An A. C. Receiver and Power Amplifier

Design and Assembly of a New High Quality Amplifier Operating from Alternating Current Together with a High-Efficiency Four-Tube Receiver with an A. C. Plate Supply

By JAMES MILLEN

IT HAS been suggested by a number of radio authorities that one of the essentials for good audio quality is high plate voltage. The most practical way in which to obtain this high plate voltage is from a current-tap operated from the a. c. electric light socket. Such a system also permits lighting the filament of the last tube with a. c., so that the use of a 5-watt power tube for this purpose is made possible.

Until now, the construction of a quality audio amplifier which would operate from the a. c. line has been almost impossible as many of the essential parts were unobtainable in the open market.

Realizing the advantages of an amplifier which would require neither A, B, or C batteries, and which at the same time would give amplification with an unusually high quality, RADIO BROADCAST has done much experimental work in order to determine the best design for the parts required.

Regardless of how fine an amplifier one has, if the loud speaker is poor, the received signal will probably sound no better, if as good, as from a poor amplifier connected to the same poor speaker. A number of good speakers are now obtainable on the radio market. Of particular merit are the cones.

In order to obtain quality output with a quality speaker, it is necessary that all the apparatus along the line be of high quality. The broadcasting station must produce high quality signals, the receiver must supply the power amplifier with high quality input and so on to the speaker.

In this paper will be described the construction of a complete receiver operated mainly from the lamp socket. The receiver employs one stage of radio frequency amplification with a regenerative detector, and an audio-frequency amplifier embodying all the requirements for high quality.

The requirements are: 1. Use proper value of C battery for the signal voltage at the grid of each tube. 2. Use plate voltage which corresponds to this C voltage. 3. Use transformers with proper primary inductances. 4. Use a. f. by-pass condensers. 5. Cable filament and plate leads. 6. Burn tubes so as to secure proper electron emission. 7. Employ an output device to keep the d. c. component of the space current on the last tube from flowing through the loud speaker.

RADIO constructors are watching with eagle eye to see what the fall season brings out in new design. The receiver and power amplifier described here so completely by Mr. Millen combines ideas far in the forefront of radio progress. The audio amplifier is a particularly interesting bit of design. Mr. Crom's article in RADIO BROADCAST *for October, 1925, laid down some theories of the audio amplifier and Mr. Millen's design puts his suggestion into definite form. And—perhaps most important of all—the plate supply of the entire receiver is drawn from alternating current; and in addition, the filament of the power amplifier is heated by A.C. The quality of the received signal, using this set-up with a cone type loud speaker, is almost beyond reproach.*—THE EDITOR.

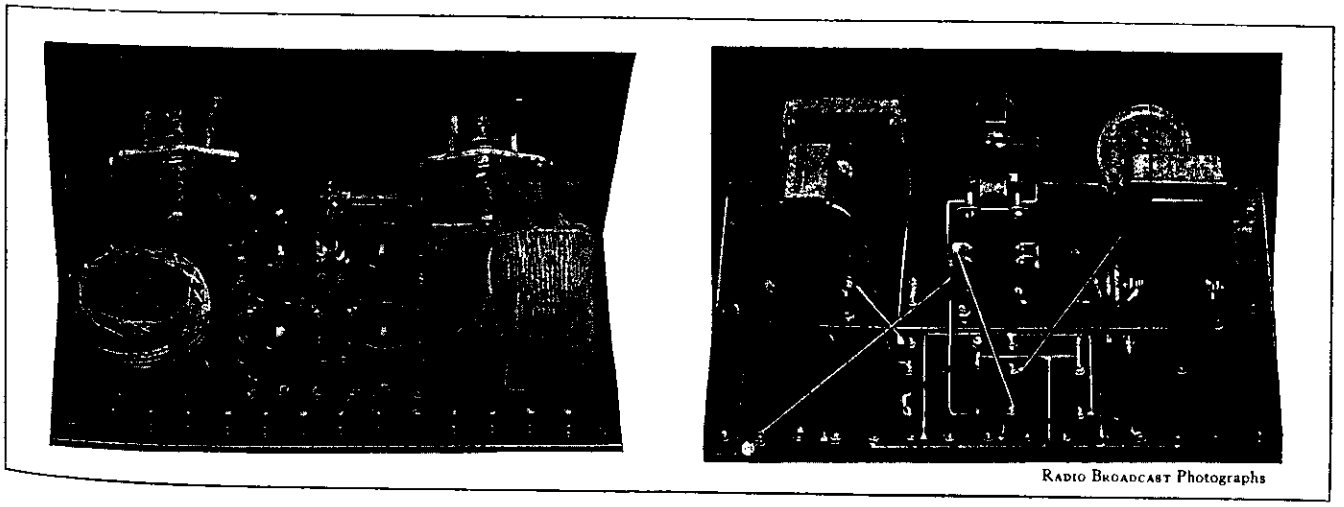
Since many of the readers of RADIO BROADCAST already have receivers of various kinds which they do not care to change, the construction of a power amplifier and power supply unit which will enable them to improve their present outfit will also be described.

The quality of output that will be obtained from the power amplifier does not materially differ from that obtained from a good resistance-coupled amplifier with a low impedance tube (so as better to match impedance of the cone type speakers) in the last stage. The main difference is that one power stage will do what three resistance stages will, and at the same time eliminate the batteries.

As the two tubes in a push pull amplifier are operated 180° out of phase, distortion due to insufficient C and B voltage cancels out, and good quality is thus obtained with low voltage.

THE CONSTRUCTION OF A KNOCKOUT SET WITH QUALITY POWER AUDIO AMPLIFICATION

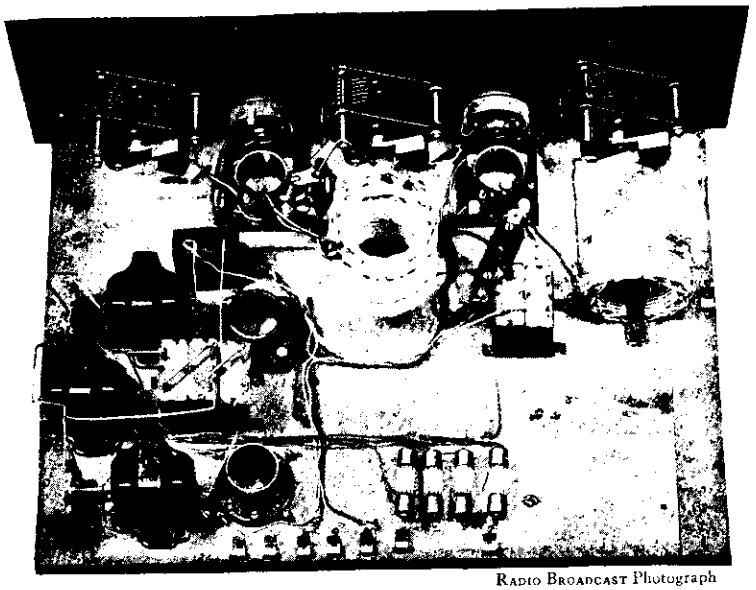
THE set proper employs the standard Roberts Knockout circuit. The writer made a number of experimental models and in some, reflexed the first audio through the radio tube. The sets shown in Figs. 1, 2, and 3 are not reflexed, and, though the elimination of the reflex requires an additional tube, such a set will give more volume without danger of overloading the first audio tube, which may happen with the reflex model on loud signals.



RADIO BROADCAST Photographs

FIGS. 1 AND 2

Fig. 1 (Top of sub-base views), The receiving set with power amplifier. The a. c. power supply unit is contained in a separate cabinet. Fig. 2 (Under sub-base) Note the output transformer, which serves the double purpose of keeping the d.c. component of the plate current out of the loud speaker and making possible the use of a low impedance speaker



RADIO BROADCAST Photograph

FIG. 3

An experimental receiver with a high quality audio amplifier. Audio frequency by-pass condensers, an output transformer, and high C and B voltages are employed. The power supply unit is contained in a separate cabinet, but in order to reduce the number of leads between the power unit and the set, the voltage dividing resistors are mounted in the set as shown

The only batteries required with this set are one small $4\frac{1}{2}$-volt C battery and three dry cells.

The first three tubes may be three-, one and a half-, or five-volt. Although the amplification obtained with the smaller tubes is somewhat less than that obtainable with storage battery tubes, there are several advantages to be gained by the use of the small tubes. *First*, the maximum output obtained from the small tubes will not be great enough to overload the power tube and thus cause it to distort. In other words, in order not to overload the power tube, the maximum signal voltage applied to the grid of this tube must not be greater than the C battery voltage. In this amplifier, therefore, a signal voltage in excess of about 22 to 24 volts (with a UV-202 or 27-28 volts with UX-210) will very likely cause distortion. As most of the input transformers, which are recommended for use with the last stage in this amplifier, have a ratio of 2:1, the output signal voltage from the first audio stage should not exceed 12 volts. Measurements made in the RADIO BROADCAST Laboratory showed that output peak signal voltages (measured with a vacuum tube voltmeter) obtained from the first audio tube using a UV-199 were never likely to exceed the 12-volt limit.

Should overloading take place in your amplifier, it will readily be detected by the plate circuit milliameter needle movement as described by Mr. Crom in his article in the October RADIO BROADCAST. In order to remedy the trouble, connect a variable resistance, such as Bradleyohm No. 10, a Clarostat, Royalty No. B, or similar resistance across the secondary of the first audio transformer and adjust it until the distortion is eliminated. The effect of this resistance is to reduce the signal voltage which will be applied to the grid of the last tube and incidentally that which will be applied to the grid of the first tube. If this resistance were connected across the secondary of the second transformer, it would accomplish the same results, as far as the power tube is concerned, but it would not have eased the load on the first audio frequency tube, and, as this amplifier has been designed so that overloading (when three volt tubes are used) will start in the first stage slightly before (if at all) it will in the

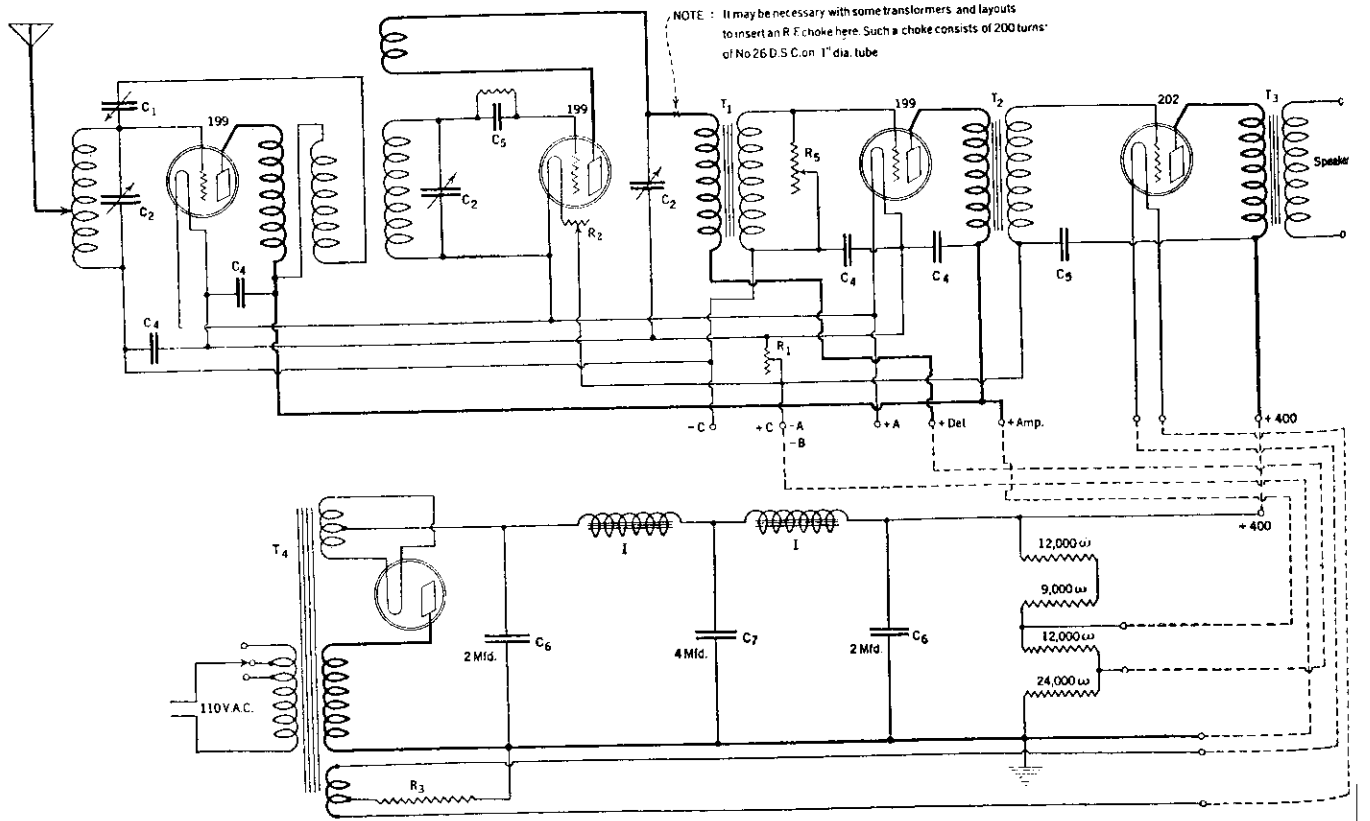


FIG. 4

The circuit diagram of the complete receiver

power stage, the proper way is to reduce the load on all tubes by means of a resistance across the first transformer secondary. Such a variable resistance also serves as an excellent volume control.

Instead of the variable tickler to control the regenerative detector, frequently in a receiver employing a circuit of this sort a fixed tickler and variable by-pass condenser are employed. With this arrangement, the tuning of the detector condenser is not affected by the regeneration control.

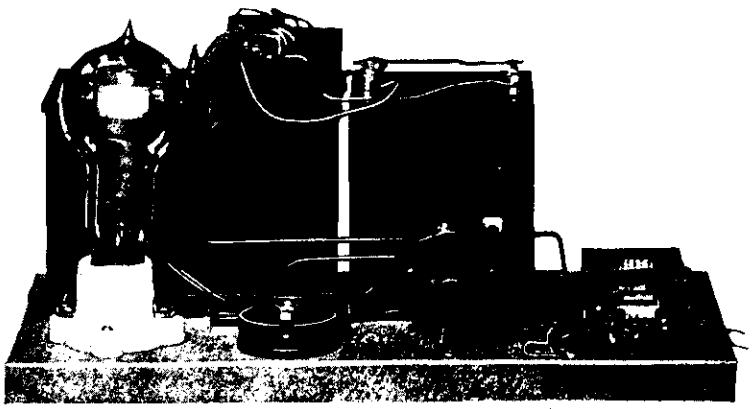
Another satisfactory method of controlling regeneration when a fixed tickler is employed, is by means of a variable resistance connected across the tickler coil.

The coils may be the standard coils made for the Roberts circuit, such as the Supercoils, Sickles diamond weave, etc., or they may be home made. The two tuning condensers have a maximum capacity of .0005 mfd., and with the coils described above cover a frequency range of from 1363 to 545 kilocycles (220-550 meters). A rheostat is provided for the detector and another for the two amplifier (r. f. and a. f.) tubes.

If three-volt tubes are to be used (and their use is highly recommended) it will be better to use them in sockets designed for them rather than using adapters in large sockets, as shown in the photographs.

All filament and plate leads are "cabled." Furthermore, large by-pass condensers are provided in all the amplifier circuits.

As the construction, neutralization, and operation of sets with neutralized r. f. amplifiers and regenerative detectors has been dealt with so many times in previous issues of RADIO BROADCAST, the subject will not be further discussed here. Those who are not already familiar with circuits of this type are referred to the article by Mr. Keith Henney in the April, 1925, RADIO BROADCAST or to any of the articles by Mr. J. B. Brennan.



RADIO BROADCAST Photograph

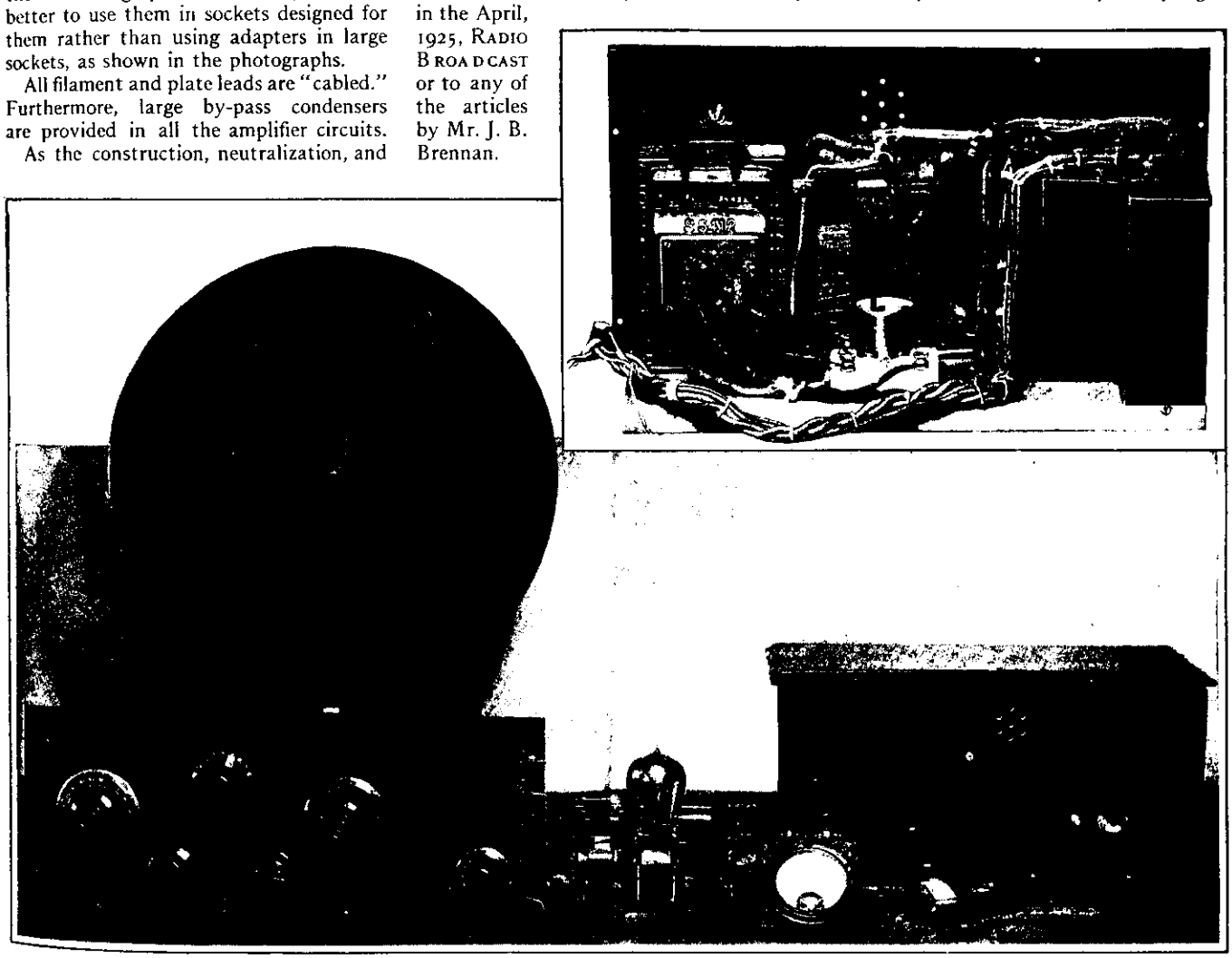
FIG. 5

A power supply unit employing an S tube as a rectifier. The transformer and the chokes are contained in separate iron boxes with bakelite panels

THE POWER AMPLIFIER

THE necessary components of the power amplifier are input transformer, power tube, by-pass condensers, and output transformer.

The input transformers may be any high-



RADIO BROADCAST Photograph

FIGS. 6 AND 7

Interior of the power supply unit shown in Fig. 7 is in the insert at the upper right. The large photograph shows an experimental layout with the high-quality amplifier and power supply unit connected to a two-tube Knockout receiver. An impedance-capacity output device is employed in the amplifier

grade low ratio audio transformer. Those successfully tried out by the writer in his amplifier were Rauland Lyric, Amertran ($3\frac{1}{2}$:1), and General Radio No.285A. They should have a turn ratio of from 2 to $3\frac{1}{2}$ to 1, not higher.

The power tube may be a UV-202 or a UX-210.

The UX-210 and the UV-202 operate from the transformers without rheostats. The UV-202 is most easily obtained by writing direct to Amateur Sales Division Radio Corporation of America, 233 Broadway, New York. It sells for $3.50. The UX-210 lists at $9.00 and is obtained from any Radio Corporation or Cunningham dealer.

Several of the independent tube manufacturers are now making power tubes with 5-volt filaments. Double rheostats, as shown in Fig. 13, will have to be used with them.

The grid return condenser may be any of the paper condensers. About one mfd. is a satisfactory size. The plate by-pass condenser, however, must be capable of continuously withstanding the full plate voltage (about 400 volts). Most of the small paper condensers, such as the No. 765 Dubilier, will not stand up when put to this use. The Dubilier No. 769, W. E., Tobe, Acme No. 750 volt, or four of the lower voltage condensers connected in a series-parallel arrangement will be necessary.

The output device serves two purposes. The first is that it keeps the direct current from going through the speaker, and, second, it "matches" impedances. Thus, if a transformer is used the primary must have the proper impedance to work with the power tube and the secondary must be designed to fit the speaker. The plate impedance of the power tubes available for use in the set is the same. The impedances of some of the high-grade loud speakers, however, are quite different, and they may be grouped into two classes, high and low impedance. The Western Electric cone is a low impedance speaker, whereas the Farrand-Godley has a high impedance. Therefore, in purchasing an output transformer, the type of speaker that it is to be used with must be kept in mind.

Some constructors may have a pair of push-pull transformers on hand. An output push-pull transformer can be used as an output transformer for the amplifier. The mid tap on the primary should be disregarded and the plate of the power tube connected to one of the terminals marked P (or plate) and the plus B to the other terminal marked P (or plate). The loud speaker (which, for most push-pull transformers, excepting the Western Electric, should be of fairly high impedance) is connected to the "output" or "speaker" posts.

There is another method of connecting the loud speaker which does not require a transformer. It is illustrated in Fig. 12, and employed in the amplifier shown in Fig. 6. The "Amerchoke" and the Thordarson Autoformer make ideal impedances for this use.

When these parts have been wired up as shown in Figs. 11 and 12 the receiver itself is complete. There then remains the construction of the power unit for operating it from the house current.

CONSTRUCTION OF POWER UNIT

THE power unit is merely an "overgrown" B-substitute with an additional transformer winding. The rectifying device should be either a thermionic or an S tube. Both have been very successfully employed. The parts required for the construction of the power unit are transformer, tube and socket, chokes, condensers, and resistance units.

Transformers suitable for this purpose are the General Radio, Amertran, Acme, Dongan, and Jefferson. A suitable transformer must have at least one 7.5-volt secondary (with mid tap), and at least one 450- to 500-volt winding.

The transformer must also have a 110-volt primary, or better yet, have taps to take care of variations in line voltage from 105 to 120. If a thermionic tube (Kenotron, UV-202, UX-210, UX-216B) is to be employed as a rectifier, then two 7.5-volt windings will be required. An S tube has no filament and, consequently, requires no filament heating winding.

Either double- or single-wave rectification may be employed. Both give excellent results, but the double-wave rectifier has the advantage of not requiring quite as elaborate a filter system as the single wave. However, for double wave rectification two rectifying tubes are required and two high-voltage transformer secondaries.

The power supply units described in this paper are of the single-wave rectification type, requiring but one rectifier tube and one high-voltage transformer secondary. The transformer should be rated at about 50 watts.

If a power tube (UV-202, UX-210, etc.) is employed as the rectifier, it is highly important that the grid and plate be connected together. The Kenotron, UV-216, which is the same as a UV-202 but designed only for rectifying and, therefore, having no grid, may be obtained from the Amateur Sales Division, Radio Corporation of America, 233 Broadway, New York. The UX-216 B, which is the rectifier patterned after the UX-210, is carried by all R. C. A. and Cunningham dealers.

Two chokes of about 50 henries each are required for the filter system. They must be designed for a total current of about 30 milliamperes and have as low a d. c. resistance as is economically practical. Such chokes may be obtained from Amertran, Jefferson, Dongan, Molliformer, Apco, or General Radio Companies, or they may be made at home as described by the writer in the June and October issues of RADIO BROADCAST.

The filter condensers must be capable of continuously withstanding the high voltage. There is generally quite a difference between "flash" voltage and "Maximum working" d. c. voltage. It is this last rating that is important and it must be at least 500 and preferably 750 volts in order to be satisfactory for use in the filter. Condensers which meet this requirement are manufactured by Dubilier (No. 769

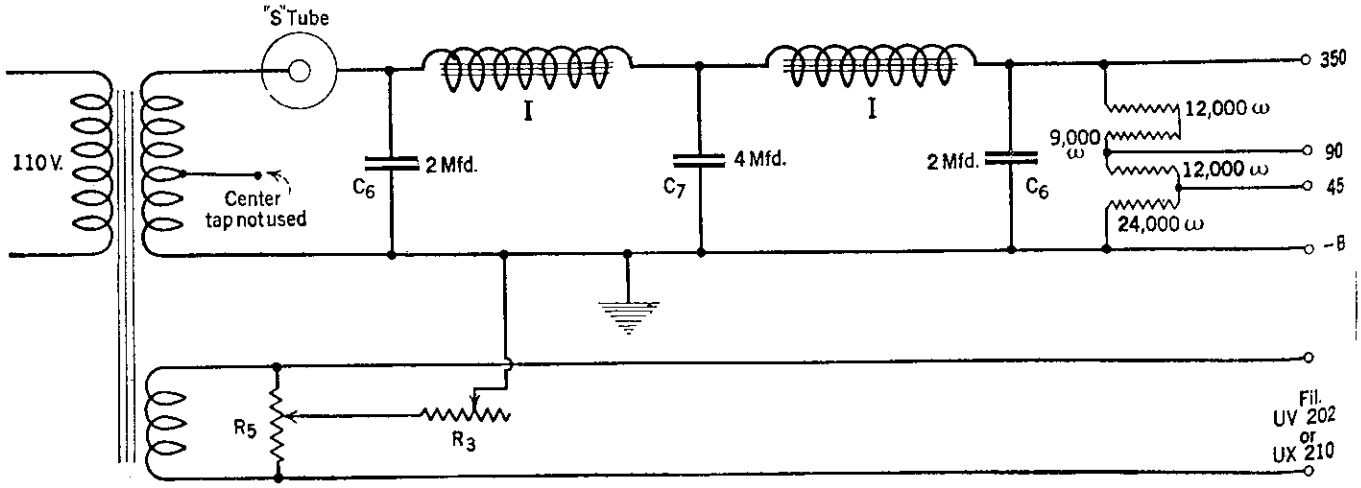


FIG. 8

The circuit diagram of the power supply unit shown in Fig. 5

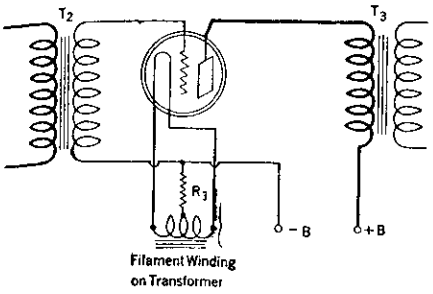


FIG. 9

The C bias is obtained by means of the voltage drop across the resistance R_3

but not No. 765), Acme, Tobe Dutschmann and Western Electric. W. E. condensers may be obtained from C. E. Jacobs, 2802 N. Kedzie Ave., Chicago.

Several resistance units are required in order to secure the proper B voltages for the detector, r. f. tube, and first a. f. tube as well as the negative C voltage for the grid of the power tube. The values and connections for these units are indicated in Figs. 4 and 8. They may be of Ward-Leonard, Crescent, or Allen-Bradley make.

In place of the fixed 1250-ohm unit employed for obtaining the proper negative bias on the power tube, a C battery of about 22½ volts (for UV-202 or 28 volts for UX-210) may be employed. The voltage should in that case be adjusted for best results as indicated by the milliammeter tests outlined by Mr. Crom in RADIO BROADCAST for October.

Another way of varying the negative bias to the power tube which does not require a separate C battery, is the use of a variable resistance such as the Clarostat or Electrad Royal. We believe this to be the best method, as the proper C bias may be obtained by varying the resistance while observing the plate milliammeter.

The power supply unit is generally most conveniently located under the table on which the set is placed. The several leads from the power unit to the set should be "bundled" together into a cable; one of the standard battery cables such as the Jones or Belden may be used for the purpose. The 110-volt a. c. cord is thus kept a fair distance away from the set proper. This is of slightly more importance in reflexed sets.

If the power unit is placed in a cabinet, such as the one in Fig. 7, it is important to provide proper ventilation so that the heat generated by the rectifier tube will be dissipated. The plate milliammeter (0-50 m. a.) may also be conveniently located if desired, on the panel of the power supply unit. This is also a good place for the 110-volt switch.

COST OF MATERIAL

Used in the Complete Receiver

	MAXIMUM PRICE
The Receiver	
Panel	
Base Board	
3 General Radio, Silver, Hammarlund, or other good condensers, max. cap. 500 mmfd.	$15.00
3 Dials	
1 Set Robert Coils	8.00
1 A. F. Transformer T_1 (*1 General Radio, No. 285, $6; 1 Amertran No. AF 6, $7*).	
1 Neutralizing Condenser C_1	
3 Sockets	
2 Rheostats R_1 and R_2	
1 Volume Control R_4 (*Clarostat, $2.25; Bradleyohm No. 10, $2.00; Royalty (Electrad) No. B, $1.50*)	
1 Grid Condenser and Leak C_6	
4 1 mfd. By-pass Condensers C_4	5.00
The Power Amplifier	
Input Transformer T_2 (*General Radio, No. 285-A, $6; Amertran, No. A F 7, $7*).	
Output Device	
General Radio Transformer No. 367, T_3 (for W. E. Cone)	7.00
Output push-pull transformer (for high Impedance Speakers) or	
Impedance-Output (for either high or low Impedance Speakers), *Thordarson Auto-former I, $5; Amer-choke No. 154, I, $6; 1-4 mfd. condenser* (or total of 4 mfd., $5).	
Socket	
1 Mfd. By-pass Condenser C_5 (*Tobe Deutschmann, $1.25; Dubilier No. 678, $1.75*).	
Power Supply Unit	
Power Transformer T_4 (*Amertran No. PF 45, $12; General Radio No. 365* (for "S" tube), *$12; General Radio No. 273M* (Additional filament winding for rectifier tube,) *$12*).	
Chokes L (*2 Amer-chokes No. 854 at $6, $12; 2 Molliformers at $6, $12; 2 apco chokes at $6, $12; 1 General Radio double choke No. 366, $12*).	
Filter Condensers (500 volt) C_6, C_7, (*4 Dubilier No. 764, $3.50, $14; 4 Tobe Deutschmann No. 709 2 mfd., $1.75, $7; 4 W. E. 2 mfd., $1.65, $6.60*).	
Socket	
Milliammeter (0.25 m.a.), (*Jewel, Weston, $8.*)	
Jones Cable (or Belden)	1.00
Resistance Units (*Bradley Units, 2 12,000 ohms; 1 10,000 ohms; 1 25,000 ohms, $.75 each; Ward Leonard H S Units; Crescent, 2 12,000 ohms; 1 9,000 ohms; 1 24,000 ohms, $2.50 each (All special) $10*).	
Grid Bias Resistance R_3 (*Ward Leonard (fixed) (L S 1250), $.85; Clarostat, $2.25; Royalty, $1.50*).	
Tubes	
UX 210	9.00
UV 202	3.50
KENOTRON	3.00
RECTRON 216B	7.50
Speaker	
Switches, Screws, Lamp Cord and Plug, Box or Base Board for Power Supply Unit.	
The completed receiver, including tubes but not speaker, will cost approximately $100.	

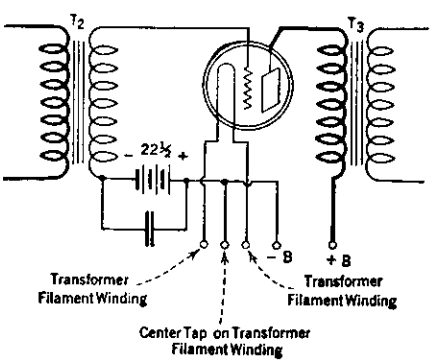


FIG. 10

A C battery may be employed with the power amplifier, if desired, instead of obtaining the grid bias from the power supply unit

OPERATION OF THE SET

AS THE operation and neutralization of receivers employing this circuit have been covered in a number of previous articles in RADIO BROADCAST, they will not be taken up again.

The adjustment of the power amplifier, however, will no doubt present some new problems to many of the readers. The filaments of both the power amplifier and the rectifier tubes must be operated at exactly the right voltage. This is particularly true of the UV-202 when used as an amplifier. If the filament voltage is too low, it will cause a great deal of distortion. On the other hand, if it is too high, the life of the tube will be materially shortened. The filament voltage of the 210 is not as critical as the 202. Ordinarily the only way to adjust the filament voltage properly is with an a. c. voltmeter, but the use of such an instrument will not be necessary with the transformers recommended in this article, as the voltage supplied is just right, providing sufficiently heavy wire, such as No. 16 or No. 18 flexible lamp cord or the equivalent solid wire is employed in connecting the tube socket to the filament winding on the transformer. Furthermore, the length of the filament line should preferably not exceed three feet. It is also highly important, especially with the UV-202, that the tube makes very good contact in the socket.

When a 6-volt tube is to be used, or if the Acme 75-watt c. w. transformer (which has a 10 instead of 7.5 volt filament winding) is used with either a 6- or 7½-volt tube, it is necessary to employ two rheostats, one in each filament lead; they must both be adjusted simultaneously in order that the resistance in each filament lead will be about the same. See Fig. 130.

When rheostats are employed to adjust the

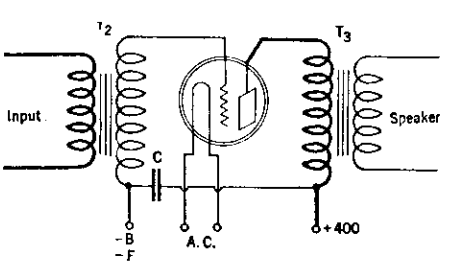


FIG. 11

The circuit diagram of the power amplifier using an output transformer

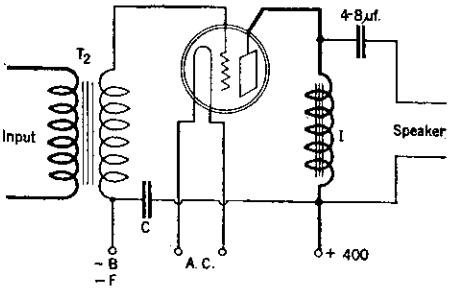


FIG. 12

The circuit diagram of the power amplifier using an impedance-capacity output device

filament voltage, it is strongly recommended that a good a. c. voltmeter be used as an aid to securing the proper adjustment. To dispense with the use of such an instrument is not economy. The life of a tube is very materially reduced when operated at higher than rated voltages.

Rheostats for this use must be capable of carrying about 2½ amperes. The resistance may be one or two ohms. Such rheostats are manufactured by Amsco, Acme, Fada, Pacent, and General Radio. If a variable resistance is employed for obtaining the grid bias, it should be adjusted so that the milliammeter in the plate circuit of the power tube remains reasonably still when receiving signals of varying intensity.

The plate current drawn by the power tube should not exceed about 20 mils. Seventeen or eighteen is about correct for most 202's and about 20 for the 210's.

If an Acme c. w. transformer is employed, it will be necessary to use an S tube as the rectifier; there being no rectifier filament winding provided on this transformer (the S tube has no filament). The No. 5000 S tube is best suited for this purpose, although the No. 4000 may be employed if desired. The No. 5000 only costs $6.50, whereas the other costs $10.00. S tubes are best obtained direct from the factory.

The voltage of one half of the split high voltage secondary on the Acme transformer is too low and the entire voltage is too high. Therefore, it is necessary to use the entire

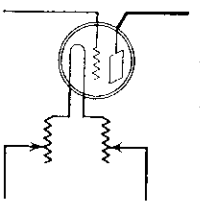


FIG. 13

The way in which rheostats must be connected when a 6-volt tube is to be operated from a higher voltage transformer winding

secondary and connect a resistance of from 5000 to 6000 ohms in series with the plus lead as shown in Fig. 14. The drop in voltage across this resistance results in the proper output voltage.

A POWER AMPLIFIER FOR YOUR RECEIVER

FIGURES 7, 11, 12, show the power amplifier, similar to the one used in the complete set, mounted on a small board by itself. The same power unit as is employed to operate the complete set (Figs. 1, 2, 3) is used to operate this amplifier as

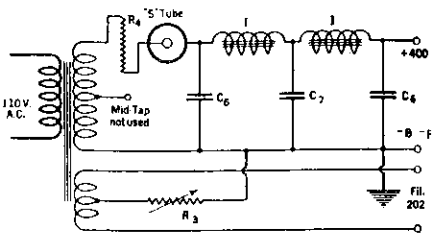


FIG. 14

Circuit diagram showing proper connections for employing a standard Acme c. w. transformer

well as supply the B voltages to the small outfit to which it is connected. Such a combination possesses most of the advantages of the complete set (for it is practically the same thing) and at the same time makes it unnecessary to discard the small set.

In most cases it will be necessary to connect a variable resistance such as a Bradleyohm No. 10, Royalty B, or Clarostat across the secondary of the reflex transformer. It is also necessary to keep the a. c. lines as far as possible from the reflex amplifier in order that a. c. "hum" will not be picked by induction, and, most important of all, ground the negative B.

Such a combination as shown in Fig. 6 results in a considerable "gain" in volume without the loss of any of the high quality for which the Roberts Knockout receiver is so well known.

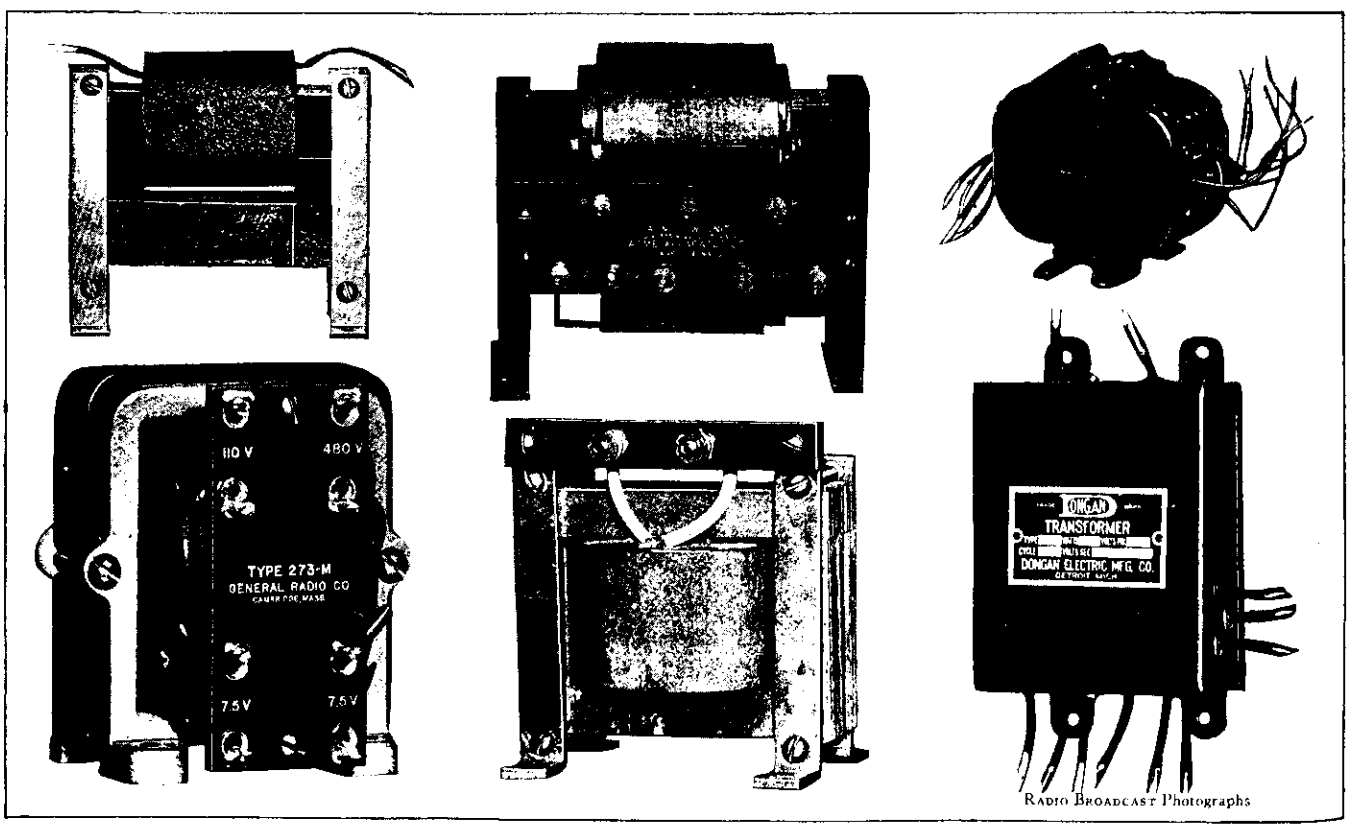


FIG. 15

There are a number of excellent transformers and chokes now obtainable in the radio market. Some which have been successfully used, but which are not shown in the other photographs, are grouped here