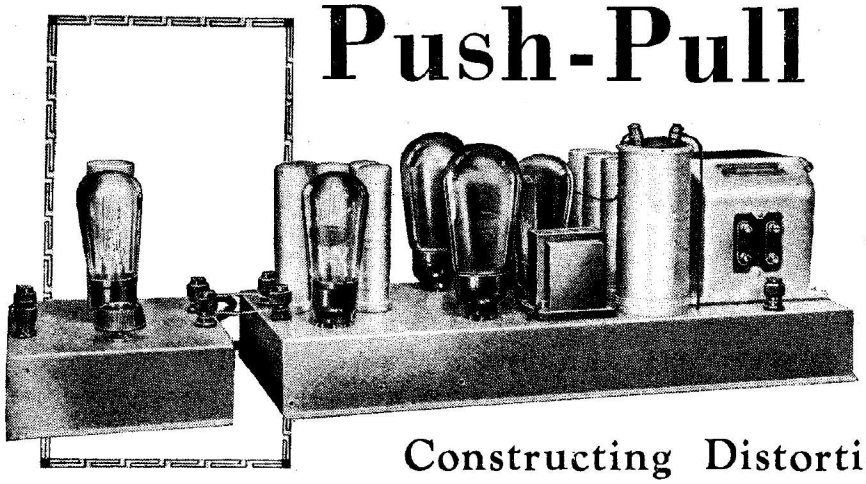

Push-Pull Quality Amplifier

By W. T. COCKING

Constructing Distortionless Equipment

THE attainment of high quality reproduction demands the closest attention to detail in design both in the choice of circuit and in the selection of the values of components. The amplifier described in this article is exceptionally free from all forms of distortion and is suitable not only for the high quality reproduction of broadcasting and gramophone records, but also for many television purposes. For gramophone work, a special feeder unit is also described, and the use of the apparatus on radio will be dealt with next week.

SOME of the chief requirements of an L.F. amplifier suitable for the highest quality sound reproduction were discussed in last week's issue of *The Wireless World*, and it will be remembered that push-pull amplification offers very decided advantages over other systems, for it permits amplitude distortion to be greatly reduced. Resistance-capacity inter-valve coupling is also desirable, partly because there is little limit to the economical response at low frequencies, partly because the coupling itself is inherently linear and cannot introduce amplitude distortion, and partly because this coupling gives a minimum of phase distortion—an important point in television work.

The question of the power output required for the highest quality is a matter of some importance, and experience indicates that about 4 watts are needed for domestic purposes. As this figure will appear excessive to many, some explanation may be advisable. In the concert hall the volume of sound from a large orchestra may vary over a range of some

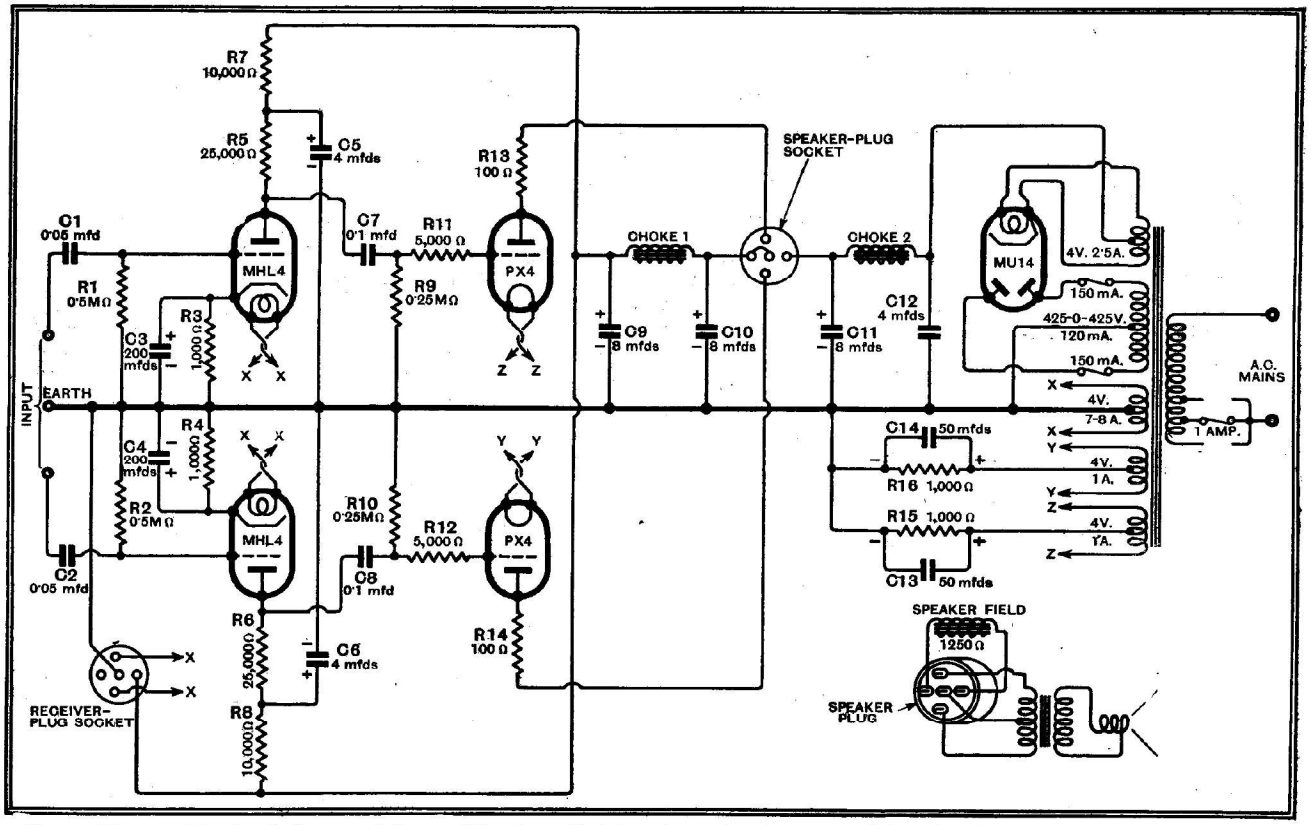

Fig. 1.—The complete circuit diagram of the amplifier shows that two stages of resistance-coupled push-pull amplification are employed. The undistorted output is 4 watts, but an output of up to 6 watts is available before the distortion exceeds the value found in normal apparatus.

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60 db. from the weakest passage of music to the loudest. In broadcasting such a wide range cannot be permitted, for either the loud passages would cause over-modulation or the weak would be below the inevitable slight background noises. It is usual, therefore, for the range of modulation in the transmitter to be kept within 30 db.

Now 80 per cent. modulation is the highest normally used in this country, and 30 db. represents a voltage ratio of about 31.6-1. If the maximum modulation is 80 per cent., therefore, the minimum is $80/31.6 = 2.52$ per cent. It is difficult to arrive at a figure for the average modulation depth on a normal musical item, but for our present purposes it will be sufficient if we assume that the weakest sounds are as much below the average as the loudest are above it. This means that the average modulation depth is 15 db. higher than 2.5 per cent., or 14.2 per cent.

If we employ an output stage capable of delivering 4 watts to the loud speaker and we adjust the circuits correctly so that this output is obtained on the loudest passages of music, equivalent to 80 per cent. modulation in broadcasting, we shall have an output of only 0.004 watt, or 4 milliwatts, on the weakest passages. On the average level the output is 126.5 milliwatts. An output of this order is easily obtainable from a small battery valve, and such a valve will give good results on the average level of music. It will be hopelessly overloaded on loud passages, however. An output stage rated for 4 watts, therefore, is necessary for the highest quality reproduction, not because the average volume must be set at a high level, but purely to avoid overloading and distortion on loud passages. If for any reason the volume is required to be unusually great, then the output must be higher than 4 watts if quality is to be maintained unimpaired.

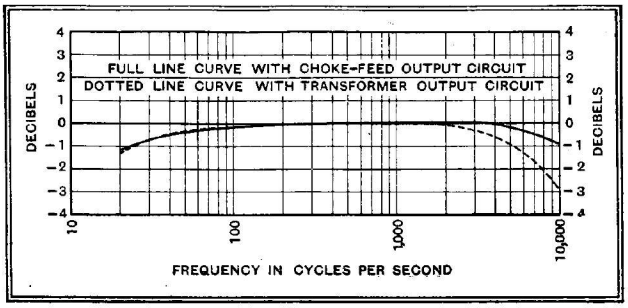
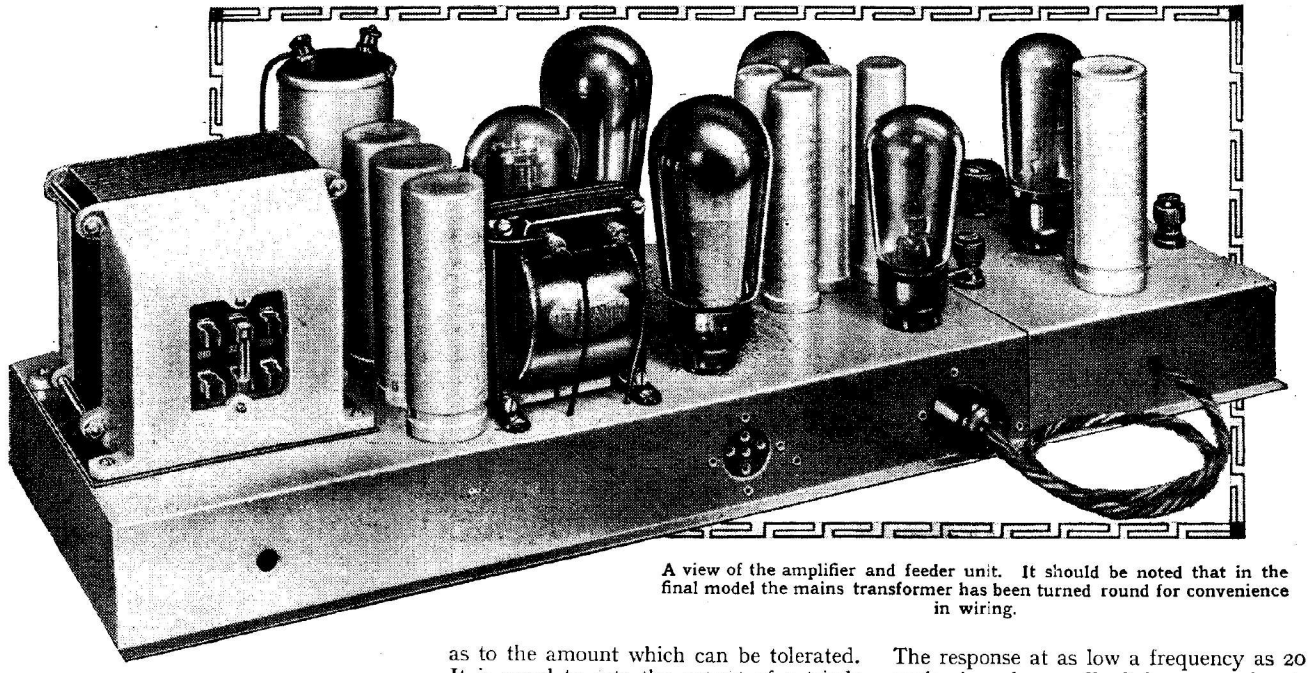


Fig. 2.—The overall frequency response of the amplifier and feeder unit is shown by the solid line curve. At 20 cycles the response falls by only 1.2 db. and at 10,000 cycles by only 1 db. The response with an output transformer included is shown by the dotted curve, and at 10,000 cycles the drop is under 3 db.—a deviation so small that it is inaudible.

No amplifier is completely free from amplitude distortion, and opinions differ as to the amount which can be tolerated. It is usual to rate the output of a triode valve for a figure of 5 per cent. second harmonic distortion, and this appears satisfactory for ordinary practice. For the highest quality, however, the distortion should be lower, and as every stage introduces some distortion, that introduced by the output stage cannot be allowed to approach 5 per cent. Under these circumstances push-pull operation is the most satisfactory and economical arrangement, and curves illustrating the performance of this amplifier were given in last week's issue of *The Wireless World*.

The Frequency Response

As regards frequency distortion, conditions are much simpler, and it will suffice if the overall response curve is flat within about 5 db. over the range of 30 to 10,000 cycles, for the ear cannot readily detect small changes of volume at different frequencies. The requirements for television, however, are more stringent, and the 30-line transmissions theoretically require an amplifier flat from 12.5 cycles to 13,000 cycles. In practice, however, an upper limit for even response of 10,000 cycles is very satisfactory, particularly if the cut-off beyond this frequency is gradual and not sudden. Phase distortion, although of little moment in sound reproduction, is important in television. Fortunately, we need not give it special consideration in this case, for with an uncorrected resistance-coupled amplifier it is at a minimum when frequency distortion also is at a minimum. The small degree of frequency distortion found in the complete apparatus is well brought out by the curves of Fig. 2. The full line curve shows the response of the amplifier with a feeder unit containing a duo-diode-triode valve, and the dotted line shows the effect of including the output transformer.



A view of the amplifier and feeder unit. It should be noted that in the final model the mains transformer has been turned round for convenience in wiring.

The response at as low a frequency as 20 cycles in only 1.2 db. below normal output, and at 10,000 cycles the loss in the amplifier is under 1 db.; even including the output transformer the loss at 10,000 cycles is below 3 db.

The Push-Pull Quality Amplifier fulfils the requirements of the most exacting, and it is suitable for high quality sound repro-

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duction of both broadcasting and gramophone records, and it may also be used in the reception of 30-line television whether a neon tube, Kerr cell, or cathode-ray system be employed. The circuit diagram of the amplifier proper appears in Fig. 1, and it should be understood that the feeder and output circuits adopted will vary according to the use to which the amplifier is to be put. This will be dealt with in detail later, however.

The amplifier is essentially two resistance - capacity coupled amplifiers to which the inputs are applied in opposite phase, and the outputs also joined with a phase reversal thus giving push-pull operation, and a balancing out of second harmonic distortion. The output stage consists of two PX4 valves in push-pull, and to prevent parasitic oscillation the usual grid and anode stopping resistances are included. Each valve is independently biased by the voltage drop along the 1,000 ohms resistances R15 and R16 in the cathode circuits. The valves are operated under slightly different conditions from the maker's rating, which calls for an anode supply of 250 volts and grid bias of 33 volts, giving an anode current of 48 mA. for each valve. Actually an anode potential of about 250 volts is used, but the grid bias is increased to 35 volts, at which the anode current for each valve is 35 mA. It should be understood that these figures are nominal and may vary somewhat with different valves.

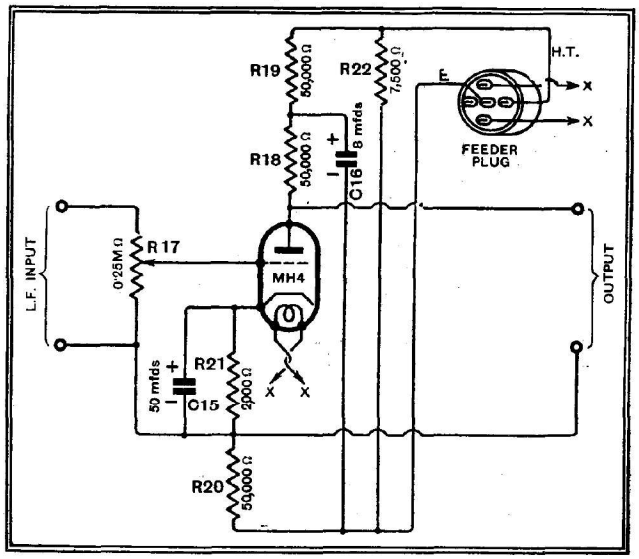

Fig. 3.—The circuit of the feeder unit which is needed only for gramophone work. The input is applied to the valve in the usual way, but the output is split across R18 and R20 for feeding the amplifier in the correct phase.

Valve Handling Capacity

A push-pull output stage under these conditions is quite linear up to about 4 watts output when operated with a total load impedance of 10,000 ohms. This load is higher than the maker's figure, and is the change brought about by the different value of grid bias used. The total anode dissipation of the two valves is 17.5 watts, and for the true undistorted output of 4 watts the efficiency is 22.9 per cent., which is unusually high for the very low degree of amplitude distortion which is introduced. A single P.X.4 under the rated operating conditions gives an output of 2.5 watts for a dissipation of 12 watts—an efficiency of 20.8 per cent.—and this is for 5 per cent. distortion, which is greater than in the push-pull case.

The output stage can accept an input of 35 volts peak per valve, or 70 volts total, so the previous stage must be capable of an output of this order without distortion. No single valve is suitable with resistance coupling, so that a pair of MHL4 valves in push-pull is used. With the values of components selected the stage gain is 9.86 times, so that the total input to these valves is 70/9.86 = 7.1 volts peak; the input to each valve, therefore, is 3.55 volts peak. In the case of output valves it is unwise to use a high value of grid leak, and 250,000 ohms is considered about the safe maximum. For the proper reproduction of the lower frequencies, therefore, a fairly large coupling condenser has been chosen, and a value of 0.1 mfd. is used. Very high insulation resistance is important in such condensers, otherwise the grid of the following valve may take up a positive potential, with disastrous results to valve life in the case of an output valve. Although they are fairly expensive, therefore, mica dielectric condensers have been chosen for use in the couplings to the output valves, for they give a higher factor of safety than paper types. For the couplings to the MHL4 valves, however, paper condensers are used, since the results of a leakage would not be so serious at this point. Any leakage would still result in a positive bias being applied to the valve, of course, and would upset its operation. It is not so likely to have a harmful effect on the valve, however, since the high resistances in the anode circuit severely limit the possible anode current.

Before proceeding to a discussion of the various input and output arrangements, it may be as well to deal with the mains equipment. The mains transformer is rated to deliver 425-0-425 volts at 120 mA. to the MU14 indirectly heated rectifier, which gives an unsmoothed output of 450 volts at 120 mA. A winding of 4 volts 2.5 amperes is provided for the rectifier heater, two of 4 volts 1 ampere for the two output valves, and one of 4 volts at 7/8 amperes for the two MHL4 valves and up to five other valves in early stages which may or may not be used, according to circumstances.

The Smoothing Circuits

The reservoir condenser C12 has the usual value of 4 mfd., and preliminary smoothing is effected by an 8-H. choke with a resistance of 215 ohms, followed by an 8-mfd. electrolytic condenser C11. The current then passes through a further choke or a speaker field having a resistance of 1,250 ohms and an inductance of some 25 henrys or more, the smoothing being effected by the combination of this with the 8-mfd. condenser C10. The drop across this is 150 volts, or a total drop with Ch2 of 175 volts, leaving 275.5 volts for the output stage. There is a small drop in the output transformer primary, but this may

LIST OF PARTS

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

AMPLIFIER

1 **Mains transformer,** primary, 200 to 250 volts, 50 cycles; secondaries, 425-0-425 volts, 120 mA.; 4 volts 2.5 amps. centre-tapped; 4 volts 1 amp. centre-tapped; 4 volts 1 amp. centre-tapped; 4 volts 7/8 amp. centre-tapped **Sound Sales Type PP/QA**
(B.S.R., British Radio Gramophone Co., Bryce, Challis, Heayberd, Claude Lyons, Parmeko, R.I., Rich and Bundy, Varley, Vortexion, Wearite.)

1 **Smoothing Choke,** 7/30 henrys at 120 mA, 215 ohms, **Ch2** **Ferranti B2**

1 **Smoothing Choke,** 20 henrys at 50 mA, 400 ohms, **Ch1** **R.I. "Hypercore"**
(Alternatives same as mains transformer above)

3 **Electrolytic condensers,** 8 mfds., 500v. peak, **C9, C10, C11** **Dubilier 0281**

1 **Fixed condenser,** 4 mfds., 450v. working, cylindrical container **C12** **Dubilier LEG/9204**

2 **Electrolytic condensers,** 4 mfds., 500v. peak, **C5, C6** **Dubilier 0283**
(Ferranti, Peak, T.C.C.)

2 **Electrolytic condensers,** 50 mfds., 50v. peak, **C13, C14** **Dubilier 3003**

2 **Electrolytic condensers,** 200 mfds., 10v. peak, **C3, C4** **Dubilier 0283**
(T.C.C.)

2 **Fixed condensers,** mica, 0.1 mfd., **C7, C8** **Dubilier B775**
(T.C.C.)

2 **Tubular paper condensers,** non-inductive, 0.05 mfd., **C1, C2** **Dubilier 4403**
(Graham-Farish, Peak, T.C.C., T.M.C.Hydra)

2 **Resistances,** 1,000 ohms, 2 watts, **R15, R16** **Claude Lyons**

2 **Resistances,** 100 ohms, 1 watt, **R13, R14** **Claude Lyons**

2 **Resistances,** 1,000 ohms 1 watt, **R3, R4** **Claude Lyons**

2 **Resistances,** 5,000 ohms 1 watt, **R11, R12** **Claude Lyons**

2 **Resistances,** 10,000 ohms 1 watt **R7, R8** **Claude Lyons**

2 **Resistances,** 25,000 ohms 1 watt, **R5, R6** **Claude Lyons**

2 **Resistances,** 250,000 ohms 1 watt, **R9, R10** **Claude Lyons**

2 **Resistances,** 500,000 ohms 1 watt, **R1, R2** **Claude Lyons**
(Dubilier, Erie, Ferranti, Graham-Farish, Sheradex, Watmel)

7 **Valve holders,** 5-pin **Clix Chassis Mounting Standard Type**

1 **5-pin plug** **Bulgin**
(British Radio Gramophone Co.)

3 **Ebonite shrouded terminals,** Input (2), Earth (1) **Belling-Lee Type "B"**

1 **Metal Chassis** **C.A.C.**

Valves:—2 Marconi or Osram MHL4; 2 Marconi or Osram PX4; 1 Marconi or Osram MU14

FEEDER UNIT

1 **Electrolytic condenser,** 8 mfds., 500 volts peak, **C16** **Dubilier 0281**
(Ferranti, Peak, T.C.C.)

1 **Electrolytic condenser,** 50 mfds., 6 volts peak, **C15** **Dubilier 3001**
(T.C.C.)

1 **Resistance,** 7,500 ohms 10 watts **R22** **Dubilier "Spirohm"**
(Bulgin)

1 **Resistance,** 2,000 ohms 1 watt, **R21** **Claude Lyons**

3 **Resistances,** 50,000 ohms 1 watt, **R18, R19, R20** **Claude Lyons**
(Dubilier, Erie, Ferranti, Graham-Farish, Sheradex, Watmel)

1 **Tapered volume control potentiometer,** 250,000 ohms, with knob, **R17** **Ferranti Type "P"**
(Claude Lyons, Magnum, Rothermel)

1 **Valve holder,** 5-pin **Clix Chassis Mounting Standard Type**

1 **5-pin plug** **Bulgin**
(British Radio Gramophone Co.)

1 **5-way cable with twin 70/36 leads** **Harbros**
(Goltone)

4 **Ebonite shrouded terminals,** Output (2), Input (2) **Belling-Lee Type "B"**

1 **Metal chassis** **C.A.C.**

Valves:—1 Marconi or Osram MH4

Push-Pull Quality Amplifier—

be ignored, so that the 275 volts is split for the anode and bias supplies for the output stage.

At this point the current for the output stage is tapped off and the remaining current of 50 mA. passes through the 20-henry choke Ch1, where further smoothing takes place in conjunction with C9. This choke has a resistance of 400 ohms, so that there is a drop of 20 volts across it, and a supply of 255 volts is available. The MHL4 valves are fed from this point and take about 4.3 mA. apiece, so that some 41 mA. is available for operating a radio receiver.

Turning now to methods which may be used for feeding the amplier, several alternatives present themselves according to the use to which the amplifier is to be put. For gramophone operation an additional stage of amplification is needed, and if the amplifier is to be used only for such work, the feeder unit described in this article should be built. This consists of a single MH4 valve, and the circuit appears in Fig. 2. Owing to the necessity for obtaining a phase reversal in one-half of the output, the arrangement is unusual. It will be seen that two coupling resistances R18 and R20, each of 50,000 ohms, are used, and that while one of these is in the anode circuit the other is in the cathode. Since the resistances are of equal value, the anode and cathode of the valve are always at equal and opposite A.C. potentials, and the required phase reversal for push-pull operation of the succeeding stages is obtained.

Unlike the ordinary push-pull system, an amplifier of this type is not balanced as regards disturbances in the H.T. supply; thorough decoupling of the anode circuit of the first stage is necessary, therefore, and is provided by the 50,000 ohms resistance R19 and the 8-mfd. condenser C16. Grid bias is obtained by the voltage drop across the 2,000 ohms resistance R21, and as the anode current is about 1.2 mA., a bias of 2.4 volts is obtained. A 250,000 ohms tapered potentiometer in the grid circuit of the valve provides volume control. It is important to note that neither of the input terminals to which a pick-up is connected is earthed, this being an inevitable consequence of the particular method adopted for feeding the push-pull stage. Care must be taken, therefore, to see that the pick-up leads do not become accidentally earthed, for they are about 60 volts above earth potential.

The full output is obtained with an input of only 0.265 volt R.M.S., so that it is possible to obtain adequate volume from the more insensitive types of pick-up. The range of control afforded by the volume control is adequate, however, even when a component giving a large output is used. On radio, or when both radio and gramophone are required, alternative methods of feeding the amplifier are available, and these will be dealt with next week.

News *of the* Week

Current Events in Brief Review

Radio at Paris Fair

THE Foire de Paris, which opened on Wednesday last, May 9th, includes a radio show in the Electricity Hall and in the Pavilion of Music.

The P.O. Will Help

ELECTRICAL interference which cannot be traced should always be referred to the Post Office. With an "electrical interference questionnaire," obtainable from any Post Office, the listener can explain the situation in a way that enables the engineers to trace the trouble with the minimum amount of delay. The Post Office makes no charge for the investigation.

More American Wavelengths

A DOWNWARD extension of the broadcast wavelength band has been authorised by the American Federal Radio Commission. Within the next few months four new stations will operate on wavelengths between 180 and 200 metres. Hitherto, broadcasting in North America has been confined to ninety-six wavelengths, spaced 10 kc/s apart, between 550 and 1,500 kc/s. Three of the four new stations are concerned with television.

A Veteran on 30-line Television

HIGH praise for 30-line television as broadcast by the B.B.C. comes from Dr. Lee De-Forest in a letter to the President of the National Radio Institutes and quoted in the *New York Sun*. Says Dr. De Forest:—

"I found the British Baird Company making fine progress in commercial television. Four nights each week they broadcast one hour of genuine artistic entertainment. . . . Baird is limited by British regulations to 9,000 k/c side bands. Imagine getting a good picture out of that! Yet Baird does it—by use of 30-line picture and 12½ pictures a second. Considering the handicaps, the results are amazing. Vertical scanning is the answer—incomparably superior to horizontal scanning when less than 120 lines are employed."

Encouraging

TO encourage the local tramway company to fit antistatic devices the Berne Posts and Telegraphs Department has provided a subsidy of 60,000 francs.

Physics and Science Museums

ON Tuesday next, May 15th, at 5.15 p.m., the President of the Institute of Physics, Sir Henry G. Lyons, D.Sc., Sc.D., F.Inst.P., F.R.S., will deliver the Presidential Address on "Physics and Science Museums" in the Royal Institution, 21, Albemarle Street, London, W.1. Tickets of admission may be obtained from the Secretary of the Institute, 1, Lowther Gardens, Exhibition Road, London, S.W.7.

Recording on Film

PHOTOGRAPHIC aspects of sound recording will be discussed by Dr. C. E. Kenneth Mees, F.C.S., of the Eastman-Kodak Company, in a lecture before the Royal Society of Arts, London, W.C.2, on Wednesday next, May 16th, at 8.30 p.m. The lecture will be illustrated by lantern slides and cinematograph films, including sound records.

Wave "Squatting" in Mexico

THE prospect of a radio "bombardment" from Mexico is now facing the U.S. Federal Radio Commission, following the announcement that Mexico has ordered a sweeping re-allocation of the wavelengths of its sixty stations. Mexico has no broadcasting channels regularly assigned to it, having been unable to reach an agreement with the U.S. and Canada. The result is that for several years the Mexican stations have been "squatting" on wavelengths allocated to more than a hundred stations in the U.S.

Listen to Warsaw

MR. THAD ORDON, who broadcasts frequently in English from Warsaw, has begun a "radio mail box" for British listeners. Letters received will be answered once a month at the Warsaw microphone. The time-table of the "Warsaw Radio Mail Box" will appear in *The Wireless World*.

New Radio Menace

MARSEILLES, home of tall stories, is the origin of a fine radio yarn. It appears that when gangsters recently attacked an elderly man in his flat, the neighbours, on hearing the shrieks, imagined it to be the wireless functioning in its normal manner.

In justice to the particular make of set, it should be stated that Marseilles is noted for its man-made static.

More Money for French Radio

AN idea of France's broadcasting ambitions is furnished by the Post Office demand to Parliament for new credits. The 65,000,000 francs voted by Parliament in 1931 have been allocated to the purchase of Radio Paris and the construction of seven transmitters, namely: Villejust, Paris, 120 kW.; Tramoyes, Lyons, 100 kW.; Antibes, Côte d'Azur, 60 kW.; Realtor, Marseilles, 100 kW.; Muret, Toulouse, 120 kW.; Thouries, Rennes, 120 kW.; and Camphin, Lille, 60 kW.

The "second instalment" is required for the Paris "Radio House," studios in the provinces, and many power increases.

Whitsun "Smalls"

WITH the approach of the Whitsun holidays slight alterations are necessary in our printing arrangements. Miscellaneous advertisements intended for *The Wireless World* of May 25th should reach the offices of the Publishers not later than first post on Friday, May 18th.

SPEED BOAT RADIO. Dashboard-operated wireless sets will be included in the equipment of many speed boats this summer. This photograph, taken on a Yorkshire cruising ground, shows how the radio can be manipulated from the steering wheel. The loud speaker is on the left.