

# The Wireless World

THE  
PRACTICAL RADIO  
JOURNAL  
26<sup>th</sup> Year of Publication

No. 866.

FRIDAY, APRIL 3RD, 1936.

VOL. XXXVIII.

No. 14.

Proprietors: ILIFFE & SONS LTD.

Editor:  
HUGH S. POCOCK

Editorial,  
Advertising and Publishing Offices:  
DORSET HOUSE, STAMFORD STREET,  
LONDON, S.E.1.

Telephone: Waterloo 3333 (50 lines).  
Telegrams: "Ethaworld, Sedist, London."

COVENTRY: Hertford Street.

Telegrams: "Autocar, Coventry." Telephone: 5210 Coventry.

BIRMINGHAM:

Guildhall Buildings, Navigation Street, 2.  
Telegrams: "Autopress, Birmingham." Telephone: 2971 Midland (4 lines).

MANCHESTER: 260, Deansgate, 3.

Telegrams: "Iliffe, Manchester." Telephone: Blackfriars 4412 (4 lines).

GLASGOW: 26B, Renfield Street, C.2.

Telegrams: "Iliffe, Glasgow." Telephone: Central 4857.

PUBLISHED WEEKLY. ENTERED AS SECOND  
CLASS MATTER AT NEW YORK, N.Y.

Subscription Rates:

Home, £1 1s. 8d.; Canada, £1 1s. 8d.; other  
countries, £1 3s. 10d. per annum.

*As many of the circuits and apparatus described in these  
pages are covered by patents, readers are advised, before  
making use of them, to satisfy themselves that they would  
not be infringing patents.*

## CONTENTS

	Page
Editorial Comment .. ..	331
Wireless World PA Amplifier ..	332
New Electron Multipliers ..	336
Set-Making at Hayes .. ..	339
Listeners' Guide for the Week ..	340
New Apparatus Reviewed .. ..	342
Why Not Frame Aerials? .. ..	343
Five-Metre Field Days .. ..	345
Current Topics .. ..	347
Broadcast Brevities .. ..	348
Letters to the Editor .. ..	349
Parmeko Recording Equipment ..	351
Principal Broadcasting Stations ..	352
Recent Inventions .. ..	354

## EDITORIAL COMMENT

### Short-wave Receivers A British Opportunity

**I**N the B.B.C. Annual just published there is included a special article discussing the development of the Empire Broadcasting Service, and much interesting information is included. There is, however, one paragraph on the subject of short-wave receivers to which we should like to call particular attention. The paragraph reads:—

"Not only does the design of the short-wave receiver play a large part in the amount of interference a listener will experience, but it also materially affects the general standard of reception of the Empire Service. The Empire Broadcasting Service has considerably increased the sale of American all-wave receivers, not only in the U.S.A. but also in Empire countries. The 1935 Olympia Radio Exhibition, however, showed that the British manufacturer is at last making an effort to meet the demand for British receivers suitable for use in Empire countries to receive the short-wave service from Daventry. The production of good receivers at a price the Empire listener can pay is a most important factor of the development of the Empire Service."

We have already expressed the view that the British manufacturers have been so slow to market efficient short-wave receivers that their present position in relation to the competition of foreign producers, and in particular those of the U.S.A., makes it seem rather hopeless to begin now with the idea of being able to catch up to a level with competitors in this field unless unusual methods are adopted.

We therefore take this opportunity, on the strength of the views expressed

in the paragraph quoted above, to reiterate our suggestion for a standard short-wave Empire Receiver of competitive design to be agreed upon by British manufacturers collectively and manufactured to the same specification and to sell at an agreed price. We believe that by this means alone could a set be produced having all the necessary features which would ensure a welcome for it whilst keeping the price competitive at the same time. But perhaps the greatest advantage of a standard set for this purpose would be the simplicity of supplying spare parts and servicing.

Great responsibility would rest upon those whose duty it was to approve the final design, but it is a responsibility which we have every confidence could be ably shouldered by technicians in the various manufacturing firms in the radio industry. If success is to attend such a scheme it must be put in hand at once, there is no *more* time to be lost

### Noise Suppression

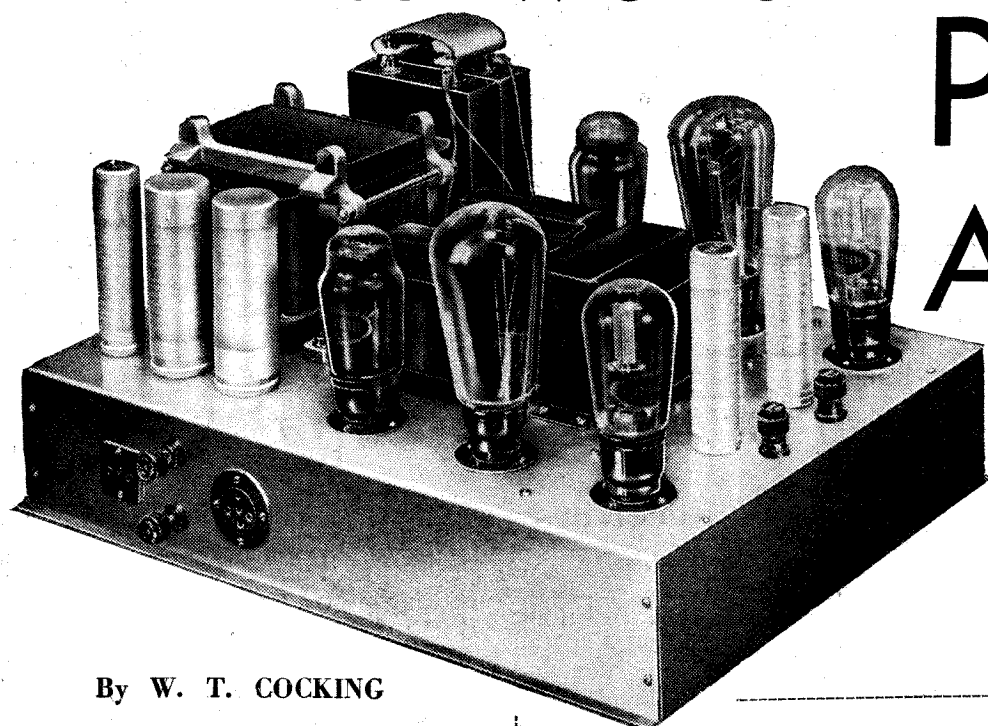
#### Importance of a New Development

**T**HE system of noise suppression just developed in America and described in our issue of last week is one which appears, on theoretical grounds, to show great promise.

The system works when the peaks of interference are short and stronger than the signal.

It seems likely that its most useful application will be in SW reception. It should be clearly understood that the system is not likely to be of any benefit in the case of certain types of interference; the claims made for it, and they are substantiated by theoretical considerations, and practical tests carried out by *The Wireless World*, are only that it will reduce those forms of interference which consist of short and strong pulses.

# Wireless World



# PA Amplifier

TWELVE-WATT  
HIGH-FIDELITY  
EQUIPMENT

By W. T. COCKING

**A**LTHOUGH most domestic requirements are met by an amplifier having an undistorted output of 4-6 watts, there is no doubt that there are many cases where a larger output is needed. When rooms are exceptionally large or it is desired to operate several loud speakers together, an output of about 12 watts becomes necessary, while an output of this order will often suffice for many public address requirements. The figure needed for PA work naturally varies considerably in different cases, but some 12 watts will be found sufficient for most purposes, such as dancing in small halls, announcements at local functions, and so on.

The *Wireless World* PA Amplifier is based on the well-known Push-Pull Quality Amplifier, which has proved itself over a period of years to be reliable and trouble-free while giving practically perfect results from the electrical point of view. The circuit diagram of the amplifier appears in Fig. 1, and it will be seen that the output stage consists of two PP5/400 valves in push-pull operated in accordance with their maker's rating. The maximum undistorted output of 12 watts is secured with a total load impedance of 6,000 ohms, and the stage requires a total input of about 64 volts peak. This is too much to obtain safely from a single valve with resistance coupling, so that the penultimate stage is also of the push-pull type.

In order to prevent parasitic oscillation both grid and anode stopping resistances are employed in the output stage. In the anode circuits R13 and R14 are given the usual values of 100 ohms each, but the resistances R11 and R12 in the grid circuits have values of 1,000 ohms only, since it has been found that higher resist-

ances lead to considerable attenuation of the upper frequencies with the output valves employed. This is because the PP5/400 has a much higher input capacity under operating conditions than the smaller PX4, principally because of its higher mutual conductance.

### The LF Stages

The valves in the penultimate stage are of the MHL4 type, and the coupling resistances R5 and R6 have values of 25,000 ohms. Decoupling is provided by the 10,000-ohm resistances R7 and R8 in conjunction with the 8-mfd. electrolytic condensers C5 and C6. Grid bias is naturally derived from resistances in the cathode circuits, and R3 and R4 have values of 1,000 ohms and are shunted by the 250-mfd. condensers C3 and C4. The grid leaks of the output stage R9 and R10 have values of 0.25 megohm, and the coupling condensers associated with them C7 and C8 have capacities of 0.1 mfd. Since any leak in these condensers would have a disastrous effect not only upon the performance, but also on the life of the output valves, these condensers are of the mica-dielectric type, and are rated for working at 500 volts. In the case of the coupling to the intermediate stage, a leak would not be attended by such serious results, and paper-type condensers of 0.1 mfd. (C1 and C2) are accordingly employed at this point, in conjunction with

0.5-megohm grid leaks R1 and R2.

The two output valves are operated from separate filament windings on the mains transformer, and grid bias is derived from the voltage drop across resistances connected between negative HT and centre-tappings on these windings. These resistances R15 and R16 have values of 500 ohms, and are shunted by the 50-mfd. by-pass condensers C9 and C10.

Turning now to the HT system, two entirely separate supplies are used—one for the output stage alone and the other for all early stages and speaker fields. Although at first sight wasteful, this course is not really so, for at most it involves an extra smoothing choke and a slightly more expensive mains transformer. In compensation, however, most of the smoothing condensers can be of comparatively low voltage rating, no difficulties arise about voltage dropping nor about energising field windings of widely different characteristics, and, furthermore, feed-back effects from the output stage, their usual source, are entirely eliminated.

Referring to Fig. 1, it can be seen that the 500-0-500 volts 120 mA. winding on the mains transformer supplies the HT for the output stage in conjunction with the 406 BU rectifier valve which has its filament heated from one of the 4-volt 2.5-amp. windings. The reservoir condenser C12 has a capacity of 4 mfd., and is rated for 1,000-volts working. Smoothing is

*THERE are many cases where an undistorted output of 12 watts is necessary in sound reproduction, and an amplifier which combines this output with an exceedingly good frequency response is described in this article. Details are also given of a feeder-unit embodying a wide range tone-control circuit of novel design.*

**Wireless World PA Amplifier**—effected by the 12 H. choke Ch1 in conjunction with another 1,000-volts condenser C11 of 4 mfd. capacity.

The total voltage required by the output stage is some 400 volts for the anodes, 32 volts for grid bias, 6 volts loss in R13 and R14, and, say, 9 volts loss in the output transformer, or roughly 450 volts. The unsmoothed output of the rectifier is some 510 volts, and the requisite voltage drop is obtained partly in the DC resistance of the smoothing choke (200 ohms) and partly in the 300 ohms resistance R17. The 0.5 megohm resistance R18 is included to prevent their being any possibility of the condensers retaining a charge when the amplifier is switched off.

Now the second HT supply is obtained

mA. is drawn a potential of some 250 volts appears across this last condenser and constitutes the HT supply for the early stages. As will be shown later, speaker fields can be energised by being connected across the HT supply at this point.

**The Feeder-Unit**

The amplifier proper, with its mains equipment, can be used with any feeder-unit or receiver which is designed for the Push-Pull Quality Amplifier without alteration to either. A special feeder-unit has been designed for it, however, since in PA work a microphone is commonly employed, and, moreover, a wide range tone-control is often needed. The use of this unit, however, is not confined to this

bias is obtained by the 2,000-ohm cathode resistances R26 and R31 shunted by the 50-mfd. condensers C23 and C26. In the anode circuit of the amplifier a 50,000-ohm coupling resistance R28 is used with a 50,000-ohm decoupling resistance R27 and 8-mfd. decoupling condenser C24. A 0.1-mfd. coupling condenser C25 to the phase-changer is employed and a 2-megohms grid leak R29. This next valve has 50,000 ohms coupling resistances R32 and R30 in anode and cathode circuits respectively, and the AC voltages developed across these are used to feed the push-pull amplifier. Anode circuit decoupling is provided by the 50,000-ohm resistance R33 and the 8-mfd. condenser C27.

The phase-changer gives an effective

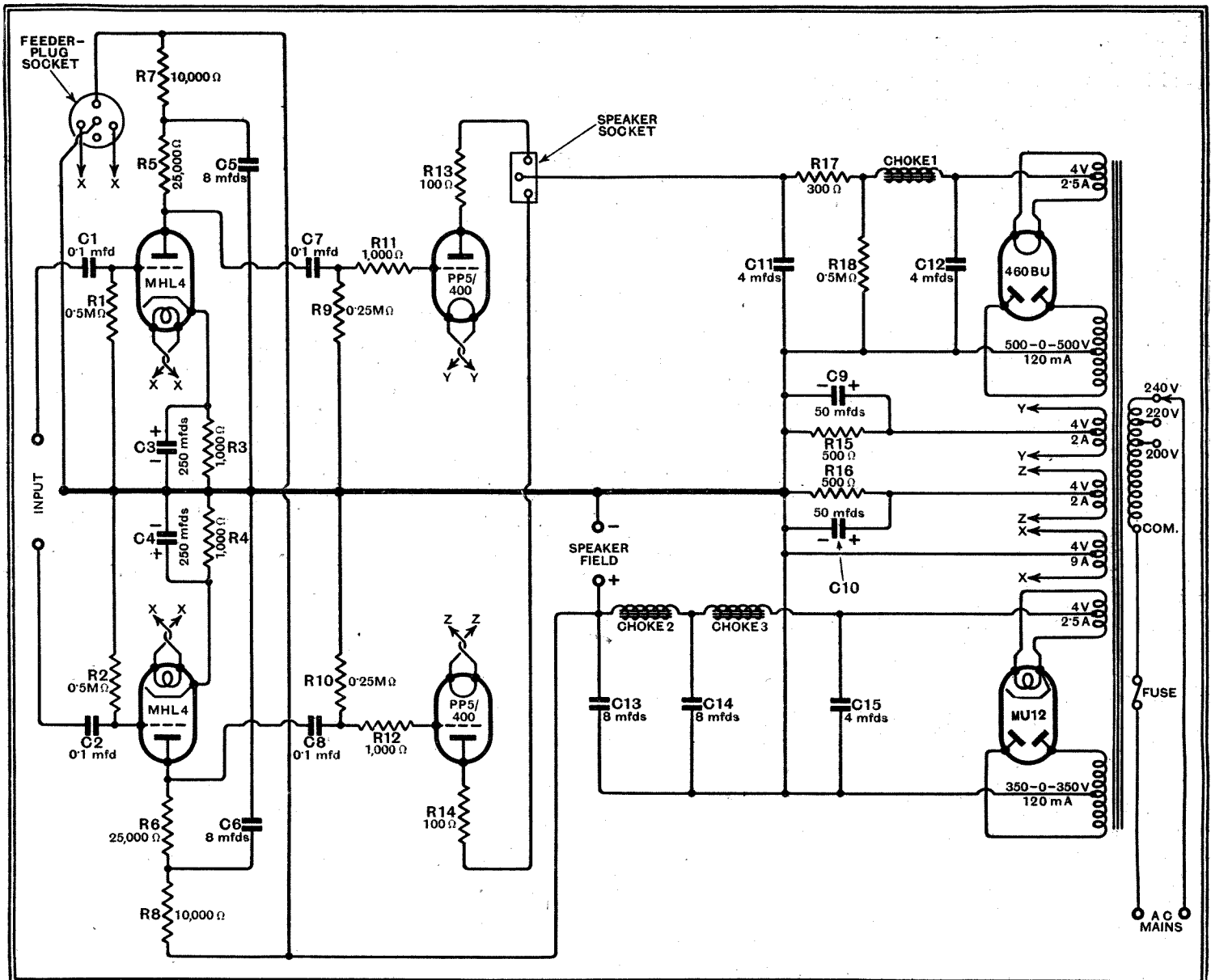


Fig. 1.—The complete circuit diagram of the amplifier. Two separate rectifiers and smoothing systems are used in the HT supply.

from the 350-0-350 volts winding and the MU12 indirectly heated rectifier. The reservoir condenser C15 has a capacity of 4 mfd., and is of the electrolytic type. Preliminary smoothing is effected by means of a 12 H. choke Ch3 and an 8-mfd. condenser C14, and it is completed by the 36H. choke Ch2 and another 8-mfd. condenser C13. When a total current of 120

amplifier, and it can equally well be used with the PPQA when the smaller output will suffice.

The circuit appears in Fig. 2, and three valves are used; of these one is a phase-changer, another an amplifier, and a third a part of the tone-control system. The amplifier and phase-changer are straight-forward; D4 type valves are used and

gain of about 1.8 times, and the amplifier preceding it a gain of roughly twenty-five times, or a total of about forty-five times. This is nearly enough, and the amplification given by the first valve and its coupling is only two or three times. This first valve is fitted primarily to make up for the loss introduced by the tone-control circuit.

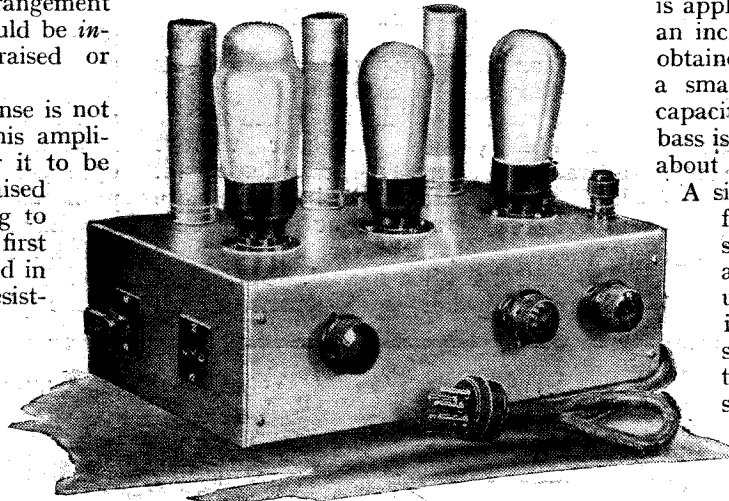
**Wireless World PA Amplifier—**

The tone-control normally fitted to receivers and amplifiers merely permits the response at the upper audible frequencies to be reduced when required. This is by no means an ideal arrangement, but it is the simplest method. A better system would undoubtedly be an arrangement whereby the bass and treble could be independently controlled and raised or lowered as required.

A reduction in the bass response is not often needed, however, so in this amplifier arrangements are made for it to be lifted only. The treble can be raised or lowered, however. Referring to Fig. 2, it will be seen that the first valve is conventionally connected in that a 50,000-ohm coupling resistance R21 is used with a 50,000-ohm decoupling resistance R22 and 8-mfd. decoupling condenser C18. Grid bias is obtained by means of the 2,000-ohm resistance R20 shunted by the 50-mfd. condenser C16, while two input plugs are provided with a fader-volume control R19. This permits a microphone and pick-up to be permanently connected and a rapid change-over from one to the other to be made.

The tone-control circuit comes in the coupling between the two valves. Consider the state of affairs when all switches are in their centre positions. The 3,000-ohm resistance R24 is then connected to the earth line, and it forms a potentiometer with the 50,000-ohm resistance R23, so that only 3/53rds. of the voltage across R21 is applied to the second valve. This

valve is provided with a grid leak R25 of 0.5 megohm in order to prevent an open grid circuit being obtained at certain settings of the switches. In view of the low effective value of the circuit resistances the coupling condenser C17 has the large capacity of 0.5 mfd.



A view of the feeder-unit showing the controls.

Now, in these switch positions the frequency response is normal, and the two resistances R23 and R24 merely throw away most of the amplification given by the first valve. When S1 is moved to the next stud, however, a condenser C20 of 0.25 mfd. is interposed between R24 and the earth line. As long as the reactance of this condenser is small compared with 3,000 ohms it has negligible effect and the response at medium and high frequencies remains normal. At low fre-

quencies, however, the reactance is no longer negligible, for it increases in a manner inversely proportional to frequency. The total impedance between the grid of the second valve and the earth line consequently rises, and a greater proportion of the voltage developed across R21 is applied to the second valve. Actually, an increase at 50 c/s of some 10 db. is obtained. On the next stud of the switch a smaller condenser, C19, of 0.1 mfd. capacity, is inserted, and a greater rise in bass is secured. The rise at 50 c/s is then about 20 db.

A similar arrangement is used at high frequencies, but here a choke is inserted. When S2 is fully rotated in a clockwise direction (on the feeder unit) the 0.54 H. coil L is inserted in series with R24, and a rise of some 20 db. at 10,000 c/s is obtained. The next position of the switch connects R24 to the tapping point on L and the inductance in use is 0.18 H., giving a rise of some 10 db. The switch S3 gives a control reducing the response at high frequencies, again in steps of about 10 db., by shunting R24 by the condensers C21 or C22 of 0.015 mfd. and 0.05 mfd. respectively.

The two switches S2 and S3 are in practice on a common shaft and form the treble control.

When the control knob is fully rotated in an anti-clockwise direction the response at 10,000 c/s is about -20 db.; in the next position it is some -10 db., while in the centre position a flat characteristic is obtained. The two further positions give responses of +10 db. and +20 db. re-

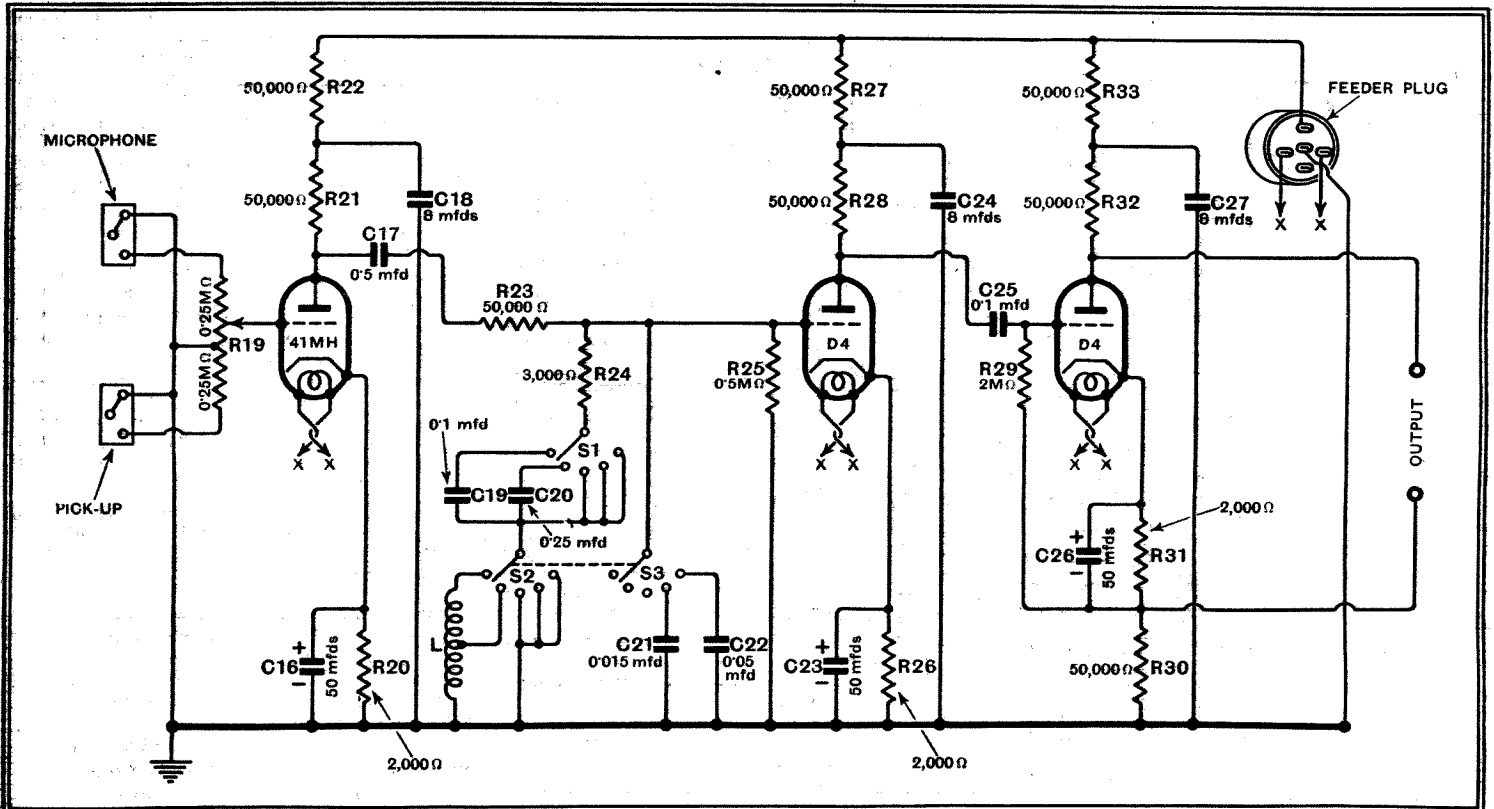
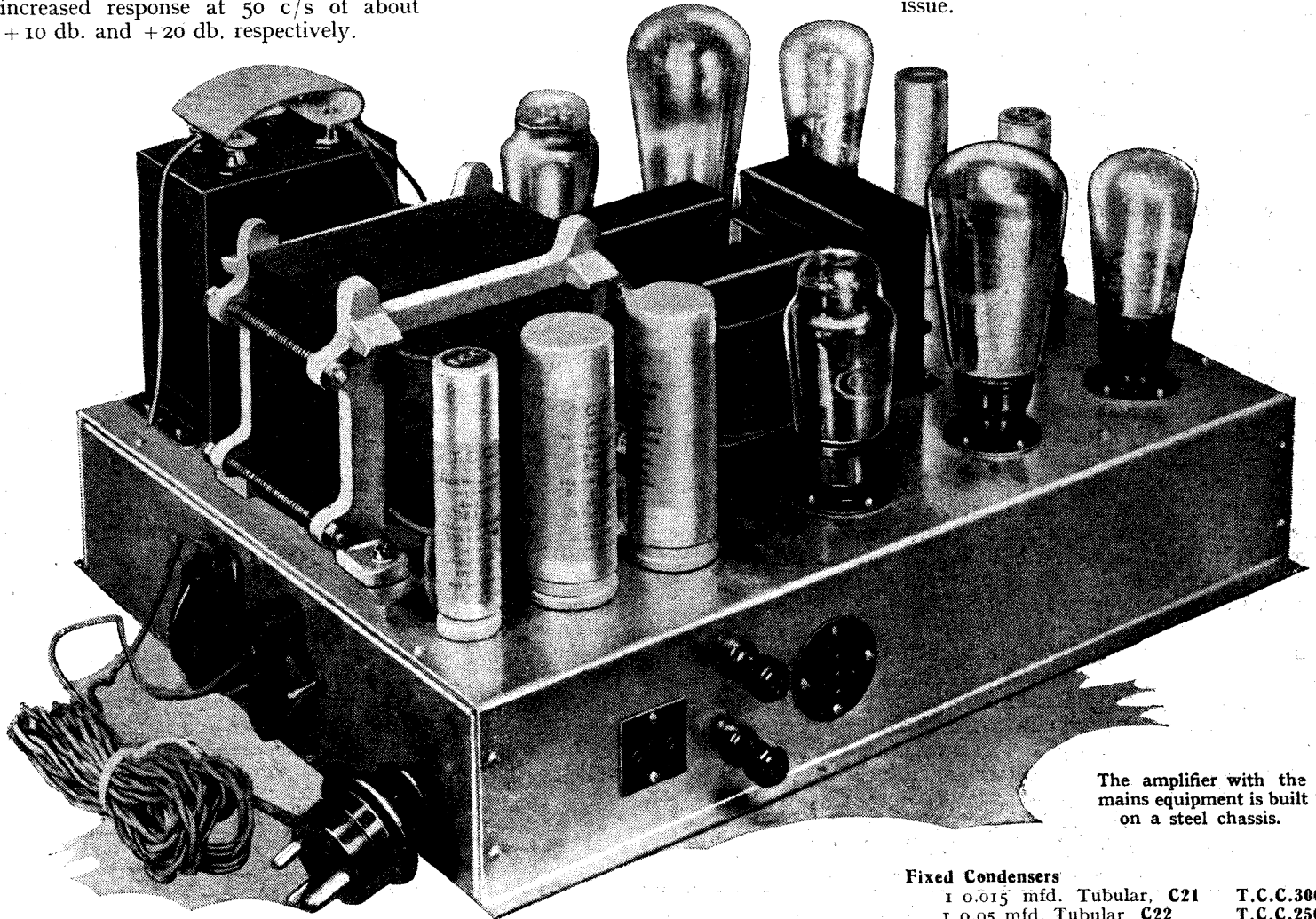


Fig. 2.—A fader-type volume control is used in the feeder-unit, while a wide-range tone control is included. This permits the bass response to be raised and the treble response to be raised or lowered at will.

**Wireless World PA Amplifier—**  
spectively. In the case of the bass control S1, the first three positions are the same, and the two last (clockwise) give an increased response at 50 c/s of about +10 db. and +20 db. respectively.

If it should be required to obtain a reduced bass response this may readily be done by arranging the unused half of the switch assembly to connect additional con-

densers in series with C17. The assembly of the components, wiring and operation of the amplifier and its feeder-unit will be fully dealt with in next week's issue.



The amplifier with the mains equipment is built on a steel chassis.

**AMPLIFIER.**

**1 Mains Transformer, Primary;** 200/250 volts 50. c/s. Secondaries; 4 volts 2.5 amps. C.T., 500-0-500 volts 120 mA, 4 volts 2 amps. C.T., 4 volts 2 amps. C.T., 4 volts 2.5 amps. C.T., 350-0-350 volts 120 mA, 4 volts 9 amps. C.T., with screened primary.

London Transformer Products L.608

(All Power Transformers, Bryce, B.T.S., Challis, Heayberd, Partridge, Savage, Sound Sales, Vortexion.)

**2 Smoothing chokes** 12 H. 120 mA, 200 ohms Ch1, Ch3 N. Partridge WW12

**1 Smoothing choke** 36 H. 120 mA, 500 ohms Ch2 N. Partridge WW36

(Bryce, B.T.S., Davenset, Ferranti, Heayberd, London Transformer Products, Sound Sales, Varley, Vortexion.)

**7 Valve holders** 5-pin (without terminals) Clix Chassis Mounting Type V1

**Fixed Condensers**

2 4 mfd. 1,000 volts DC working, C11, C12 T.C.C.111

2 0.1 mfd. Mica, 500 volts DC working, C7, C8 T.C.C.340

2 0.1 mfd. Tubular, C1, C2 T.C.C.250

2 8 mfd. 500 volts peak working, Electrolytic, C13, C14 T.C.C.902

1 4 mfd. 500 volts peak working, Electrolytic, C15 T.C.C.902

2 8 mfd. 450 volts peak working, Electrolytic, C3, C4 T.C.C.501

2 50 mfd. 50 volts DC working, Electrolytic, C9, C10 T.C.C.521

2 250 mfd. 12 volts DC working, Electrolytic, C3, C4 T.C.C.501

(Dubilier, Ferranti, T.M.C.-Hydra, Peak, Polar-N.S.F.)

**Resistances**

2 100 ohms 1/2 watt, R13, R14 Bulgin HW37

**LIST OF PARTS**

After the particular make of component used in the original model, suitable alternative products are given in some instances.

4 1,000 ohms 1/2 watt, R3, R4, R11, R12 Bulgin HW3

2 10,000 ohms, 1/2 watt, R7, R8 Bulgin HW15

2 25,000 ohms 1/2 watt, R5, R6 Bulgin HW20

2 250,000 ohms 1/2 watt, R9, R10 Bulgin HW28

2 500,000 ohms 1/2 watt, R1, R2 Bulgin HW31

1 500,000 ohms 1 watt, R18 Eric

2 500 ohms 3 watt, R15, R16 Claude Lyons

1 300 ohms 20 watt, R17 Bulgin PR1

(Amplion, Bryce, Dubilier, Graham Farish, Ferranti, Claude Lyons, Polar-N.S.F.)

1 3-pin plug and socket Belling-Lee 1119

1 5-way connector Bryce

1 Fuseholder complete with 3 amp. fuse Belling-Lee 1045

4 Shrouded terminals, Input (2), LS (2). Belling-Lee "B"

Miscellaneous:— Scientific Supply Stores

6 length systoflex, 2 ozs. No. 18 tinned copper wire, etc. Screws:—4 2BA 1/4 in., 34 6BA 1/4 in., 22 4BA 1/4 in., 12 6BA 1/4 in., all with nuts and washers.

Metal baseplate with mounting screws B.T.S. Valves:—

2 MHL4, 1 MU12 Osram or Marconi

2 PP5/400 Mazda

1 460BU Cossor

**FEEDER UNIT**

1 Tone correction choke, L B.T.S. WW1

**Fixed Condensers**

1 0.015 mfd. Tubular, C21 T.C.C.300

1 0.05 mfd. Tubular, C22 T.C.C.250

2 0.1 mfd. Tubular, C19, C25 T.C.C.250

1 0.25 mfd. Tubular, C20 T.C.C.250

1 0.5 mfd. Tubular, C17 T.C.C.250

3 50 mfd. 12 volts DC working, Electrolytic, C16, C23, C26 T.C.C. "FT" or "AT"

3 8 mfd. 450 volts peak working, Electrolytic, C18, C24, C27 T.C.C.502

(Dubilier, Ferranti, T.M.C.-Hydra, Peak, Polar-N.S.F.)

**Resistances**

3 2,000 ohms 1/2 watt, R20, R26, R31 Bulgin HW5

1 3,000 ohms 1/2 watt, R24 Bulgin HW7

8 50,000 ohms 1/2 watt, R21, R22, R23, R27, R28, R30, R32, R33 Bulgin HW23

1 500,000 ohms 1/2 watt, R25 Bulgin HW31

1 2 megohm 1/2 watt, R29 Bulgin HW34

(Amplion, Bryce, Dubilier, Graham Farish, Ferranti, Claude Lyons, Polar-N.S.F.)

1 Volume control 0.25 megohm + 0.25 megohm R19 Dubilier "Fadover"

1 4-way connector, light type Bryce

1 5-way cable with twin 70/36 leads and 5-pin plug Goltone

3 Valve holders 5-pin (without terminals) Clix Chassis Mounting Type V1

2 Switches, Double-pole, five-way, with knobs B.T.S. C125

2 3-pin plugs and sockets Belling-Lee 1119

3 Shrouded terminals, Output (2) Earth Belling-Lee "B"

Miscellaneous:— Scientific Supply Stores

2 lengths systoflex, small quantity No. 18 tinned copper wire, etc. Screws:—16 6BA 1/4 in., 2 4BA 1/4 in., all with nuts.

Metal baseplate with mounting screws B.T.S. Valves:—

1 41MH, metallised Cossor

2 D4 Ferranti



# New Electron Multipliers

## HIGH-POWER HF GENERATORS DEMONSTRATED

**R**ECENT advances in "multipactor" tube design, announced by P. T. Farnsworth before the Institute of Radio Engineers in New York on March 4th, make it possible to generate kilowatts of power in a "cold-cathode" tube, at frequencies as high as 300 megacycles. Applications of the new tubes in oscillators and radio-frequency amplifiers give efficiencies not possible with conventional hot-cathode thermionic tubes.

**N**EW tubes, capable of producing several kilowatts of high-frequency power without the aid of a hot filament, at frequencies even higher than the "ultra-high" region, with efficiency as high as ninety per cent., were demonstrated in New York on March 4th by Philo T. Farnsworth, Vice-president in Charge of Research of Farnsworth Television Incorporated. Following closely on the heels of a paper delivered by Dr. V. K. Zworykin on Electron Multipliers (see report in *The Wireless World*, November 22nd, 1935), Mr. Farnsworth's demonstration held unusual interest because, while using the same basic phenomenon, his tubes perform in a manner quite different from those of Dr. Zworykin and lead to results quite as spectacular and perhaps of even greater immediate practical value.

Both the Zworykin and Farnsworth tubes depend on "secondary emission" of electrons from a cold cathode. In the conventional thermionic valve, the electrons are emitted by heating the cathode to a sufficiently high temperature; in the electron multiplier tube electrons are caused to bombard the cathode. As each electron hits the specially prepared surface of the cathode it liberates from three to ten "secondary" electrons—that is, the original electron is multiplied, or "amplified," three to ten times. By this method the electron current in the tube is ampli-

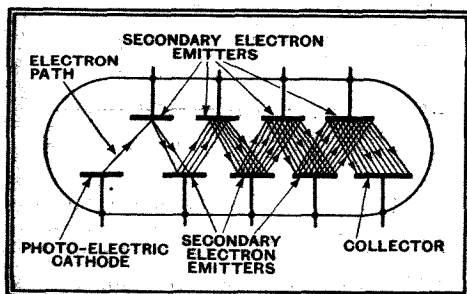


Fig. 1.—Principle of the electron multiplier.

fied, and if the newly liberated "secondaries" are made to strike the cathode again, each one liberates from three to ten additional secondaries. By successive impacts of this kind the electron multiplication is made to build up cumulatively until the original electron impact has been amplified many millions of times. This

manner of operation is the basis of all electron multiplier tubes; it permits exceedingly great amplification to be obtained in a single tube, and because it amplifies the current directly (without the necessity for converting the current into a voltage drop and then amplifying the voltage, as is done in conventional circuits), the signal-to-noise ratio of the electron multiplier tubes is many times higher than that of the usual valve amplifier. A tube of this kind has provided several watts of audio power when its input was a few microamperes of photoelectric current; this feat, accomplished by Dr. Zworykin, was hailed as a great advance. But the power output of the Zworykin tubes was not more than a few watts, although they could probably be made to deliver higher power.

### Up to Four Kilowatts

The Farnsworth tubes, on the other hand, are expressly designed for high-power output. Three distinct forms of "multipactors," as Farnsworth calls his tubes, were shown; their tentative power output ratings are 200, 1,000, and 4,000 watts. The largest size was about a foot long and four inches in diameter. This great increase in power-handling ability is based on two factors: the method of obtaining the electron impacts, which is described below, and the material used in the cathode surface which emits the secondary electrons. The surface used by Dr. Zworykin and other workers in the field of electron multiplication is a caesium-oxide-silver deposited on a silver base, and is very similar to that used in high-vacuum photocells of the caesium type. The disadvantage of this type of surface is the fact that it cannot stand high temperatures, and that it can be destroyed by bombardment of positive ions formed within the tube; because of these limitations, high-power tubes, which must necessarily operate at high temperatures, cannot be built using the caesium-silver surface. A new material, the details of which are not yet available, has been developed by Farnsworth, however, which will operate satisfactorily up to 1,000 deg. C., and which will deliver as many secondaries per electron impact as the caesium-silver surface. The material, which is an alloy

By Our New York Correspondent

having a special surface treatment, can be used even at red heat, making possible compact and efficient high-power multiplier tubes.

The electron multiplication action depends upon many successive impacts of secondary electrons. Various arrangements have been used to obtain the required action. In the Zworykin tubes many separate cathodes are used, each maintained at successively higher positive voltage. The original electron, attracted to the first cathode and liberating several secondaries, produces an amplified electron flow, which is then directed to the second cathode, and so on, each cathode liberating a current multiplication of from three to ten times. This action is shown in Fig. 1. The final amplified current is collected at the plate and conducted to the external circuit. The original electron is produced by illuminating the surface of the first cathode, which is photo-electric.

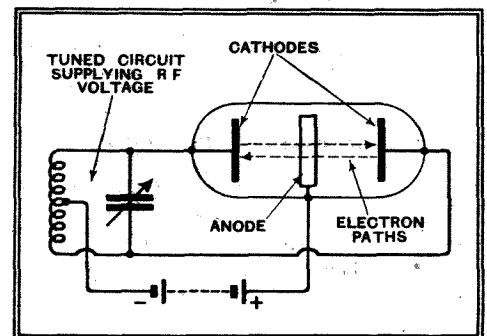


Fig. 2.—The new Farnsworth tube in its elementary form.

In the Farnsworth tube, in its elementary form (see Fig. 2), only two cathodes are used, and they are maintained at the same potential. The electrons are caused to fly back and forth from one cathode surface to the other (multiplying as they go) by applying a very high frequency voltage between the two cathodes. First one cathode and then the other is made positive by this HF voltage, and the electrons fly back and forth in response to the pull of whichever cathode is positive at the time. The central anode is maintained positive at all times by the battery, and serves to attract the electrons in their flight. To prevent the electrons being collected by this anode, in the simple form of tube, a magnetic field has been used to direct the electrons away from the anode and toward the cathodes. In this manner the number of free electrons inside the tube is enormously increased, until a cloud of electrons (a "space charge") is formed. This cloud prevents further increase of current (space-charge equilibrium) unless