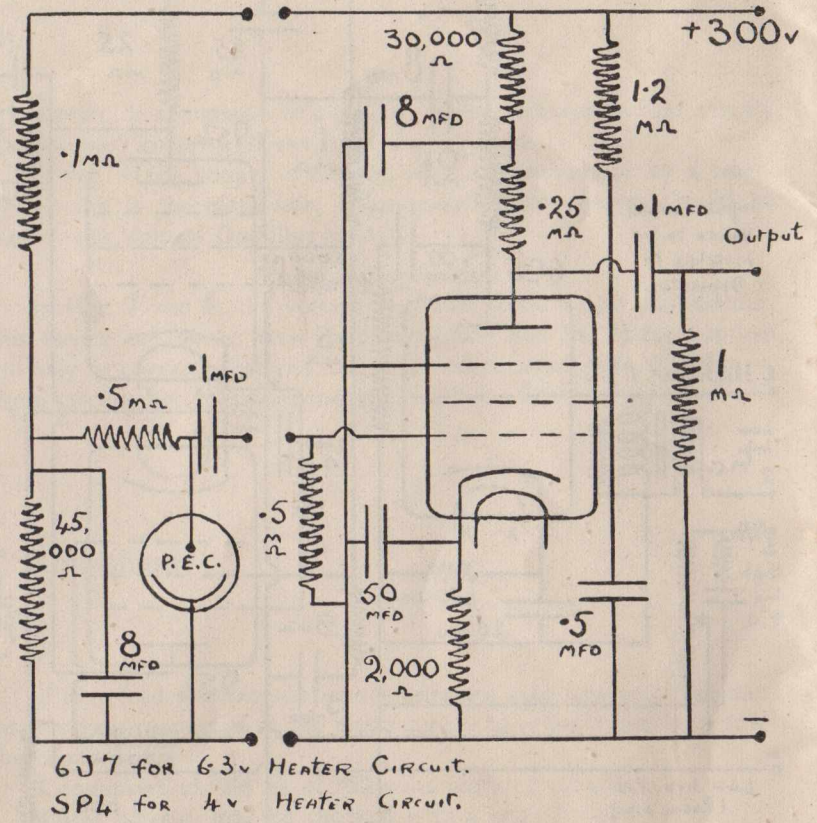


NO. 23. 50 WATT A.C. AMPLIFIER (CLASS AB_2)

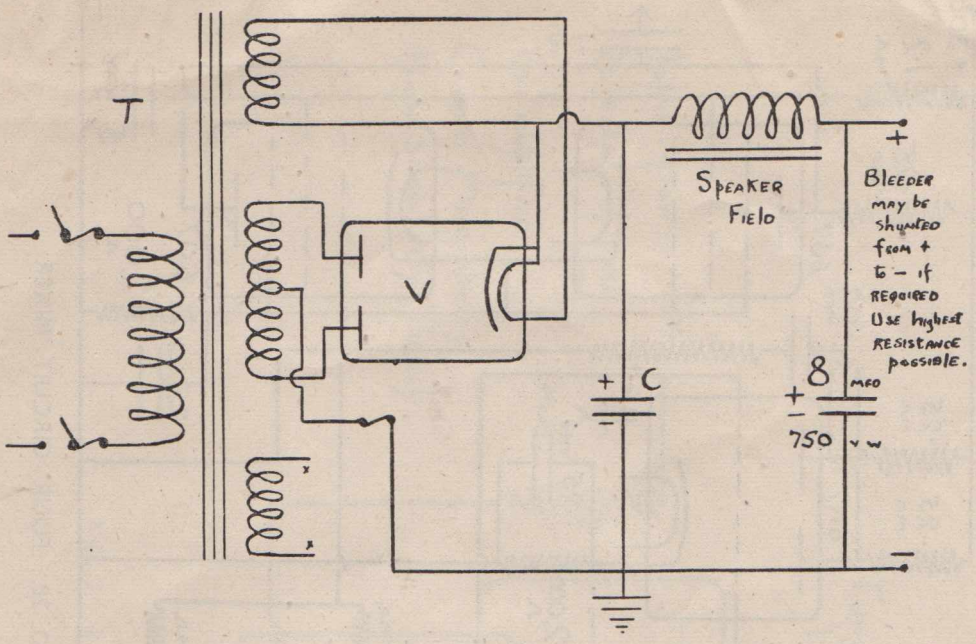
Basic circuit by kind permission of G. I. Turner.



NO. 24. POWER PACK FOR CIRCUIT NO. 23



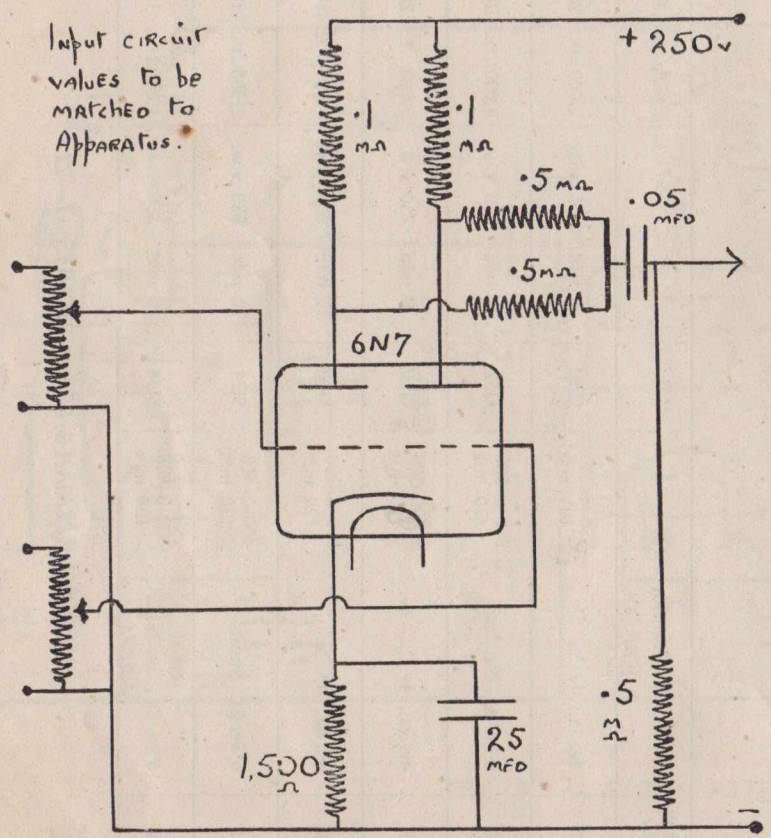
NO. 25. GENERAL PURPOSE PRE-AMPLIFIER WITH PHOTO-CELL CIRCUIT



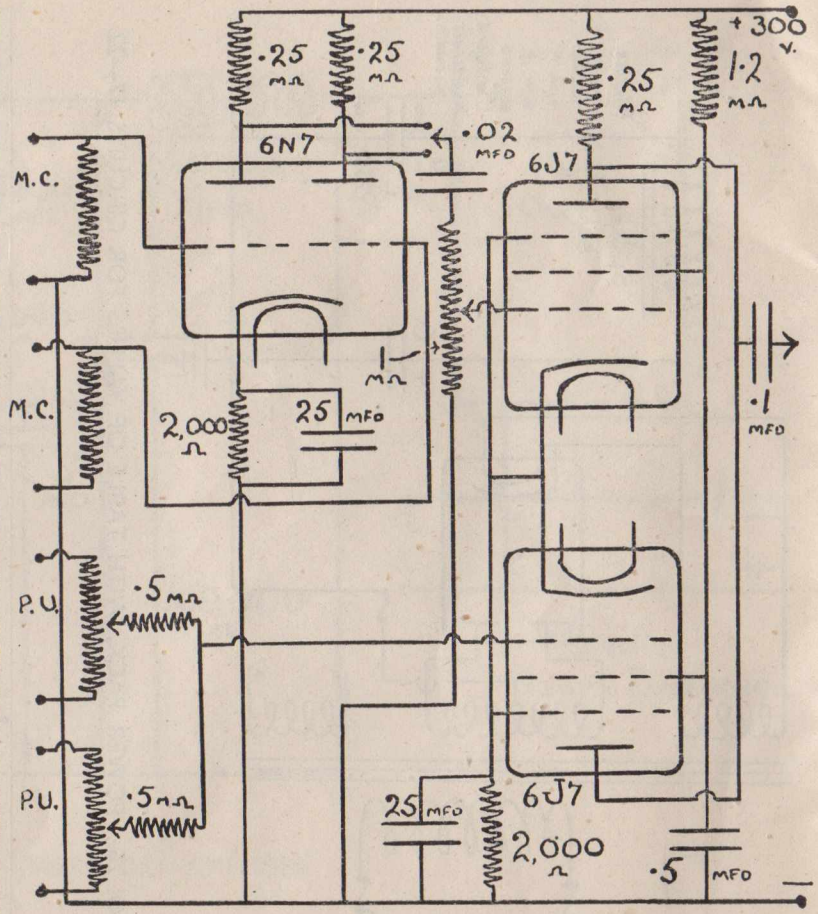
NO. 26. POWER PACK, WITH TABLE OF VALUES FOR CIRCUITS 17—22

Circuit No.	T (Transformer)		V	C	Speaker Field
17	4v. 3a., 4v. 3a.	350–0–350 100 m/a	UU5	9 mfd. 500 v.w.	2,000 ⎓ 20 watts
18	6·3v. 2a., 5v. 3a.	500–0–500 120 m/a	U52	10 mfd. 750 v.w.	2,000 ⎓ 20 watts
19	4v. 2a., 4v. 2a., 4v. 3a.	500–0–500 120 m/a	UU5	8 mfd. 750 v.w.	2,000 ⎓ 20 watts
20	4v. 6a., 4v. 3a.	350–0–350 120 m/a	UU5	15 mfd. 500 v.w.	1,000 ⎓ 10 watts
21	6·3v. 2a., 5v. 3a.	400–0–400 120 m/a	5U4	12 mfd. 550 v.w.	1,500 ⎓ 10 watts
22	6·3v. 3a., 5v. 3a.	400–0–400 120 m/a	5U4	10 mfd. 550 v.w.	1,000 ⎓ 15 watts

TABLE OF VALUES FOR CIRCUITS 17—22



NO. 27. TWO CIRCUIT MIXER



NO. 28. FOUR CIRCUIT MIXER

SECTION 9—Loudspeakers and Output Matching

The design and characteristics of loudspeakers vary so greatly in different models that it is impossible to give any simple rule for choosing a reproducer to suit any given amplifier. Obviously, the loudspeaker must be able to handle the full power output of the circuit, and in some cases—the 30 and 50 watt amplifiers, for example—it is rarely that a single speaker is called upon to stand up to the strain of the full load.

Whatever speaker is chosen it must be mounted either upon a substantial baffleboard—5 feet square, if possible—or in a heavy, solid cabinet with an openwork back. As a very approximate rule it is suggested that an 8 in. speaker may be loaded up to 3 or 4 watts, a 10 in. speaker up to 6 or 8 watts, and a 12 or 15 in. speaker may advantageously be used for outputs above 10 watts.

Where rules do rigidly apply is in the matching of speaker to output valves. No matter what the rated power output of the amplifier, it will only be passed on to the reproducer if the transformer linking the two is accurately matched. The diagrams in this book each have the optimum output load given in the loudspeaker circuit, and any speaker may be matched to these figures providing the impedance of its speech coil is known.

The law relating to valve load, speaker impedance and transformer ratio is :—

$$\text{Ratio} = \frac{\text{Optimum load impedance}}{\sqrt{\text{Speech coil impedance at 400 c.p.s.}}}$$

For example, if a 3 ohm speech coil speaker were to be used with Circuit No. 15, it would need to be matched into 5,000 ohms. Using the above rule it is found that :—

$$\text{Ratio} = \frac{5{,}000}{\sqrt{3}} = \sqrt{1666.6} = 40.8$$

therefore the transformer ratio used is 40.8 : 1.

If, on the transformer, a choice must be made between ratios such as 35 : 1 and 45 : 1, the higher ratio should always be taken.

In the case of push-pull amplifiers the optimum load is the impedance from anode to anode of the two valves.

There follows a table of ratios which will cover various combinations of valves and loudspeakers.

Much may be said concerning the design of these transformers, but it is presumed that the average reader will leave such details to the manufacturers and content himself merely with discovering the ratio for his particular case.

TABLE OF RATIOS

Valve Load (Plate to Plate for P.P. Operation)	Speech Coil Impedances 2 Ω	3 Ω	5 Ω	8 Ω	10 Ω	15 Ω
4,000	44·7	36·5	28·3	22·4	20	16·4
5,000 ... ... ↑	50	40·8	31·6	25	22·4	18·3
6,000 ... ... Ratios	54·8	44·7	34·6	27·4	24·5	20
8,000	63·3	51·6	40	31·6	28·3	23
10,000	70·7	57·7	44·7	35	31·6	25·8
12,000 ... ... ↓	77·5	63·3	49	38·7	34·6	28·3
14,000	83·7	68·3	53	41·8	37·4	30·6
16,000	89·4	73	56·6	44·7	40	32·8

Where the amplifier is required to work a number of speakers they must be supplied from individual secondary windings unless the speech coil impedances are identical when they may be joined in series or parallel, whichever is more suitable. Transformer ratios will need corresponding adjustment.

SECTION 10—Tone Control

In the ideal amplifier the response would be linear and level over the whole audio frequency range, but in practice this effect is rarely obtained. No matter how excellent the circuit, it depends on the excellence of its input voltages for the ultimate performance and often the pickup or microphone leaves much to be desired, whilst gramophone records all have a noted fall off in bass response. At frequencies below 250 c/s the amplitude of the needle movement becomes progressively greater for a given input voltage until there is a danger of one groove cutting through into the next. Thus, below 250 c/s there is a drop in the output from gramophone records which amounts to a loss of 6 decibels per octave.

There must be some compensation for this effect, and while such compensation (called Bass Boosting) is sometimes artificially introduced into the pickup by mechanical resonances it can be given by a simple filter circuit in the pickup leads.

Another form of tone control provides for Treble Boosting, the emphasising of the higher frequencies which is useful in reproducing speech, and both Bass and Treble Boosting can be combined in a third type of control.

Individual taste may be catered for by a simple circuit using a condenser and variable resistance so that a controllable degree of the higher frequencies may be attenuated.

The circuits show :—

Fig. 29—Bass Boosting on the pickup.

Fig. 30—Bass and Treble Boosting after the first amplifying stage.

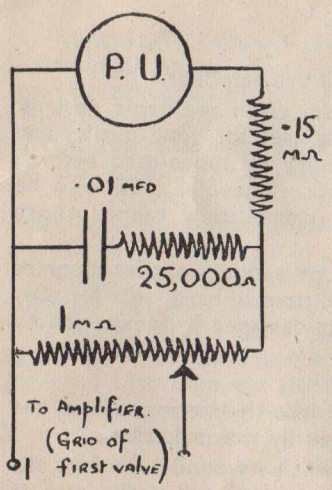
Fig. 31—Bass and Treble attenuation after the first amplifying stage.

Fig. 32—Simple Tone control after the first amplifying stage.

It must be noted that in Figs. 30 and 31 where resonant circuits are shown the choke is very liable to pick up hum and must be placed with due regard to avoiding interference.

Like most tone controls, these circuits will also cause a small apparent loss of volume, but the amplifiers should all have sufficient gain to off-set this disadvantage.

It will be noted that in Figs. 18 and 23 a different form of tone control is used. Here rotary switches are used to select condensers which pass varying frequency bands from stage to stage, with regard to bass response, or allow varying degrees of the higher frequencies to leak to earth.



Approx. 3dbs per 8ve

Load on pickup =

·25 MΩ

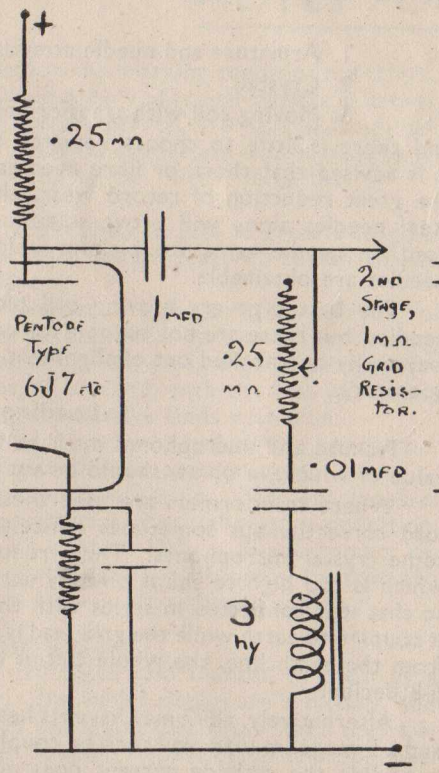
If required load is X × ·25 MΩ

adjust as :—

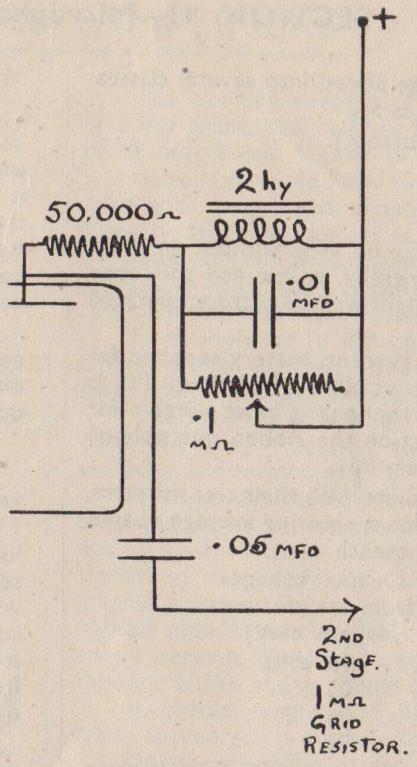
Resistances × X

Capacity ÷ X

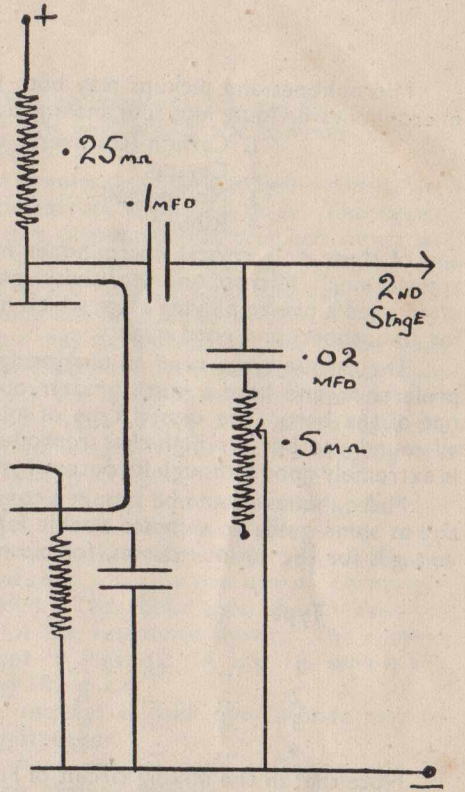
NO. 29



NO. 30



NO. 31



NO. 32

SECTION 11—Microphones and Pickups

Microphones and pickups may both be placed into several classes, microphones dividing into four main groups :—

1. Carbon (transverse current).
2. Crystal.
3. Moving coil.
4. Ribbon.

and of these only crystal microphones may be used without an input transformer. Microphone sensitivity, generally, is low and they may often need a pre-amplifying stage which might well be battery operated for smoothness and good quality.

The carbon types need an energising current, battery supplied for preference, and have a much greater output although their quality is not of the best. The crystal type of microphone is most suitable for all-round use but for high-class reproduction the ribbon microphone is extremely good although its output is very low.

Microphones should be supplied complete with their transformers, and as some guide to a choice a table follows, showing average output voltages for the various classes, for close speech :—

Type	Output voltages (from transformers where used)
1	·15 volts
2	·03 ,,
3	·06 ,,
4	·02 ,,

Note that in the mixing circuit of Fig. 28 pre-amplification is given to the microphones.

Pickups will generally provide adequate voltage for driving any amplifier. Their three main classes are :—

1. Armature and needle armature.
2. Crystal.
3. Moving coil with transformer *or* pre-amplifier.

and there is little to choose between them given reputable designs. It is advised that thorn or fibre needles be used for good quality and the great reduction of record wear, although on much-used records steel needles alone will prove suitable. Steel needles must also be used on needle armature pickups unless magnetically capped thorn needles are obtainable.

The best type are moving coil pickups with permanent sapphire needles, but these are not suitable for conditions of hard wear for they may easily be knocked out of alignment and damaged by inexperienced operators.

Loading

Pickups and microphones must be fed into their correct load, the value of which, in ohms, should be supplied by the makers.

Where transformers are used these will be wound to reflect the load correctly, but sometimes difficulties are met, as in the case of some crystal microphones. These require a load of 4 or 5 megohms, which is too high to shunt directly across the grid of the input valve so that it is connected in series with the microphone with one side of it coupled to earth while the grid lead is tapped off at a point 2 megohms from the earth line, the whole circuit having a loss of gain of roughly 6-8 decibels.

Alternatively, a 6J7 may have its heater voltage reduced to 4·5 volts and a 5-megohm load may then be coupled directly into the grid circuit, providing the cathode current does not exceed 1 milliampere. This must only be done, when using other classes of valve, when the maker's directions permit.

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