NATIONAL RADIO INSTITUTE

Complete Course in PRACTICAL RADIO

NRI

Radio-Trician
REG. U. S. PAT. OFF.

Lesson Text No. 24
(3rd Edition)

ALTERNATING CURRENT OPERATED RADIO RECEIVERS

Originators of Radio Home Study Courses
···Established 1914···
Washington, D. C.

THE SECOND READING

A Personal Message from J. E. Smith

One reading is insufficient, if one is going to make a real study of a work. The second reading should be slower, but not too slow. The actual speed will depend, as in the first reading, upon the character of the book, the difficulty of the subject matter, the difficulty of the style, the reader's familiarity or unfamiliarity with the material. If in doing your first reading, you are jotting down words whose meaning you do not know, these should be looked up before the second reading. If you have not followed this practice, you should have a dictionary beside you for the second reading.

BF75C51230 Printed in U.S.A

Radio-Trician's
REG. U. S. PAT. OFF.
Complete Course in Practical Radio
NATIONAL RADIO INSTITUTE WASHINGTON, D. C.

ALTERNATING CURRENT OPERATED RADIO RECEIVERS

All radio receivers may be divided into two groups. There are the various types of radio receivers you have studied in previous lessons and which are in whole or in part operated by the current from batteries. They form one group. The other is made up of receivers that do not use batteries in any form. In this lesson, we shall study the operation of the most important type of batteryless receiver, the so-called "electric" set.

The term "electric" is confusing and really means nothing because, as your studies already have shown you, all radio receivers are operated by electricity. However, the average man has been educated to accept "electric" as meaning operated directly from the current flowing from the light wires without any intermediate apparatus such as a storage battery. Strictly speaking, a battery type receiver operated by "A" and "B" eliminators is an electric receiver, but while a "B" eliminator in some form is a vital part of all electric receivers, the use of special tubes makes it possible to do away with the "A" eliminator.

And so the radio receiver we are studying is one adapted for the A. C. tubes and fitted with a "B" eliminator. The "B" eliminator is, of course, merely an extra circuit in the receiver that takes the raw alternating current from the electric light wires and converts it into smooth direct current for use in the "B" and "C" circuits of the receiver. No way has been found to operate a radio receiving circuit on raw alternating current applied to the "B" and "C" circuits, and so the "B" eliminator which actually is a rectifier and filter circuit, is an absolutely indispensable part of every electric set. Get that firmly fixed in your mind. There is no such thing as a radio receiver that uses electric light current (alternating current) as it comes from the wires in the "B" and "C" circuits.

Before we take up the detailed study of the electric receiver, it may be well to see what possible advantages there are in this type of set as compared with the battery operated receivers studied in previous lessons.

Just as single dial tuning was developed to simplify the operation of a radio receiver, so A. C. operation literally has been forced on the manufacturers of radio receivers by the insistent demand of the average radio fan for simpler, more care-free operation.

A single dial tuned receiver will not bring in any more stations or give more selectivity than a radio receiver fitted with a separate dial on every tuning condenser. Similarly, the electric set considered from the point of view of radio reception results is no better than a battery operated receiver. From a radio standpoint, battery current is ideal. All that an electric set can do is to approach as closely as possible to the practically perfect operation of an equivalent battery operated set. The modern electric set has, however, reached that ideal so far as the ear can detect.

So much for the theoretical side of the matter. In actual operation, the electric receiver has many obvious advantages. When you want to listen, you snap the switch. When you are through, snap it again. Go away for six months and when you come back there is the set all ready to give you perfect results at the snap of the switch. No batteries to run down. Nothing to require any attention whatever unless a tube goes dead or something goes out of order inside the cabinet and such possible troubles are not peculiar to electric sets. Battery type tubes go dead and battery type sets are subject to breakdowns also.

To sum up, the electric set has no advantages over a battery operated set as far as receiving is concerned, but the electric set has manifest advantages from the standpoint of simple, care-free use.

THE A. C. TUBES

At first glance, the student who has mastered the operation of the battery type receiver is likely to think that the electric receiver using the alternating current tubes is a mysterious and complicated piece of apparatus. But the mystery, like all other mysteries, fades out of the picture when you begin to understand just how the A. C. tube differs from the battery operated tube with which you are familiar. (See Fig. 1.)

As far as the essential parts of the radio-frequency, detector and audio-frequency amplifying circuits are concerned, A. C. tubes are used just like battery tubes such as the 201A. There are the same tuning inductances, variable condensers and audio transformers used in ordinary battery circuits. And these parts differ in no particular way from the similar parts used in battery operated receivers. The wiring, too, is the same except for the filament circuits, the volume control and the method of obtaining the "C" bias.

Each of these peculiarities of alternating current operation will be treated at length, but first we must find out wherein the A. C. tube differs from the ordinary battery tube, the use of which you have mastered.

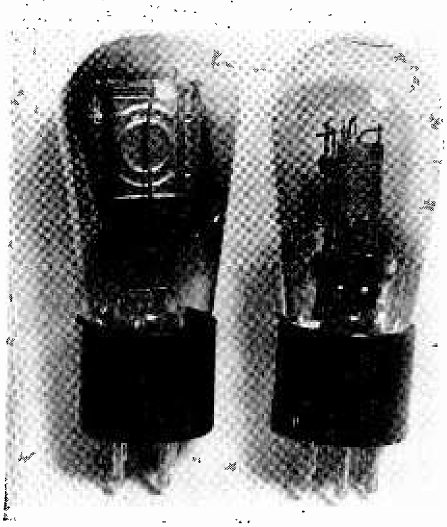


Fig. 1.—At the left is the type 226 A. C. tube which is operated by a 1½-volt A. C. current applied directly to the filament. It looks just like the 201-A battery-operated tube. At the right is the type 227 A. C. heater tube which is operated by a 2½-volt A. C. current applied to the heating filament which is inside of and insulated from the cathode from which the electron flow is obtained.

The ordinary battery operated vacuum tube has three electrodes, the plate, the grid and the filament. Just what these electrodes are for and how they work was the subject of previous Lesson Texts. In those lessons we found that the operation of the vacuum tube depends on the flow of electrons from the filament to the plate and that the function of the grid is to act as control gate to regulate the flow of these electrons. We found, also, that the "A" current which flows through the filament and heats it, performs no electrical function. If the filament could, in some way, be heated by a gas flame the tube would function.

In other words, we found that it was the heat which produced the electron flow and not the current that was passing through the filament.

Now, alternating current will heat a wire just as well as direct current. An electric soldering iron, for instance, works as well on alternating current as it does on direct current.

At this point you will quite naturally ask: If it is only the heating effect of the current that counts, why not apply alternating current to the ordinary battery tube?

As a matter of fact, you can do just that. The tube will function. The electron flow will be produced and the grid will regulate its flow to the plate. However, the experiment will not be successful because there will be a terrific humming noise from the loud-speaker.

So the problem before the scientists who developed the alternating current tube was first to find out what conditions caused the hum and then to find a way to eliminate the hum.

You can try a very simple experiment that will demonstrate quite clearly why the ordinary battery type tube will not work on alternating current. Screw a ten or fifteen watt electric light bulb in a socket supplied with alternating current. Now take some bright object such as a metal pencil or a piece of shiny wire and, while holding it so that the light glints on it, wiggle it back and forth a distance of a couple of inches, as shown in Fig. 2. You will notice that the wire seems to move in a series of tiny jumps. Try it again by candle light and the motion of the wire will seem uniform.

The flickering or jumping motion is due to the flickering of the electric light bulb. While you are moving the wire from one position to the other, the flow of the current through the filament of the lamp shifts from one direction to the other a number of times and, of course, no current flows while the voltage changes. During these extremely brief intervals when no current is flowing, the filament in the light bulb cools a trifle and the light drops off in consequence.

This is exactly what happens when you apply alternating current to the filament of a 201A tube. The temperature of the filament and consequently the flow of electrons from it increases and decreases in time with the alternations of the current.

Overcoming this flickering or pulsating effect was the chief problem in the development of the A. C. tube. It has been solved in two different ways.

One way, exemplified by the UX-226 and the CX-326 A. C.

vacuum tubes, has been to make the filament relatively very thick and heavy so that it will hold the heat and not flicker in time with the alternations of the current. (See Fig. 3.) Making the filament thicker, of course, cuts down its resistance and also makes it necessary to pass more current through it to heat it to the proper temperature. And so the 226 type tube operates on a filament voltage of 1½ and draws 1.05 amperes or slightly more than four times the current used by a 201A tube.

Other constructional details of the 226 type tube are practically the same as the 201A. The filament itself is of the same shape, an inverted V, and so are the connections to the base prongs. The 226 tube does excellent work as a radio-frequency amplifier and in the first audio stage, but it cannot be used as a detector. It could also be used in the last audio stage but as it

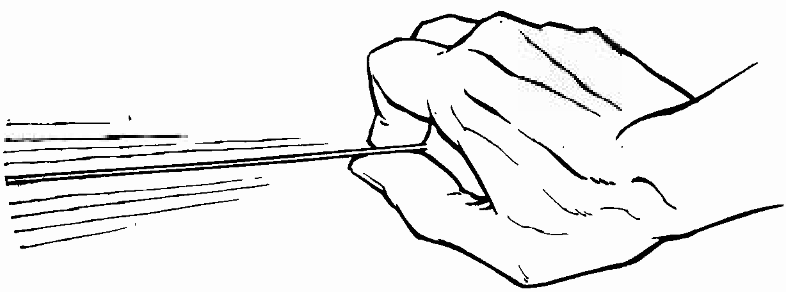


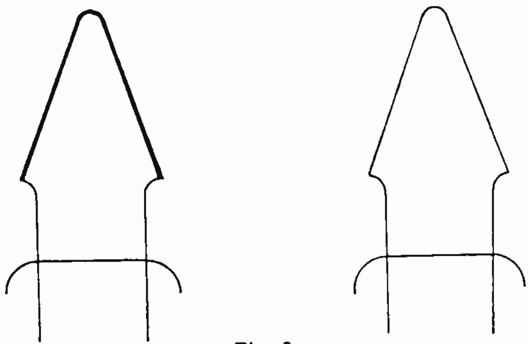
Fig. 2—Illustration showing a hand holding a thin flexible strip vibrating back and forth in front of a lamp bulb in which the filament is heated by alternating current.

would not give any better results in this stage for volume and tone quality than a 201A, it is not used in the last stage in any commercially built receiver.

THE A. C. HEATER TUBE

The detector stage of any radio receiver is, by far, the most sensitive stage in a radio receiver. Any A. C. hum introduced into the circuit at this point results in a terrific hum in the output to the loud-speaker. The type 226 tube is unsatisfactory as a detector because the residual ripple voltage that cannot quite be balanced out would cause trouble.

So the engineers have developed a still more perfect type of alternating current operated tube. The type 227 and 327 are outstanding examples. The construction of these tubes is radically different from that of the 201A. (See Fig. 4.) The plate is cylindrical and is made of fine meshed screening instead of sheet metal. The grid is a spiral of wire placed just inside the plate. Inside that is a tiny cylinder of sheet metal that is coated with oxides. This cylinder is called the cathode and emits a copious flow of electrons when heated to redness. No alternating current flows through it, however. In fact, there is no metallic connection between the cathode and the actual filament. The latter is a plain tungsten wire threaded through two extremely small holes in a tube of porcelain-like insulating material. This insulating tube is fitted inside the cylindrical cathode so that when alternating current is sent through the filament, the porcelain-like tube is heated and, in turn, communicates heat to the cathode.



Filament 226 Tube. Fig. 3. Filament 201-A Tube.

You can see that the possibility of an A. C. hum getting into a tube constructed in this way is very small. The plain tungsten heating filament, at the temperatures at which it is operated, radiates but few electrons and by establishing a positive potential on the heating filament, there can be practically no flow of electrons direct from the heating filament to the plate of the tube. All of the electron flow is produced by the cathode and this is not connected to the alternating current. This positive biasing of the heating filament will be discussed in detail later on in this lesson.

The type 227 tube operates on a filament voltage of 2.5 and draws 1.75 amperes. This low voltage and heavy current means that the heating filament is exceptionally heavy and the actual mass, consisting of the heating filament, the insulating tube and the metal cathode, causes the tube to get into action very slowly. From 15 to 45 seconds elapse from the time the current is turned on until the cathode becomes hot enough to throw off the maximum flow of electrons. Obviously, the rapid fluctuations of the alternating current cannot be reflected in corresponding changes in the heat of the cathode. In fact, so sluggish are the heat changes that you can break the 2½-volt circuit of any set using this type of tube for an appreciable length of time without causing any drop in the flow of sound from the loud-speaker.

By far the largest number of radio receivers sold today that are operated on alternating current use the type 227 tube in the detector stage. The 227 is, however, more expensive than the 226. Therefore in low priced receivers only one of them ordinarily is used.

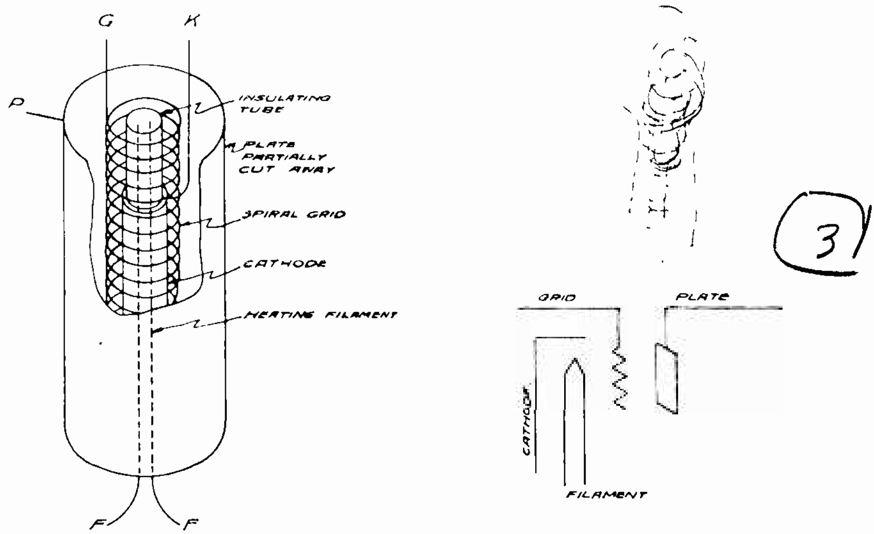


Fig. 4—Sketch showing details and symbols of AC Heater Tube (227 Type).

The 227 tube, otherwise known as the A. C. heater type, could be used in every stage of a radio receiver except, of course, the last as it is an excellent amplifier at radio and audio frequencies. Its hum-free characteristics make it even better than the 226 A. C. type as a first stage audio amplifier, and as its internal capacity is less than that of the 226 tube, it is somewhat better in the radio-frequency stages because of the lessened tendency toward oscillation.

The 226 A. C. tubes and the 227 heater type tubes are made by a number of different manufacturers and the different makes vary slightly in characteristics but these variations usually are not sufficiently great to prevent using the tubes in standard circuits. It is, however, a mighty good plan to have all the tubes of the same make as far as the radio-frequency stages are concerned as any variations in internal capacity would tend to throw the tuning out of synchronism.

Besides these two widely used tubes, there are types such as the Kellogg which is somewhat like the 227 except that instead of using a five-prong base and a socket with five holes, the Kellogg uses the standard X-type base and the heater filament terminals are brought out at the top of the tube to binding posts mounted in a cap of insulating material.

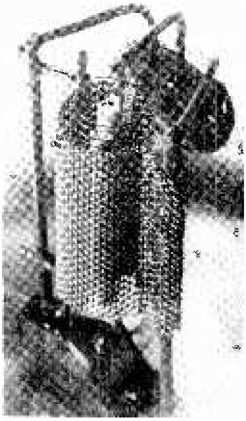


Fig. 5.—A photomicrograph of the electrodes of the type 227 A. C. heater tube (three times full size) taken through the glass of the tube. Note the wire screen plate, the spiral grid wire, the white, porcelain-like cathode insulator, at the top of which you can see the heater filament where it passes from one hole in the insulating tube to the other one.

Then there is another heater type tube known as the Arcturus.

This tube fits the standard X-type socket. This result is accomplished by connecting the cathode to one end of the heating filament.

Doubtless other types of alternating current tubes will appear on the market from time to time but it seems safe to predict that they will, in principle, be like the ones described.

POWER AND RECTIFIER TUBES

All alternating current operated receivers make use of power tubes and rectifier tubes as well as one or both of the strictly alternating current tubes described, which we have discussed under the type numbers 226 and 227.

We need not spend much time on the power tubes because you are already familiar with them in battery circuits. No special tubes have been found necessary in the last audio stage. The regular battery type power tubes will do very nicely when their filaments are supplied with alternating current at the same voltages required when direct current from batteries is used.

The type 171A tube is most widely used. It is always to be found in the last audio stage of the lower priced receivers. Two 171A tubes in a push-pull circuit are used in some receivers and more expensive sets use the 210 or even the 250.

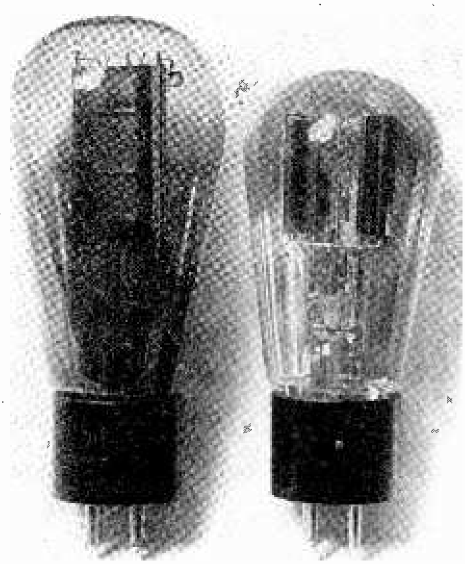


Fig. 6.—At the left is the type 281 heavy-duty, half-wave rectifier. It contains but two electrodes, the conventionally shaped plate and a heavy filament that is looped back and forth in the shape of an inverted W. At the right is the type 280 full-wave rectifier which is fitted with two plates and two filaments. The latter are connected in series.

The rectifier tubes are, of course, used in the "B" voltage supply circuits of the alternating current receivers. Three types are in common use.

THE GAS RECTIFIER TUBE

When the air in a closed vessel is partly pumped out with only a relatively few air molecules remaining, these molecules will become ionized if a high voltage is applied across two electrodes inside the vessel or glass container.

While air in its ordinary state is an almost perfect insulator, when it is ionized, it becomes a fair conductor owing to the countless number of electrons on which the current can, so to speak, ride from one electrode to the other. Now, if you make one electrode quite large and the other one very small, the current will flow much more easily in one direction than the other because many more of the flying electrons will hit the larger plate than will hit the smaller one. By a proper choice of the gas, this effect can be greatly magnified so that current in usable quantities can be passed from one electrode to the other.

This, briefly, is the principle on which the Raytheon and other similar rectifier tubes operate. (See Fig. 7.) The glass bulb is fitted with a large electrode that fits like a soldier's "tin hat" over two small electrodes that are merely wire ends. When the small electrodes are connected to the terminals of a high voltage winding on a transformer, a direct current will flow through a wire connecting the large electrode or plate and the center terminal of the winding. This direct current will, of course, be a pulsating one not suitable for "B" supply until it is smoothed out by means of a filter circuit.

The Raytheon Type BH rectifier tube and other similar tubes are operated for maximum output from a transformer winding that develops 350 volts on each side of the center tap, and the maximum current that can be drawn is 125 milliamperes. This output is more than sufficient to run any radio receiver using up to ten tubes with a 171A push-pull stage.

THE FILAMENT TYPE RECTIFIER TUBES

As you learned in a previous Lesson, a current will flow in only one direction in a vacuum tube. If an alternating current is applied across the plate and filament terminals while the filament itself is heated from an independent source of current, no flow of current will take place when the voltage is in one direction during one-half of the cycle. During the other half of the cycle, current will flow and the tube will, therefore, convert alternating current into pulsating direct current.

This is exactly the action that takes place in the type 281 half-wave rectifier tube which is used in the A. C. receivers that employ either a 210 or 250 tube in the last audio stage.

The type 281 half-wave rectifier tube has a filament that operates on 7.5 volts A. C. and draws 1.25 amperes. The maximum voltage which can safely be applied to the plate is 750 volts A. C., but in practice, usually not over 600 volts are applied. The maximum direct current output is 110 milliamperes.

We mention the type 281 half-wave rectifier tube first because it is the simplest possible type of rectifier tube. It has only two electrodes, the filament and the plate.

A far more widely used tube is the type 280 filament type full-wave rectifier tube. (See Fig. 8.) In construction it is much like the type 281. It has, however, two plates and two separate filaments. The two plates, each with an inverted V filament strung up inside, are mounted side by side and the two filaments are connected in series. In operation the current flows between one plate and the filament inside it during one-half of the cycle and between the other plate and filament during the other half of the cycle. The filament operates on 5 volts A. C.

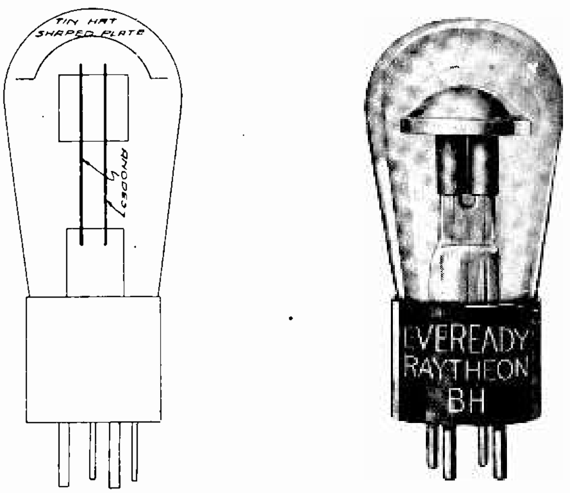


Fig. 7—Drawing and photo showing details of Raytheon Type BH Rectifier Tube.

and draws 2 amperes. The maximum safe voltage per plate is 350 and the combined output of the pair of plates and filaments is 125 milliamperes of pulsating direct current. From the output rating, you can see that the type 280 filament rectifier tube and the type BH gaseous rectifier tube have the same current output and for that reason any receiver that can be operated with one could be designed to operate the other.

When the "B" current and voltage requirements are greater than the capacity of either the type 280 full-wave rectifier or the type 281 half-wave rectifier, it is customary to connect two type 281 half-wave tubes with the filaments in parallel and apply up to 600 volts to each plate from a center tapped 1200-volt winding and in this way secure full-wave rectification. Such a circuit will supply up to 220 milliamperes at an actual working voltage of

500. This amount of current will take care of two type 250 power tubes in the push-pull circuit, supply all "B" and "C" current for any receiver, and in addition, supply 40 or 50 milliamperes to energize the field winding of a dynamic loud-speaker.

A CURRENT FOR A. C. TUBES

Perhaps the most valuable characteristic of alternating current is that you can take it at any voltage and by a simple piece of apparatus containing no moving parts, step it up to any desired higher voltage, or down to any wanted lower voltage. This you cannot do with direct current unless you employ an expensive motor-generator or rotary converter. That is why the use of alternating current is steadily increasing, while the use of direct current is largely confined to small, isolated power plants and to a few large cities where direct current was in use before alternating current became a practical possibility.

Stepping the voltage of alternating current either up or down is accomplished by means of a piece of apparatus known as a transformer. You already are familiar with it as the audio transformer used in each stage of a transformer coupled audio amplifier. It consists of a laminated iron core with two or more coils of wire wound around one leg of the core. One coil is connected to the source of current. This is called the primary. The other coil is called the secondary, and from its terminals, a current may be drawn, the voltage and amperage of which will depend on the size of the core, the number of turns in the primary and the number in the secondary. If the core is of adequate size, the voltage induced in the secondary winding will be in proportion to the number of turns in the primary as compared with the number of turns in the secondary. If, for example, the secondary has twice as many turns as the primary, the voltage developed will be twice the voltage applied to the primary. If half the number of turns, the voltage will be one-half and so on.

You must get clearly fixed in your mind that an alternating current transformer does not increase the total power. That would be impossible. When the voltage is stepped up, the output current is cut down. When the voltage is lowered, the output current is increased. The voltage applied to the primary, multiplied by the amperes flowing in the primary winding, always is a trifle greater than the voltage developed in the secondary multiplied by the current in amperes that can be drawn from the secondary winding. Remember this simple relation because it will enable you to figure out the current drawn from the light line for any electric receiver if you know how much "A" and "B" current is used in the set and the voltages.

From this discussion of alternating current transformers, you can see how the necessary low voltage alternating current required by the tubes we have discussed can be obtained.

Transformers with a winding suitable for connection to 110-volt alternating current are constructed with a secondary winding that will deliver the required low voltages.

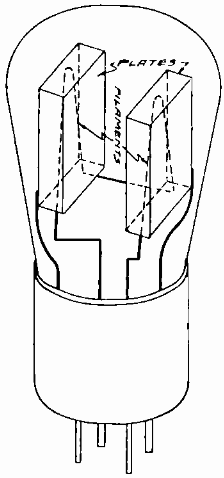


Fig. 8—An exposed view of the filaments and plates of a 280 filament type full-wave Rectifier Tube.

As a large number of electric receivers use types 226, 227, 171A and 280 tubes, four different low voltages are needed, and several secondary windings are placed on the same core. Each of these windings must be separate and distinct from all of the other windings and most carefully insulated from them. Each of these windings, except the 1½-volt winding that is to supply the 226 tubes, must have a tap brought out from the exact electrical center of the winding.

"B" CURRENT FOR A. C. RECEIVERS

We have seen that it is possible to use a transformer to step up the voltage as well as to step it down and these two functions can be performed by the same transformer. It is common practice to do this in electric receivers. In addition to the low voltage windings already mentioned, a high voltage secondary winding is placed on the same transformer. This ordinarily has about five to six times as many turns as the primary and is center-tapped so that there is available from 250 to 300 volts alternating current on each side of the center tap.

This high voltage alternating current is first rectified into a pulsating direct current, then sent through a filter circuit consisting of chokes and condensers to take out the pulsations and smooth it into usable direct current, and after that it is applied to a resistance network to cut the voltage down to the amount required for each of the "B" circuits in the receiver.

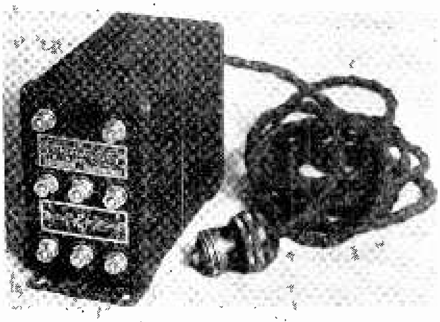


Fig. 9.—A typical filament heating transformer suitable for heating the filaments of the tubes in the conventional type of electric set. The two binding posts at the top give 1½ volts. The middle row, 2½ volts with a center tap and the lower row, 5 volts with a center tap. The size can be judged by comparing it with the electric plug beside it.

Figure 10 shows a standard circuit used to accomplish these results and we will study it very carefully because if you understand it thoroughly you will know how all "B" supply circuits work since they vary only in minor details.

At the left is a transformer such as is used in thousands of electric receivers. Note the four low-voltage windings and the high-voltage winding. The 1½ volt, 2½ volt and one of the 5-volt windings are used to supply the "A" current for the tubes in the radio receiving circuit. The remaining low-voltage (5-volt) winding is connected to the filament terminals of the socket in which the type 280 full-wave rectifier tube is inserted. The ends of the high-voltage winding are connected to the two plates of the 280 tube (the G and P binding posts of the X-type socket). As soon as the current is applied to the primary of the transformer, the twin filaments in the 280 tube heat and current starts to flow first from one plate and then the other, the center tap of the 5-volt winding always being positive with respect to the center tap of the high-voltage winding.

This high-voltage pulsating direct current first flows into and charges the condenser C1. Then it starts to flow through choke A. The choke consists of an iron core with a coil around one leg containing a large number of turns of wire. The electromagnetic action of a choke is such that it violently resists any change in the amount of current flowing through it. As long as a steady direct current flows through a choke, it offers no more resistance to the flow than would an equivalent amount of wire wound around a wooden spool, but as soon as the rate of flow starts to change, the magnetic field goes into action and does its best to prevent the change. It makes no difference to

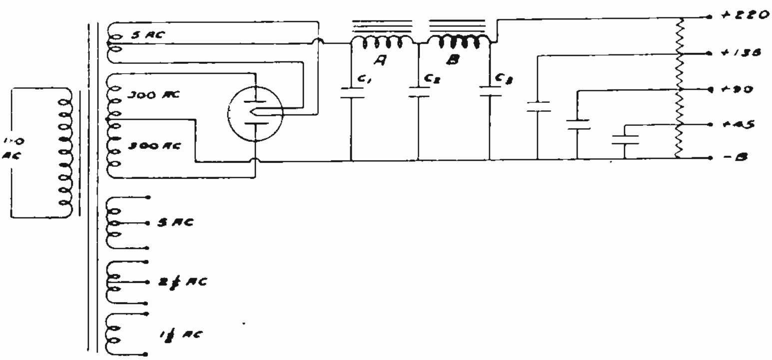


Fig. 10—Circuit diagram showing power transformer and "B" supply unit.

the choke whether you try to increase the flow or to decrease it. The choke is dead set against any change.

The choke in the world of electricity is the equivalent of the "stand-patter" in politics. He is the fellow who always is opposed to any change no matter what it is.

As a result of the opposition of choke A, the flow of current from condenser C1 into C2 is impeded and the peak voltage of the pulsation is removed. The same thing happens again as the current flows from condenser C2 into C3 because of the effect of choke B so by the time the current reaches the end of the resistance, it is practically smooth direct current.

There is nothing mysterious about the action of a filter circuit such as this. Any degree of filtering action can be obtained by increasing the capacity of condensers C1, C2 and C3 and the inductance (ability to resist change in current flow) of the chokes A and B. Of course, the larger the chokes and condensers are made, the more expensive they become, so the manufacturer of the low-priced set is forced to use the smallest chokes and the least amount of condenser capacity that will give reasonably satisfactory filtering action. From this you would expect to find that the amount of hum produced in the loudspeaker by a low-priced set would be more pronounced than that produced by a very high-grade outfit and this actually is the situation.

However, it is well to remember that elaborating the filter system beyond a certain point is not worth while even in the highest priced receivers. A lingering trace of alternating current hum always creeps into the receiver due to capacity pick-up between wires and the A. C. operation of the filament circuits.

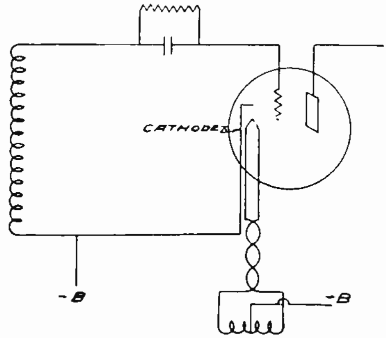


Fig. 11—Detector circuit using 227 type vacuum tube.

As long as the filter system of the "B" circuit is adequate to prevent adding appreciably to this residual hum, additional condenser capacity or the use of larger chokes would represent money spent uselessly.

OBTAINING THE VARIOUS "B" VOLTAGES

In Figure 10 you will note that after the current has passed through the filter it reaches the resistance that is used to obtain any desired voltage below the maximum.

Theoretically, the voltage measured from any point on the resistance to the minus or negative end is proportional to the resistance between that point and the negative end as compared with the value of the entire resistance. Thus, if 180 volts is applied to the ends of the resistance, a very high resistance voltmeter would register 90 volts between the negative end and the mid-point on the resistance. This is true no matter what value in ohms is the resistance of the unit that is connected across the 180-volt terminals.

In practice, however, this result is not obtained because the effect of drawing current from the taps lowers the voltage obtained below the no current voltage at that point. And the greater the resistance of the whole unit, the greater the drop will be for any given current drain.

That is why, in the "B"supply circuit diagrams you examine, you will find that the values of the resistances between the various taps do not agree with the theoretical voltage drops. The 90-volt tap is always nearer the high-voltage end than the negative end and so on.

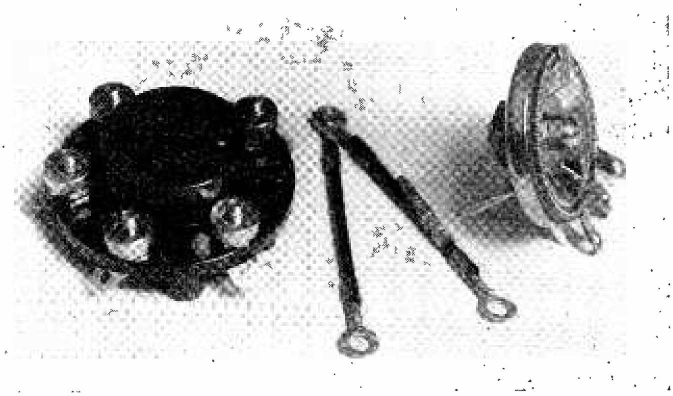


Fig. 12.—The socket at the left is the UY type which takes the type 227 A. C. heater tube. It has five holes. The one slightly separated from the others is the grid connection. At the center is an ingenious arrangement for securing a neutral grid-return for use on filament heating transformers not equipped with center tapped windings. It consists of two exactly equal wire wound resistances fastened together at one end flexible enough so that it can be fitted to the filament terminals of any socket. At the right is a low resistance potentiometer designed for use in balancing out the hum on the 226-type tubes.

You will note that a condenser always is connected between each voltage tap and the negative end. These act as small current reservoirs and steady the voltage. Without them, the tone quality would be affected, especially on the low notes, and the radio-frequency stages would have an uncontrollable tendency to oscillate because each voltage change in any stage would be impressed on the other stages.

All "B" supply circuits are, in principle, exactly like the one in Fig. 10, so that once you have mastered what goes on in this circuit, you will have a good working knowledge of all others. Sometimes only one large choke is used and all sorts of variations exist in the resistance network. You will find by a careful study, other resistance arrangements are merely different paths to the same goal—the matter of obtaining lower voltage by putting a resistance in the path of the current.

OBTAINING "C" BIAS IN ELECTRIC RECEIVERS

In your study of battery operated radio receiving circuits, you have found that the grid circuit, which is connected to the grid of the tube, has its other end always connected to one side of the filament, either directly to the filament terminal of the socket or by way of the filament wiring.

In electric receivers, the same procedure may be followed only with the detector tube which is of the type 227 heater variety. However, the grid-return wire in this case is connected to the cathode terminal as the cathode supplies the electron flow, and not the filament which is merely a heating element and takes no part in the action of the tube. The cathode also is connected to minus B. By this arrangement, the conventional grid leak and grid condenser can be used. Figure 11 shows a type 227 tube in a detector circuit. Note that the center tap of the filament transformer secondary is connected to —B terminal so as to place a difference of potential between the cathode and filament to minimize hum.

With tubes such as the type 226 used in the radio and first audio amplifier stages, and the type 171A used in the last audio stage, where the electron emitting filament has alternating current passing through it, the grid-return must be made to the filament at a point where there is no alternating current voltage. A center tap on the 5-volt winding that furnishes current for the 171A tube supplies the required no voltage point for this tube.

In the case of the 226 tubes, however, it is necessary to use a potentiometer in order to obtain an adjustable center point on the 1½-volt winding. This is needed to balance out any hum that may arise from slight irregularities in the construction of the 226 tube and variations in the A. C. power supply.

Theoretically, the same necessity for balancing exists in the case of the 171A tube, but in practice it is not necessary, because any hum introduced in the last stage is not amplified many times as is the case when the hum is introduced in the first audio stage.

Now that we have found out how to make the grid-return connection without introducing an appreciable amount of A. C. hum, we are ready to find out how to develop the required "C" voltages and to apply them to the grids of the radio and audio amplifier tubes.

In your previous studies, you have learned that whenever a current of electricity is forced to travel through a resistance that voltage is used up in the process, and that a voltmeter connected across the terminals of the resistance will indicate the amount of voltage that is used. In other words, when you pass a current of electricity through a resistance, an amount of voltage is developed at the terminals of the resistance which is determined by the value of the resistance in ohms multiplied by the amount of the current in amperes.

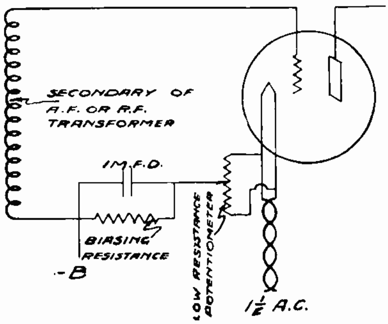


Fig. 13—Circuit of A. C. tube showing connections to "C" biasing resistance.

So, all we have to do to obtain a "C" voltage for our electric receiver is to pass some current through a resistance and the desired "C" voltage will appear at the terminals of the resistance provided, of course, that the resistance is of the right value in ohms.

The only current we have available for passing through the resistance is the plate current of the tubes, so we place the resistance where the plate current will be forced through it in its travel between the plate and the filament. This means, of course, that whatever "C" voltage we develop in this way will be subtracted from the effective plate voltage, but that is no disadvantage since we can increase the plate voltage to make up for the loss.

Figure 13 shows the circuit for a single tube. Note that the "C" biasing resistance is connected between minus B and the movable arm of the potentiometer that is connected across the A. C. filament winding. We could substitute the center tap of the low voltage winding for the movable arm with exactly the same result, as the resistance of the potentiometer is so low that it can be neglected in the calculation of "C" bias voltages. Also, coil A may be either the secondary of a radio-frequency transformer or of an audio transformer. The result as far as the "C" bias is concerned is the same in either case.

The plate current necessarily must flow through the resistance in traveling between minus B and the filament. The direction of flow is such that the end of the resistance connected to the filament is positive with respect to the other end which is connected to the grid of the tube by way of the secondary winding.

Now, suppose we want to find the value in ohms of a resistance which will properly bias a type 226 A. C. tube. We have, for instance, decided to operate the tube on 90 volts B. We find, on looking up the rating of the tube, that the "C" voltage should be minus 6 when the plate voltage is 90. If we don't know what the plate current should be under these conditions, all we can do is to put an adjustable resistance in the circuit and keep changing it until we have the "C" voltage reading 6. But if we also know what the plate current should be, we can divide the rated "C" voltage by the rated plate current and the result will be the value of the biasing resistance in ohms. Assuming that the plate current of the type 226 tube should be 3 ma. at 90 volts B with a 6-volt C bias. Dividing 6 by .003, the value of the plate current in amperes gives us 2000 ohms as the correct biasing resistance. It so happens that the 2000 ohms biasing resistance which is correct for a single 226 tube operated on 90 volts B also is correct for a 171A tube operating on 180 volts B. The 171A tube requires 40 volts C bias and the plate current is 20 ma. Forty volts divided by .02 amperes gives 2000 ohms. In the one case, the 2000-ohm resistance produces a 6-volt C bias and yet exactly the same resistance produces 40-volt C bias in the second case because of the heavier plate current.

When more than one tube is biased by the same resistance, the value of the resistance must be lowered in proportion to the increase in the plate current. Thus in a receiver using three 226 tubes in the radio-frequency stages, the biasing resistance should be one third of 2000 ohms which would amount to 666 ohms. Similarly, when two 171A tubes are used in a push-pull circuit, the plate current is doubled and the biasing resistance is halved to 1000 ohms.

When a biasing resistance is common to more than one tube it should be by-passed by a 1 microfarad condenser to prevent interaction and the consequent tendency to oscillation, and for best results, every biasing resistance should be by-passed.

VOLUME CONTROL ON A. C. SETS

Controlling the volume of a battery set is easy. Decreasing the filament current of one or more of the radio-frequency amplifier tubes by means of a rheostat gives complete control from full volume to absolute silence.

In A. C. sets, this simple procedure cannot be followed for two reasons. First, because it would be necessary to use a complicated double rheostat so as to add resistance to both sides

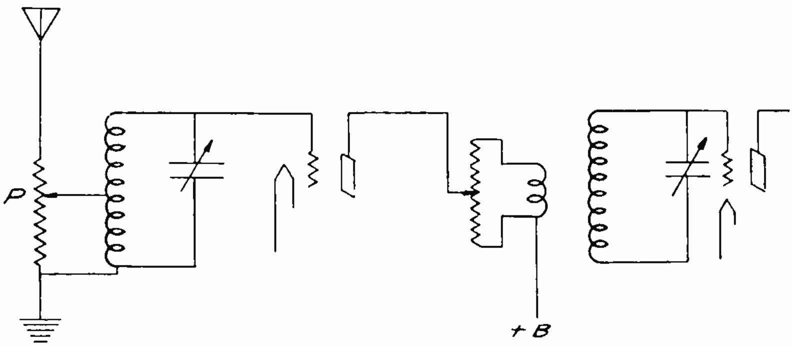


Fig. 14.

of the A. C. filament winding at the same time. Second, because the balance between plate voltage, C bias and plate current would be disturbed resulting in a critical control that would be particularly bad on tubes that respond slowly to changes in filament current.

The best practice is to allow all the tubes to operate at maximum efficiency and then "kill" the signal either before it reaches the first tube or as it passes from one radio-frequency stage to another. In some very sensitive receivers, both methods are resorted to.

The first method is carried out by fitting a high resistance, non-inductive, non-capacitive potentiometer in the antenna circuit as shown in Fig. 14. The reason why the potentiometer must have little capacity between its terminals or in the resistance element is because on strong local signals, capacity of this type will permit the radio signals to pass to the radio receiver around the resistance by way of the capacity.

When the volume is controlled between two of the radio-frequency stages, the usual method is to fit a potentiometer across the plate coil. The signal can then be shunted around it and thus not affect the grid coil of the following stage.

Now that we have studied the peculiarities of alternating current operated tubes which distinguish them from battery type tubes, we can proceed to investigate the circuits of a number of electric receivers and see how the A. C. tubes are used in actual practice.

MANUFACTURE OF A. C. RECEIVERS

Before we take up the examination of the actual circuits of a number of factory built receivers, it will be well to look into some of the factors that govern the design and production of radio receivers and every other manufactured product for that matter.

First and foremost is the cost of production. The shadow of the dollar sign hangs over every step in the making of a radio receiver. The radio manufacturer is not in business for his health any more than the maker of any other product. He must make a profit or cease operations, and if he is to make a profit in a highly competitive market, he must economize at every point where economy is possible.

Naturally, the fiercest competition is between the makers of the lowest priced receivers, and least in the higher priced classes where the difference of a few dollars in the selling price is of less relative importance.

This explains why, in spite of advertising claims to the contrary, a low-priced radio set is not as good as one that costs a lot more money, assuming, of course, that each of the sets compared is the product of a reliable manufacturer who is turning out the best set he can for the price at which he sells it.

In this lesson, we are interested in this matter only in so far as it applies to A. C. sets. So let us examine the ways by which a manufacturer of A. C. sets may reduce his costs without seriously impairing the product.

Really high-grade audio transformers are available today that will reproduce audio frequencies with considerable intensity below 60. Cheaper audio transformers can be substituted that will not respond to frequencies below 200. This means an economy in the cost of the audio transformers, but what is still more important to the maker of an A. C. set, the use of the cheaper transformers will permit him to use smaller chokes and

T
'16

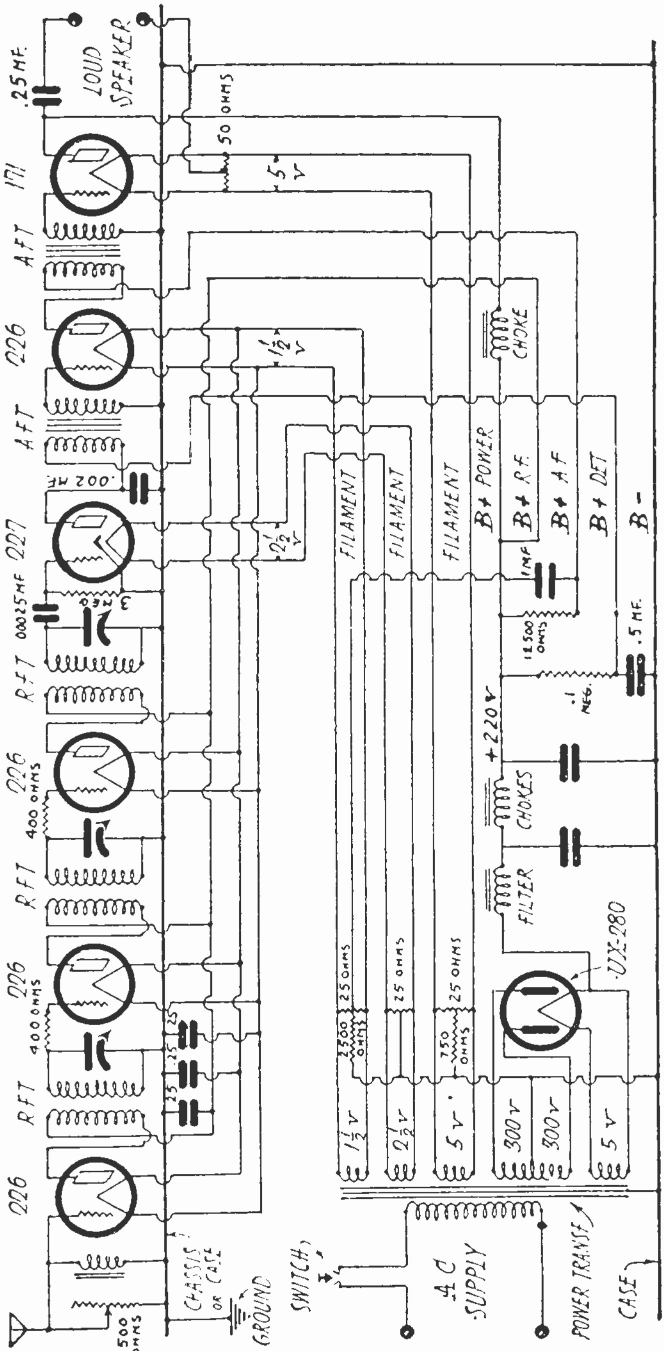


Fig. 15.—Circuit of Atwater Kent Model 37 Receiver.

lower capacity condensers in the "B" supply filter system because the cheap transformers will not reproduce the alternating current hum of either 60 or 120 vibrations.

Curiously enough, a receiver with poor audio transformers may appear to be capable of giving more volume without distortion than can be obtained from a set using high-grade transformers. This is because the low notes require more power to reproduce in sound waves.

Another possible change that brings manifold economies is to operate the 171A power tube at 135 instead of 180 volts. The lower voltage imposes less strain on the filter condensers and cheaper condensers can be used. An indication that the power tube is being operated at less than its full rated voltage is the rating of the resistance that is used to obtain the C bias. If materially below 2000 ohms for a single 171A tube, you can be sure that the "B" voltage also is below 180.

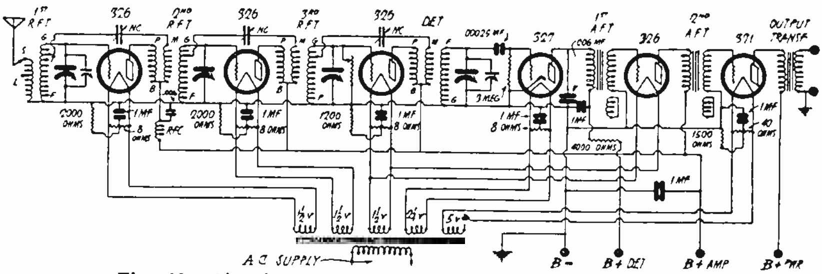


Fig. 16.—Circuit for A. C. Bremer-Tully Counterphase 8.

Of course, you must understand that an almost limitless number of minor variations can be made in individual circuits. Not all of these are for the sake of economy. In most cases, they are made to secure maximum results under the conditions existing in the particular circuit.

FACTORY BUILT A. C. RECEIVERS

The circuit of the Atwater Kent Model 37 A. C. receiver is shown in Fig. 15. This receiver has a 3-stage tuned radio-frequency amplifier using type 26 A. C. tubes, a type 27 detector, and two stages of transformer coupled audio-frequency amplification, using a —26 and a —71 tube. The latter is impedance coupled to the loud-speaker and has its filament operated from a 5-volt winding on the power transformer.

Filament balance in the radio-frequency and first audio-frequency stages is obtained by means of a center tapped fixed

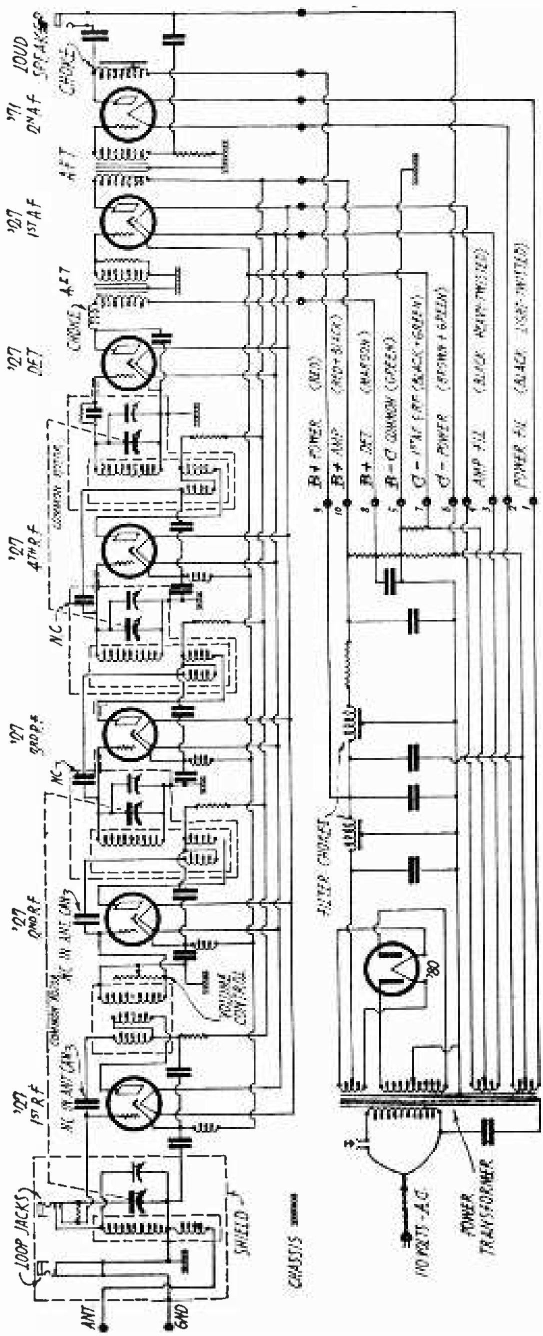


Fig. 17.—Circuit of the Fada 7-tube A. C. Receiver.

resistance located in the power unit, and in the case of the power tube, —71, a balancing resistor for the loud-speaker return lead is shunted across the filament circuit in the receiving set, and another center tapped resistor is placed across the filament lead, for the negative B connection, in the power unit. Fixed resistances cut down the effective "B" voltage from 220 volts to 45 and 90 volts, for the detector, radio-frequency and first audio-frequency tubes, and a total of 180 volts is supplied to the power tube, with 40 volts negative bias through the voltage drop in the resistance placed in the negative "B" circuit. The volume control on this receiver is obtained by means of a 500-ohm potentiometer shunted across the radio-frequency choke, which is placed between the antenna and ground connections, with the grid of the first radio-frequency tube connected to one side of the choke. The filament circuit of the radio-frequency amplifier is by-passed with .25 mfd. condensers to prevent oscillation due to the presence of resistance in the grid-return lead to the radio-frequency tubes.

In Figure 16 is shown the circuit diagram of the Bremer-Tully Counterphase 8 A. C. receiver, which is a 6-tube set, having three stages of neutralized radio-frequency amplification, detector and two stages of audio. Radio-frequency amplifying tubes are balanced individually with center tapped 8-ohm resistances and a C bias for each tube is obtained by the voltage drop in the "B" negative connection to the center tap of the 8-ohm resistance. A 1 mfd. condenser is connected across the C biasing resistance in each stage and in the first radio-frequency amplifier, a .006 mfd. fixed condenser is connected between the positive B terminal of the first radio-frequency amplifier and the center tapped resistance. No positive bias is placed on the detector tube heater element, but a system of A. C. balance is installed, consisting of an 8-ohm center tapped resistance with a 1 mfd. condenser between the center tap and the cathode. No circuit is shown for the "B" voltage supply but it is practically the same as for any other factory built receiver.

Figure 17 shows the circuit diagram of the Fada 7-tube A. C. receiver, together with the power equipment. This receiver supplies four stages of tuned radio-frequency, with either loop antenna or outdoor antenna. The radio-frequency stages are of the neutralized type and by the use of an elaborate system of shielding, together with other precautions, such as radio-frequency chokes in the leads to the cathode of each A. C. tube in

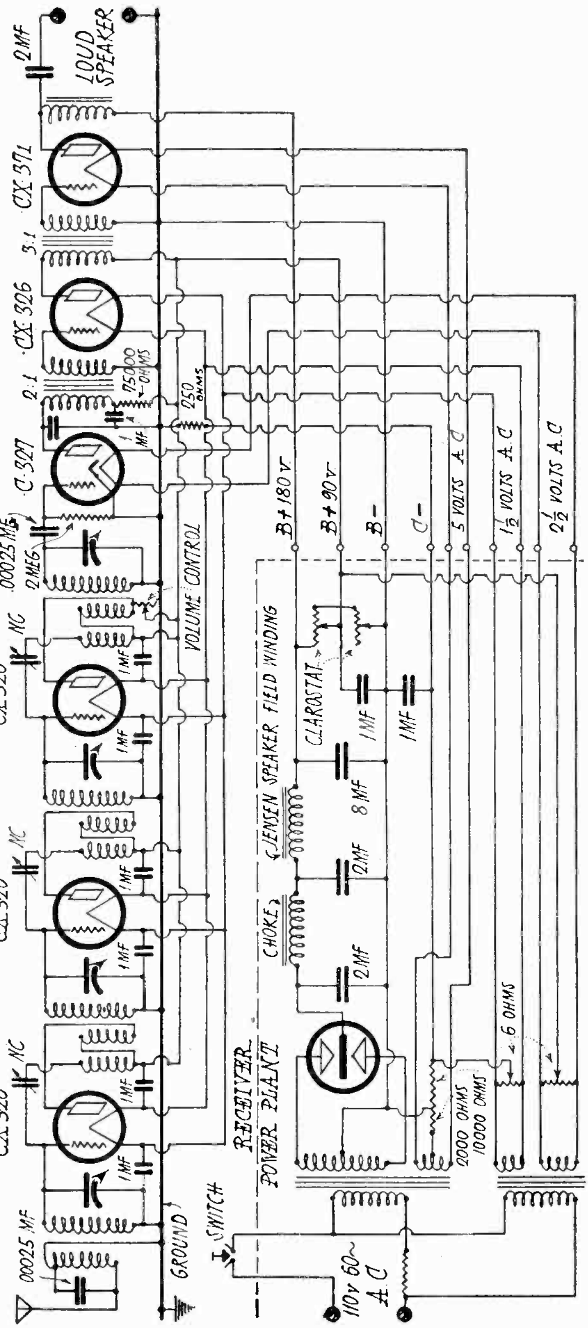


Fig. 18.—Circuit of the Gilfillan A. C. Model 60 Receiver.

the radio-frequency amplifier, a non-oscillating receiver is produced. Volume control is obtained by shunting a variable high resistance across the secondary of the first radio-frequency transformer. The power unit consists of a full-wave type 380 rectifier tube, supplying 180 volts for the 71 power tube and the various intermediate voltages for the radio-frequency, audio and detector tubes. It will be noted that all the tubes in this receiver, except the power tube, are of the heater type; only two windings for filament supply are contained in the power transformer.

Figure 18 shows the circuit diagram of the Gilfillan A. C. receiver, Model 60, which is a 6-tube Neutrodyne. The volume control, instead of being in the antenna circuit like a good many

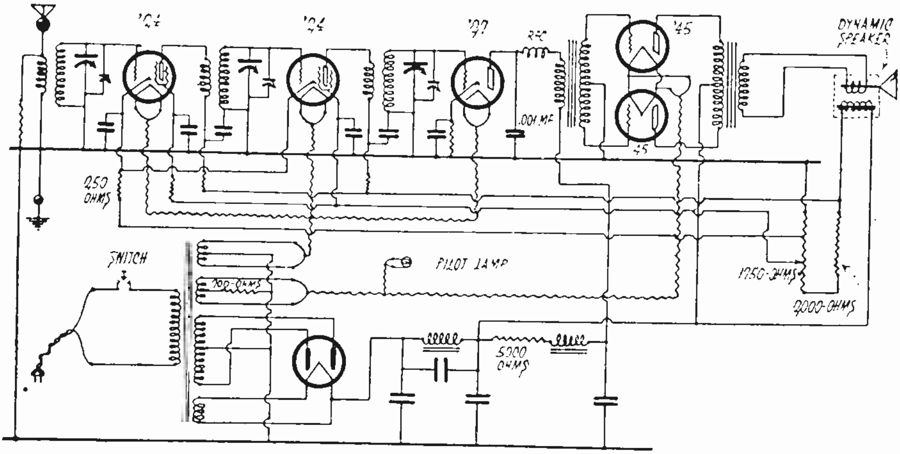


Fig. 19—Circuit diagram of Philco Receiver, Model 65.

A.C. receivers, consists of a 2000-ohm variable resistance shunted across the primary of the last radio-frequency transformer so as to control the input to the detector tube.

The circuit diagram of the Philco Model 65 A. C. five-tube receiver is shown in Figure 19.

Two —24 A. C. screen grid tubes are used as R. F. amplifiers, —27 power detector with plate rectification and two —45 tubes in push pull. Each R. F. stage and detector are tuned by one of the gang of three condensers.

Transformer coupling is used in both R. F. stages and in the detector circuit. An R. F. choke is in series with the detector plate and the primary of the A. F. input transformer, and a .001 mfd. feedback condenser by-passes the R. F. in the detector output to ground. A variable resistor with one fixed tap is connected across the D. C. output of the rectifier tube and serves as a volume control and C bias voltage divider, providing the variable screen grid voltage and the cathode voltages for the R. F. tubes. The plate voltage for these tubes is supplied from the maximum positive output less the drop encountered in the field of the dynamic speaker. The grid bias for the detector tube is obtained from the voltage drop through a resistor which separates the cathode and ground.

The grid bias is supplied to the —45 tubes by the drop from a 700-ohm resistor in the power pack. This resistor is connected between the center tap of the filament secondary and ground.

TEST QUESTIONS

Number your Answer Sheet No. 24—3 and add your
Student Number

1. Is it possible to use raw alternating current applied directly to the "B" and "C" circuits of an A. C. receiver?
2. Why is it not possible to successfully use alternating current, of the correct voltage, on the filament of the ordinary direct current tube?
3. Draw a diagram showing the construction of the heater type tube, naming the four elements of the tube.
4. What is the filament voltage and filament current of the 226 and 227 type tubes?
5. Describe briefly the changes that are necessary before the 110-volt alternating current can be applied to the "B" circuits of a receiver.
6. Draw a diagram showing the "B' supply circuits of the ordinary A. C. receiver.
7. Draw a diagram showing the way the 227 type tube is connected in a detector circuit.
8. Why is it not possible to control the volume of an A. C. set by means of a filament rheostat in the radio-frequency circuits?
9. Describe two good methods of controlling the volume of A. C. receivers.
10. Explain fully how the use of the cheaper grade of audio transformers can lower the manufacturing cost of A. C. receivers.

RADIO BY MAIL

National Radio Institute

STUDENTS ALL OVER THE WORLD