Practical - Technical

TRAINING IN **RADIO AND TELEVISION**

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EXPERIMENT LESSON NO. FG-1

BASIC RADIO EXPERIMENTS

The experimental and practical work, which you are now ready to begin, is one of the most important and interesting phases of your study. As you no doubt realize,it is highly important that you master thoroughly the basic principles governing the operation of radio receivers, in order to become a fully trained and qualified technician. It is for this reason that we furnish you with a complete series of experimental kits, together with this special series of Experiment Lessons.

As you continue with this phase of your Training, you will receive complete instructions with each individual kit, showing you exactly how each apparatus should be constructed and how to perform the various experiments related thereto. This does not mean that you must confine your studies to these experiments alone. On the contrary, you should always be on the lookout for new methods of experimentation, as in this way you will acquire experience which will be of tremendous value to you. At the same time, you will successfully overcome the "fear" that most beginners experience when they face their first radio service job.

The experiments which you will perform are in progressive order, and in accord with our method of teaching which has been time-tested by years of experience in the field of technical education. Therefore, it is important that you follow our instructions carefully and perform these experiments exactly as presented. Under no conditions, should you skip any of the experiments, regardless of how simple they might appear to you, for in performing even the most simple experiment you will learn something new and valuable.

YOUR FIRST KIT OF PARTS

The first kit consists of the following parts:

1 - Eight-prong socket
1 - Grid cap for metal tube
1 - .00025 mf mica condenser
1 - 500,000 ohm carbon resistor
1 - Input push-pull transformer
1 - Headset (headphones)
20 feet of push-back wire for connections

Remember, too, that as you advance through the series of construction projects and experiments, the kits become more elaborate,and contain more parts. Thus, you progress into the advanced experimental and constructional work step by step.

When you receive a kit, your first action should be to carefully examine the parts received, so as to become thoroughly familiar with them. Then, with this equipment before you, you should read this lesson very carefully.

The TUBE SOCKET is a very simple item,so we will say very little about it, except to make this observation. Some sockets are equipped with many terminals that are placed quite close to each other. When mounting such sockets on the metal chassis, be careful that the mounting screws or nuts do not touch any of the socket terminals and thus ground them.

The GRID CAP is also very simple and therefore needs little explanation. When soldering your connections be sure that they form solid and neat unions. Poorly soldered connections will increase the resistance and may cause serious difficulties.

Now, for the MICA CONDENSER and the CARBON RESISTOR. In some cases, you will find the electrical value marked on these units in some such form as .00025 mf or 1000 ohms. However, it is the more general practice among radio parts manufacturers to indicate the electrical value of the unit by means of a color-code.

It is advisable that you learn the color code, which has been adopted by all leading radio manufacturers. This code is known as the "RMA code" -- RMA being the abbreviation for Radio Manufacturer's Association. It is applied by giving a fixed value to each color, so that combining the several colors will result in the total value of the resistor or condenser. The numerical equivalents of the different colors used in the "code" are as follows:

Black	0	Green	5
Brown	1	Blue	6
Red	2	Violet	7
Orange	3	Grey	8
Yellow	4	White	9

The value of a resistor is determined by noting the colors in the following order: The body, the end, and a dot or stripe. The last color indicates the number of ciphers (zeros) to be added to the first two numbers. The method of "coding" resistors is illustrated in Fig. 1.

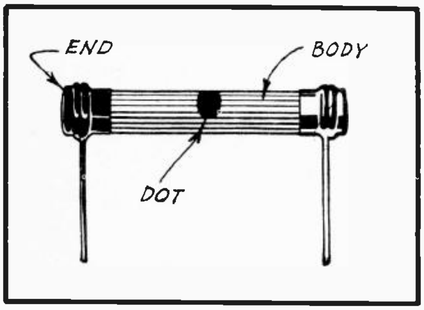

Fig. 1
Color-coded Resistor

A 500,000-ohm resistor has a green body (5), a black end-color (0), and a yellow stripe or dot. The yellow stripe or dot means that we are to add 4 ciphers to numbers ascertained previously. Our numerical values thus take the form 5-0-0000, giving us the figure 500,000 ohms. In the same way,a resistor with a red body, green end-color and an orange dot,would have the value of 2-5-000, or 25,000 ohms. A resistor with a green body, black end-color,and a black dot or stripe would have a value of 5-0, or 50 ohms. Note carefully in the latter example, that we do not add any ciphers beyond the first two figures, because the black dot or stripe indicates zero, showing us that no ciphers are to be added.

CONDENSER VALUES are indicated by the same color code, but you must remember that when dealing with condensers, the values are expressed in micromicrofarads (mmf). When reading the color code of condensers, the condenser is held in such a position that the trade-mark is right side up, as in Fig. 2. The values of the colors are then read from left to right. For example, if a condenser has a red, green and brown dot (in reading order) its value is 2-5-0 = 250 mmf or .00025 mf.

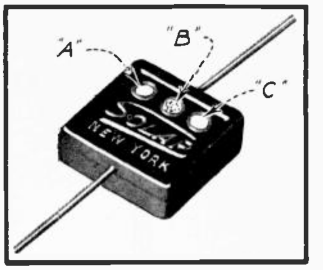

FIG. 2
COLOR-CODED CONDENSER

THE INPUT PUSH-PULL TRANSFORMER

The input push-pull transformer is the small transformer contained in your first kit. This transformer consists of a primary and secondary winding placed on a laminated steel core. The primary winding is easily recognized by the fact that it is provided with only two terminals. The secondary is wound over the primary and has three terminals --- one for each of the two ends and one for the center-tap.

In the illustrations of this transformer, appearing in this lesson, the terminals of the primary are placed on one side and those of the secondary on the other side. This is not always the case, as some transformers have all five terminals on one side while others use flexible insulated wires instead of terminals.

It is a very simple matter to identify the terminals of these transformers. We do this in the following manner: Connect one lead of your headphones to the positive terminal of a $1\frac{1}{2}$-volt dry cell. Then, connect one of your test leads to the other headphone tip and attach your other test lead to the negative terminal of the battery. You can then test the windings of the transformer by touching the test points to the various terminals of the transformer. If you hear a "click" as the test points are brought into contact with two terminals, it shows that the circuit is complete. You will find three of the terminals to indicate a complete circuit between themselves -- these are the secondary terminals. The two remaining terminals are connected to the ends of the primary winding.

By using the same headphone test, it is also a simple matter to determine which of the three inter-connected terminals is the center-tap. Contacting the terminals which are connected to the ends of the winding will produce a more faint "click" in the headphones than will contact between the center-tap and either end-terminal. Having thus definitely identified the ends of the winding, the remaining terminal of the group is connected to the center-tap.

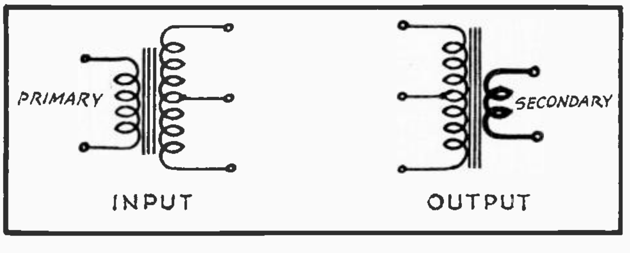

FIG. 3
PUSH-PULL TRANSFORMER

OUTPUT PUSH-PULL TRANSFORMERS are also equipped with one group of three terminals and one group of two terminals. However, upon inspecting the transformer more closely you will see that one winding consists of a much larger wire-size than the other. The larger wire-size is used for the secondary winding of the output push-pull transformer. Fig. 3 shows the difference between an input and an output push-pull transformer.

With these instructions you will have no difficulty in identifying the terminals of "push-pull" transformers.

TESTING THE HEADPHONES

Let us now examine the headphones. Notice first that the metal head-band can be bent to fit your head, and that you can also fit the phones to your ears by sliding them up or down upon the rod.

Now unscrew from one phone unit that part (the cap) which contacts your ear. IMPORTANT -- do not remove any nuts or screws from the unit during this process as otherwise the entire assembly will fall apart.

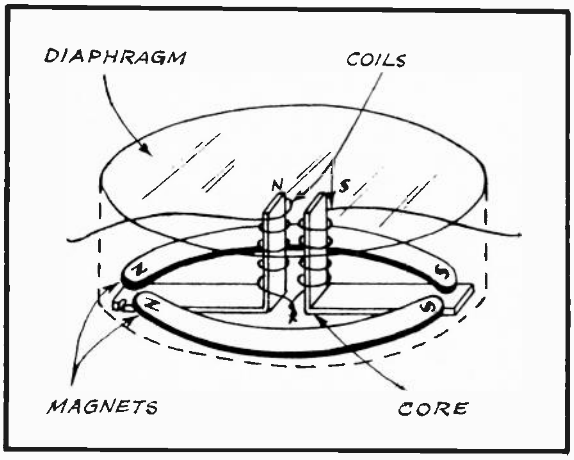

FIG. 4
TYPICAL HEADPHONE CONSTRUCTION

Slide(do not lift) the diaphragm off the phone,and you will notice that two small coils of very fine wire are wound upon steel cores. Now slide the diaphragm back into position on the phone very slowly; notice that there is a very small clearance between the ends of the cores and the diaphragm, and that it is magnetically attracted by them. This attraction is caused by two small permanent magnets touching the lower parts of the iron cores.

Fig. 4 shows you the inner construction of an earphone (headphone) in a simplified form. Notice how the poles of the magnet are placed (S with S and N with N). This makes one core-end a south pole and the other core-end a north pole. Therefore, a magnetic field will be established between both cores, causing the diaphragm to be attracted.

The headphone coils are made of many turns of very fine wire. As a general rule, the wire used in each coil offers a resistance of 500 ohms. Taking into consideration the fact that the two coils in each phone unit are connected in series, the total resistance of the four coils used in the headset is 2,000 ohms.

By studying Fig. 4 and the headphones, you will notice that current will flow in opposite directions through the two coils. Therefore, the outer end of one of the coils will be of a north polarity, while the outer end of the other coil will be of a south polarity.

When the headphones are connected to a receiver, a pulsating signal current flows through the coils. As a result, there will be a constant change in the intensity of the magnetic field, and the attraction on the diaphragm will vary accordingly. Thus, the movement of the diaphragm produces sound waves which reach our ear.

If you stop to think, you will reach the following conclusion: The current should flow through the phone windings in such a direction that the magnetic field produced by the current will be added to that caused by the magnets. Thus, the sound waves will be stronger and the magnetism will be retained by the permanent magnets for a longer period of time. To prevent the current from demagnetizing the magnets, manufacturers generally color-code the phone leads for identification purposes.

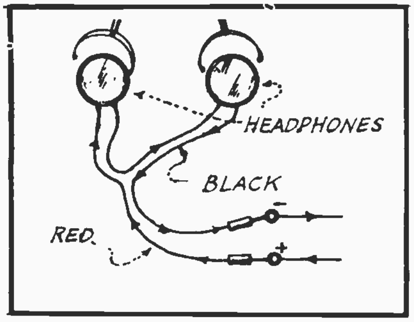

FIG. 5
HEADPHONE CONNECTIONS

Fig. 5 shows you how the headphones are connected to the circuit. Notice that the red lead is connected to the positive side of the circuit and the black lead to the negative side. However, when the polarity of the circuit is unknown, the headphones will still function regardless of the connections as to polarity.

AN EXPERIMENTAL TELEPHONE

Let us now use our headphones to form a simple telephone system as illustrated by the drawing appearing in Fig. 6. Observe that the phones are connected together with a long piece of wire. For this purpose you may use the hook-up wire sent to you in this kit. When disconnecting the regular leads from the phone during this experiment be careful not to damage the units.

The length of "line" between the two phones should not be too great. Just enough wire should be used so that one phone may be placed in one room and the other phone in another room. The object is to listen at one phone unit while another person speaks into the other phone unit. The latter unit will at this time function as a microphone. ("Cupping" one of your hands around the "microphone" will assist in focusing the sound waves toward its diaphragm.)

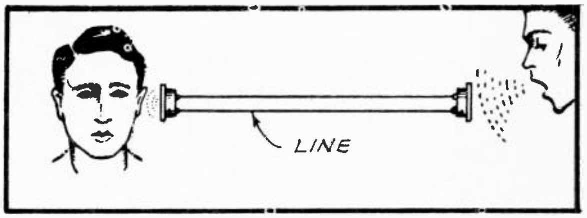

FIG. 6
SIMPLE TELEPHONE CIRCUIT

Fig. 7 is a side view of an earphone. As you can see, the diaphragm completes the magnetic circuit produced by the magnets. By talking into this phone at close range, the sound waves will act upon the diaphragm, causing it to vibrate vigorously.

The movement of the diaphragm, illustrated by the dotted lines in Fig. 7, deflects the magnetic field and thus generates a small voltage that causes a tiny current to flow through the coils. This phenomenon is described fully in the regular lessons of your course, and corresponds to the same principle which makes possible the operation of generators, transformers, etc., by the fluctuation of a magnetic field.

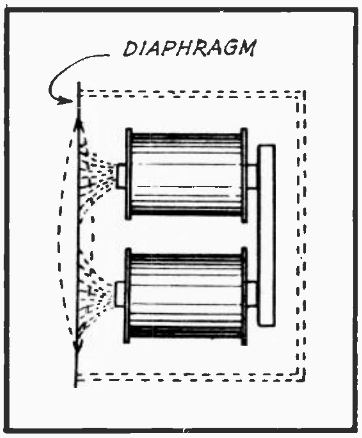

FIG. 7
MAGNETIC INFLUENCE
UPON THE DIAPHRAGM

Having connected your phones as shown in Fig. 6, the weak signals generated in the coils of the one are used as a microphone pass to the other, where they reproduce the original sound uttered into the "microphone." When the phones are connected in this way, they can be used interchangeably as the microphone or reproducer.

While conducting this experiment, you must bear in mind that the phones were not constructed to serve as a microphone and should therefore not be expected to operate efficiently, as a regular microphone. However, using them in this experiment does demonstrate clearly the principle of telephony. If you have a small battery or dry cell handy, try connecting it in series with this system -- you will find it to increase the volume considerably. In any case, the phone being used as the microphone must be held directly in front of the mouth and you must talk into it loudly so as to cause the diaphragm to vibrate vigorously.

DIRECT OR ALTERNATING CURRENT

We will now use the headphones in a more practical manner. First, we shall use them to determine whether a circuit is passing an a-c or d-c current. With the help of the headphones, this is a simple matter.

Keeping in mind the manner in which the headphone functions, you can readily see that the only effect on the diaphragm, when connecting the phones to a d-c circuit, will be a slight "click" as the circuit is closed or opened. This is true because d-c current is of constant intensity.

However, when the phones are connected to an a-c circuit, a constant hum will be produced, because the current is constantly changing its intensity. This hum will be of the same frequency as the a-c current. In other words, if the a-c is of the 50 or 60 cycle type -- the more common frequencies -- the diaphragm will vibrate rapidly and reproduce the low tone of that frequency.

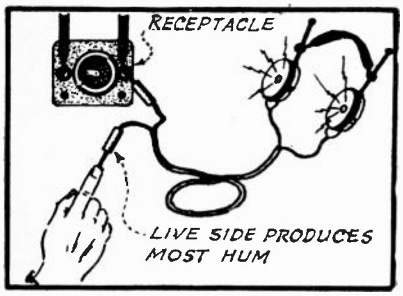

FIG. 8
IDENTIFYING THE "LIVE-SIDE" OF THE LINE

Fig. 8 illustrates a practical way of performing this test, and at the same time serves to show us which is the "live-side" of any wiring system.

> **CAUTION**
> It is important that you be on a DRY wooden floor while conducting the experiment illustrated in Fig. 8. This is necessary to avoid a dangerous electrical shock. For the same reason, be careful not to contact both sides of the lighting circuit with your hands.

In almost all a-c lines, as well as many d-c lines, one side of the circuit is permanently connected to a ground, either at the power house or at the distribution transformers. The object of this connection to ground is to protect the system against electrical discharges and lightning, by dissipating any excess voltage directly to ground. This will result in the least amount of damage to the system or equipment. The ungrounded side is usually called the "live-side" of the circuit.

It is often necessary to determine which side of the line is grounded and which is the live side, as when connecting an outlet plug or lamp receptacle to the system. If this is not done correctly, it is quite probable that any handling of the equipment, as when turning a lamp on or off, will result in an electric shock.

To conduct the "line test", proceed as follows: Connect the headphones into the lighting system as illustrated in Fig.8. That is, touch one of the phone tips with one of your fingers. Touch the other phone tip alternately to both sides of the line, without touching this tip. If you hear a loud hum when the line is contacted in this way, it indicates that alternating current is energizing the circuit, and that you are touching the "live side" of the system. The phones are so sensitive that you need not be actually grounded when performing this test.

If no hum is heard at all, the circuit is of the d-c type. The live side in this case is the one which produces a definite "click" in the headphones.

IMPORTANT: The headphones should never be connected directly across a power line unless a .00025 mf condenser is connected in series so as to reduce the current. By no means should you connect your phones directly to an a-c line, as this is certain to cause the magnets to lose their polarity and thus damage them beyond repair.

A good way to avoid this form of damage to your phones, when using them in a radio circuit operating at voltages exceeding 45 volts, is to connect a .05 mf condenser in series with them -- thereby allowing only the audio signals to pass through them and rejecting the d-c. Never connect the phones across the primary or secondary winding of a power transformer, as the current circulating through them is then of the a-c type and may destroy the polarity of the magnets.

CONTINUITY TESTS

Another application of the headset is its use in conducting continuity tests. That is, determining whether or not a circuit, or part of a circuit, is complete. In this way, the windings of transformers, chokes, coils, condensers and other radio parts can be checked. Because of their sensitivity, the phones are also useful in ascertaining the condition of high-ressitance coils, high-value resistors, etc.

Fig. 9 shows the method of using a dry cell in series for this purpose. (This cell may be of the flashlight type.) Note that the contact on top of the cell is connected to the positive lead of the phones. The other phone terminal is used as a test lead, as is also the wire which is connected to the metal can (negative terminal) of the dry cell.

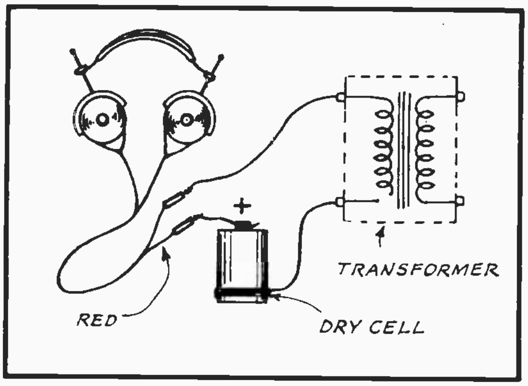

FIG. 9
HEADPHONE CONTINUITY TEST

Note that a "click" is heard in the phones, when bringing your test leads in contact with each other. This also happens when the circuit is completed through a coil, resistor, or any radio part that permits the flow of d-c. Fig. 9 shows that the winding under test is open; therefore, no "click" is heard.

TESTING RADIO PARTS FOR CONTINUITY

R-F TRANSFORMERS: By means of the continuity test just described, you can determine the condition of a coil, and also identify the ends of the secondary and primary windings. To do this, simply touch one of the test leads to a terminal, and then with the free lead, touch one terminal after another until you hear a "click" in the phones. The "click" indicates that these two terminals are connected together by a winding. These circuits are of low resistance; therefore, the sound produced will be about the same as that experienced when touching the leads together.

A-F TRANSFORMERS: By applying the continuity test to a-f transformers, you can determine the condition of the primary or secondary winding, locate shorts between either winding and the core, distinguish the primary from the secondary, or identify the terminals of the unit.

For this test, connect one test lead to one of the lugs or terminals and touch the other lead to each of the other terminals in successive order. When contacting in this manner the terminals corresponding to the ends of the winding, you will hear a soft but definite "click." Do this repeatedly, so that you may get an idea of the audible effects obtained under such circumstances.

You can proceed to identify the terminals of the other windings in the same way -- notice particularly if the "click" is strong or weak. As a general rule, the primary winding produces a louder "click" due to its lesser resistance.

If the transformer is of the input push-pull type, a louder click will be produced when testing through the primary winding. When testing through an output push-pull transformer, the secondary will produce a much louder click then the primary. If any of the windings are open, there will be no click whatsoever.

Sometimes, you may come across a transformer which apparently tests normal; however, if the circuit is kept intact for a while, you may hear rasping sounds, indicating a defective winding. When the windings are in good condition, the click will be heard only at the instant that the circuit is closed or opened.

The final test is to determine the probability of current-leakage between the windings and the core. To conduct this test, simply touch one of your leads to the core, and with the other lead touch the various terminals, one at a time. If the insulation is perfect between both windings and the core, no click will be heard in the headphones. If the click is anywhere near as loud as the one heard when testing between the ends of either the primary or secondary, it indicates current-leakage through the insulation. Such a transformer is either entirely unserviceable or else will cause noisy (raspy) reception.

CHOKES: Test across the terminals. If the winding is in good condition, a strong click will be heard in the phones. Also, test between the core and the windings, checking for imperfect insulation as already explained relative to a-f transformers.

R-F CHOKES: Test across the terminals. This should produce a loud click.

RHEOSTATS, RESISTORS, ETC: Place your test leads across the resistor or rheostat. The intensity of the click should be in accordance with the resistance value of the part being tested. High-resistance units produce a slight click, whereas low-resistance units produce a louder click.

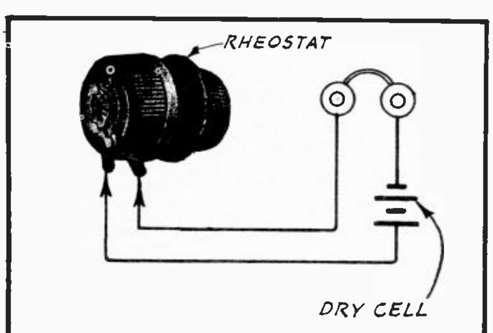

FIG. 10
CHECKING A RHEOSTAT

When testing rheostats and resistors in general, connect them as in Fig. 10. Turn the control-arm slowly, listening for noises in the phones. A noisy unit may either be shorted or simply dirty.

LIGHTNING ARRESTORS: Connect your test leads across the terminal posts of the lightning arrestor and listen for a click. If you do hear a click, it indicates that the arrestor is defective, for there should be no flow of current whatsoever when conducting this test. When performing this test, be certain that the arrestor is in no way connected to the circuit which it is intended to protect.

RADIO TUBES: This test does not permit us to determine whether or not the tube is in working order, but it does enable us to test the filament, and to determine if any internal short circuits exist within the tube.

To conduct such a test, remove the tube from the socket, and place a test point on one of the base prongs. With the other lead, alternately touch the other prongs. If no click is heard, change the first test lead to the next prong and repeat the test. Normally, a complete circuit should be available through the filament, but no click should be heard when testing between either of these two terminals and the other prongs. If, however, no click is heard when testing across the two prongs of the filament, the test indicates that this element is open.

VARIABLE CONDENSERS: To test a variable condenser, disconnect it from its circuit and place one of the test leads on the terminal of a stationary plate-group and touch the other one to the terminal of the rotor plates. (The rotor plates are generally grounded to the frame, in which case the frame is considered as the terminal for the rotor plates.) No sound whatsoever should be heard in the phones upon completing the connections in this manner. If a sound is heard, you can be sure that a stationary plate is touching a rotor plate or else a stationary plate is contacting the frame. Inspect the plates carefully; straightening bent plates will usually correct this defect.

Now, leave your test leads connected as described above, and turn the rotor plates slowly. You will hear crackling sounds in the phones, in case some of them are out of line or are dusty or dirty. If everything is in perfect order, you will hear no noises of any kind.

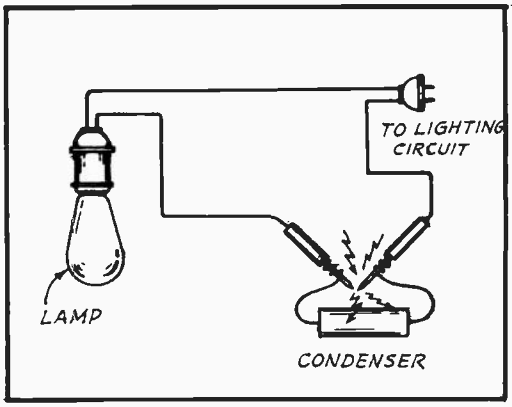

FIG. 11
TESTING A CONDENSER

TESTING CONDENSERS

Condensers cannot be tested accurately with the headphones. However, since we have shown you in this lesson how to test various other circuit components, we may as well go a step farther and discuss the more reliable but simple condenser tests.

FIXED CONDENSERS: The best way to test condensers of this type is to use line-current, either a-c or d-c. For this purpose, we connect a pair of test leads in series with a lamp of the same voltage as the line (see Fig. 11). The condenser under test is connected between the test leads. If the line-current is d-c, the lamp should not light. Also, if the line-current is a-c, the lamp should not light, unless the capacity of the condenser is very large, and in this case, only a dim glow should be emitted by the lamp. If the lamp lights at normal intensity, the condenser is shorted.

Now, we proceed to test for an open circuit. We do this by simply touching together our test leads, as in Fig. 11. If the condenser is in good condition, a small, sharp spark is produced as the leads are touched together. The intensity of this spark is determined by the capacity of the condenser. The above tests are more or less exact for condensers ranging from .05 mf upward, except in the case of electrolytic condenser.

The following test is used to determine whether or not the condenser "holds its charge," as sometimes small discharges occur across the dielectric -- this permits the condenser to dissipate its charge. As shown at the left of Fig. 12, we first charge the condenser by touching the test leads to it for a moment. Next, we short circuit the terminals with a screwdriver as shown at the right of Fig. 12.

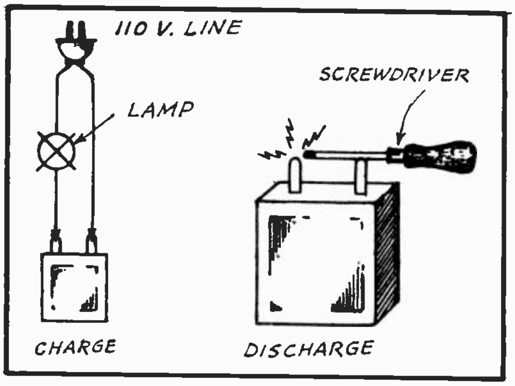

FIG. 12
ANOTHER CONDENSER TEST

A sharp, cracking spark will be produced upon thus shorting a condenser that is capable of holding its charge.

In order to charge a condenser properly, d-c energy of 110 volts or more should be used. However, one can also use a-c as long as one is careful in establishing very rapid contact. When using a-c, repeat this test several times, as frequently you may touch your leads to the condenser at an instant when the varying line voltage is at a low value.

Condensers smaller than .05 mf may be tested by the same method, but the results are not as definite. It is true that all condensers can be charged; yet, if the capacity is rather low, this charge becomes so small that the spark occurring during the discharge test cannot be seen easily.

Conditions being such, we emphasize the fact that testing smaller condensers by this method is only approximate. In other words, they may at times appear to test O.K. and still fail to function in a receiver -- hence, if in doubt, such condensers should be replaced with new ones that are known to be in good condition. Fortunately, the smaller condensers do not break down as often as do the condensers of larger capacity-rating.

TESTING ELECTROLYTIC CONDENSERS

This type of condenser is not so easy to test. However, you can get an idea of their condition, especially if they are shorted internally. For this test, connect your test leads in series with a lamp and the lighting circuit, as shown in Fig. 12. Touch your leads to the terminals of the condenser. If the current is a-c, the lamp will light dimly. If the lamp burns brightly, the condenser is shorted. Disconnect the circuit immediately after making the test.

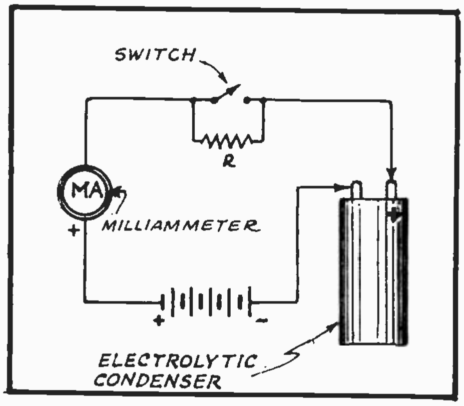

FIG. 13
TESTING AN ELECTROLYTIC CONDENSER

If the current being used is of the d-c type, be careful to connect the positive side of the line to the positive condenser terminal and the negative line to the negative condenser terminal. In this case, the bulb might light for a moment, but it will be extinguished as soon as the condenser is charged. Fig.13

illustrates a more exact method for testing a condenser of the electrolytic type. In this case a d-c line or a 90-volt battery is used. DO NOT USE A-C.

The resistor "R" which is used in this circuit should have a value that will limit the flow of current to the maximum reading provided on the meter scale. To determine the value of this resistor, simply divide the voltage being used by the maximum current-capacity of the milliammeter. For example, if you are using 90 volts and the maximum current value marked on the milliammeter's scale is 15 ma, the minimum value of the resistor should be 90 ÷ .015, or 6000 ohms. This is the smallest value that you should use in this case. Larger values can be used if they are available, as they will serve to protect the meter in case the condenser under test is shorted.

To conduct this test, proceed in the following manner: With the switch open as in Fig. 13, touch the test points to the condenser terminals and watch the deflection of the milliammeter needle. As soon as the condenser acquires its full charge,its counter-electromotive force will cause the current to stop flowing,and the meter needle will then move toward the zero mark of the scale.

When the needle drops to a low steady reading, close the switch. In so doing, the resistor is omitted from the circuit, and the meter will indicate exactly the amount of current leaking through the dielectric of the condenser.

Some leakage current always passes through these condensers. It varies with the capacity,age and make of condenser. As a general rule, the leakage should not exceed one-half milliampere for each microfarad of the condenser's capacity. If the leakage is greater, it may be caused by the destruction of the insulating film that is formed normally while the condenser is in use. If the condenser is left connected to the test circuit for a few minutes, the excess leakage should diminish considerably, unless the condenser is old or has other internal defects.

It is also well to note that electrolytic condensers may sometimes test as being serviceable, but still will not function properly in the circuits to which they are connected. In such a case, the only sure way to determine the condenser's condition is to replace it with a new one, noting the effect on the receiver. If this causes the symptom of the defect to disappear, then discard the old condenser, regardless of how well it may test.

CONSTRUCTING AN A-F OSCILLATOR

Your first construction project will be to build an audio-frequency (a-f) oscillator. Such an oscillator will produce a signal-voltage of low frequency that can be heard in the headphones. In Fig. 14 is shown a schematic diagram of this oscillator which, as you will observe, is extremely simple.

Let us proceed to examine this diagram very carefully. At the same time, we will bring up a few points which will make you familiar with other diagrams that are used in the more advanced experimental lessons.

The tubes are the principal objects that we must keep in mind when studying a diagram. Notice in Fig. 14 that we use a tube which is a combination of two diodes and a triode section. However, no circuit connections are made at the diodes, as they are not used in this particular experiment. In fact,we could use a simple triode tube instead;

nevertheless, we suggest that you use a double diode-triode for this purpose, as you will need this tube in the receiver which you will construct later. In this way, it will not be necessary for you to buy tubes which you cannot use later on.

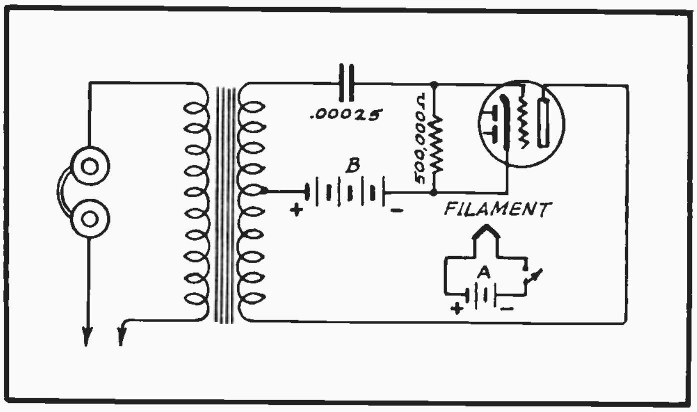

Fig. 14
Diagram of the A-F Oscillator

If your house-lighting system is of either the 110-volt or 220-volt type (a-c or d-c), you should buy a 6Q7 tube. This is a metal tube. If you are going to use batteries to operate your final receiver, then you must buy a 6T7G tube.

At this time, we also wish to direct your attention to the manner in which we represent a tube in a diagram. We follow this same system throughout our experimental lessons. Notice that the symbol of the tube is drawn so as to represent the true relation between the elements in the tube. This is why in Fig. 14 the two diodes are placed independently of the triode section, with the exception of the cathode which is common to both. You will also note that the grid is placed between the cathode and the plate, just as it is within the tube.

For greater clarity, the filament of tubes using indirect heating (cathode-type tubes) will be shown separately. This makes it possible to show the other elements more clearly. After all, the filament in this type of tube serves no other purpose but to heat the electron-emitting cathode.

Another original and practical method which we use is to place the tube element in our drawings in such manner as to show the actual connections to the socket. For example, Fig. 15 shows the correct connection for the 6Q7 and 6T7G tubes. The illustration does not show the exact form of the socket, but it does show very clearly the position of the contacts, with reference to the central-guide on the tube. The latter makes it impossible to insert the tube in more than one position.

Note the numerical order of the contacts and placement of the elements. As the grid of the triode is on top of the tube, it is indicated as being outside of the socket. The shield or metal casing of the tube is indicated by the heavy circle surrounding the elements.

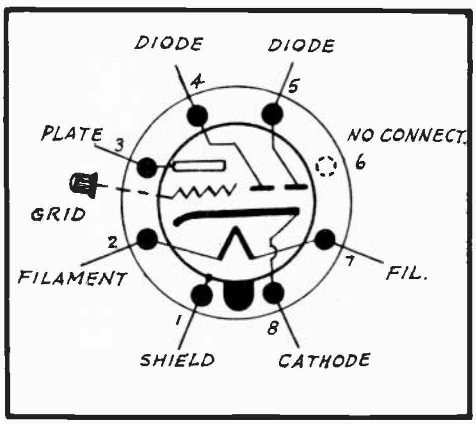

Fig. 15
Vacuum-Tube Connections as Viewed from Below

No element is connected to contact #6 of this particular tube. Therefore, we indicate this contact with dotted lines. You must bear in mind that in Fig. 15 you are looking at the socket from below.

Now let us turn to Fig. 14, where you will note that the filament circuit consists of the "A" battery, the filament and the wiring.

The diagram also shows that a switch is incorporated in the filament circuit so that the oscillator may be turned "on" or "off."

The plate circuit is comprised of the "B" battery, half of the a-f transformer's secondary winding, the plate of the tube, and finally the cathode -- whence we return to the negative terminal of the "B" battery. This battery may have a voltage ranging from 22.5 to 45 volts.

The 500,000-ohm resistor forms part of the grid circuit in that it connects the grid to the cathode. The .00025 mf condenser connects the grid to the upper end of the a-f transformer's secondary winding. The primary winding of the transformer is connected in series with the headphones and the two test leads, which, when touched together, complete the circuit.

HOW THE OSCILLATOR OPERATES

Although the operation of tubes is thoroughly discussed in other lessons of the course, we do give you at this time an explanation of the work done by the triode in the oscillator of Fig.14.

To begin with, bear in mind that the oscillator produces or generates oscillations that are identical to those obtained from an a-c generator. This being true, you are no doubt probably wondering how a tube operating with d-c applied to its elements is able to furnish an a-c output. To clear up this point, let us analyze Figs. 16 and 17, where is shown the same circuit as in Fig. 14, with the exception of the filament circuit and the primary winding of the a-f transformer.

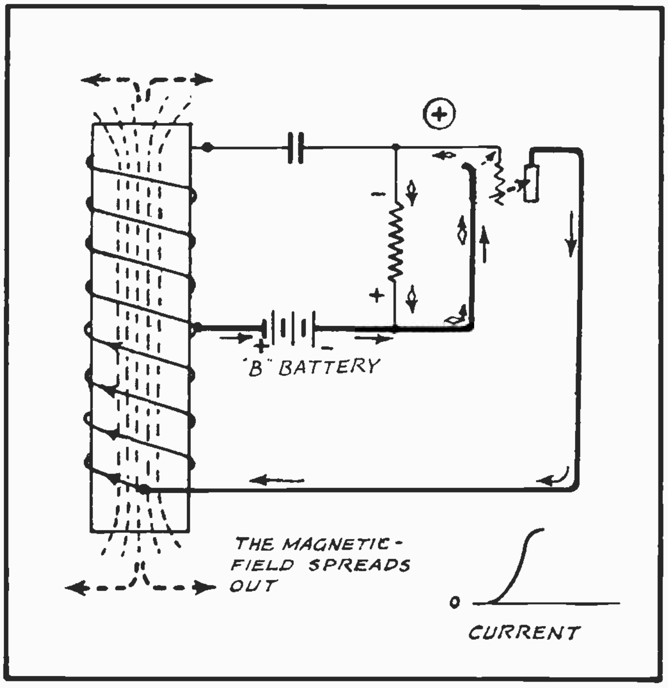

FIG. 16
CIRCUIT ACTION AS GRID BECOMES POSITIVE

As we have already mentioned, the filament serves no other purpose than to heat the electron-emitting cathode; therefore, we can eliminate it from our explanations.

Once the filament has been heated sufficiently to raise the temperature of the cathode and cause it to emit electrons, the path of electrons will be as follows: Starting from the negative terminal of the B-battery, they flow to the cathode, from whence they pass to the plate, continuing to the lower end of the winding, and finally returning to the positive terminal of the battery. This path is illustrated by the heavy black arrows in Fig. 16, and shows clearly how the current flows through the lower half of the winding during this time.

We should take into consideration that the current (electron-flow) does not reach its maximum value instantaneously, but increases gradually, even though only a millionth part of a second is required for it to increase from zero to the maximum value.

As a weak current begins to flow through the lower-half of the winding, a magnetic field is formed, extending outside of the solenoid. As a result, we have a moving magnetic field that cuts through the upper-half of the winding and generates therein a self-induced voltage.

As a result of the above action, the upper-half of the coil acquires a positive bias. This bias is applied to the grid through the condenser, causing the grid to become charged slightly positive. This allows the plate current to increase. Hence, the magnetic field will also be increased, the induced voltage becomes greater, and the grid becomes still more positive -- this will cause a further increase in plate current. The entire process repeats itself again and again until the plate current reaches its maximum value.

Upon examining Fig. 16 closely, you will notice that the positive potential on the grid will cause electrons to flow through the resistor in such direction as to make the grid negative, in relation to the cathode.

As the plate current increases in value, the positive voltage applied to the grid by means of induction also increases. At the same time, the negative voltage produced by the resistor also increases. Finally, a point is reached where these opposing voltages become equal and are thus neutralized.

If we were to illustrate graphically the increase in plate current during this period, we would obtain the curve shown in the lower right-hand corner of Fig. 16. This curve illustrates the action during which the plate current attains its maximum or peak value.

As soon as the current reaches its peak value, the magnetic field ceases to build up and remains stationary, and while there is no action in the field, no voltage is induced in the upper part of the coil. Since the grid is connected to the upper part of the coil, it will lose its positive potential, causing an immediate interruption in plate current. As soon as the current begins to decrease, a change takes place in the magnetic field -- that is, the field commences to collapse.

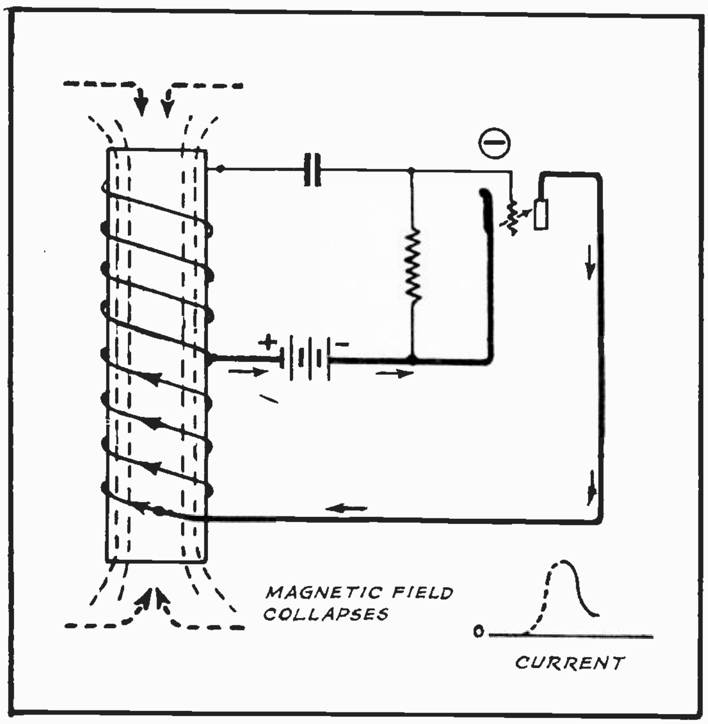

FIG. 17
CIRCUIT ACTION AS GRID BECOMES NEGATIVE

The condition which causes the voltage-induction in the upper-half of the coil again comes into action, but as the lines of force are now moving in a direction opposite to their former movement, the induced voltage will be in opposition to that which existed previously. This causes the grid to become negative, and as we can easily see, it also causes the plate current to decrease. As the plate current decreases, it con trols the action of the magnetic field, and a voltage continues to be induced in the upper half of the winding, causing the grid to gradually become more negative.

Finally, an instant is reached where the current has decreased to such an extent that the induced voltage is very small --- at this time the grid cannot cause a greater reduction in voltage than that which has already been attained. Fig. 17 illustrates the condition as the plate current is about to reach its minimum value. (The dotted section of the curve in the lower right-hand corner of Fig. 17 shows how the current increases as the grid becomes more positive. The solid part of the line illustrates the decrease in current resulting from the grid becoming negative.)

Now, as soon as the plate current reaches its minimum value, the magnetic field reaches a stationary condition and the induction of voltage in the upper half of the coil ceases. The grid then loses its negative bias, allowing the current to again increase. The magnetic field then again begins to move outwardly and in so doing, causes the grid to gradually become positive.

Again, we find the same conditions as when we first started our analysis of Fig. 16. This cycle repeats itself as long as the cathode remains heated. The result is shown in Fig. 18, where the curve indicates the changes in plate current as the grid alternately becomes positive and negative.

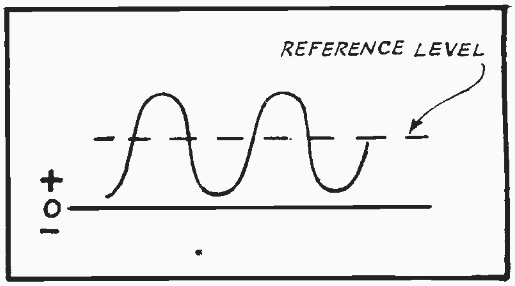

FIG. 18
PLATE CURRENT VARIATIONS CAUSED BY ALTERNATING GRID VOLTAGE

Note how the plate current has maintained the same direction of flow. However, if we compare its variations with a zero reference line, we can immediately see that the curve is the same as that representing alternating current. Thus, although we are actually using pulsating d-c, its effects are exactly the same as those of a-c. Therefore, if we couple another independent circuit to the coil, a-c will be induced in it.

In the case of the transformer which is used in the oscillator, the so-called primary winding is inductively coupled to the center-tapped secondary winding. Therefore, a-c will be induced in the primary winding and the current flow therein will undergo the same changes that occur in the plate current of the tube.

The a-c, which is induced in the primary winding, will circulate through the headphones each time that the test leads are touched together, and will produce a musical note of the same frequency as the a-c.

The frequency of these changes is controlled by the relation between the inductance and capacity of the oscillator circuit, or "tank circuit," as it is commonly called when referring to transmitting oscillators. When dealing with a winding of many turns wound on an iron core, it is easy to understand that its inductance is very high and that the frequency of the oscillations will be in the audible range.

The capacity in this circuit is really quite small, as we only have the distributed capacity of the windings, the internal capacity of the tube, and the capacity of the connections to deal with. Nevertheless, the inductance is sufficiently high to keep the oscillations within the audible band, as desired.

Should we desire to produce r-f oscillations, then we would use a coil of low inductance and a condenser of low capacity, for, as you will learn in one of your regular lessons, the frequency of the oscillations depends on the product of the capacity and the inductance. This product is known as the "LC" factor; the smaller this product, the higher will be the frequency of the oscillations.

WIRING THE A-F OSCILLATOR

Now that we have studied the theoretical functions of the oscillator, let us continue with its construction. In radio work, the correct construction of the apparatus is as important as the preparation of the diagram or the design of the circuit. It would be of no value to carefully calculate the components, and then encounter difficulties because of the improper placement of parts and poorly-connected conductors. The correct construction of any radio receiver is relatively easy when the following important points are kept clearly in mind.

1 - Connections must be made directly from one terminal to the other, without splicing the wire at some intermediate point.
2 - The control grid circuit must be as short and direct as possible.
3 - The control grid circuit must be placed away from the plate circuit whenever conditions permit.
4 - Connections must be mechanically secure and well soldered.
5 - Conductors must not obstruct the contacts or terminals, so as to allow enough room to apply test leads later on.
6 - It is advisable to group the conductors against the base of the chassis, in order to allow sufficient space for condensers, resistors, etc.
7 - In complicated circuits,it is advisable to use wire equipped with an insulation of different color -- the different colors designating the various circuits.

The importance of the above points will become clearer as you progress with your practical construction jobs. However, the a-f oscillator falls into the category of a simple construction project and therefore requires no undue caution. In fact,these first jobs present no difficulty at all.

In constructing a set, the first step is to make a list of the parts needed, which information is acquired from the diagram. This means that you must carefully study Fig. 14 and then prepare your list.

Now comes the problem of deciding on the dimensions of the chassis, base or cabinet for the set. The simplest method is to use a piece of wood or thick cardboard for the base, the dimensions for which can be determined by provisionally placing upon a sheet of paper all of the parts and components to be used, arranging the parts to conform with the layout as given.

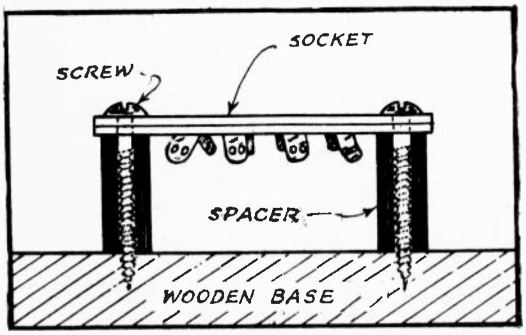

FIG. 19
SOCKET MOUNTING

The socket furnished by us is designed to be mounted on a metal chassis, but you can use it for the oscillator without difficulty by fastening it in place with two large screws and wooden spacers, as shown in Fig. 19.

Now,to continue with the placement of the parts. It is advisable

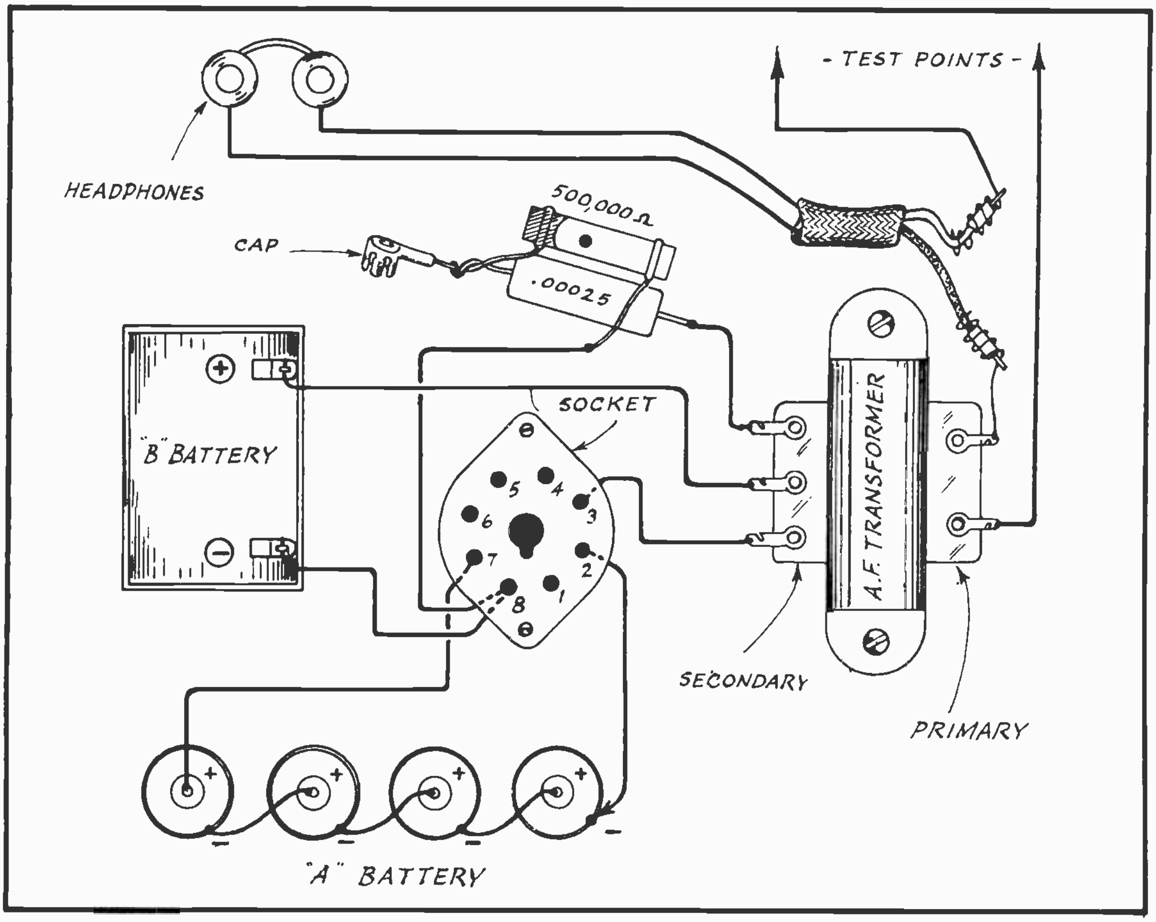

FIG. 20
PARTS ARRANGEMENT AND WIRING OF A-F OSCILLATOR

to draw a simple plan of the components and the wiring, placing them in their approximate positions. This will serve to show you how to place the equipment most conveniently and will enable you to wire the set in such manner as to avoid undesired coupling.

Even though the a-f oscillator is quite simple to construct, it is advisable for you to prepare the drawing or layout for the sake of experience. When you have determined the most convenient placement of the various parts, compare your layout with that shown in Fig. 20. This layout is not the only permissible way in which to arrange the parts -- in fact, it is only one of many ways. The same results would be obtained if we placed the transformer on the left and the battery on the right side, etc. The only thing we are striving for in this case is to arrange the parts so that the connections will be short and direct.

In Fig. 20 the different parts are illustrated as viewed from above, with the connections clearly shown so that you will have no difficulty whatsoever. With the exception of the wire leading from the negative side of the "A" battery, all connections should be made in a permanent manner. The negative A-lead serves the purpose of a switch so that the circuit can be opened and closed at will.

The plate circuit requires no switch because it is automatically interrupted when the filament of the tube becomes cold; that is, when no electrons are emitted by the cathode.

It is advisable to solder all of the permanent connections, with the exception of the headphone and battery connections. The headphones can be connected to the circuit by twisting the bared ends of the circuit wires around the phone tips, as shown in Fig. 20.

THE BATTERY-OPERATED OSCILLATOR

The oscillator diagrammed in Fig. 14 and constructionally illustrated in Fig. 20, is battery-operated. If you use a 6Q7, or 6T7G tube, the filament voltage should be 6.3 volts, which can be acquired from a 6-volt storage battery or from four series-connected dry cells of 1½ volts each (see Fig. 20).

The polarity of the "A" battery is not of great importance, as the filament has no direct bearing on the operation of the oscillator. Therefore, contact #7 of the socket may be connected to the negative terminal and contact #2 to the positive terminal, or vice versa.

However, this is not true of the "B" battery. In order for the plate current to flow through the tube properly, it is necessary that the plate be positive with respect to the cathode. This is accomplished by connecting the positive side of the battery to the center-tap of the a-f transformer's secondary winding.

HOW TO OPERATE THE OSCILLATOR FROM THE 110-VOLT LIGHTING CIRCUIT

This type of oscillator may also be operated by using the current supplied by a lighting circuit. Let us first consider a 110-volt line, whether it be of the a-c or d-c type.

As the line voltage is too high for the filament circuit, we must use a resistor in series, so that only 6.3 volts will be applied to the tube's filament. This resistance may be furnished by a common 110-volt lamp bulb, rated at between 25 and 40 watts.

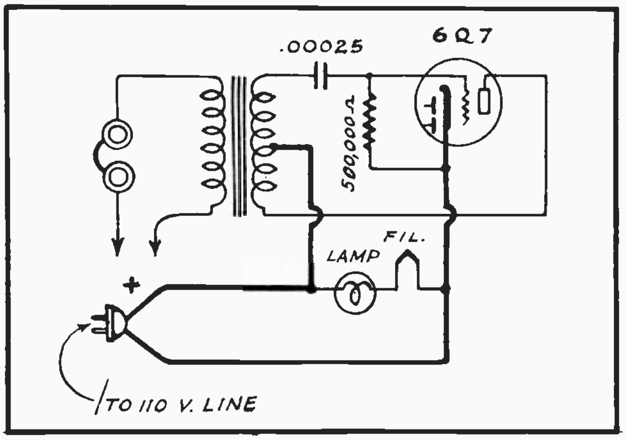

FIG. 21
OSCILLATOR OPERATED FROM 110-VOLT LINE

For the plate circuit we can use the full voltage of the line. However, if the lighting circuit is of the d-c type, we must be careful to connect the positive side of the line to the tube's plate. If the line is of the a-c type, there is no definite polarity, and we can then connect either side of the line to the plate.

You are probably now wondering how the tube can function with a-c applied to its plate. This can be explained as follows: The tube functions also as a rectifier, allowing current to flow during only every half-cycle. The direct current, thus obtained, will not be continuous, but will consist of pulsations that will produce a hum in the output of the oscillator. This is of no importance to the various uses to which the oscillator is tobe applied, but if you first operate your oscillator with batteries and then with a-c, you will notice that the resulting note is not clear when a-c is used.

Fig. 21 shows how the above requisites are put into practice. Notice how the filament is connected in series with a lamp and that the

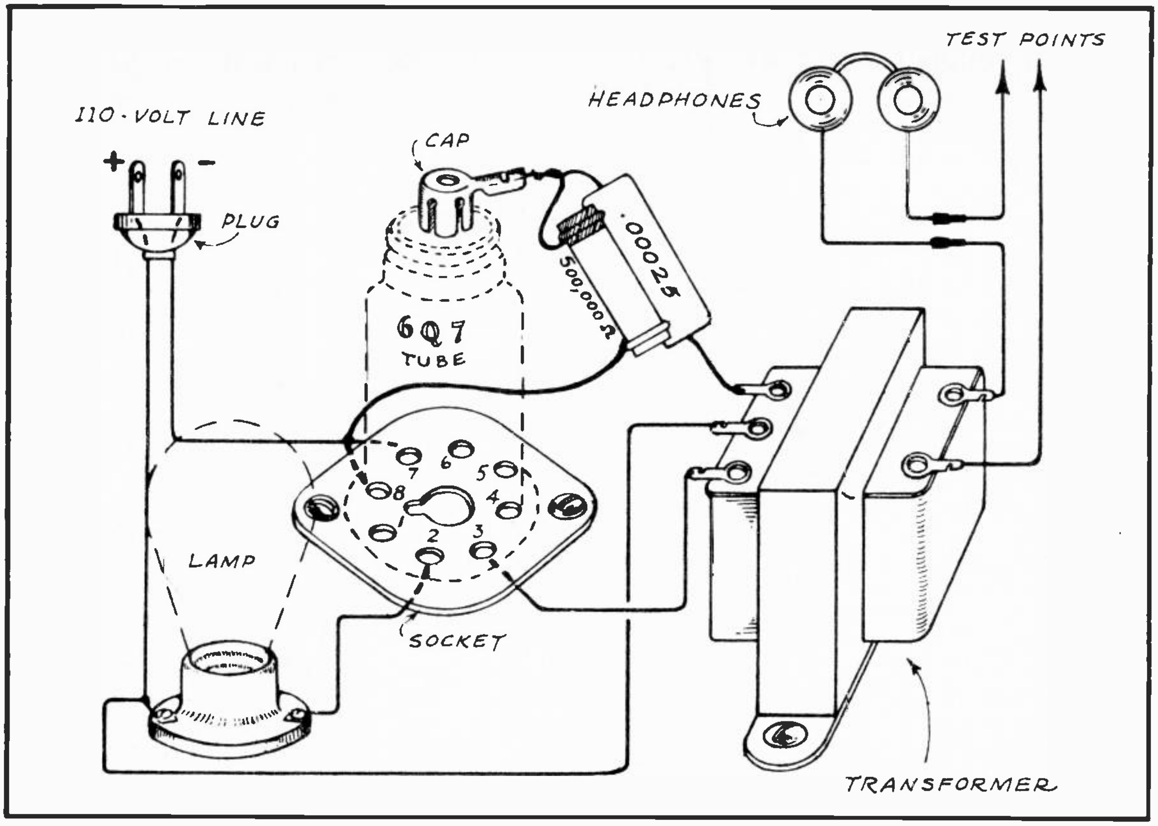

FIG. 22
PARTS ARRANGEMENT AND WIRING OF 110-VOLT OSCILLATOR

two sides of the line are also connected to the transformer's center-tap and also to the cathode. Fig. 22 will also assist you in making the connections correctly. As we have already mentioned, the polarity shown on the plug applies only to d-c operation.

HOW TO OPERATE THE OSCILLATOR FROM A 150 OR 220-VOLT CIRCUIT

To operate this oscillator from a 150-volt lighting circuit, simply replace the 110-volt series lamp, previously prescribed, with a 150-volt lamp of any watt-rating between 30 and 50 watts.

If the oscillator is to be operated from a 220-volt circuit, it is necessary to reduce the plate voltage so as to permit the oscillator to operate in a stable manner. The solution in this case is to connect two ordinary lamp bulbs in a voltage divider arrangement as shown in Fig. 23. Approximately, only one-half of the line voltage, or 110 volts, will now be applied to the plate of the tube.

The construction of this oscillator needs no additional explanation. The connections

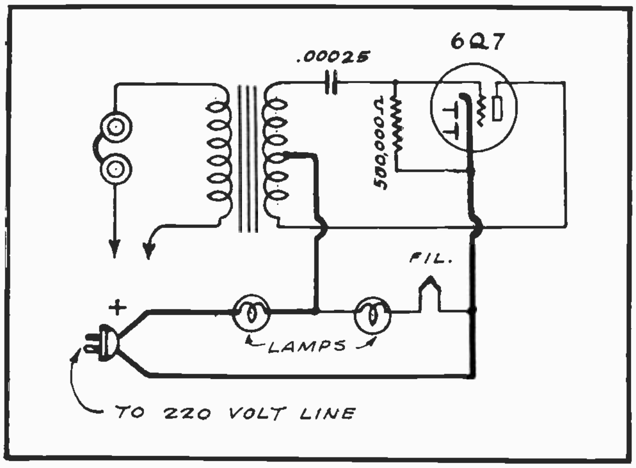

FIG. 23
OSCILLATOR OPERATED FROM 220-VOLT LINE

are identical to those shown in Fig. 22, with the exception of the second lamp, which is connected in series with the line and the B+ lead. For this purpose, the lamps should be of the 40-watt, 110-volt type, or 200-watt, 220-volt type.

APPLICATION OF THE A-F OSCILLATOR

A very useful application of the oscillator is for testing the audio amplifying stages of a receiver. All that is required for this purpose is to connect one test-lead to the control grid of the first a-f tube, and the other to the chassis. If the amplifier is in good condition, the note produced by the oscillator should be heard loudly through the speaker.

By applying the leads to the control grid of the remaining a-f tubes, you can determine if trouble exists in preceding a-f stages.

The r-f or detector stages cannot be tested with the a-f oscillator, as such circuits operate at radio frequencies rather than audio frequencies. In this case you must use an r-f oscillator, like the one you will build in accordance with later experiment lessons.

TESTING RADIO PARTS

The a-f oscillator can also be used for testing the components of a receiver. These tests are carried out in the manner already explained relative to continuity tests; that is, instead of hearing only a click when testing through a complete circuit, you will now hear the musical note of the oscillator.

The results of these tests are practically the same as those already mentioned in connection with the simple continuity tester consisting of the headset connected in series with a battery. With a little practice, you will learn how to perform these tests most efficiently.

This completes the work outlined in this experiment lesson. We are confident that you have found it interesting and instructive, and that you appreciate the fact that the principles and instruction included herein will be of a definite value to you. As you progress with your studies, you will have the opportunity to conduct experiments of a more advanced nature, until you arrive at the point where you will construct a modern superheterodyne receiver, analyze circuit troubles, etc.

SPECIAL INSTRUCTIONS ON HOW TO USE THE OSCILLATOR AS A CODE-PRACTICE SET

Later in the course, you will receive intensive instruction on the International Continental Code (telegraphic code). However, we are furnishing the following basic instructions and suggestions for those who are interested in using the a-f oscillator at this time for beginning the study of "the code."

Since this type of communication consists of sending messages by means of dots and dashes, properly grouped, a telegraph key should be connected in series with your headphones and the primary winding of the oscillator's transformer. Thus, by depressing the key for only an instant, the "dot" of the code signal will be heard in your phones as the sound "dit." Holding the key closed for a longer interval of time will enable you to form the "dash" of the code signal, which will be heard in your phones as the sound "dah."

In case that you have no key, you can open and close the circuit with the ends of the circuit wires. One of the wires can then be braced on a table, and the other held between your fingers and manipulated as though it were the knob of a key. It is also very easy to construct a makeshift key for this purpose.

In Table I are given the alphabet, numerals, most commonly-used punctuation marks and common signals that are employed in the transmission of messages by means of the International Continental Code. There are still other characters to be learned but, for the present, this is all with which you need be concerned.

TABLE I

THE INTERNATIONAL CONTINENTAL CODE

ALPHABET

A	•—	N	—•
B	—•••	O	———
C	—•—•	P	•——•
D	—••	Q	——•—
E	•	R	•—•
F	••—•	S	•••
G	——•	T	—
H	••••	U	••—
I	••	V	•••—
J	•———	W	•——
K	—•—	X	—••—
L	•—••	Y	—•——
M	——	Z	——••

NUMERALS

1	•————	6	—••••
2	••———	7	——•••
3	•••——	8	———••
4	••••—	9	————•
5	•••••	0	—————

PUNCTUATION

Period	(.)	•• •• ••	Colon	(:)	———•••
Interrogation	(?)	••——••	Semicolon	(;)	—•—•—•
Break	(--)	—•••—	Quotation Marks	(" ")	•—••—•
Exclamation	(!)	——••——	Parenthesis	( )	—•— —•—
Comma	(,)	•—•—•—			

COMMON SIGNALS

Wait	•—•••	Distress Call (S.O.S.)	•••———•••
End of Message	•—•—•	General Call (C.Q.)	—•—• ——•—
End of Transmission	•••—•—	From	—•• •
Received (O.K.)	•—•	Error	••••••••
Invitation to Transmit	—•—	Repetition	•• ••

To produce and group the dots and dashes of any code character correctly, the following rules should be observed:

(1) A dash is equal in length to three dots.

(2) The interval of silence between parts of the same letter is equal to one dot.

(3) The space between two letters is equal to three dots.

(4) The space between two words is equal to five dots.

In memorizing the code, do not think of the various signals in terms of dots and dashes, but rather in terms of the "sound." That is, the letter "A" should be learned as the sound "dit dah" and not as "dot dash."

To simplify learning the code, it is advisable that you start with the alphabet, mastering the first five letters thoroughly before continuing with the next five, and so on. After the alphabet has been learned perfectly, start learning the numerals in groups of five. Later on, you can devote your attention to the punctuation marks, and finally, to the common signals.

The important thing is to take your time and "send" slowly at first, and do not start learning a new group until you have mastered the preceding ones. Your speed of sending will increase gradually and automatically, with practice.

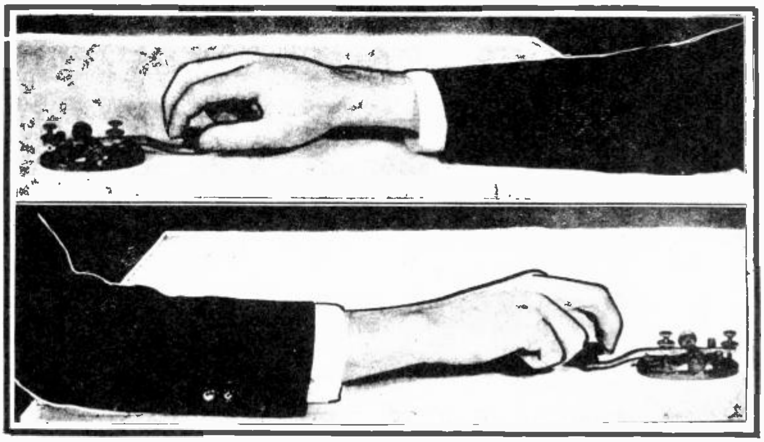

FIG. 24
CORRECT METHOD OF MANIPULATING THE "KEY"

If you are right-handed, the key should be placed in the position illustrated in Fig. 24. The thumb should be held against the left side of the key, whereas the first and second fingers should be bent slightly so as to hold the center and right side of the knob. Observe in the illustration that these three fingers are partly on top of the knob, while the remaining two fingers are entirely free of the key. The hand should rest lightly on the key, without actually grasping the knob in a firm grip.

The elbow should be rested on the table -- the wrist being held above the table at all times. The entire forearm should be used to manipulate the key, the elbow serving as the pivot. Do not use finger movement or a wrist motion.

You can obtain excellent experience in receiving code messages by simply tuning any ordinary shortwave or all-wave receiver to those wave bands on which telegraphic communication is being conducted. It is advisable that you select stations from which the messages are sent at a slow rate.

******

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. FG-1

Ans Nov 13/1941

1. - Describe a practical method for checking the condition of a paper condenser.

2. - What is the value of a resistor that has a red body, a green end and a yellow spot?

3. - What will happen if the headphones are connected directly across an a-c lighting circuit?

4. - A certain mica condenser has three colored dots, whose order of reading is as follows: Green-black-brown. What is its capacity?

5. - Mention three important points that should be considered when wiring a radio receiver?

6. - When the a-f oscillator described in this lesson is connected directly across the a-c line, how is a direct current obtained for the plate circuit?

7. - What precautions should be taken when connecting the a-f oscillator to a d-c lighting circuit?

8. - Describe briefly a practical test for determining the condition of the windings on an a-f transformer.

9. - How would you proceed to test a lightning arrestor?

10. - Does a direct current or an alternating current flow through the headphones when they are connected to the "primary" winding of the a-f oscillator?

EDUCATION

"MAKE A RESOLUTION THAT YOU ARE GOING TO BE AN EDUCATED MAN."

"THE BEST EDUCATED PEOPLE ARE THOSE WHO ARE ALWAYS LEARNING, ALWAYS ABSORBING KNOWLEDGE FROM EVERY POSSIBLE SOURCE AND AT EVERY OPPORTUNITY."

"SOME PEOPLE ARE ALWAYS AT SCHOOL, ALWAYS STORING UP PRECIOUS BITS OF KNOWLEDGE."

"THE MAN WHO HAS LEARNED THE ART OF SEEING THINGS LOOKS WITH HIS BRAIN."

"IT CANNOT BE DONE," CRIES THE MAN WITHOUT IMAGINATION. "IT CAN BE DONE, IT SHALL BE DONE," CRIES THE DREAMER.

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EXPERIMENT LESSON NO. FG-2

AUDIBLE AND VISUAL TESTS

Before continuing with the various experiments that can be performed with the parts you received in the second kit of equipment, it is well for us to first consider some important points which have a very definite influence upon the performance of all types of radio apparatus. In fact, you will also find the information given at the beginning of this lesson to be quite helpful in applying your present knowledge to the simpler type of radio service jobs conducted in your spare time. First, let us consider the correct method of soldering.

SOLDERING

Soldering, as applied to radio, is generally done with the aid of an electric soldering iron or with a soldering iron of the flame-heated type. In radio work, it is recommended that the best kind of solder be used -- regular radio solder of the rosin-core type being preferred. In the event that rosin-core solder is not available, the solid type may be used, but it should always be employed in combination with a non-corrosive soldering paste that is suitable for soldering electrical connections.

HOW TO "TIN" A SOLDERING IRON: The soldering iron must be perfectly clean, tinned properly, and at the correct temperature so that solder will melt immediately upon contacting the tip of the iron. Whenever the tinned surface on the tip of the iron deteriorates, the iron should be re-tinned immediately. This is done in the following manner:

First, clean the tip of the iron with a wire brush until the copper surface shines brightly. Then heat the iron to a temperature where it will cause solder to flow freely. Next, apply a small amount of soldering paste to the tip and then apply a generous quantity of solder so as to cover the tip. After having coated the tip with solder in this manner, wipe the tip against a clean rag so as to remove all surplus solder. The tip will thus be furnished with a thin even coating of solder as pointed out in Fig. 1. We then say that the soldering iron has been properly tinned.

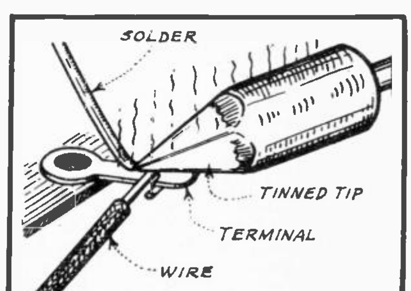

FIG. 1
TERMINAL CONNECTION

IMPORTANT POINTS TO BE CONSIDERED: Soldering acid should never be used for radio work, nor for any other type of electrical work.

Another point to bear in mind while soldering, is to make sure that the two surfaces being joined are kept in close contact with one another during the entire soldering procedure. This is necessary if a well soldered electrical connection is to be obtained.

Also, always bear in mind that the main object for soldering an electrical connection is to protect it from corrosion and to insure a good electrical contact under all normal conditions.

HOW TO SOLDER A WIRE TO A LUG: The correct method of soldering a wire to a lug is shown in Fig. 1. Here you will observe that the end of the wire has first been inserted through the hole in the lug, and then doubled back. The soldering iron is then applied to both the lug and the wire so that the heat from the iron will be transferred to the parts being joined.

When the temperature of the lug and the wire has been raised sufficiently, a little solder is applied to the tip of the soldering iron and allowed to run or spread over both surfaces being soldered. Should the solder run off the points being joined, it can be returned to the area desired by proper manipulation of the iron. However, when so doing, caution should be exercised so as not to move the parts being joined until the flowing solder has enveloped them completely and solidified.

HOW TO SOLDER A CONNECTION TO THE CHASSIS: When soldering a connection to the chassis, it is important that the chassis be scraped perfectly clean at the intended point of contact. Also, the iron should be well heated. The iron should then be held firmly against that point of the chassis where the solder is to be applied, allowing that portion of the chassis to become well heated. Next, pick up a small amount of soldering paste with the end of the solder and touch this end of the solder to the tip of the soldering iron, without withdrawing the iron from the chassis. Upon moving the tip of the iron gently around the heated area of the chassis, the solder will commence to flow,forming a bright spot on the chassis. The next step is to solder the wire or terminal to that point, being careful that the wire or terminal does not move until the solder has solidified.

As soon as the solder has solidified, test the mechanical strength of the connection by pulling slightly on the wire or terminal.

CLEANLINESS IS VITAL: Before soldering the terminal wires of condensers or resistors, always make sure that they are perfectly clean. Some of these wires or terminals are tinned at the factory and therefore require no further cleaning. Others need to be cleaned with the aid of sandpaper or scraped with a dull-edged knife before soldering. Whenever you find that solder does not "stick," always clean the surfaces involved until they are brilliant. All nickel-plated surfaces must be filed until the plating has been removed completely, as solder will not adhere to nickel.

Hook-up wire of the push-back type can be soldered easily, as it is generally well tinned at the factory. Rubber-covered wire, on the other hand, must be cleaned with a knife or sandpaper so as to remove all rubber and to provide a bright surface that will "hold" solder.

Whenever it is necessary to solder several wires to one terminal, it is good practice to bend all the wires over the terminal so as to prevent them from separating during the soldering procedure.

WHY PARTS SHOULD BE CHECKED BEFORE CONNECTIONS ARE SOLDERED: It is important to check all parts before soldering the connections of the circuits being wired. These tests have already been explained in other parts of your course, particularly as they apply to bypass condensers, electrolytic condensers, a-f and r-f transformers, etc. If all of the parts have first been checked in this manner, the testing procedure is greatly simplified in case the receiver does not operate satisfactorily upon completion.

Having covered the procedure of soldering, we are now ready to continue with our experimental work. The experiments, now to be described, will help you to better understand some of the more important basic principles of electricity as applied to radio. Therefore, no matter now simple they may seem, the knowledge acquired through this means will always be helpful to you.

HOW TO GENERATE AN ELECTRICAL CURRENT BY CHEMICAL MEANS

One of the simplest experiments, but also one of the most important, is that of generating electricity by chemical means. We shall therefore begin our experiments by constructing an elementary cell with the aid of various common materials.

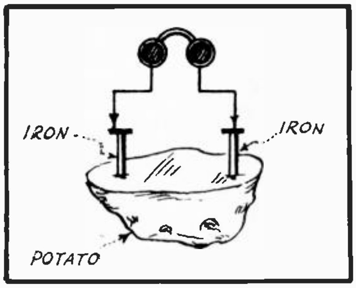

FIG. 2
NEGLIGIBLE VOLTAGE

For this experiment you will be required to use your headphones, a fresh raw potato, several iron nails, and a short piece of copper wire.

The potato will in this case serve as an electrolyte, as its juice contains acids which affect the electrodes being used. The headphones can be used to detect any existing voltage because when an electric current flows through their windings,a "click" will be heard every time the circuit is interrupted or completed. The stronger the current flow through the windings, the more noticeable will be the "click" upon interrupting or completing the circuit.

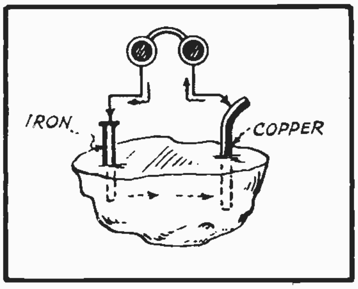

FIG. 3
A VOLTAGE IS GENERATED

We shall begin our first experiment by inserting two iron nails into one-half of a potato, as shown in Fig. 2. The headphones are then connected between the two nails. Under normal conditions, no click will be heard when either interrupting or completing this circuit, as no voltage is developed by this arrangement.

In the illustrations appearing in Figs.2 and 3, you will notice that the electrodes are shown as being widely spaced; however, you should place them rather close together while performing the experiment,being careful that they do not touch each other. Also be sure to insert them deep in the potato so that more electrode surface will be exposed to the electrolyte (potato juice).

If the electrodes are made of pure iron, no voltage at all will be generated. However, nails are not made of pure iron; therefore, impurities contained in their structure will develop a potential difference, which, though insignificant, exists.

Now repeat the experiment,but this time use two pieces of copper wire instead of the two nails. The result will be exactly the same as in the previous case. That is, no "click" will be heard in the headphones. In the event that a very faint noise is perceptible upon interrupting or completing the circuit, it indicates only the presence of impurities in the electrodes.

From the above experiments, you have learned that electrodes of the same metal do not develop any potential difference.

Next, try using a piece of copper wire as one electrode and an iron nail as the other (see Fig. 3). Upon interrupting or completing this circuit, you will hear a rather strong "click" in your headphones. This indicates that the combination of metals now used as electrodes will enable the cell to generate an electromotive force of noticeable intensity, causing a current to flow through the windings of the headphones.

What really takes place in an arrangement as just described, is that the acids in the potato juice or electrolyte attack the iron more than they do the copper -- the chemical action being such as to generate an electromotive force. The combination of electrodes need not necessarily be copper and iron -- combinations of other metals will also produce an electromotive force. However, certain combinations of metals develop more voltage and others less. For instance, the combination of carbon and zinc when submerged in an ammonium electrolyte, such as used in the construction of present-day dry cells, develops a fairly high electromotive force.

The important fact to be acquired from these experiments is that the combination of different metal electrodes will generate an electromotive force when exposed to a suitable electrolyte.

CONSTRUCTION OF A SECONDARY CELL

Continuing with our electrochemical experiments, let us now consider the theory of the secondary cell or storage battery. However, since it is not practical to handle sulphuric acid and lead while conducting your experiments at home, we will again use the potato and two pieces of copper wire.

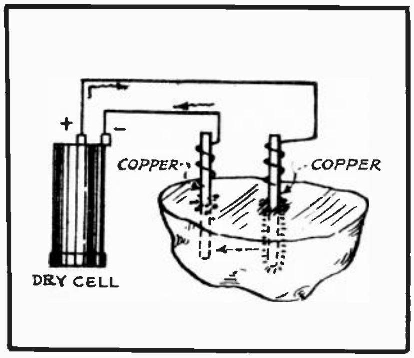

FIG. 4
CHARGING THE CELL

Once again, let us remind you that when inserting the copper wires into the potato, be sure that they are as close together as possible, without touching each other. Now, connect the headphones across the copper wires as done previously -- you will find that since both electrodes are made of the same metal, no "click" will be heard in the phones. Next, connect a dry cell across the electrodes in the manner illustrated in Fig. 4, thus permitting an electric current to flow through the circuit.

After a short while you will notice that a green substance will begin to form around the wire which is connected to the positive terminal of the dry cell, whereas a foamy substance will appear around the other wire.

The chemical action of the current flow through the circuit is now such that it combines the copper of one electrode with the electrolyte (potato juice) so as to form copper nitrate (the green substance). Hydrogen is liberated from the potato juice at the other electrode, forming bubbles that resemble foam. In other words, electrical energy is converted into chemical energy as the original chemical conditions in the arrangement are altered.

Upon disconnecting the dry cell from the circuit, you will have a secondary cell, the chemical composition of one of the copper electrodes having been changed with the current flow so as to become copper nitrate, while the other remains in the state of pure copper.

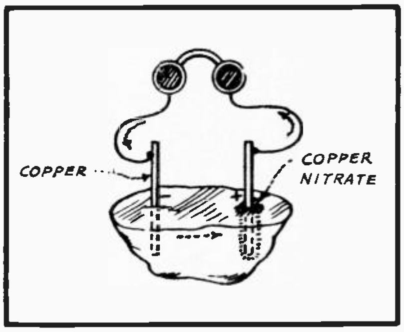

FIG. 5
DISCHARGING THE CELL

Upon connecting the headphones as shown in Fig. 5, you will hear a very distinct "click". This indicates that the cell was being charged during the time that the electric current from the dry cell flowed through it, and that it discharges when connecting the headphones across it. You must bear in mind that by "charging" a cell, is meant that electrical energy is being converted into chemical energy, whereas "discharging" a cell means the opposite -- that is, chemical energy is being converted into electrical energy. Another important point to remember is that the electrode that is connected to the positive terminal of the dry cell becomes the positive terminal of the secondary cell. This is also true in the case of a conventional storage battery.

HOW TO DETERMINE THE POLARITY OF D-C CIRCUITS

The foregoing explanation of the electrochemical action is very valuable in that it helps one to determine which is the positive side of a d-c circuit.

In the experiment illustrated in Fig. 6, the bare copper electrodes are inserted in a potato. Upon waiting a few seconds, copper nitrate will be seen to form around the wire that is connected to the positive side of the line.

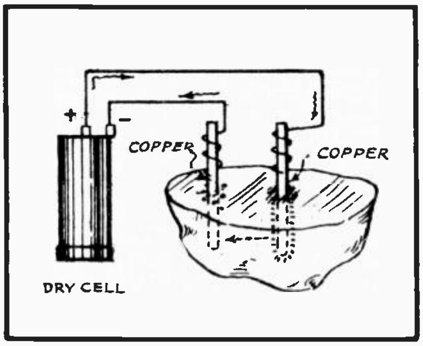

FIG. 6
HOW TO DETERMINE THE POSITIVE SIDE OF THE CIRCUIT

HOW TO DETERMINE IF A CIRCUIT IS OF THE A-C OR D-C TYPE

The experiment just described can also be applied to determine if an alternating or direct current is flowing through a given circuit. If the circuit in question is of the low-voltage type, as is the case when checking a circuit energized by batteries or a low-voltage (bell-type) transformer, simply insert the two bared ends of the copper wire in a potato as shown in Fig. 6, and observe results.

If green-colored copper nitrate forms around one of the wires and hydrogen bubbles around the other, you will know that the circuit is of the d-c type and that the wire surrounded by the copper nitrate is connected to the positive side of the circuit.

Repeating this same experiment with an alternating current circuit will disclose the presence of hydrogen bubbles around both wires and also a slight tinge of green copper nitrate around each of them. In other words, since alternating current flows through the arrangement first in one direction and then in the opposite direction, the electrodes will acquire both positive and negative characteristics.

Having applied an a-c voltage to the electrodes, no clicking sound will be heard upon applying the headphone test illustrated in Fig. 5, as alternating current is not suitable for charging a secondary cell. The reason for this is that the flow of a-c will charge and discharge the cell alternately in accordance with the current reversals.

If the tests just described are performed on circuits operating at voltages of 110 volts or more, special precautions should be taken so as not to blow a fuse in the circuit nor to subject yourself to an electric shock. To avoid these dangers, be sure that you are standing on a dry wooden floor, and that the insulation of the wire being used is dry and of adequate insulating ability for the voltage involved. When handling such circuits, never touch the bare wires while the circuit is closed, and be sure to include an incandescent lamp in series with the circuit under test. The lamp used for this purpose should be rated at about 40 watts and of the same voltage as the line. The set-up for this a-c line test is shown in Fig. 7.

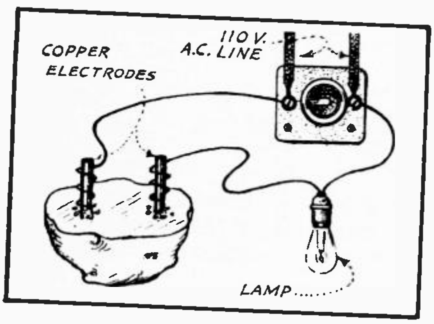

FIG. 7
EFFECT OF ALTERNATING CURRENT

THERMAL EFFECT OF AN ELECTRIC CURRENT

The experiment illustrated in Fig. 7 can also be used to demonstrate the effect of reducing the resistance in a circuit, and at the same time show how the temperature increases very rapidly with any increase in current flow. For this experiment, simply move the two line-wires closer and closer together, being careful that they do not touch each other at any time. You will observe that bringing the wires together will cause the lamp to burn brighter. More bubbles will also form around the wires, and the potato will become noticeably warm.

This action can be explained as follows: Moving the electrodes closer together reduces the resistance and permits a greater current to flow through the circuit. The chemical action is so rapid at this time that considerable heat is generated.

The chemical action as outlined for this experiment will be the same when d-c is used but the voltage must of course be much higher than the 1.5 volts furnished by the dry cell. A good radio "B" battery can be used effectively to demonstrate this.

WATER RHEOSTATS

The chemical decomposition of water by a flow of electric current can also be used to determine the polarity of d-c circuits, as well as to determine whether the circuit in question is of the d-c or a-c type. The decomposition of water by this means is called ELECTROLYSIS.

Such an experiment can be performed by connecting two pieces of copper wire to the terminals of a dry cell,and inserting the bare ends of these wires into a glass of water, as shown in Fig. 8.

This arrangement is called a water rheostat. The resistance value of this water rheostat depends upon the effective area of the electrodes, the separation betweem them and the conductivity of the liquid being used. By using ordinary drinking water and two pieces of wire, separated from each other by about 2 inches, the resistance of the rheostat will be approximately 7,000 ohms. However, moving the wires closer together -- say, until they are about one inch apart -- will reduce the resistance to about 4,000 ohms. (The wires are submerged in the water to a depth of about 12 inches.)

Now, by moving the wires still closer together, but being careful that they do not touch each other, you will observe numerous bubbles accumulating around the submerged wire that is connected to the negative electrode of the cell. If a battery voltage of 4.5 volts is employed, a still greater number of bubbles will form around the negative wire.

The reason for the formation of the bubbles is that the passage of an electrical current through the water decomposes the water into its chemical elements,oxygen and hydrogen. Oxygen bubbles form around the positive electrode and hydrogen bubbles around the other electrode, but there are more hydrogen bubbles than there are oxygen bubbles.

The chemical formula for water is expressed as H_2O, meaning that it consists of two atoms of hydrogen and one atom of oxygen. The fact that there are twice as many atoms of hydrogen as oxygen in a molecule of water explains why more bubbles form around the negative electrode than around the positive electrode. Since oxygen combines readily with the metallic substances of the electrode around which it is liberated, very little gas will escape to the top of the water in the form of bubbles.

THE EFFECT OF SALT UPON THE ELECTROLYTE

Now leave the circuit connections as shown in Fig. 8, and drop a little salt into the water. You will observe that adding more salt to the water will cause more current to flow through the arrangement. This increase in current intensity is indicated by the greater number of bubbles that form around the electrodes. The same results would be obtained if sulphuric acid were mixed with the water. However, since salt can be obtained more readily and handled more conveniently, it will serve our purpose better.

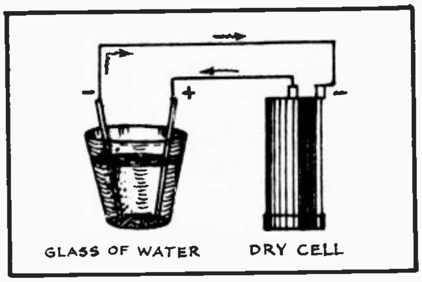

FIG. 8
WATER RHEOSTAT

During this experiment,you will also observe that the current flow through the circuit will increase momentarily and then immediately commence to decrease again. The reason for this is that the negative electrode eventually becomes covered with a hydrogen film that insulates this electrode from the electrolyte. Upon removing the wires, cleaning them and again inserting them in the water, you will observe the current to increase.

The type of current flowing through a circuit can also be determined by applying the principles of the electrolysis of water, as just described. However, when handling high voltage circuits, it is important to connect a lamp in series with the circuit and the electrodes that contact the water, the same as suggested for the experiment illustrated in Fig. 7.

When conducting this test,a d-c current will form an appreciable number of bubbles around the negative electrode only, whereas an alternating current will form bubbles around both electrodes equally.

Water rheostats are sometimes used in circuits where it is necessary to control a great amount of current for a short time. Current can be made to flow through a rheostat of this type even though the water temperature rises considerably. Such rheostats also provide a very effective and simple means for altering the resistance of a circuit. This is generally done by submerging more or less of the electrode in the water and thereby varying the electrode area that contacts the water. The resistance of the water rheostat can also be varied by altering the distance between the electrodes.

EXPERIMENTS WITH MAGNETISM

In the regular lessons of the course, we have mentioned that an electrical current forms a magnetic field around the conductor through which it flows. You can now prove this to your own satisfaction in the following manner:

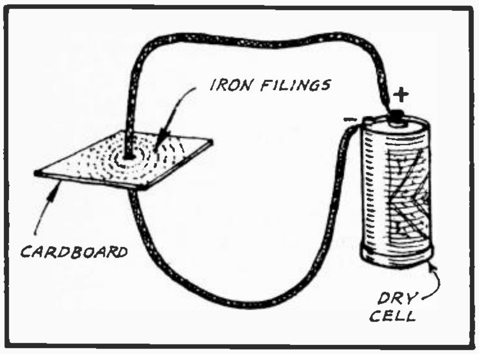

FIG. 9
LINES OF FORCE SURROUNDING A CONDUCTOR

Punch a hole in the center of a piece of cardboard, making it just large enough so that a piece of copper wire can be passed through it. The wire used for this purpose may be either of the bare or insulated type, as magnetism is not affected by insulation.

Support the wire in a vertical position as shown in Fig. 9, and connect its ends to a dry cell. It makes no difference which end is connected to the positive terminal of the cell and which to the negative terminal. The cardboard can be supported between two books, two glasses or by any other means that is convenient.

The only resistance offered by this circuit is that introduced by the wire itself, and therefore the cell will force considerable current through the circuit. For this reason, the circuit should remain closed only long enough to complete the test. Closing the circuit for a longer period will discharge the cell completely in a very short time.

Now then, while current is flowing through the circuit, drop some iron filings on the cardboard and while so doing, tap the edge of the cardboard lightly with your fingers. You will observe the iron filings to form a pattern of concentric circles around the conductor, as pictured in Fig. 9. These rings of iron filings mark the "path" of the invisible lines of magnetic force that surround the conductor.

Continue by opening the circuit and remove all of the iron filings from the cardboard. Now, upon sprinkling iron filings on the surface of the cardboard, you will find that the filings will not arrange themselves in any definite pattern. The experiment thus proves that magnetic lines of force surround a conductor that is carrying a current but do not surround a conductor that is not carrying a current. (Note: You can obtain the iron filings required for this experi-

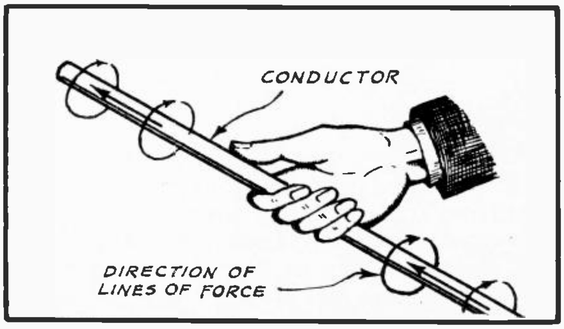

FIG. 10
THE RIGHT-HAND CONDUCTOR RULE

ment by filing a large nail and gathering together the filings thus produced.)

The magnetic field surrounds a conductor in one direction only, in accordance with the direction of current flow through the conductor. For example, by grasping the wire with the right hand, so that your thumb extends in the direction of current flow (see Fig. 10), the other four fingers will point in the direction in which the magnetic field encircles the conductor. This can be proven with the aid of a pocket compass. (It is to be noted that this is a practical electrician's rule, and for this reason the flow of current is considered as being from positive to negative.)

Upon bringing the compass near the conductor, the north end of its needle will always point in the direction in which the magnetic field encircles the conductor. Reversing the battery connections will cause the compass needle to reverse its position, thus showing that the lines of force are now encircling the conductor in the opposite direction.

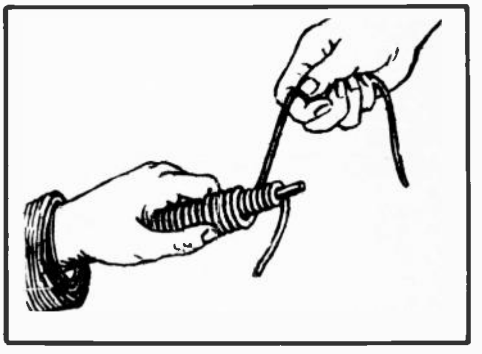

FIG. 11
CONSTRUCTING AN ELECTROMAGNET

SOLENOIDS AND ELECTROMAGNETS

Wrap a piece of heavy paper around a nail and then wind as many turns of insulated wire as possible over the heavy paper, as shown in Fig. 11. Upon completion of the winding, remove the nail. You will now have an air-core coil, or SOLENOID. Continue, by connecting the ends of the solenoid across the terminals of a dry cell and bring small pieces of iron or steel near the ends of the solenoid.

You will notice that while current flows through the solenoid, any pieces of iron and steel near the ends of the coil will be attracted to it. This proves that the flow of an electric current through the solenoid produces a magnetic field of such pattern that magnetic poles are formed at the ends of the coil. The attraction for iron and steel at the ends of the coil will cease the moment that the circuit is interrupted. This proves still further that it is the flow of current that produces the magnetic poles.

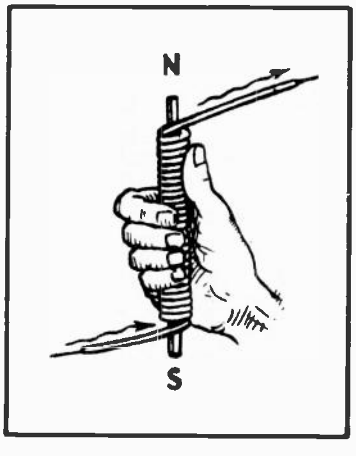

FIG. 12
RIGHT-HAND COIL RULE

The poles of a solenoid, electromagnet or any coil for that matter, can be identified by applying the right-hand rule as illustrated in Fig. 12. This rule is applied in the following manner: Grasp the electromagnet with the right hand so that the thumb is extended and so that the other four fingers follow the direction of current flow through the coil. The thumb will then be pointing toward the North pole of the coil. (Here again, current flow is considered as being from positive to negative in accordance with the practical electrician's custom.)

Now, insert the nail through the center of the coil. You will observe the intensity of the magnetic field to increase considerably, which proves that the permeability of the iron core is greater than that of the air-core. That is, iron is a better conductor of magnetic lines of force than is air.

You can perform numerous experiments with this electromagnet, such as proving with the aid of a pocket compass that the right-hand rule is true, proving that like magnetic poles repel while unlike magnetic poles attract, etc.

Also increase the voltage applied to the coil and note its effect upon the magnetic field. You can also add and remove turns of wire from the coil, observing results.

You will find that the magnetic field is affected noticeably by any increase or decrease in the number of turns of wire and also by any change in current intensity. For instance, if the number of turns of wire is increased, the intensity of the magnetic field will also increase. An increase in current intensity will also strengthen the magnetism. This experiment proves beyond any doubt what you learned in one of your regular lessons: namely, that the strength of the magnetic field of any coil depends upon the ampere-turns. You will recall that "ampere-turns" is a factor that is equal to the current flow in amperes multiplied by the number of turns of wire.

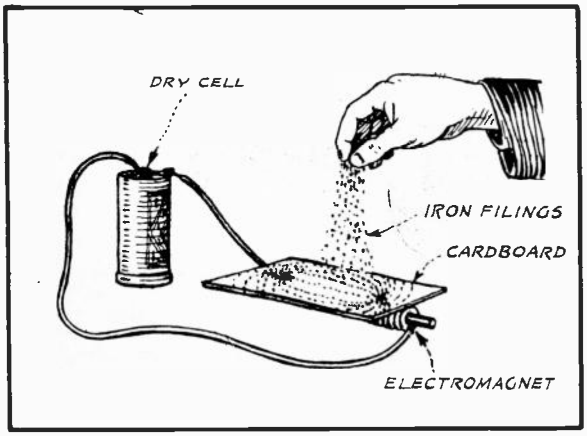

Fig. 13
Field Surrounding an Electromagnet

For example, a coil wound with ten turns of wire and carrying a current of one ampere, will have a magnetomotive force of 10 x 1, or 10 ampere-turns. This same magnetic force will be obtained from a coil consisting of five turns of wire and carrying a current of 2 amps, as 5 times 2 also equals 10.

MAGNETIC FIELD OF AN ELECTROMAGNET

Place the electromagnet on top of a table and place a piece of cardboard or glass over it, as shown in Fig. 13.

Now, scatter a few iron filings on top of the cardboard and while so doing, tap the cardboard lightly with your fingers. You will find the filings to arrange themselves in accordance with the path followed by the lines of force.

Construction Projects

So much for the basic electrical experiments. Your next experimental assignments will be in the nature of construction projects, for which the following parts are sent in your second kit:

2 - Bakelite knobs
1 - 6-prong socket
1 - 5000-ohm potentiometer
1 - 100,000-ohm potentiometer
1 - 100,000-ohm resistor (brown-black-yellow)
1 - 100-ohm resistor (brown-black)

ANOTHER FORM OF A-F OSCILLATOR

In Fig. 14 is shown the diagram of an a-f oscillator. This oscillator differs noticeably from the one you constructed in accordance with the instructions furnished in your first Experiment Lesson.

The oscillator described to you at that time employed a single winding for both the grid and plate circuits. In such oscillators, the plate current flows through one-half of the winding and induces a voltage in the other half. The latter voltage is applied to the grid of the tube.

Transformers that couple the grid and plate circuits in this manner are called <u>auto-transformers</u>. In fact, all transformers wherein a single winding is divided into two sections to constitute the primary and secondary are classed as auto-transformers.

The primary of an auto-transformer is that section of the winding through which the power supply current flows, whereas the secondary is that section across which a voltage appears by induction. The transformer that you received in your first outfit of parts has a primary winding and a secondary winding. The secondary winding is the one that is center-tapped.

In constructing the a-f oscillator described in the previous Experiment Lesson, the actual secondary winding served as both primary and secondary of an auto-transformer, one half of this winding being the primary and the other half the secondary. The actual primary winding was at that time used solely as a means for coupling the auto-transformer winding to the headphones.

However, in the oscillator circuit shown in Fig. 14 of this lesson, both transformer windings are employed in their normal manner. That is, the primary winding is actually used as the primary and the secondary winding as the secondary. In this circuit, the plate current flows from the negative terminal of the "B" battery to the cathode, through the tube to its plate, and then through the primary winding of the transformer, headphones and back to the "B" battery.

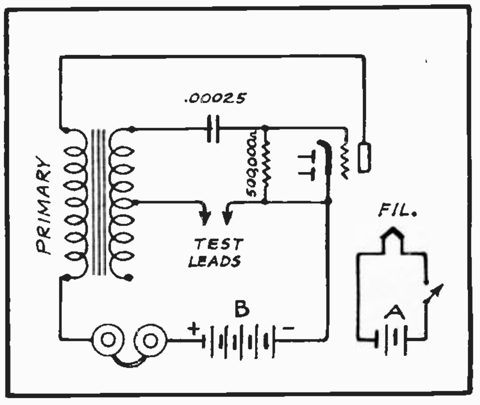

FIG. 14
DIAGRAM OF AN A-F OSCILLATOR

As the varying plate current flows through the primary of the transformer, it induces a voltage in the secondary which is impressed on the grid of the tube. The tube operates in the same manner as in the oscillator described in the previous experiment lesson. You will further notice in Fig. 14 that the grid circuit of the tube employs only one-half of the secondary, and that the test leads are connected between this winding and the cathode of the tube. The construction of this circuit is very simple. However,to still further aid you in its construction, we have prepared for you the detailed drawing appearing in Fig. 15. Here you are shown the layout of the parts and their respective connections. If upon completing this wiring job, you should find that the oscillator does not produce a sharp note when touching the test leads together, reverse the primary connections at the transformer and again listen for the signal.

The object is to apply a voltage of proper phase to the grid so that the tube will oscillate. To obtain such operation it is necessary that the current flow through the primary winding be in a definite direction. Hence, if the direction of current flow is not correct to produce oscillation, a reversal of the primary connections at the transformer will correct the condition.

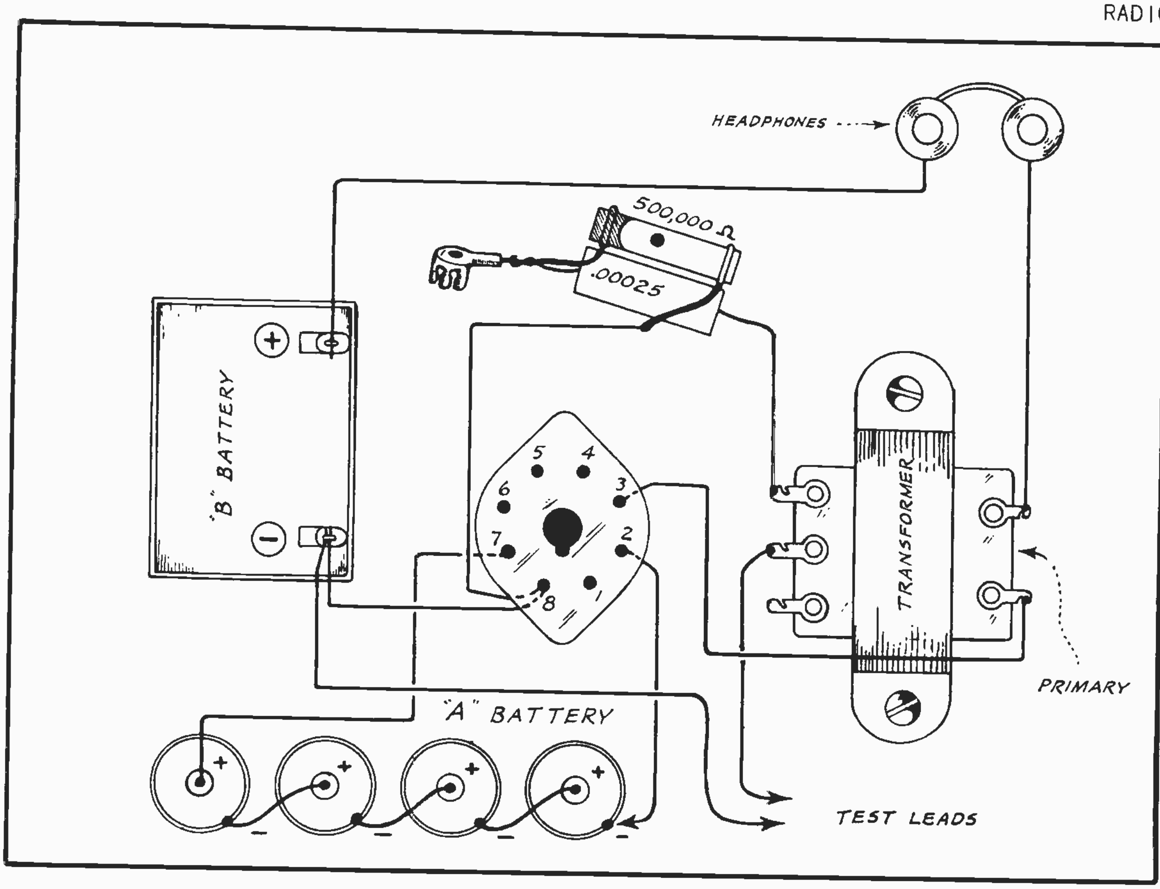

FIG. 15
PHYSICAL LAYOUT FOR THE A-F OSCILLATOR

This oscillator can be used for the same purposes as outlined in the previous experiment lesson. Although it could be connected to the lighting circuit, this is not recommended as the headphones would then also be connected in series with the line. Such a condition is likely to result in a dangerous shock. This danger does not exist in the a-f oscillator described in the previous experiment lesson,as in this case the headphones are not connected directly in series with the lighting circuit.

THE CATHODE-RAY TUNING INDICATOR TUBE

The audio oscillator, which you constructed according to the instructions furnished in the previous experiment lesson,enabled you to conduct various tests by means of audible sounds produced by your headphones. Such tests are known as AUDIBLE TESTS.

Your next construction project will be to build a tester wherein a cathode-ray tuning indicator tube will enable you to observe the results of various tests by visual means. Such tests are known as VISUAL TESTS.

The circuit diagram for the battery-operated visual tester is shown in Fig. 16. Here you will observe a 6U5 tube serving as the indicating device. However, before discussing the operating principle and application of this tester, it is well that you first familiarize yourself with the tube used herein.

The 6U5 tube was designed primarily to indicate when a receiver is tuned to resonance with any desired station. However, it is also being applied in a number of different ways, particularly in testing equipment. The tester here shown is one such application.

This tube is also known to the industry by various other names, as an "electron tuning indicator," "magic eye," etc. Besides the 6U5, other similar tubes are known as 2E5, 6E5, 6G5, 6H5 and 6N5. The only difference between these various tubes is in the voltages required for operation.

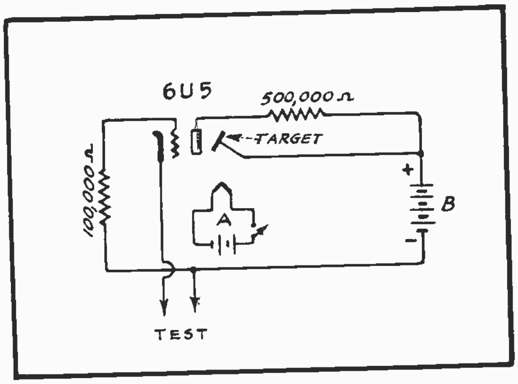

FIG. 16
BATTERY-OPERATED VISUAL TESTER

Cathode-ray tuning indicator tubes consist essentially of a heater, cathode, control grid, plate and a target. The latter is coated with a fluorescent substance that glows with a green color when "bombarded" by a stream of electrons. Basically, the tube can be considered as a triode that is fitted with the target. The triode elements are located at the lower end of the tube, but the cathode extends upward through a central opening in the target as does also a small extension of the plate. The latter is called the RAY-CONTROL ELECTRODE. Fig. 17 shows this construction clearly.

As will be seen in Fig. 16, the target of the tube is connected directly to the positive side of the "B" power supply, consisting of at least 90 volts. The plate is also connected to B+, but through a 500,000-ohm resistor. Thus, the positive potential of the plate and the ray-control electrode are lower in value than that applied to the target. Hence, the connections are such that the target will be maintained at a high positive potential of constant value, while the voltage effective at the plate varies in accordance with changes in the plate current. This can be explained in the following manner:

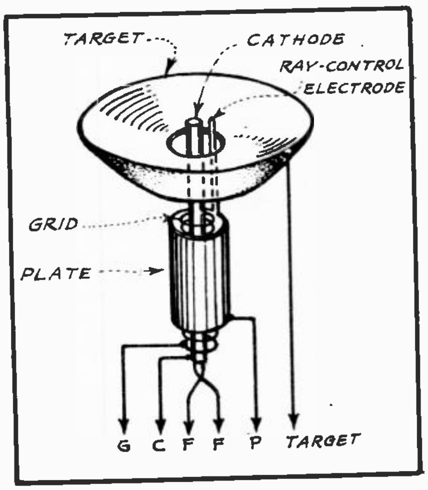

FIG. 17
DETAILS OF THE 6U5 TUBE

When no voltage is applied to the grid, the plate current will be of a relatively high value, the voltage-drop across the resistor will be considerable and the ray-control electrode will therefore be less positive than the target. Under these conditions electrons flowing toward the target are repelled by the electrostatic field of the electrode, and do not reach that portion of the target behind the electrode. Because the target does not glow where it is shielded from electrons, the control electrode casts a shadow on the glowing target. The distribution of electrons at this time is illustrated at the left of Fig. 18.

In this illustration you are looking down upon the target-end of the tube; the dotted lines represent the flow of the electrons. Notice, particularly, that the ray-control electrode deflects many electrons from a straight-line path toward the target.

Now, let us suppose that a negative voltage is applied to the grid. Under such conditions, the plate current will decrease, the voltage-drop across the resistor will decrease, and therefore a positive potential of greater magnitude than formerly will be applied to the plate and to the ray-control electrode.

The effect of this greater plate voltage is shown at the right of Fig. 18. Here you will observe that the increase in positive potential at the ray-control electrode causes this electrode to exert a lessened repelling force upon the electrons emitted by the cathode, and thus permits the electrons to follow a more straight-line path toward the target. This causes a larger area of the target to become illuminated, and thereby decreases the shadow area.

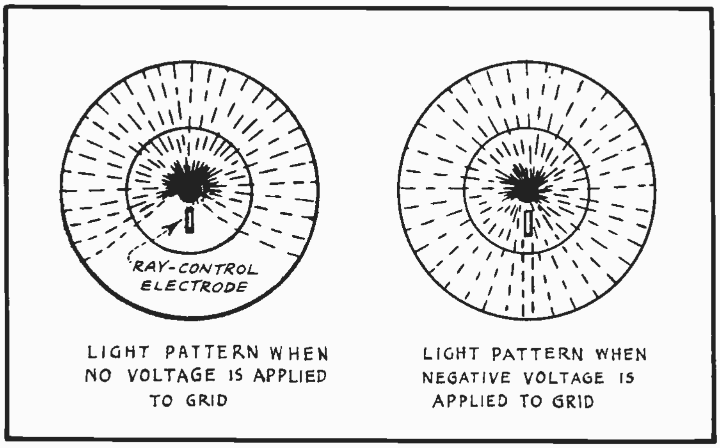

FIG. 18
EFFECT OF GRID VOLTAGE UPON THE TARGET

The higher the negative voltage applied to the grid, the lower will be the plate current and the greater the area of target illumination. In other words, the higher plate voltage alters the direction of the electrons in such a way that they are not deflected by the ray-control electrode, as at the left of Fig. 18, but follow a straight path as pictured at the right of Fig. 18.

In Fig.19 are shown the symbol and socket connections for the 6U5 tube, as viewed from below.

When using this tube as a tuning indicator in radio receivers, the grid is connected to the receiver's automatic volume control circuit, which system applies a higher negative voltage to the grid when the receiver is tuned to absolute resonance with the station being received. Therefore, the target illumination will be greater at resonance. This will be demonstrated clearly later on when you will be required to construct a receiver that employs an automatic volume control system.

So much for the action of the indicating tube. Let us now direct our attention to the problem of constructing the tester.

CONSTRUCTING A BATTERY-OPERATED VISUAL TESTER

Returning to the diagram in Fig. 16, you will note that the test leads are connected in series with the cathode circuit. Therefore, if the test points are applied across the ends of a resistor, the resistor being checked would act as a bias resistor in the cathode circuit and would thus determine the magnitude of the negative voltage that is applied to the grid. Hence, the value of the resistance between the test points would also control the area of illumination at the tube's target. This feature makes it possible to use this tester for checking radio circuits and parts, for determining the approximate value of resistors, etc.

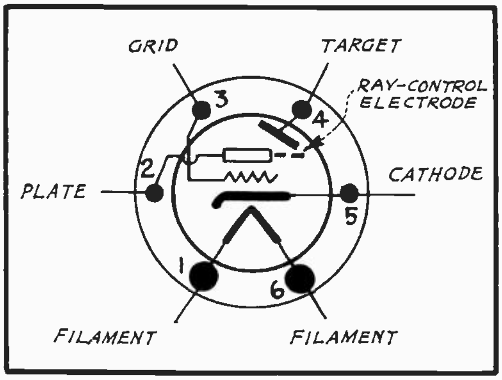

FIG. 19
SOCKET CONNECTIONS FOR THE 6U5

The visual tester is very simple to construct. However, you should first make a simple sketch of its connections and then check it with those shown in Fig. 20 before commencing the actual work of construction.

The "A" supply may be furnished by a 6-volt storage battery or four dry cells connected in series. When the tester is not being used, the filament circuit can be interrupted by disconnecting the wire at the negative terminal of the "A" battery (see Fig.20). The "B" battery used for this purpose should furnish a voltage of at least 90 volts. It is of great importance that the positive terminal of the "B" battery be connected to terminal #4 of the socket, as shown in the illustrations.

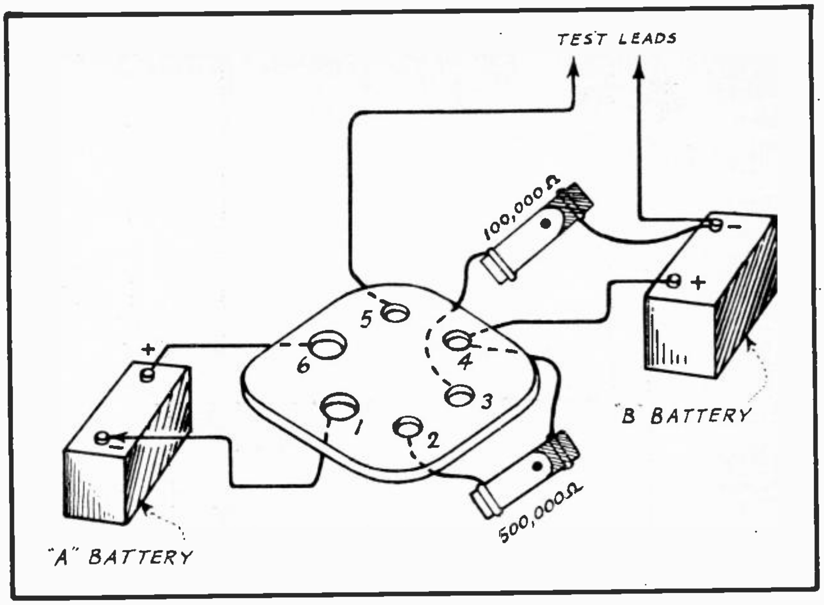

FIG. 20
PARTS ARRANGEMENT OF BATTERY-OPERATED TESTER

CONSTRUCTING A VISUAL TESTER FOR OPERATION FROM A LIGHTING CIRCUIT

Students, whose homes are wired for electric lighting, need not construct the battery-operated tester just described, but should instead build the tester diagrammed in Fig. 21. This tester is designed to be operated from either an a-c or a d-c lighting circuit.

If the lighting circuit operates at 110 volts, the tester should be wired in accordance with the solid lines appearing in Fig. 21, using a 40-watt, 110-volt lamp in the same manner as in past experiments.

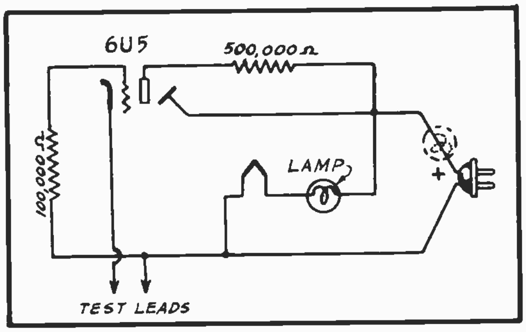

FIG. 21
A-C OR D-C OPERATED TESTER

If the line voltage is 220, it is necessary to use an additional lamp which is indicated in Fig. 21 by the dotted lines. This lamp should also be rated at 40 watts and 110 volts. In case that you are not able to obtain a lamp of this voltage, you can use two 100-watt, 220-volt lamps.

If the lighting circuit is of the d-c type, it is necessary that the positive side of the line be connected to the plate and target of the tube. If the circuit is of the alternating current type, then it is immaterial which side of the line is connected to the plate and target. As in the case of the a-f oscillator, the alternating current is rectified by the tube, the latter permitting current to flow from the cathode to the plate only, and never in the reverse direction. Before actually wiring the circuits of this tester, you should first make a diagram of it and check it with those shown in Figs. 21 and 22.

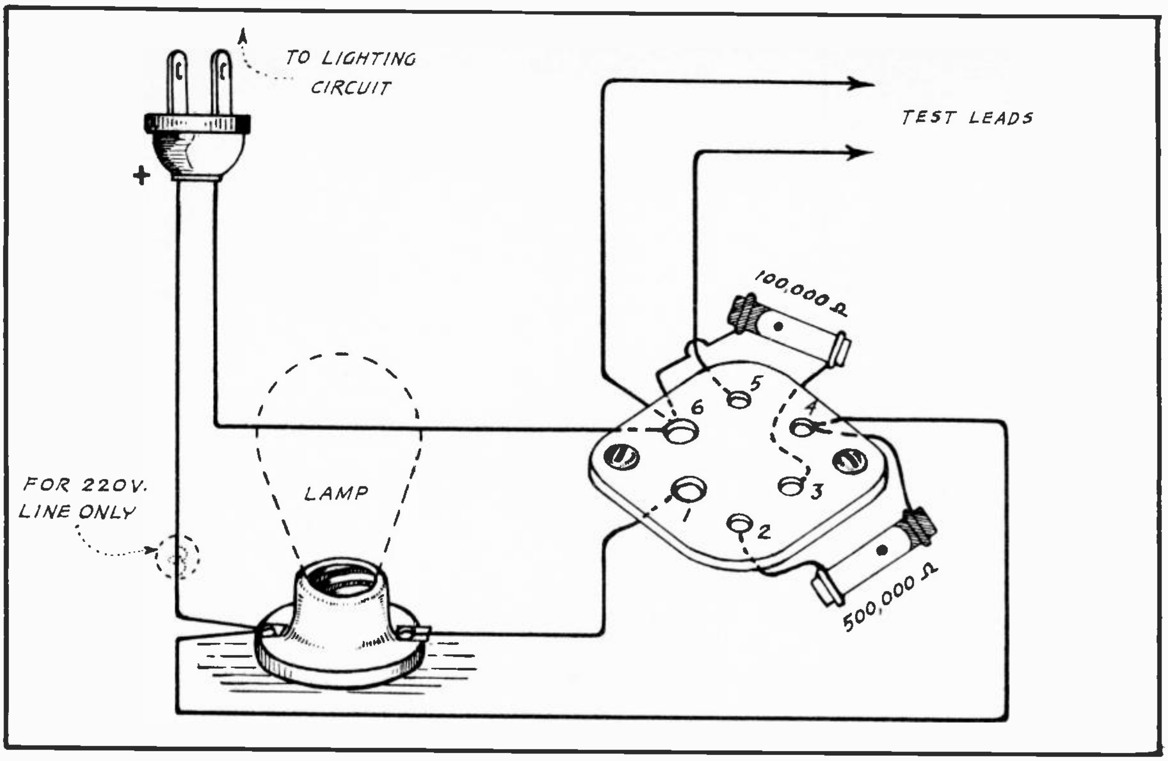

FIG. 22
CIRCUIT CONNECTIONS FOR THE 110-220 VOLT TESTER

APPLICATIONS FOR THE VISUAL TESTER

The indicator can be made to operate by connecting it to the line or closing the "A" battery circuit, according to the power supply being used. Sufficient time should then be allowed to permit the cathode temperature to rise to normal value. Upon touching together the two test points (wires) the target will become illuminated, leaving a dark area of about 90 degrees. Connecting resistors of different value in series with the test leads, will cause the illumination of the target to vary in proportion to the value of the resistor; that is, the higher the resistance value, the greater will be the area illuminated.

Resistance values exceeding 400 ohms should not be connected in series with the cathode circuit during this test, as larger values than this will reduce the plate voltage to such an extent that the target will not be illuminated at all. The behavior of the indicating tube being such, you can readily see how it can be used advantageously to determine if a short-circuit exists in a-f transformer windings, to check resistors of low values, as well as being suitable for conducting general continuity tests in low-resistance circuits that could not be tested accurately with the a-f oscillator described in the previous experiment lesson.

If you have on hand resistors of 100, 200, 300 and 400 ohms, you can calibrate the tester quite easily. To do this, fasten a piece of white adhesive tape around a portion of the tube as shown in Fig. 23, and mark on it points corresponding to the boundary of the illuminated area on the target. The calibrations are made as follows: First, connect a 100-ohm resistor in series with the test leads and mark on the tape the boundaries of the area illuminated at this time. Now, replace this resistor with another one of a different known value and mark the boundaries of the illuminated area. Continue in this manner, marking the tape with the corresponding values in ohms.

VISUAL TESTER FOR CHECKING RESISTANCES OF HIGHER VALUES

The cathode-ray tube can also be used to test circuits and components whose resistances are greater than 400 ohms and less than 100,000. However, an indirect method of testing must be employed for these tests.

In Fig. 24 is shown the circuit diagram of such a tester, operated by batteries, while Fig. 25 illustrates the connections for operating the same tester from a lighting circuit of either the a-c or d-c, 110 or 220-volt type.

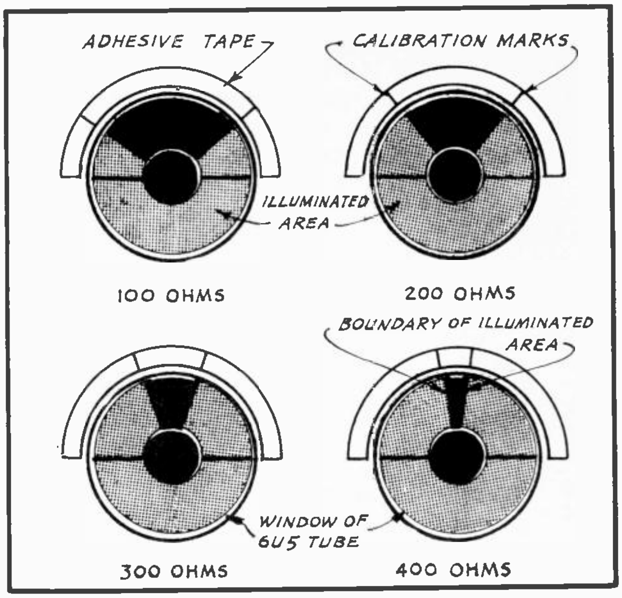

FIG. 23
CALIBRATION OF VISUAL TESTER

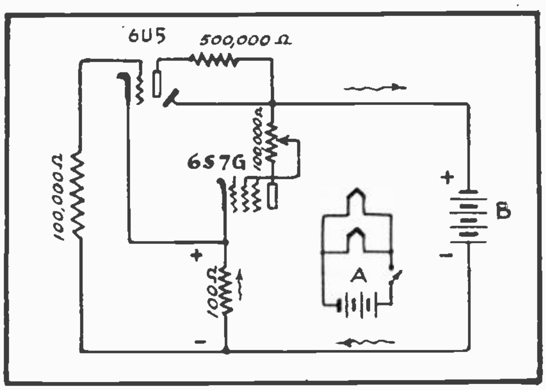

FIG. 24
BATTERY-OPERATED VISUAL TESTER

Comparing the two diagrams, you will immediately observe that the fundamental connections are basically the same. When operating the tester from batteries, the two tube filaments should be connected in parallel, as shown in Fig. 24. However, if operated from the lighting circuit, the two tube filaments should be connected in series with each other and also in series with an incandescent lamp. The series filament circuit is connected directly across the line.

If a 110-volt lighting circuit is being used, the lamp should be rated at 40 or 50 watts and 110 volts. If the lighting circuit operates at 220 volts, use another lamp of the same rating in series, as shown by the dotted lines in Figs. 25 and 26. In case that you are unable to obtain 110-volt lamps you can use two 100-watt, 220-volt lamps instead.

Also notice in Fig. 24 that a 6S7G tube and a 6U5 cathode-ray tube are specified for battery operation, whereas 6K7 and 6U5 tubes are specified for operating the tester from the lighting circuit.

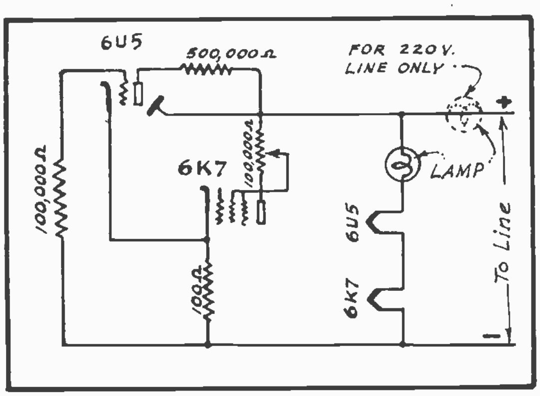

FIG. 25
LINE-OPERATED VISUAL TESTER

Both the 6K7 and 6S7G tubes are variable-"mu" amplifiers, having identical elements and base connections. These two tubes differ only as to the filament current drawn and the maximum voltage required at the plate. It is needless to say that if you have equipment for household lighting facilities, you should use a 6K7; and if your equipment is to be operated by batteries, you should use the 6S7G type tube. In either case, the tube specified will be used in receiver circuits that you will construct in accordance with later experiment lessons. Therefore, you are not being required to purchase tubes for which you will have no use later on.

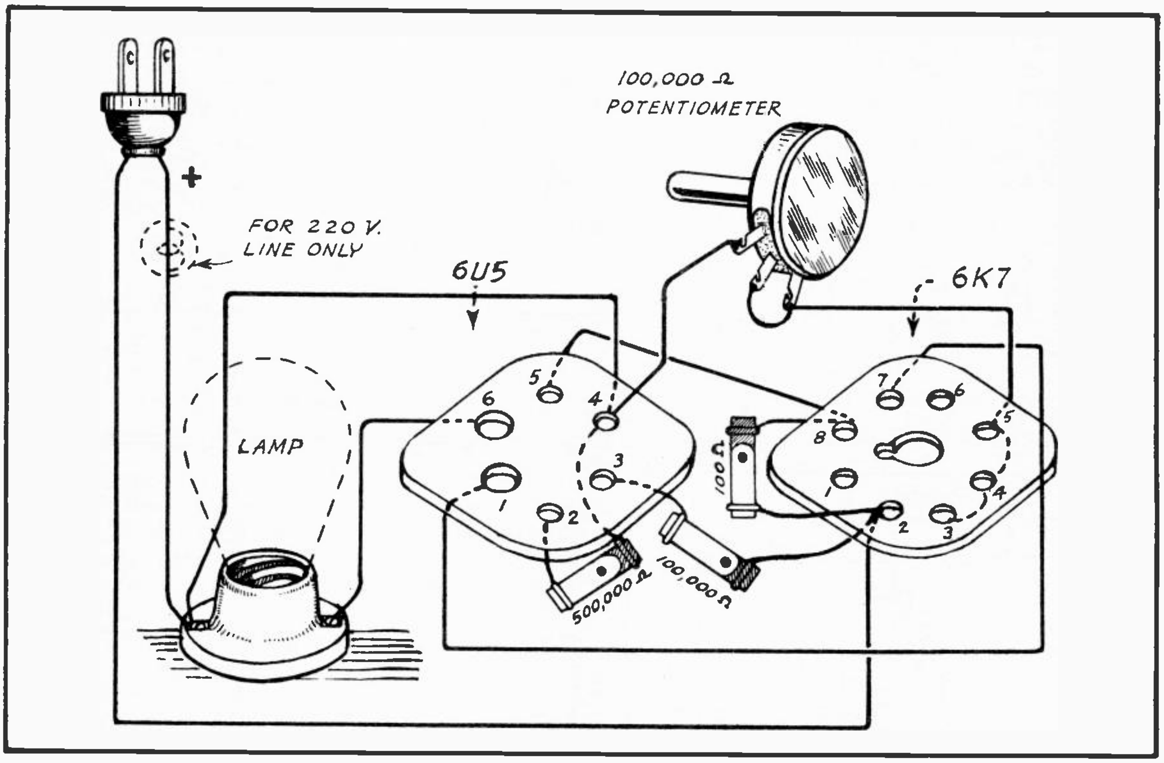

FIG. 26
CIRCUIT CONNECTIONS FOR 110-220 VOLT HIGH-RANGE VISUAL TESTER

The connections for operating the tester from the lighting circuit are shown in Fig. 26.

CIRCUIT CHANGES FOR BATTERY OPERATION

If the tester is to be operated from batteries, it is only necessary to eliminate the lamp and line cord, and to connect the #4 contact of the 6U5 tube's base to the positive terminal of the "B" battery. Contact #2 of the 6S7G tube's base is then connected to the negative terminal of the "B" battery.

The filament circuit connections should be as follows: Join terminal #6 of the 6U5 socket with #7 of the 6S7G socket; connect terminal #1 of the 6U5 socket with #2 of the 6S7G socket. Finally, connect terminal #6 of the 6U5 socket to one side of the "A" battery and connect the other side of the "A" battery to terminal #1 of this same tube.

HOW THE CIRCUIT OPERATES

Although the 6K7 and 6S7G tubes are really intended to be used as variable-"mu" amplifiers, you are in this particular case using them as rectifiers. Fig. 27 illustrates the symbol and socket connections for these tubes, as seen from below, and if this data is compared with that shown in Figs. 24 and 25, you will notice that the plate, screen grid, and suppressor grid are all connected together so as to form a single positive electrode. The cathode forms the other electrode, whereas the control grid has no connection and is therefore not being used.

As will be observed in Figs. 24 and 25, a 100,000-ohm potentiometer is installed in the plate circuit of this tube, being connected between the plate and the B+ terminal of the power supply. A fixed resistance of 100 ohms is connected between the cathode and B-.

Also notice that the cathode of the 6U5 tube is connected directly to the cathode of the 6K7 (or 6S7G), and that the grid circuit terminates at B-. Because of these connections, the plate current of both tubes will flow through the 100-ohm resistor, producing a voltage across this resistor, which is applied to the grid of the 6U5 tube as a negative bias.

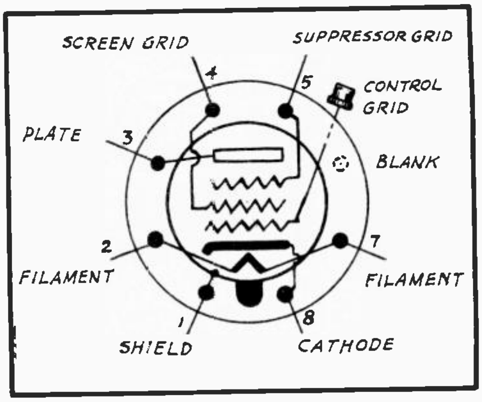

FIG. 27
SOCKET CONNECTIONS FOR
6K7 OR 6S7G TUBES

This tester operates in the following manner: Placing the potentiometer arm at its extreme right position eliminates all of its resistance from the circuit; therefore, maximum plate current will flow through the 6K7 tube. This causes the maximum voltage to be generated across the 100-ohm resistor, resulting in maximum negative bias voltage being applied to the grid of the 6U5 tube. This condition provides maximum area of illumination of the target.

If we now continue to increase the potentiometer resistance, the current flowing through the 100-ohm resistance will decrease. This in turn will bring about a decrease in the negative voltage applied to the grid of the 6U5 which will result in less target illumination.

From the above explanation you will understand that if we eliminate the potentiometer and connect in its place two long test leads, the instrument will then enable us to test resistors and circuits up to 100,000 ohms.

Smaller resistance values will cause the target of the 6U5 tube to become illuminated over a greater area than will be the case if resistances of larger value are connected in series with the test points. If the resistance is too great, or in the event of an open circuit, the target illumination will suffer no change and will remain at a maximum.

CIRCUIT FOR TESTING OPERATION OF THE 6U5 TUBE

The previous experiments with the 6U5 have shown you that target illumination depends upon the negative voltage applied to the grid. This fact makes it possible to construct a simple circuit that will show definitely how grid voltages affect target illumination, which will at the same time serve as a means for testing the condition of cathode-ray tuning indicator tubes that have a 6.3-volt filament, and which have been in use for some time.

Cathode-ray tuning indicator tubes in general, except the 6H5 and the 6U5, are subjected to a fairly large current flow between the target and cathode. For this reason, the life of these tubes is very short. As a rule, the triode section continues to function but the electron emission from the upper end of the cathode finally becomes insufficient to provide normal target illumination, and will not respond to changes in voltage occurring at the ray-control electrode.

If a tube in such condition is used as a tuning indicator, it will not be possible to determine the exact point of dial travel at which the receiver is tuned to absolute resonance with the station being received.

The circuit diagrammed in Fig. 28 will test the condition and operating ability of cathode-ray tuning indicator tubes. While the tester diagrammed in Fig. 28 is designed for operation from a lighting circuit, it can also be adapted to battery operation by making the changes shown in Figs. 24 and 25.

That is, for battery operation, connect the two filaments across a 6-volt "A" battery and connect the end marked "+" to the positive terminal of the "B" battery. The end identified as "-" should then be connected to the negative terminal. A 6S7G tube should be used as the current control tube (rectifier in the a-c version).

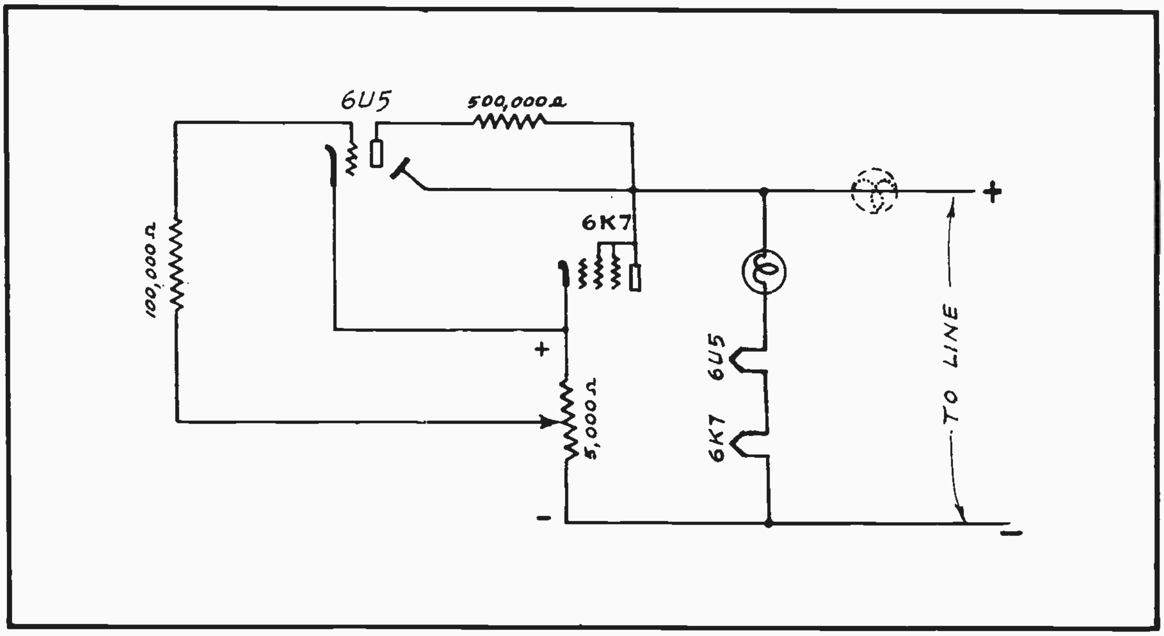

FIG. 28
CIRCUIT OF CATHODE-RAY TUNING INDICATOR TUBE TESTER

By comparing the diagrams with the pictorial drawings, you will notice that we have in all cases planned the set-up so that the circuit wires can be connected directly to the lugs or binding posts. This practice makes it possible to use a single piece of wire between connecting points instead of splicing several sections of wire together at intermediate points. The latter is very undesirable.

So that you may better accustom yourself to the correct method of wiring circuits, we are not furnishing you with a physical layout of the circuit appearing in Fig.28. Therefore, you must construct your tester with the help of the diagram alone, relying on your own initiative to apply the instruction given in other parts of this lesson.

HOW THE TUBE TESTER OPERATES

A 5000-ohm potentiometer is connected between the cathode of the rectifier tube and "B-". Thus, the current flow through it establishes a potential across its ends -- the lower end being negative with respect to the upper end.

By connecting the arm of the potentiometer to the grid circuit of the 6U5 tube, we will be able to vary the negative voltage that is applied to it.

To perform the test, the tube being checked should be inserted in the six-prong socket, the cathodes allowed to heat up and the potentiometer arm moved gradually. (The tube's target should be observed closely during this procedure.) If the tube is in good working condition, rotating the potentiometer arm through its range will cause the illuminated area on the target to vary in a progressive manner and without change in the light intensity.

GENERAL SUGGESTIONS CONCERNING YOUR EXPERIMENTS

Upon completing the wiring of any apparatus described in your experiment lessons, always make it a point to first check the wiring carefully against the diagram or pictorial drawing, before connecting it to the power supply. Such a practice will aid materially in reducing the damage to parts due to incorrect circuit connections.

Having performed all of the experiments described in any one lesson, you will often think of additional circuits and applications. In such a case, it is good practice to work out your own ideas and to perform the experiments necessary to prove your point. However, it is well that you adopt the habit of always first drawing a circuit diagram of your proposed plan so that you can study the situation carefully as to its practicability, and also to insure your circuit connections as being correct.

Also, bear in mind that many individual experiments are described in each of the lessons of this special series. It is important that you perform each and every one of them, and in the same order as given in your lessons. We suggest, however, that you budget your time for experimenting and your time devoted to the study of the regular lessons in such manner that your experimental work will be in the nature of <u>recreational study</u> -- to be done at convenient intervals between the study of the regular lessons. By following this plan, your studies as a whole will be more interesting and the time thus spent in experimenting will not slow up your progress through the course.

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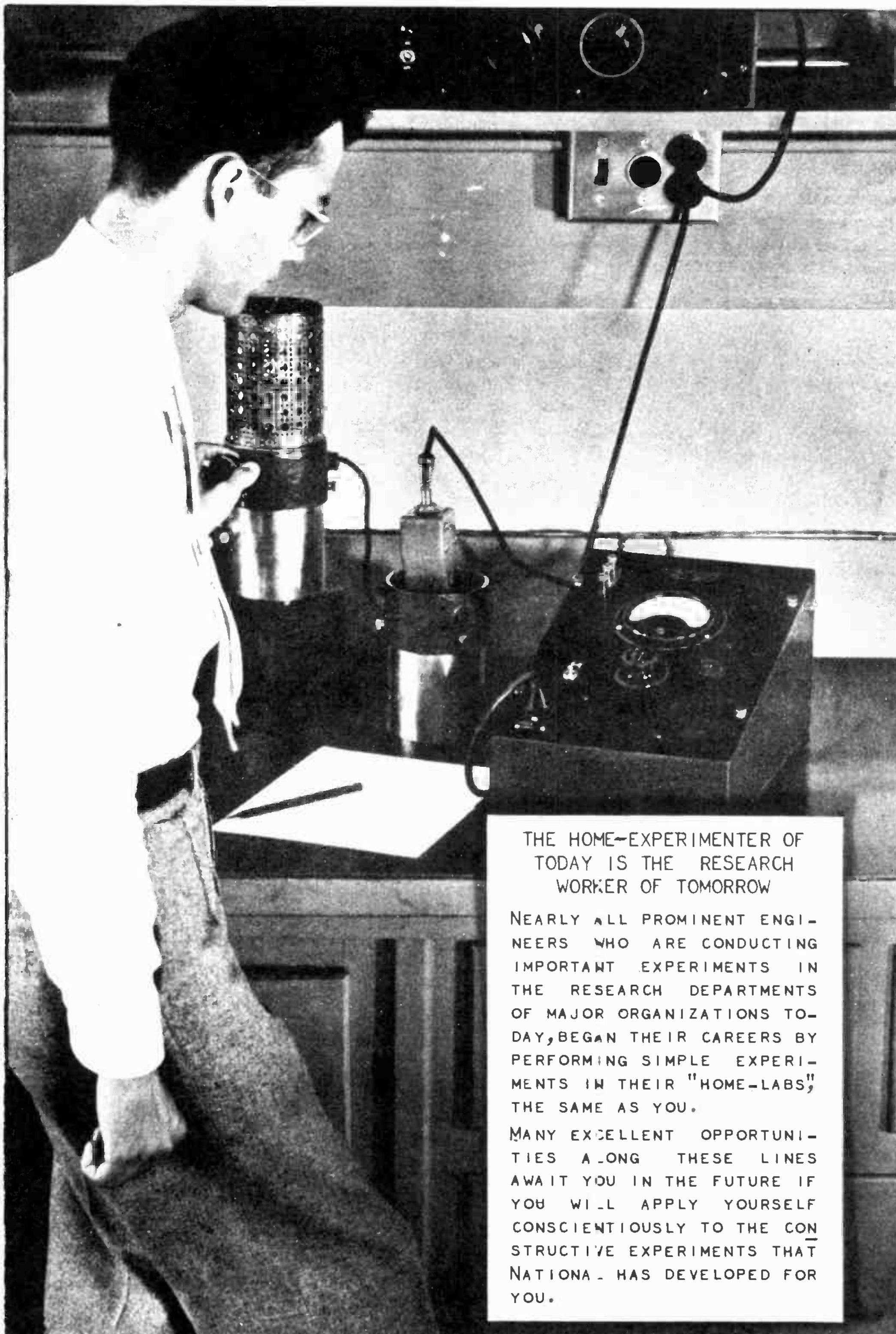

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NEARLY ALL PROMINENT ENGINEERS WHO ARE CONDUCTING IMPORTANT EXPERIMENTS IN THE RESEARCH DEPARTMENTS OF MAJOR ORGANIZATIONS TODAY, BEGAN THEIR CAREERS BY PERFORMING SIMPLE EXPERIMENTS IN THEIR "HOME-LABS", THE SAME AS YOU.

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EXAMINATION QUESTIONS

ans Nov/3/41

EXPERIMENT LESSON NO. FG-2

1. - State three ways whereby it is possible to increase the magnetic field of a solenoid?

2. - What would happen if the electrodes in the cell of a battery were constructed of the same material?

3. - If the voltage applied to the grid of a cathode-ray tuning indicator tube is made more negative will the illuminated area of the target become greater or less than originally?

4. - Why is it possible to determine the approximate value of resistors by means of the visual tester described in this lesson?

5. - What simple experiment will demonstrate that the lines of force arrange themselves in a definite pattern around a coil that is carrying an electric current?

6. - By what simple tests can you determine whether a circuit is of the a-c or d-c type?

7. - Why is a lamp connected in series with the filament of the cathode-ray indicator and the lighting circuit?

8. - Name two simple methods whereby you can demonstrate which side of a d-c circuit is positive and which is negative.

9. - What is a water rheostat?

10. - How does an auto-transformer differ from a conventional (regular) transformer?

"Opportunity Knocks at a Man's Door But Once"

Many a time you have heard that expression and perhaps it is true, but there is no law of God or man that prohibits a man from knocking at Opportunity's door just as often as he may wish. If he knocks often enough, sooner or later, he is sure to find opportunity at home. If he is ready it will mean Success.

Opportunity means nothing to the man who is not ready. If he is not prepared he won't even be recognized. Whatever we amount to in this world depends entirely upon ourselves, and our own efforts. If we make no effort we get nothing. If we make a big effort to get ahead we can and will succeed. In other words, we are going to be rewarded for exactly what we do.

Success will not come by merely wishing for it. It is something we must fight for. We have got to conquer every obstacle --- we cannot give in to pleasures or idle dreams. And the harder we fight the greater will be our success.

Opportunity waits for no one -- it's up to us to make ourselves ready and catch her.

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EXPERIMENT LESSON NO. FG-3

CONSTRUCTION OF A REGENERATIVE RECEIVER

The parts included in your third kit of equipment will enable you to begin constructing actual radio receivers. You will find this work to be especially interesting and instructive, as it will enable you to apply, practically, important principles that have been explained to you in the regular part of the course. It will also provide you with excellent experience in solving construction and trouble-shooting problems of the type with which you will be confronted later on when you have established yourself in the radio business.

The parts comprising the third kit are as follows:

1 - Antenna-stage coil, having a frequency range of 550 to 1500 kilocycles.
1 - Three-gang variable condenser with a maximum capacity of .00035 mf.
1 - 1 megohm carbon resistor.
1 - .001 mf bypass condenser.
1 - .25 mf bypass condenser.
1 - .02 mf bypass condenser.
1 - .05 mf bypass condenser.

(Note: If the plan under which you are enrolled requires your experimental equipment to be operated from an a-c or d-c lighting circuit, you will receive the .02 mf and .05 mf bypass condensers appearing in the above list. These two condensers are not required for battery-operated equipment and are therefore not included therewith.)

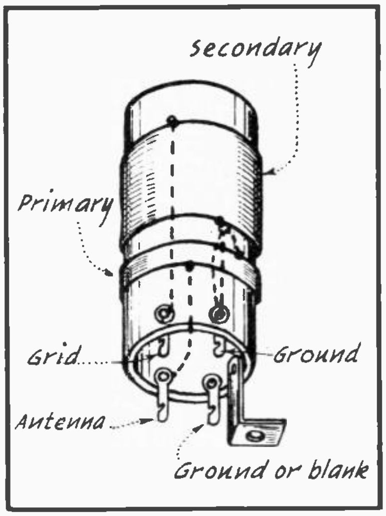

FIG. 1
ANTENNA-STAGE R-F COIL

As was already suggested relative to other kits sent you, it is advisable that you first examine all of the parts included in the kit so as to familiarize yourself with them.

THE ANTENNA-STAGE R-F COIL

Fig. 1 of this lesson illustrates the general construction of the antenna-stage r-f coil, and the manner in which the windings are connected to their respective terminals. Upon examining this unit closely you will observe that it comprises a cylinder made of insulative material, on which is placed a primary and a secondary winding. The primary winding contains fewer turns of wire than does the secondary.

Not all antenna coils are provided with a secondary of more turns than the primary, but where the number of primary turns exceed the number of secondary turns, it is customary to wind the primary in several layers so that the primary occupies a lesser winding-space than does the secondary. In the latter case, the primary can be identified by the lesser space it occupies in comparison with that of the secondary, rather than by the number of turns.

Fig. 1 illustrates the most common terminal connections for this type of coil. However, these connections vary among coils of different manufacture as well as among different coil designs of the same manufacturer. Therefore, it is advisable that you learn to identify coil connections by inspection. It is with this point in view that Fig. 2 is presented.

Fundamentally, the two windings in Fig. 2 may be considered as one continuous winding, cut at a certain point to form the primary and secondary sections of the coil. The primary and secondary windings may be easily identified in this illustration by applying the rule that the primary always occupies less space than does the secondary.

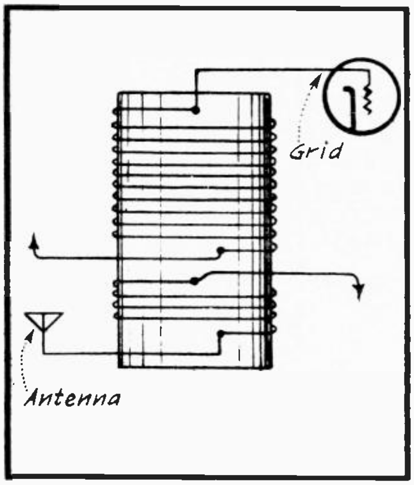

FIG. 2
R-F TRANSFORMER CONNECTIONS

To identify the terminal connections of the antenna-stage coil, consider the two outer ends of the windings as the grid and antenna leads. That is, the secondary-end which is farthest from the primary is considered as the grid lead, whereas the primary-end farthest from the secondary is considered as the antenna lead. The other ends of both windings are connected to the grid-return and grounding systems, respectively.

Since the grid-return end of the antenna coil is frequently connected to ground, it is the common practice among coil manufacturers to connect the ground-end of the primary winding and the grid-return end of the secondary winding to a common terminal as shown in Fig. 1. Thus, circuit connections need be made at only three of the coil terminals, which accounts for the unused (blank) fourth terminal in Fig. 1.

Observe if the coil you received is of the latter type or if all four terminals are used for the winding connections. In either case, mark the terminals clearly with a lead pencil or pen and ink, in accordance with the terminal-identifying method previously explained. This will facilitate matters when connecting these terminals to their respective circuits.

THE VARIABLE CONDENSER

Upon examining the variable condenser, you will observe that it comprises three separate variable condenser groups that are operated by a single shaft. The three rotor sections are mounted directly to the shaft, and since this shaft makes an electrical contact with the metal frame of the condenser assembly, all three rotor sections will be connected to "ground" automatically upon mounting the condenser-gang on a metal chassis. Bronze springs press against the shaft and frame of the unit, thereby assuring a good electrical connection between the rotor plates and the condenser frame.

All three stator (stationary) plate-groups are insulated from one another as well as from the frame of the assembly, and each stator section is equipped with a trimmer condenser, as shown in Fig. 3. Two terminals are provided for each stator plate-group, one is located next to the trimmer condenser and the other on the opposite side of the stator plate-group.

Since both of these terminals correspond to the same stator plate-section, either one may be used for connecting the condenser to the circuit. Check these terminals carefully, being sure that they do not touch the condenser frame. (These terminals are sometimes bent during shipment.) Any contact between the terminals and the frame will short circuit the particular condenser section which corresponds to those terminals. The circuit connected thereto will then be inoperative.

Each trimmer condenser is constructed in the form of a small metal plate, insulated from the condenser frame by a strip of mica. The tuning condenser frame thus serves as one trimmer plate which is connected to the rotor plates, whereas the adjustable metal plate is electrically connected to the stator plates. Each of these small semi-variable condensers is thus connected in parallel with one section of the regular tuning condenser. The separation between this small insulated metal plate and the frame of the condenser is varied by means of an adjusting screw, thereby varying the capacity of the trimmer.

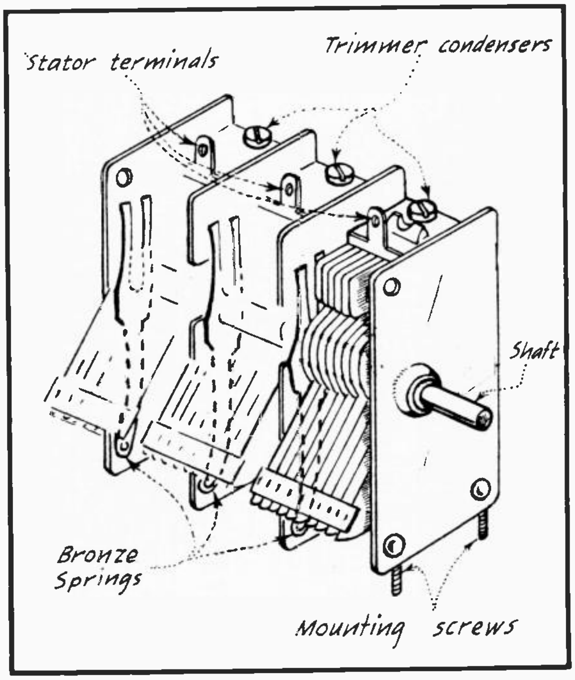

FIG. 3
THREE-GANG VARIABLE CONDENSER

The purpose of the trimmer condenser is to compensate for any differences in the tuning circuit characteristics, thereby making a more perfect alignment of the circuits possible. You will not use the trimmer condensers in the particular circuit which you are about to construct, as only one section of the three in the group is to be employed therein.

The capacity values are marked clearly on all bypass condensers that you received, whereas the resistor value is specified in accordance with the standard resistor color-code. Brown-black-green indicates a value of 1-0-00000 ohms, or 1 megohm, for the resistor which you received in the third kit.

CIRCUIT OF THE RECEIVER

In Fig. 4 of this lesson is shown the schematic diagram of the receiver that you are about to construct. As you will observe, a heater-cathode type triode is employed in a regenerative detector circuit. This type of receiver is not used commercially at present due to the extreme care required to tune-in the desired signal. However, the regenerative detector circuit is extremely sensitive. Regeneration is accomplished by using a regular antenna coil in conjunction with an additional coil, known as the "tickler" or feed-back coil. The rest of the circuit is of conventional design, the detector operating on the grid leak principle.

Further study of Fig. 4 will disclose that a 45-volt battery is used as the B supply, and that the headphones are connected in series with the B+ terminal, tickler coil and the tube's plate. The .001 mf condenser is connected across the headphones to bypass the r-f component of the plate current. The same applies to the .25 mf condenser which is connected across the B battery. The filament circuit has been omitted from Fig. 4, because it has no direct bearing upon the operation of the receiver. However, it is shown in detail in Fig. 5.

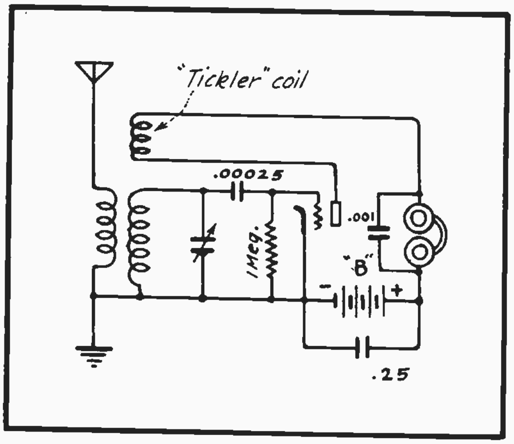

FIG. 4
REGENERATIVE DETECTOR CIRCUIT

If no electric lighting circuit is available in your district, you may use circuit (A) of Fig. 5 by employing a type 6T7G tube and connecting its filament across a 6-volt storage battery or across four dry cells connected in series. If an a-c lighting system is available for your experiments, you can eliminate the battery from the filament circuit and instead connect the filament of your 6Q7 tube across the a-c line, also connecting a lamp in series with the circuit as shown at (B) of Fig.5. If the circuit is of the 110-volt type, use a 110-volt lamp of a 25 to 40-watt rating; if the circuit is of the 220-volt type, use a 75-watt, 220-volt lamp.

Those students whose lighting system is of the d-c type may operate their receiver direct from the line, as shown later in this same lesson, using a 6Q7 tube.

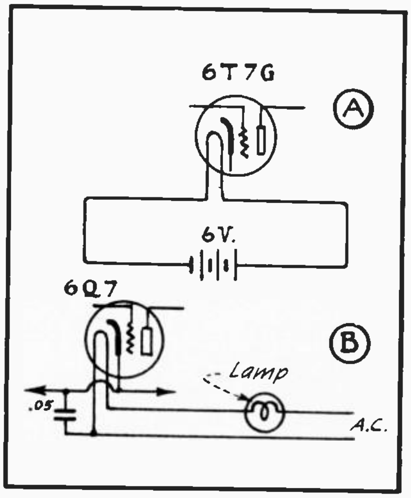

FIG. 5
FILAMENT CIRCUIT

MODIFYING THE ANTENNA COIL FOR REGENERATION

Your first step toward constructing the receiver will be to add the "tickler" coil to the antenna coil. This is done by winding six turns of insulated wire over the upper section of the transformer's secondary winding as shown in Fig. 6. The wire used for this purpose may be any insulated copper wire of small size,or if you prefer, you can use some of the hook-up wire that you received with your experimental kits.

The "tickler" coil must be just large enough in diameter so that it can slide up and down over the secondary of the antenna transformer, thus affording a means for varying the coupling between the two windings. This can be accomplished easily by wrapping a piece of paper around the secondary, winding the six turns of wire for the "tickler" coil over this paper and then removing both the paper and the tickler coil from the transformer. The paper may then be thrown away. It is recommended that you tie the turns of the tickler coil together at convenient intervals with adhesive tape so as to keep the tickler coil intact -- this is shown in Fig. 6.

The ends of the tickler coil must be long enough so that they can be used for completing the circuit and at the same time allow the coil to move freely over the entire length of the transformer's secondary. When placing the tickler coil over the secondary, be sure that the turns of the tickler are wound in the same direction as those of the secondary. The lower end of the tickler coil will then correspond to the plate connection of the tube.

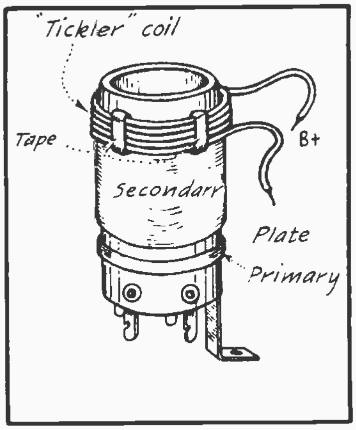

FIG. 6
MODIFIED ANTENNA COIL

CONSTRUCTION OF THE RECEIVER

The actual construction of the receiver is simple enough in itself. However, to derive all of the experience possible, it is recommended that you first make a drawing of the physical layout, showing the actual connections to the different parts of the receiver. Upon completing this drawing, compare it with the physical layout of the receiver appearing in Fig. 7. (The circuit in Fig. 7 is designed for battery operation). Also note that the tickler is shown only as a symbol, but as we have already explained, its correct location is over the upper end of the transformer's secondary as illustrated in Fig. 6.

All connections must be well soldered, except those to the batteries and the headphone terminals.

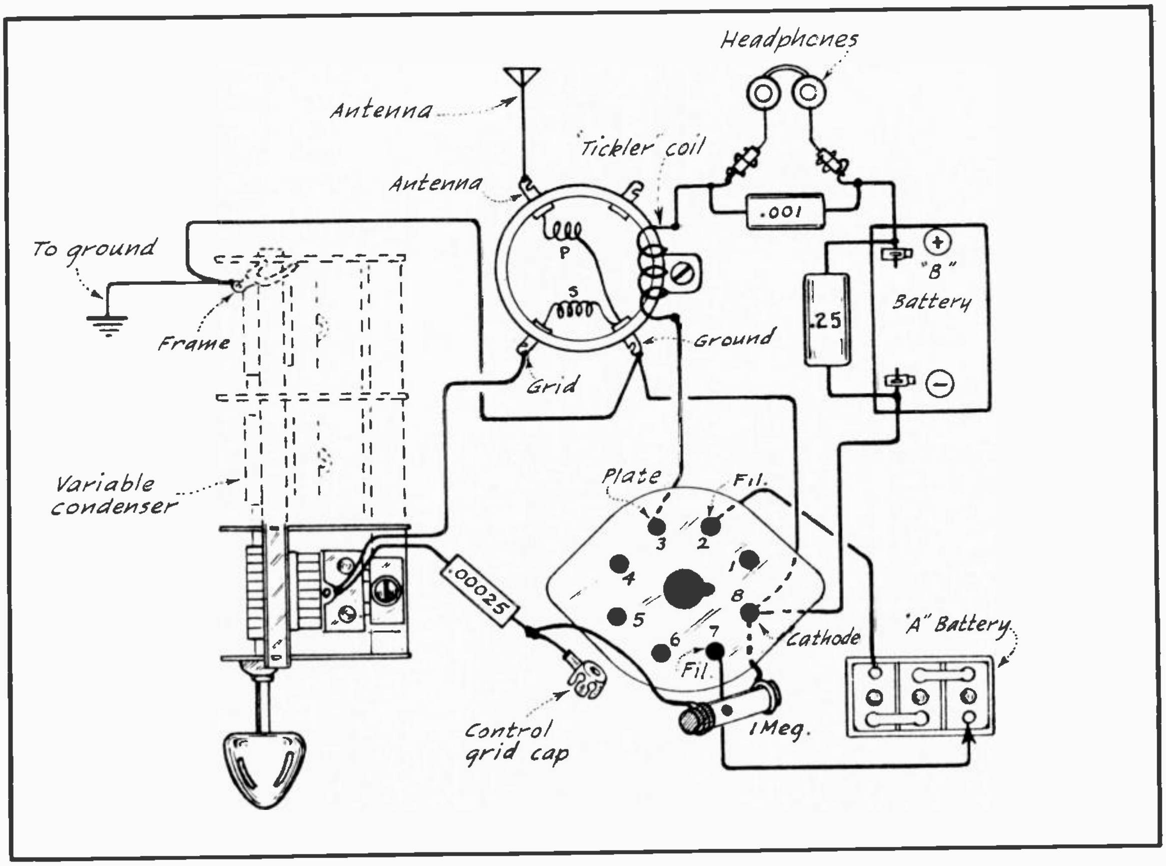

FIG. 7
TOP VIEW OF BATTERY-OPERATED RECEIVER

As a base on which to construct this experimental receiver, use a wooden board, bakelite, or heavy cardboard, cut to the shape of a square. All parts should be mounted on the board with wood-screws --- the tube socket can be mounted on small wooden separators or blocks as shown in previous lessons of this series.

If you so desire, you can construct a base-board or chassis by placing several sheets of strong cardboard on top of one another. The same wood screws as used for mounting the parts can then also be made to keep the cardboard sheets together. To protect this base against humidity, its surface can be coated with shellac.

The 45-volt B battery may be connected to the receiver in a permanent manner, as disconnecting one side of the filament circuit will make the receiver inoperative -- this is pointed out by the arrow in Fig. 7.

RECEIVER WITH A-C OPERATED FILAMENT

To operate the filament of the tube directly from an a-c lighting circuit, eliminate the A-battery and connect an ordinary incandescent lamp in series with one side of the tube filament and the line, as mentioned earlier in this lesson. Other sections of the receiver circuit remain the same, with the exception that a .05 mf by-pass condenser should be connected between one side of the line and ground so as to eliminate interference disturbances that might otherwise enter the circuit through the line. These changes are clearly shown in Fig. 8.

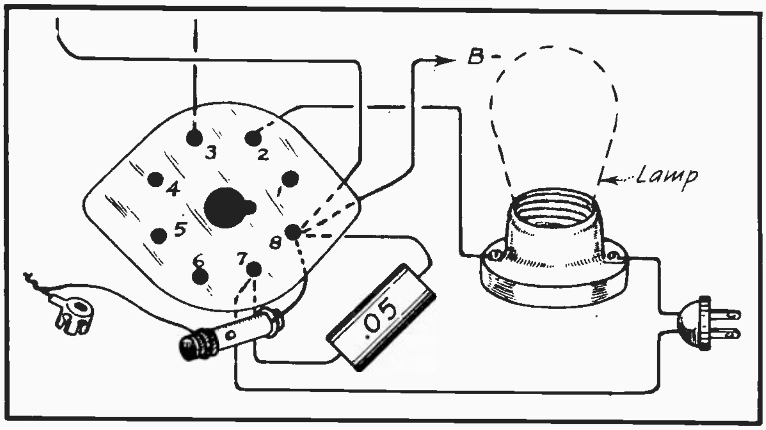

FIG. 8
A-C FILAMENT CIRCUIT

The use of a-c in the plate circuit of the tube is out of the question, for even though the circuit would operate with the tube being used as a rectifier, the signals would nevertheless be distorted by an excessive hum component. Therefore, the B-battery must be used in this circuit.

D-C OPERATED RECEIVER

This receiver may be operated directly from a d-c lighting system, without the aid of batteries, by employing the circuit diagrammed in Fig. 9. Here, the filament of the tube is connected in series with an ordinary incandescent lamp, and the plate circuit is also connected to the line.

Even though the lighting system is in this case of the d-c type, the current is nevertheless not sufficiently uniform in value to permit its being fed to the plate circuit of the tube directly. Therefore, a filter choke and two bypass condensers are interposed between the line and the tube's plate circuit. The primary winding of your a-f transformer should be used as the filter choke, while the .25 mf and .05 mf condensers serve as the filter condensers.

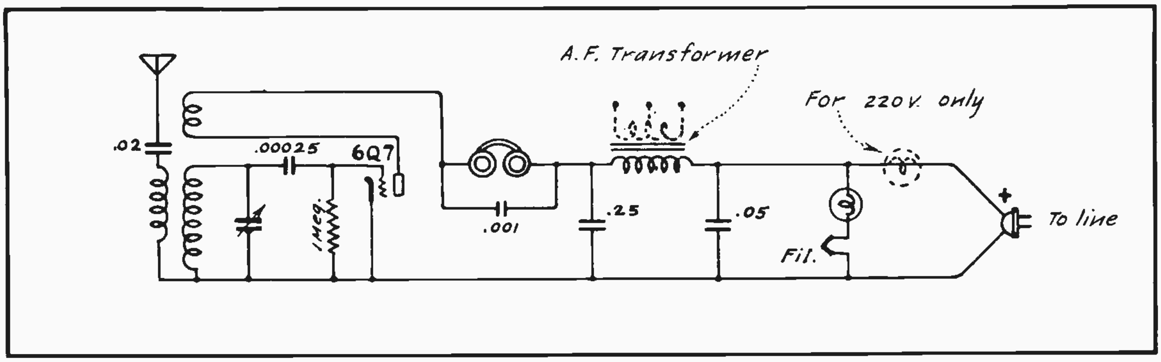

FIG. 9
DIAGRAM OF D-C RECEIVER

The primary of the a-f transformer has an inductance of about 100 henrys which is more than sufficient for filtering this circuit. Furthermore, since the current drawn by this receiver is very small, the size of wire used for the primary winding of the transformer is sufficiently large for this particular application. The secondary terminals of this transformer are not used and are therefore indicated on the diagram by dotted lines.

The use of the .02 mf condenser in the antenna circuit of Fig. 9 is of special importance and can be explained in the following manner:

The negative side of the lighting circuit is generally connected to ground by the power company, which ground connection will then also serve as the ground for the antenna system. Placing the .02 mf condenser between the antenna and the primary winding of the antenna coil will prevent d-c line current from passing through this winding in the event that the line plug should be reversed in its receptacle momentarily while the antenna is partially grounded through faulty installation. Line-current passing through the antenna coil would burn it out instantly. However, the r-f signals can pass through the .02 mf condenser with ease.

The physical layout and connections for this 110-volt d-c circuit are shown in Fig. 10. Should the line be of the 220-volt d-c type, then it will be necessary to connect an additional lamp in this circuit as indicated by the dotted symbol in Figs. 9 and 10.

CHECKING THE CIRCUITS

We wish to emphasize again that it is not good practice to connect any radio apparatus to the line or batteries immediately upon completion in order to find out "what will happen", or in the hope of finding everything O.K. Instead, you should always first check each connection carefully against the diagram. In fact, it is a good policy to "check off" each individual circuit on the diagram as it is found to be correct. For example, commencing with the filament circuit, trace it from beginning to end. Next, examine the plate circuit, followed immediately by a thorough examination of the control grid circuit, then the screen grid circuit, etc. This systematic inspection should be followed by a complete check-up of all bypass and filter condensers, making sure that all units are installed in their respective circuits and that they are well soldered.

By checking the wired circuit a few hours after completing the job of wiring, you are more likely to detect a mistake than will be the case if you check the circuit immediately upon completion of the wiring job.

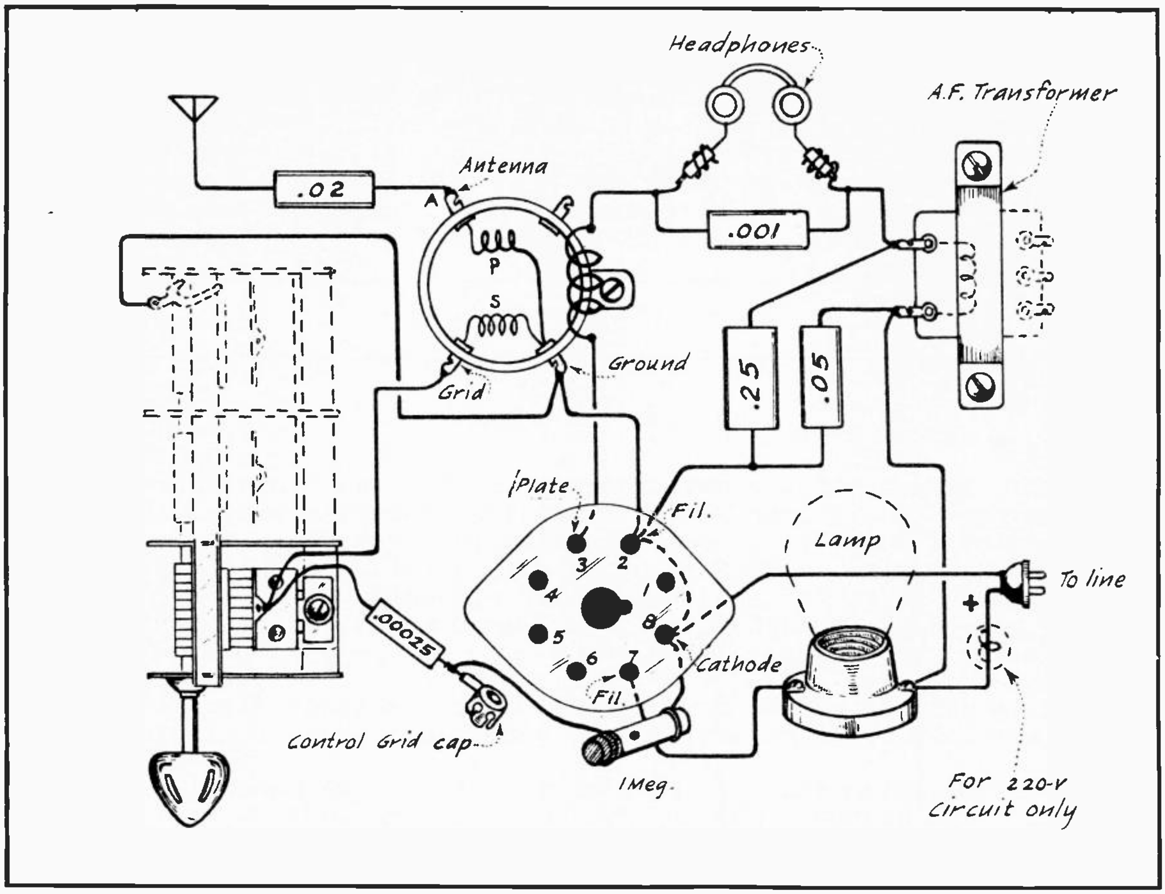

FIG. 10
TOP-VIEW OF D-C OPERATED RECEIVER

It is also advisable that you inspect the insulation of the different parts, as well as that of the wiring. There is nearly always a probability that two wire leads may contact each other, resulting in a short-circuit that may cause serious damage or at least keep the receiver from operating properly. There is also a probability that an excess of molten solder may become lodged between two terminals or between a terminal and the metal chassis, and in this way produce a short-circuit.

Another common source of trouble is where a mounting screw of excessive length contacts some part that normally must be well insulated. Besides those mentioned, many other apparently insignificant circumstances may arise which will cause difficulties and loss of time unless the circuit is checked carefully before "turning on the power."

PREPARING THE RECEIVER FOR OPERATION

Having assured yourself that the receiver is in a condition to be operated, you may proceed by connecting the filament circuit to the A battery or to the lighting system. Since the tube is of the heater-cathode type, it does not make any difference which side of the filament circuit is positive and which negative, as the sole purpose of the filament is to heat the cathode.

Continue by connecting the negative terminal of the B battery to the cathode, and its positive terminal to the headphones. (Note: No batteries are required for the d-c receiver that is connected directly to a d-c lighting circuit.)

Now, connect the antenna and grounding systems to the receiver. Since this receiver employs only one tube, its sensitivity or ability to receive distant stations depends much upon the type of antenna being used. For best results, the antenna should be quite long, erected at a considerable height from the ground, and placed in a favorable location. The ground connection should be made according to good practice. (We recommend that you review your regular lessons treating with antenna and ground connections, while formulating plans for your own.)

HOW TO OPERATE THE RECEIVER

While operating the receiver, it is important to bear in mind that cathode-type tubes do not begin passing plate current immediately upon closing the filament circuit. Several seconds are required for the cathode temperature to rise to a value sufficiently high for electron emission to begin. The new rapid-heating tubes require from 10 to 15 seconds for the cathode to reach its normal operating temperature, while the older tubes require as much as one-half minute or more to begin operating satisfactorily.

As was mentioned previously, the detector circuit being used at this time is of the regenerative type. By means of the tickler or feed-back coil, some of the signal energy is returned from the tube's plate circuit to its grid circuit. This results in better selectivity and a considerable increase in volume and sensitivity.

To make regeneration possible, the feed-back signal must be in-phase with the station signal appearing in the grid circuit. There will be a marked decrease in amplification if the feed-back energy is out-of-phase with the signal energy in the grid circuit, as these two energies would then partially neutralize each other. (Connecting the leads of the tickler coil to the circuit in accordance with instructions given earlier in this lesson will insure the feed-back energy being in-phase with the signal energy in the grid circuit.)

Regeneration can be controlled by increasing or decreasing the amount of energy feed-back. However, there is a limit to the amount of feed-back that can be handled in this way. If this limit is exceeded, the circuit will oscillate, thereby converting the receiver into a small transmitter. Excessive regeneration or oscillation makes itself known through whistling and howling noises in the headphones, especially when operating the tuning condenser.

These whistling noises will be radiated by your antenna and will be picked up as interference disturbances by receivers in your locality. You must, therefore, prevent your circuit from oscillating in consideration for your neighbors,as well as to avoid annoying whistles in your own headphones.

Oscillation of the circuit offers a means for checking if the circuit is wired correctly. To do this, proceed as follows: With the tube at operating temperature and the B battery connected in the circuit correctly, alter the position of the tickler coil until a whistling noise is heard in the headphones. Bear in mind that the closer you bring the tickler coil to the center of the secondary, the closer will be the coupling between these two windings. Such movement of the tickler coil will increase regeneration until the point of oscillation is finally reached. Once the circuit has commenced oscillating, you may rest assured that it is functioning.

Having thus located the tickler coil position to promote oscillation, slide the tickler coil upward very slowly until oscillation just stops. This position of the tickler will provide the greatest sensitivity. Upon tuning-in a stronger signal, the circuit may commence oscillating again, in which case the tickler coil should be moved upward a little more until oscillation stops.

If the circuit oscillates, even though the tickler is moved to its maximum position at the upper end of the antenna coil, reduce the number of turns used on the tickler, removing one turn at a time and testing for results.

The number of tickler-turns recommended earlier in this lesson is satisfactory for general purposes. However, since the operating characteristics of different tubes vary considerably, as does also the distributed capacity of the receiver's wiring, it is well to experiment with regard to the number of turns used on the tickler coil. Bear in mind that regeneration increases with an increase in the number of turns and decreases as the number of turns is reduced.

When tuning-in a station, always be sure that the tuning condenser is adjusted to the exact point where the signal is heard best. If the desired signal "comes-in" very weak, a slight alteration of the tickler coil will often improve reception.

EXPERIMENTING WITH YOUR RECEIVER

Although this experimental receiver is rather small, it nevertheless offers you a splendid opportunity to conduct numerous instructive and interesting experiments.

EXPERIMENT #1: Disconnect the end of the tickler coil that is attached to the plate terminal of the tube socket and leave that wire free. Now connect another wire from the plate terminal of the tube socket to the B+ end of the tickler coil as shown in Fig.11. Under these conditions, the detector will no longer be of the regenerative type. This will result in a noticeable decrease in its sensitivity and selectivity.

EXPERIMENT #2: Reverse the tickler coil connections, and at the same time remove the additional wire which you used during the previous experiment. That is, the end of the tickler coil that was originally connected to the plate terminal of the tube socket, should now be connected to the headphones and vice versa. This change in the circuit will cause the feed-back energy to be out-of-phase with the grid circuit energy. The sensitivity of the receiver will be impaired by this change in connections.

EXPERIMENT #3: Re-connect the tickler coil for normal operation and reverse the B battery connections. That is, connect the positive terminal of the B battery to the cathode and the negative terminal to the plate of the tube. Under these conditions, no electrons will be attracted by the plate of the tube and the receiver will therefore be inoperative. (If your experimental receiver is of the d-c type, reverse the connecting plug in the receptacle of the line.)

EXPERIMENT #4: Re-connect the B battery to the circuit correctly. Then,disconnect the grid leak resistor from the cathode terminal of the tube socket and connect this free end of the leak resistor to the other side of the grid condenser as shown in Fig. 12.

This connection for the leak resistor is very common in the older receivers and results in almost identical performance as when the "leak" is connected directly between the grid and cathode.

EXPERIMENT #5: Disconnect one end of the grid leak resistor from the circuit. The passage of electrons from the grid of the tube will now be interrupted, causing the grid to become highly charged. The tube will thus be "blocked" so that it can no longer operate properly.

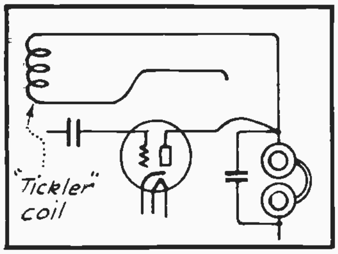

FIG. 11
ELIMINATING REGENERATION

EXPERIMENT #6: Connect two sections of the tuning condenser in parallel as shown in Fig. 13. To do this, simply connect a piece of wire from one stator section to the other. (The rotor plates are already connected together through the common shaft.)

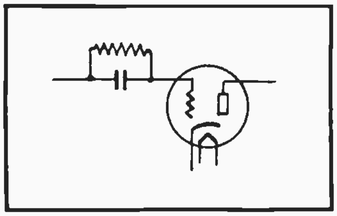

FIG. 12
CHANGED LEAK CONNECTION

The combined capacity will now be double that of a single section, and the receiver will therefore tune over a lower frequency band than originally. That is, the receiver will now tune-in signals of a lower frequency than before, but will not be capable of tuning-in stations at the high-frequency end of the broadcast band. You may be able to tune-in commercial code stations, ships at sea, etc., with the receiver operating in this condition.

When receiving c-w (continuous wave) code signals, it is recommended to have the circuit oscillate a little. This will serve to modulate the code signals, so that they can be heard distinctly.

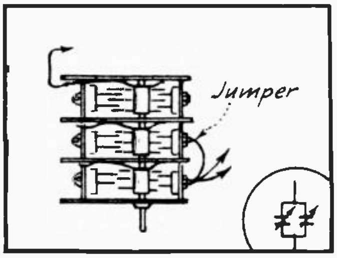

FIG. 13
PARALLELED CONDENSER SECTIONS

EXPERIMENT #7: Now remove the small wire that you used to connect two condenser sections in parallel and connect two sections of the tuning condenser gang in series as shown in Fig. 14. To do this, simply move the ground connection from the first tuning section of the condenser gang to the insulated terminal of the second stator-plate-section as also indicated in Fig.14. (The condenser shaft forms the connection between the two sections, since the rotor plates of all sections are mounted on the same shaft.)

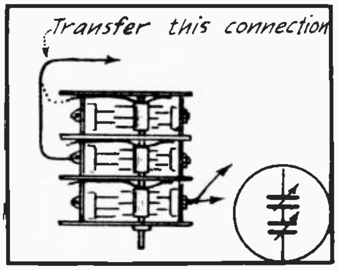

FIG. 14
SERIES-CONNECTED CONDENSER SECTIONS

The tuning capacity is now only one-half that of the actual capacity of any one section of the gang, which means that the receiver will now tune to higher frequencies than was originally possible. You may also hear code signals in this higher frequency band. It will now be impossible to tune-in some of the stations at the low-frequency end of the broadcast band.

EXPERIMENT #8: Connect the tuning circuit to only one section of the tuning condenser, in the normal manner, but reverse its connections. That is, the wire that was originally connected to the stator plates should now be connected to the rotor plates and vice versa.

Even though the circuit will operate under this condition, you will notice that tuning will be affected quite noticeably up on touching the tuning control knob and then removing your hand. This condition is due to body capacity, and can be corrected by simply connecting the rotor plates to ground and the stator plates to the grid of the tube as shown in Fig. 10.

EXPERIMENT #9: With the receiver in a condition for normal operation, disconnect one end of the condenser that is connected across the headphones. You will notice that regeneration will now be reduced considerably, and that the circuit will not oscillate as readily when the bypass circuit for the r-f component in the plate circuit has been eliminated. The chief purpose of this condenser is to pass the high frequencies (r-f) and at the same time block the audio frequencies, forcing the latter through the headphones.

EXPERIMENT #10: Interchange the primary and secondary windings in the circuit by using the latter in the antenna circuit and the primary as the tuning coil. Under these circumstances, a very pronounced effect will be observed due to the inductances not being properly matched to the circuits.

Besides the experiments herein outlined, you can also devise others by referring to your regular lessons for suggestions.

OPERATING PRINCIPLES OF THE RECEIVER

Having had the opportunity to experiment with a grid condenser and leak-type detector, you will no doubt be interested in learning more about its principles of operation. The illustrations appearing in Figs. 15 and 16, together with the following explanation, should give you a clear understanding of the theory involved.

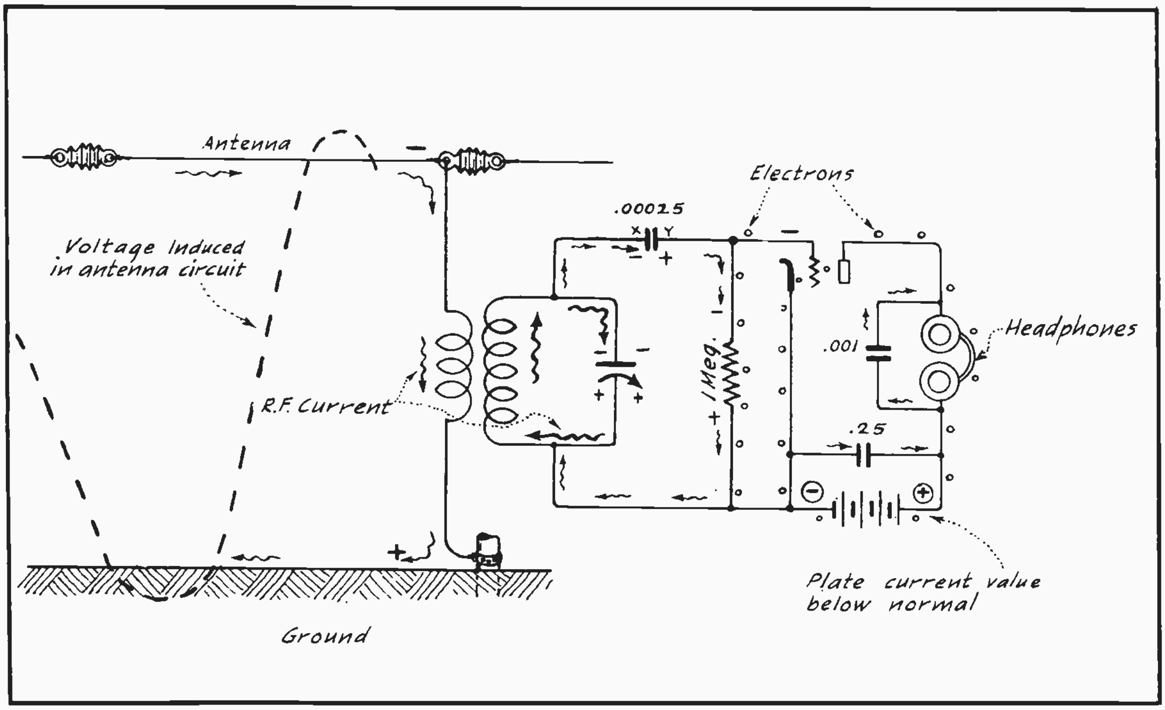

FIG. 15
CIRCUIT OPERATION DURING FIRST ALTERNATION OF SIGNAL VOLTAGE

With the receiver in operating condition, and no signals being received, plate current of constant value will flow through the plate circuit.

Now, let us assume that the signal wave, striking the antenna at one particular instant, causes the elevated portion of the antenna to become negatively charged with respect to ground as shown in Fig.15.

This condition will cause an electron-flow through the primary winding of the antenna coil in the direction indicated by the arrows. This electron-flow in turn builds up a magnetic field around the primary winding which links the secondary and induces therein a voltage that causes electrons to flow into the plates of the tuning condenser in such manner that a negative potential is produced at the stator (upper) plates and a positive potential at the rotor (lower) plates, as shown in Fig. 15.

Since the .00025 mf grid condenser is connected in parallel with the tuning condenser through the leak resistor, some electrons will also flow into plate X of the grid condenser, charging it to a negative potential with respect to plate Y. As this charging action of the grid condenser takes place, some electrons leave plate Y, flow through the 1 megohm leak resistor in the direction indicated, and over toward plate X. The direction of electron-flow being from the grid-end of the leak resistor toward its cathode-end causes its grid-end to become negative with respect to its cathode-end.

At radio frequencies, the capacitive reactance of the grid condenser is practically negligible in comparison to the resistance value of 1 megohm possessed by the leak resistor. Therefore, the voltage-drop produced across the leak resistor is far greater than that generated across the plates of the grid condenser. Such being the case, the net or effective voltage applied across the tube's grid and cathode terminals is practically equal to that produced across the ends of the leak resistor by the flow of electrons through it,and also of like polarity. Thus, during the instant illustrated in Fig. 15, the tube's grid is <u>negative</u> with respect to its cathode.

The grid of the tube, now being negative, decreases the flow of electrons between the cathode and plate, and in this way decreases the plate current below its normal value.

As the following alternation of signal-voltage occurs, the elevated portion of the antenna becomes electrically positive, and the grounding system, negative. The electrons through the antenna circuit will then reverse their direction of flow in accordance with the arrows appearing in Fig. 16. Similarly, the electron-flow in the tuning circuit, caused by induction, will also reverse its direction in accordance with the arrows in Fig. 16. The upper tuning condenser plates will therefore now be charged to a positive potential and the lower ones to a negative potential.

This action causes plate X of the grid condenser to become positively charged with respect to plate Y. During this charging period of the grid condenser, the electron-flow through the leak resistor is in such direction that its cathode-end becomes negative with respect to its grid-end. Also, the voltage-drop across the leak resistor is again much greater than that across the plates of the grid condenser for the reason given previously. Therefore, the voltage that is effective across the tube's grid and cathode is again practically equal to, and of the same polarity as, that appearing across the ends of the leak resistor. In other words, the tube's grid is now <u>positive</u> with respect to its cathode, which condition accelerates the flow of elec-

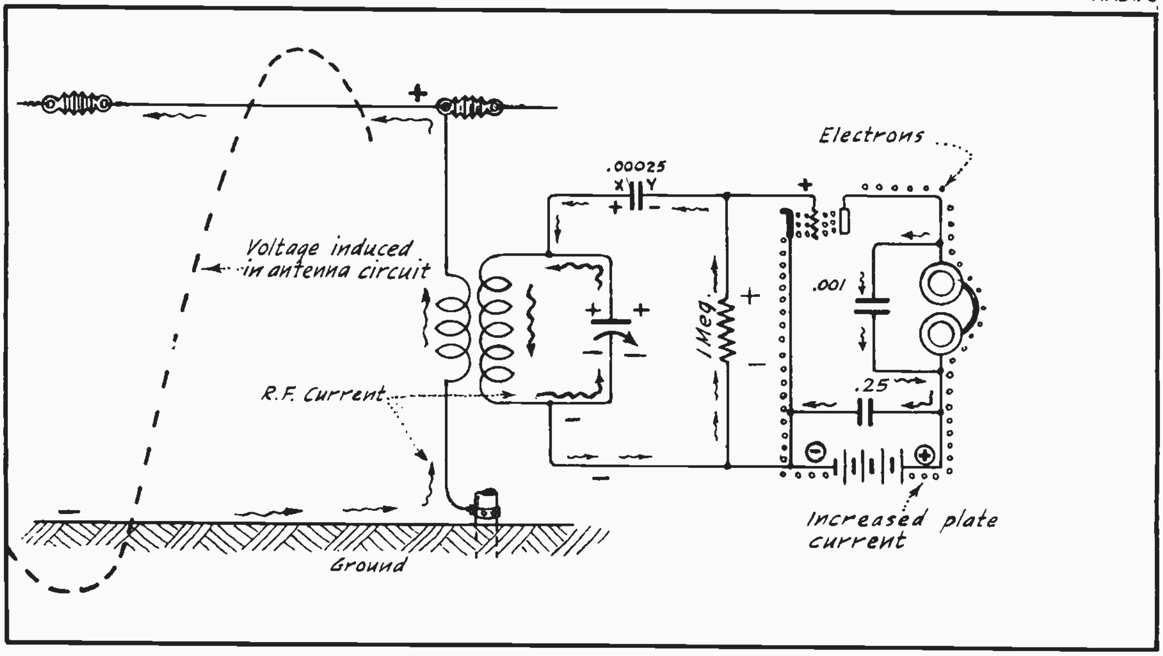

FIG. 16
CIRCUIT OPERATION DURING SECOND ALTERNATION OF SIGNAL VOLTAGE

trons between the cathode and plate, causing the plate current to increase above its normal no-signal value.

However, it is also to be noted that each time the grid is positively charged (as in Fig. 16), it acts somewhat as a "plate" and attracts a few of the electrons emitted by the cathode. Assuming for the moment that the 1 megohm leak resistor is not included in the circuit, it is apparent that such electrons as are attracted by the grid, would become isolated because they cannot flow through the insulation of the grid condenser --- and, since they bear a negative electrical charge, they have a natural tendency to partially neutralize the positive signal potential and also to maintain a negative charge on plate Y of the condenser. Therefore, as the signal-voltage reverses to re-establish conditions as shown in Fig. 15, causing the grid to become negatively charged, the condenser plate Y and the grid will already be slightly negative. (This is due to the accumulation of electrons that are trapped on those parts, on account of this portion of the circuit being isolated during the absence of the leak resistor.) Thus,it is apparent that whenever the control grid is "swung" negative by the signal voltage, it will be slightly more negative than is made possible by the signal voltage alone,and the flow of plate current is therefore reduced accordingly.

Since electrons are accumulated by the grid during each positive alternation of signal-voltage, the average positive potential of the grid and its corresponding effect on the plate current will gradually become less during each successive cycle, for any given constant signal intensity. Also, the increasing effect of the negative grid potential during the negative alternation of each successive cycle will cause a steady decrease in the average plate current. Thus, these two factors, together, cause the average plate current to decrease in value during each successive cycle of the r-f wave-train.

In the absence of the leak resistor, this action would continue for a number of cycles of the signal voltage until so many electrons have collected on plate Y of the grid condenser that their charge would cause the grid to become so much negative that the flow of plate current would be stopped entirely. The tube would then be "blocked," and the system paralyzed.

The leak resistor prevents the occurrence of conditions described in the preceding paragraph. It does this by offering a high-resistance path between the tube's grid and cathode so that the excess electrons may drain off the grid before the state of blocking occurs. In fact, the relation between the values of the grid condenser and the leak resistor is such as to allow the excess electrons, accumulated during the r-f cycles constituting one-half of the audio cycle, to drain off the grid at the time that the following half of the modulated signal comes in. This draining of electrons by the leak resistor is illustrated in Fig. 15 by means of the small circles spaced along this path.

The action of the grid condenser and leak being as described, the plate current will vary as shown by the curve in Fig. 17. Notice that the average change in plate current has little ripples incorporated in it, which represent remaining r-f variations. These ripples, being an a-c component of the plate current, can be shunted or bypassed around the windings of the headphones by the .001 mf condenser and also around the B battery by the .25 mf condenser.

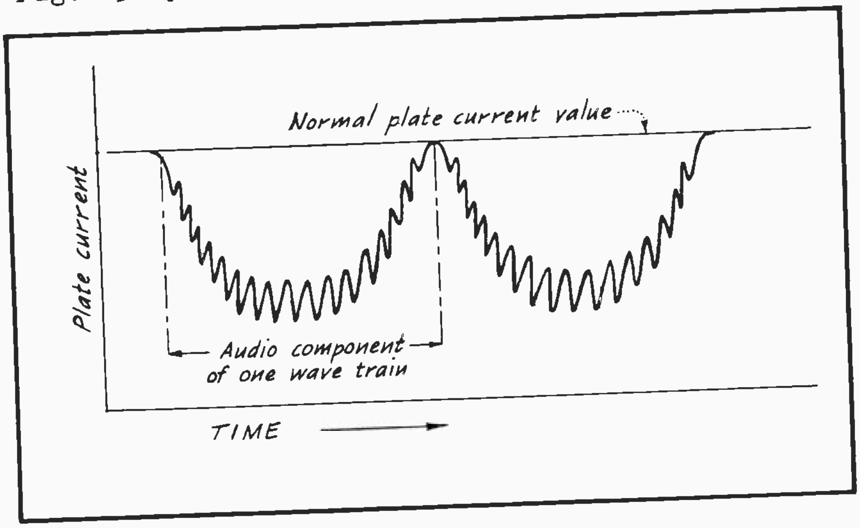

FIG. 17
AVERAGE CHANGE IN PLATE CURRENT

The manner in which these r-f ripples are bypassed through these condensers is indicated by the small arrows in Figs. 15 and 16. It will be noted that the alternate charge and discharge of these bypass condensers is such as to store electrons during the peaks of the plate current r-f pulses and to deliver them to the plate circuit during the depressions, thereby acting as a filter and thus causing the flow of plate current through the headphone windings to more nearly conform with the curve appearing in Fig. 18. Thus, clear, audible sounds are produced by the headphones.

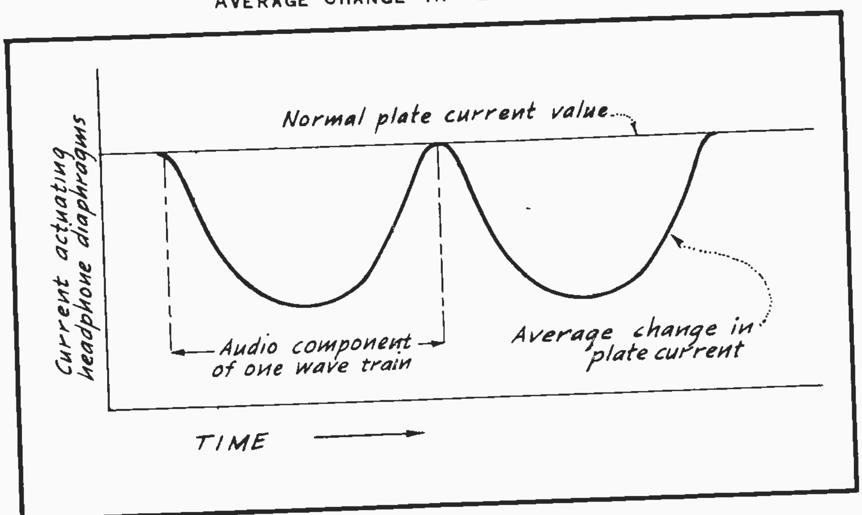

FIG. 18
HOW FILTERING AFFECTS PLATE CURRENT

NOTICE TO STUDENTS WHO ARE TO RECEIVE A-C RECEIVER EQUIPMENT

If your enrollment-plan calls for a-c operated experimental equipment, you must continue using the B battery for the first experiments until you receive the necessary parts for the B power supply. The latter will enable you to operate from the a-c line all of the more complex circuits that are constructed with the parts and instructions furnished with future kits.

One must also bear in mind that thousands of battery-operated receivers are being used in localities where electric lighting facilities are not available. It is therefore necessary that all students become familiar with the application of batteries in receivers. If you are in the "a-c group", and do not wish to buy a B battery, you may lay this experiment lesson and kit aside until you receive the parts for the power pack, at which time you may conduct the experiments described in this lesson. However, we assure you that the small additional expense incurred by the purchase of a B battery will provide you with excellent practical experience which you would not obtain otherwise.

answered Nov 14, 1941

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. FG-3

1. - What precautions should be exercised as to the direction of winding the tickler coil and the connections of its ends to the receiver circuit?
2. - If the terminals of an antenna-stage r-f transformer are not marked, how can you determine which end of the secondary is to be connected to the control grid circuit and which end of the primary to the antenna?
3. - Why is the .02 mf condenser connected in series with the antenna system in the circuit diagrammed in Fig. 9?
4. - How can you determine whether or not regeneration is actually taking place in a regenerative type detector circuit, such as described in this lesson?
5. - What would happen if the grid leak resistor should accidentally become disconnected in the detector circuit?
6. - How is the performance of the receiver affected by reversing the tickler coil connections?
7. - What is the purpose of the .001 mf condenser that you connected across the headphones?
8. - How will an increase in the tuning circuit's capacity affect the performance of the receiver?
9. - How will a decrease in the tuning circuit's capacity affect the performance of the receiver?
10. - Is the signal-voltage across the grid and cathode of the tube in this receiver more nearly equal to the voltage-drop across the grid leak resistor or that across the grid condenser?

Practical - Technical

TRAINING IN **RADIO AND TELEVISION**

ESTABLISHED 1905 J. A. ROSENKRANZ, Pres.

NATIONAL SCHOOLS

LOS ANGELES, CALIFORNIA

EXPERIMENT LESSON NO. F-4

RECEIVER CONSTRUCTION ON METAL CHASSIS

With the parts included in your fourth outfit of experimental equipment, together with those that you received previously, you will now be able to construct a receiver on a metal chassis. Since this form of construction is used exclusively by receiver manufacturers, you can readily see that the experience acquired in this way will be of great value to you.

Your kit of additional parts sent you at this time is comprised of the following:

- Cadmium-plated chassis
- Antenna-ground post assembly
- Twin-jack
- Hook-up wire
- No. 6-32 machine screws and nuts

THE CHASSIS

The chassis is already provided with all of the holes necessary to accommodate the various parts required for the superheterodyne receiver that you will construct in accordance with instructions furnished in the last lesson of this special series. The chassis, as a whole, has been planned so that the completed receiver will have an attractive commercial appearance, as well as being arranged to make an efficient circuit possible.

During your preliminary construction projects you will of course not use all of the space and holes provided on the chassis, as the circuits being constructed at this time will employ only a limited number of tubes. However, as you progress with this work, guided by succeeding lessons of this series, you will gradually add more tubes and thereby enlarge the receiver until you finally arrive at the stage where you build the final master set -- a modern superheterodyne.

MOUNTING THE PARTS

So that you may become familiar with the problems involved when constructing a receiver on a metal chassis, you will build the same one-tube receiver that you constructed in accordance with instructions furnished in your previous experiment lesson, only that you will now use the metal chassis as its base. Fig. 4 illustrates the chassis as it will appear with all parts and wiring in their correct positions. To familiarize yourself with this circuit, it is well that you make a similar drawing before commencing the actual work of construction.

Fig. 4 shows clearly the position occupied by all parts, while Figs. 1, 2, 3, and 5 illustrate in detail the mounting of the individual parts.

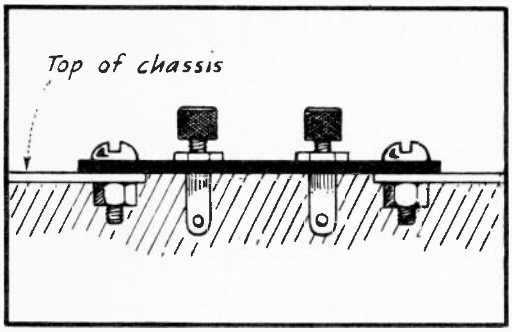

FIG. 1
ANTENNA-GROUND POST MOUNTING

ANTENNA-GROUND POST MOUNTING: Fig. 1 shows you the correct method for installing the antenna-ground post over the oblong hole on top of the chassis, near the rear edge. (The front and rear edges of the chassis can be identified in the following manner: The front of the chassis has four 3/8" holes arranged in a straight line. The rear of the chassis is provided with one large hole, another smaller one, and an oblong perforation -- the latter being similar to the one used for the antenna-ground post assembly on top of the chassis.)

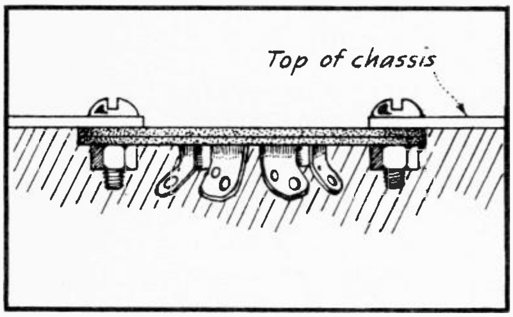

FIG. 2
TUBE-SOCKET MOUNTING

The antenna-ground post assembly is mounted on top of the chassis so that neither the antenna wiring nor its connections will contact the metallic structure of the chassis. You will further observe in Fig. 1 that the insulative terminal strip is held in place by screws and nuts.

TUBE SOCKET MOUNTING: The correct method for installing the tube sockets on the chassis is clearly shown in Fig. 2. Notice that the socket is mounted on the underside of the chassis, care being exercised that the terminal prongs are kept more or less in the center of the chassis' socket hole.

R-F TRANSFORMER MOUNTING: Place the r-f transformer on top of the chassis, directly over the chassis hole, as shown in Fig. 3. For the one-tube receiver now being constructed, use the hole designated for this purpose in Fig. 4 so that the connecting leads between it and its associated parts may be as short as possible.

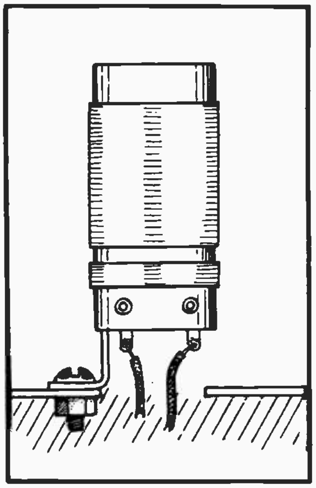

FIG. 3
R-F TRANSFORMER
MOUNTING

TUNING CONDENSER MOUNTING: The gang tuning condenser should be installed so that its trimmer condensers face upward, and also so that the end of its shaft points toward the front edge of the chassis as shown in Fig. 5. Mounting screws have been riveted to the frame of the condenser at the factory and should be inserted in the holes provided for that purpose on the front center-section of the chassis deck (top). Upon inserting the screws in their respective holes, and applying the nuts from underneath the chassis, the tuning condenser will be held in place securely.

Before installing the tuning condenser in position, solder a piece of wire (about six inches long) to each of the three stator terminals on the mounting-screw side of the condenser and insert the free ends of these wires through the three

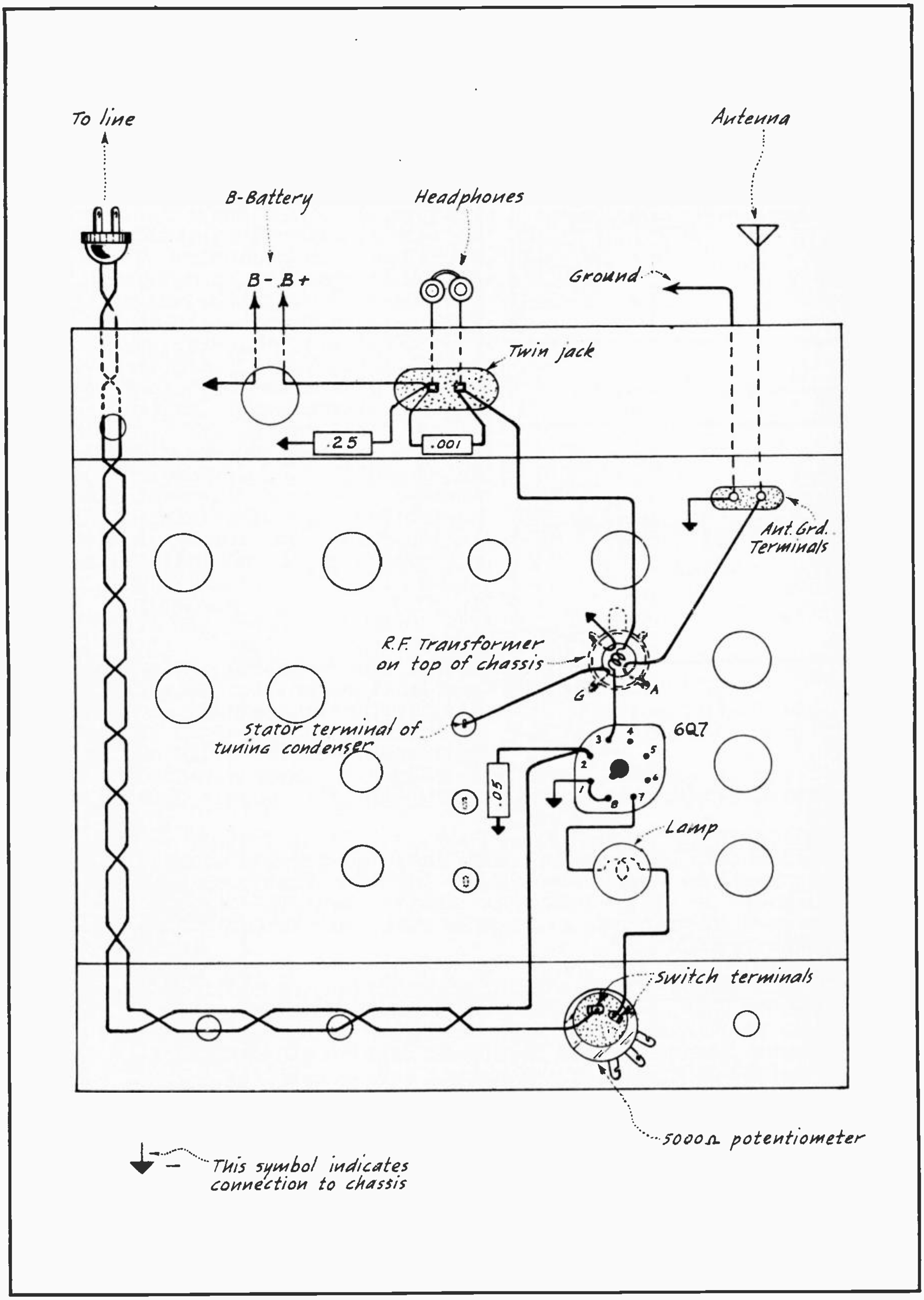

FIG. 4
CIRCUIT CONNECTIONS (CHASSIS VIEWED FROM BELOW)

holes of the chassis that line up with these terminals. Make sure that these leads are soldered to the condenser terminals securely so that they will not become loose and make removal of the condenser and re-soldering necessary. (Bear in mind that for this one-tube receiver you will use only one section of the three-gang condenser. The other two sections which are not used at this time should not be connected to any circuit.)

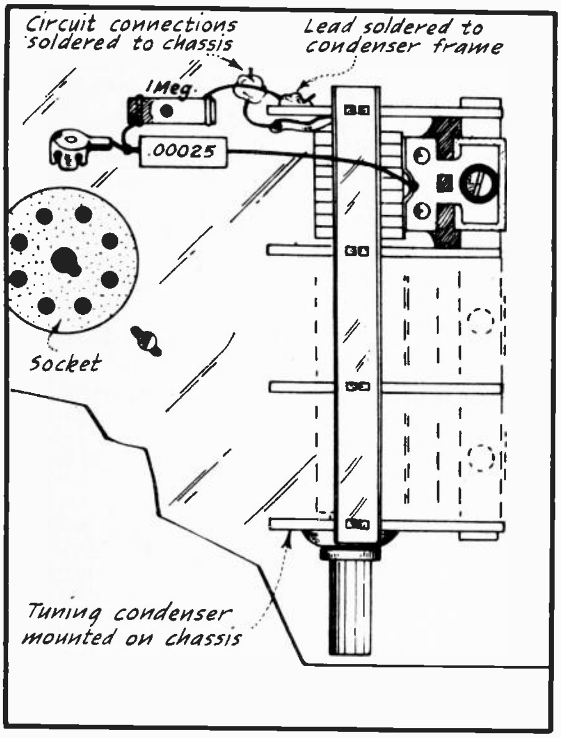

FIG. 5
GRID CIRCUIT WIRING

As soon as the tuning condenser has been mounted on the chassis, solder one end of a short length of hook-up wire to one of the rotor-plate terminals and the other end to the chassis. The purpose of this wire is to establish a more effective electrical connection between the condenser frame and the chassis.

POTENTIOMETER MOUNTING: So as to have a means for switching this receiver "on" and "off", mount your 5000-ohm potentiometer to the front edge of the chassis as shown in Fig. 4.

WIRING THE ONE-TUBE RECEIVER CIRCUIT

The complete wiring for this receiver is illustrated in Fig. 4, where the chassis is shown as viewed from below. For the sake of simplicity, the sides of the chassis are shown extended outward. All parts shown with dotted lines are installed on the outside of the chassis.

The cadmium plating on the chassis permits connections to be soldered to its surface readily. In the circuit which you are now about to wire, it is necessary to solder several connections to the metal chassis; therefore, it is well that you first read the following instructions carefully.

HOW TO SOLDER A CONNECTION TO THE CHASSIS: When soldering a connection to the chassis, it is important to first clean the surface thoroughly at the intended point of contact. This can be done by rubbing it briskly with a clean, soft rag until it is free of any oil film that is sometimes applied over the plating.

The soldering iron should be well heated, and the flat section of its point held firmly against the chassis where the solder is to be applied, allowing that area of the surface to become well heated. Next, pick up a small amount of soldering paste with the end of the solder and touch this end of the solder to the tip of the soldering iron, without withdrawing the iron from the chassis.

Upon moving the tip of the iron gently around the heated area of the chassis, the solder will commence to flow, forming a bright spot on the chassis. The next step is to solder the wire or terminal to that point, being careful that the wire or terminal does not move until the solder has solidified.

WIRING PROCEDURE: Do not start wiring until all parts are installed in their respective positions. It is good practice to begin wiring with the filament circuit, to be followed by the cathode circuit, plate circuit and then the grid circuit. The antenna circuit should be wired last. With respect to Fig. 4, this wiring job could be done as follows:

Insert the free end of the line cord through the smaller hole at the rear of the chassis, and solder one of its wires to terminal #2 on the 6Q7 tube socket; then solder the other line-cord wire to one of the switch terminals on the back of the 5000-ohm potentiometer. Next, solder one lead of the .05 mf condenser to terminal #2 on the tube socket and its other lead to the metal chassis

Now, run a piece of wire from terminal #7 of the tube socket to one of the terminals on the lamp socket and connect the other terminal of the lamp socket to the vacant terminal on the potentiometer switch.

Connect a short length of wire between terminals #1 and #8 of the tube socket, extending this same wire to the chassis and soldering it at this point. Connect the ground terminal of the r-f transformer (that terminal to which one end of the primary and one end of the secondary are connected) to the chassis. Follow this by connecting the ground terminal of the antenna-ground post to the chassis.

Check the r-f transformer terminals and make sure that they do not contact the chassis and, if necessary, bend them away from the chassis. Connect one of the three leads previously soldered to the tuning condenser to the grid terminal of the r-f transformer (use that lead nearest the transformer).

As the next step, connect one end of the tickler coil to terminal #3 of the tube socket, and the other end of this coil to one of the twin-jack terminals. Connect a .25 mf condenser between the other jack terminal and the chassis. Also, run a long piece of wire from this same jack terminal to the positive terminal of the B-battery. Connect another long lead between the negative B-terminal and the metal chassis (the battery may be placed on top of the chassis for convenience). Continue by connecting a .001 mf condenser between the two jack terminals and then connect the antenna terminal of the r-f transformer to the antenna post

The final step is to complete the grid circuit outside of the chassis. To do this, connect a .00025 mf fixed condenser and a 1-megohm resistor to the control grid clip, as shown in Fig. 5. You will observe that the free end of the condenser is connected to the stator plate terminal of the tuning condenser section being used, and that the free end of the resistor is soldered to the tuning condenser frame, which is equivalent to connecting it to the chassis.

When you have installed the tube in its socket and placed the control grid clip over the cap on top of the tube, make sure that the .00025 mf condenser does not touch the tuning condenser frame nor any other nearby object. If necessary, bend it away from any metallic object which it is likely to contact.

Proceed by inserting the headphone leads into their respective jacks; connect the batteries, the ground wire, the antenna lead-in, and also plug the line cord into the nearest lighting circuit outlet. The receiver will now be ready for operation upon closing the switch.

USING THE CHASSIS AS A RETURN-CIRCUIT

Upon comparing your present circuit with that constructed according to the previous experiment lesson, where you employed the "breadboard" method of construction, you will observe that the new system is much more simple. Under the new method, you have eliminated all long leads that were used previously as ground circuits to complete the cathode circuit of the tube, to connect the tuning condenser frame to ground, etc. In your new receiver, the metal chassis is used to complete all these ground-return circuits and thereby eliminates the need for the additional wiring otherwise required.

In most modern receiver circuits, as well as in other radio apparatus, the metal chassis serves three distinct purposes: first, it accommodates all parts; second, it serves as a base for the entire unit and at the same time acts as a shield for the greater part of the circuit wiring; and third, it is used as a common "return" for the various circuits.

Since the chassis forms part of the general shielding system, it must always be kept at a low potential with respect to ground. This means that it must not be used as the positive side of the plate circuit (B+), or for the control grid circuit of the tubes. However, it may be used to complete the negative or return-side of either the plate or control grid circuits.

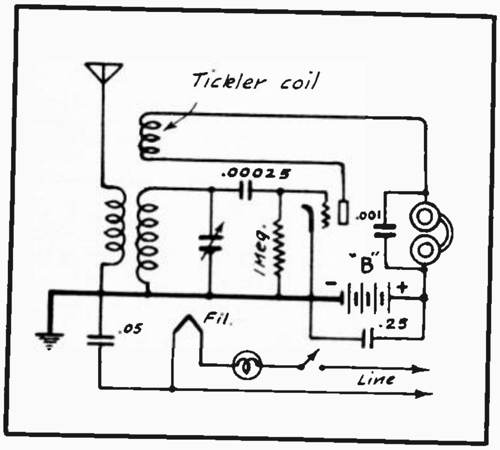

Fig. 6
Circuit with A-c Filament Supply

In the case of the receiver that you have just constructed, those connections that have been made directly to the chassis are indicated by the heavy lines on the diagram of Fig. 6. This can be verified readily by comparing the circuit connections in Figs. 4 and 6.

It must be understood that radio diagrams in general do not always show the connections to the chassis by means of heavy lines as we have done in Fig. 6. Instead, such connections are usually designated by the standard "ground symbol," as is employed in Fig. 7 of this lesson as well as in other diagrams in our course. The latter practice eliminates all possibility of errors during the wiring procedure, and is therefore used extensively throughout the industry.

ONE-TUBE RECEIVER FOR D-C OPERATION

The circuit shown in Figs. 4 and 6 is designed for using alternating current for the filament supply, while a B-battery is used to furnish the plate current for the tube. Later on, you will be furnished with the parts necessary for obtaining the B-supply from the house-lighting circuit as well.

If the lighting circuit in your district is of the d-c type, you can eliminate the B-battery and connect the plate circuit of your receiver to the lighting circuit through a filter system. The schematic diagram for such a receiver is shown in Fig. 7, and though there is very little difference between it and the circuit shown in Fig. 6, we feel that an explanation of the changes made will help you to better understand the d-c circuit. To simplify our explanation, the necessary changes for the plate circuit of the d-c receiver are illustrated in Fig. 8.

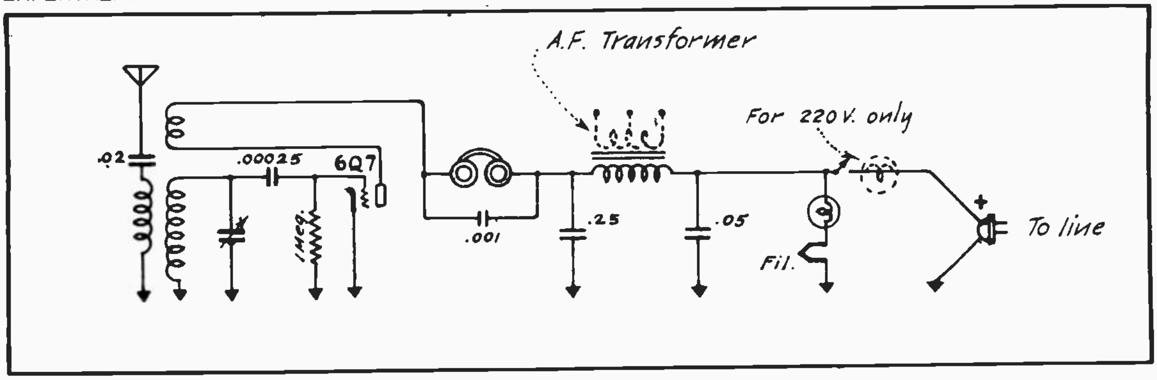

FIG. 7
D-C RECEIVER CIRCUIT

In addition to those instructions that have already been given relative to the a-c receiver, we will now furnish the necessary instruction for installing the a-f transformer which is to be used as the filter choke. This unit can be placed in any convenient location inside the chassis, care being taken that the side having only two terminals (corresponding to the primary winding) faces the tube socket.

Connect the wire marked B+ in Fig. 8 to one of the primary terminals on the a-f transformer. Connect the other primary terminal to that side of the .05 mf condenser that was originally connected to the chassis, and from the same primary terminal of the a-f transformer, run a wire to that switch terminal on the potentiometer to which also is connected one side of the lamp.

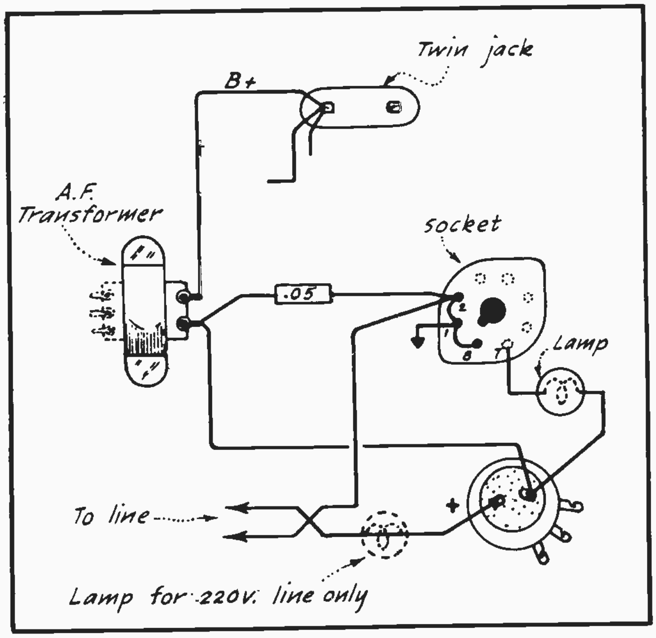

FIG. 8
CHANGES NECESSARY FOR THE D-C CIRCUIT

Proceed by connecting terminal #2 of the tube socket to terminal #1. This connects terminal #2 to ground, as terminals #1 and #8 have been connected to the chassis previously.

Connect a .02 mf bypass condenser between the antenna post and the antenna terminal of the r-f transformer (see Fig. 7). Disconnect the wire marked B- in Fig. 4, and also the external ground wire that is connected to the ground terminal of the antenna-ground post assembly. NO EXTERNAL GROUND CONNECTION IS NECESSARY for the d-c receiver, as the antenna circuit is completed through the lighting system.

Another point to bear in mind is that the line cord of any d-c receiver must always be plugged into the lighting system so that the switch and filter choke of the receiver are in series with the positive side of the line, as shown in Figs. 7 and 8.

SPECIAL INSTRUCTIONS FOR 220-VOLT CIRCUITS

When the line voltage is 220 volts, or any voltage near this value, the receiver may be connected to the line in the same manner as before, the only exception being that under these circumstances it is necessary to insert another lamp in series with the receiver and the positive side of the line, as shown in Figs. 7 and 8.

Answered November 14, 1921

EXAMINATION QUESTIONS

EXPERIMENT LESSON NO. F-4

1. - What are the advantages of using a metal chassis for a receiver?

2. - What precautions should be exercised when mounting the r-f transformer on the chassis?

3. - Why isn't an external ground wire necessary for the d-c receiver circuit described in this lesson?

4. - Is it the general practice to use the chassis as a part of the high or low potential side of the circuit?

5. - What means may be employed to assure a perfect electrical connection between the rotor plates of a variable tuning condenser gang and the metal chassis?

6. - In what order may the various circuits of a receiver be wired conveniently?

7. - What is the correct procedure for soldering a wire to the metal chassis?

8. - How does the antenna circuit of the a-c receiver described in this lesson differ from that of the d-c receiver?

9. - What is the customary method for designating on a wiring diagram that a certain circuit is connected to the metal chassis?

10. - In a d-c receiver, should the filter choke and switch be connected in the negative or positive side of the line?

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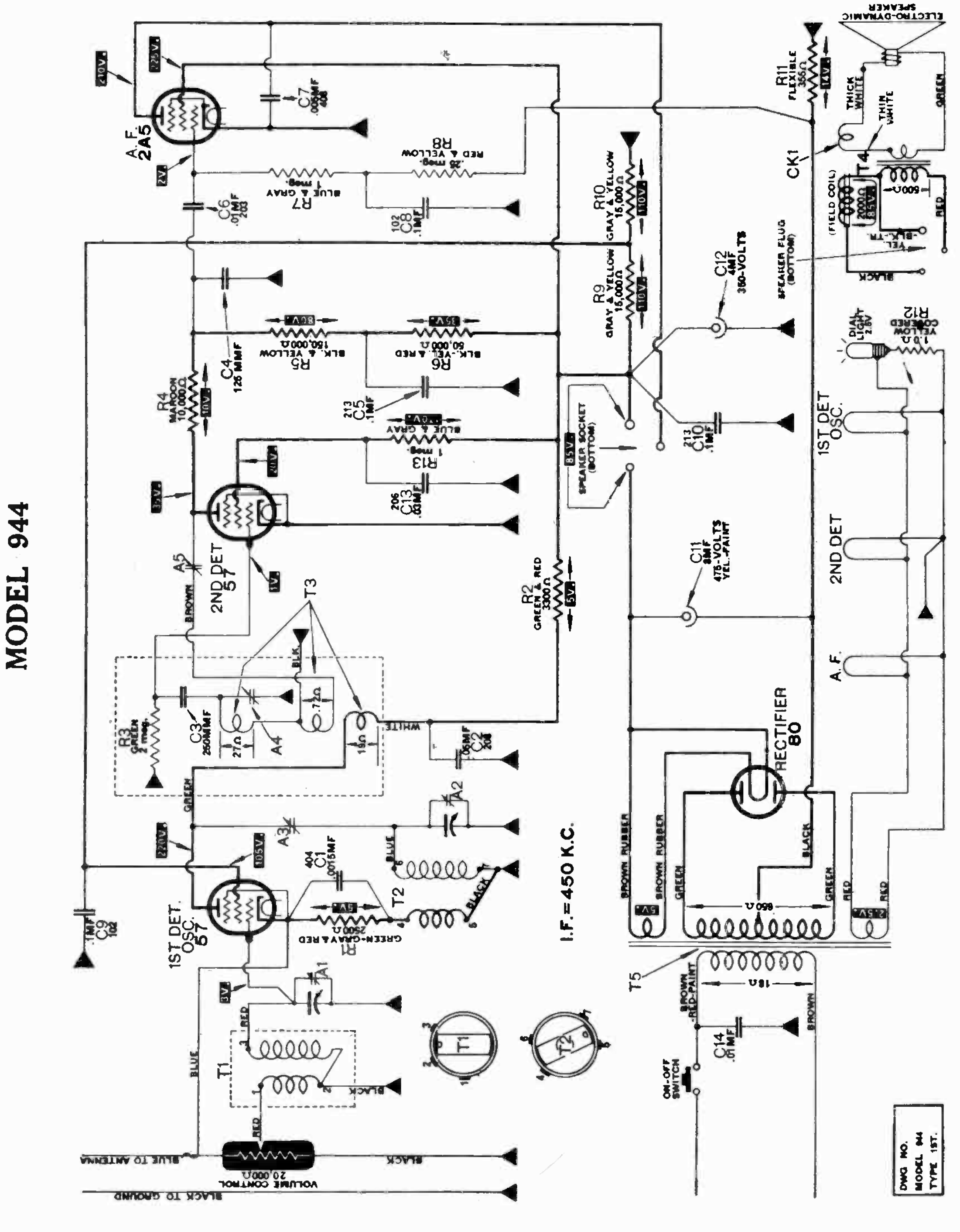
COMMERCIAL CIRCUIT DIAGRAM
ATWATER-KENT



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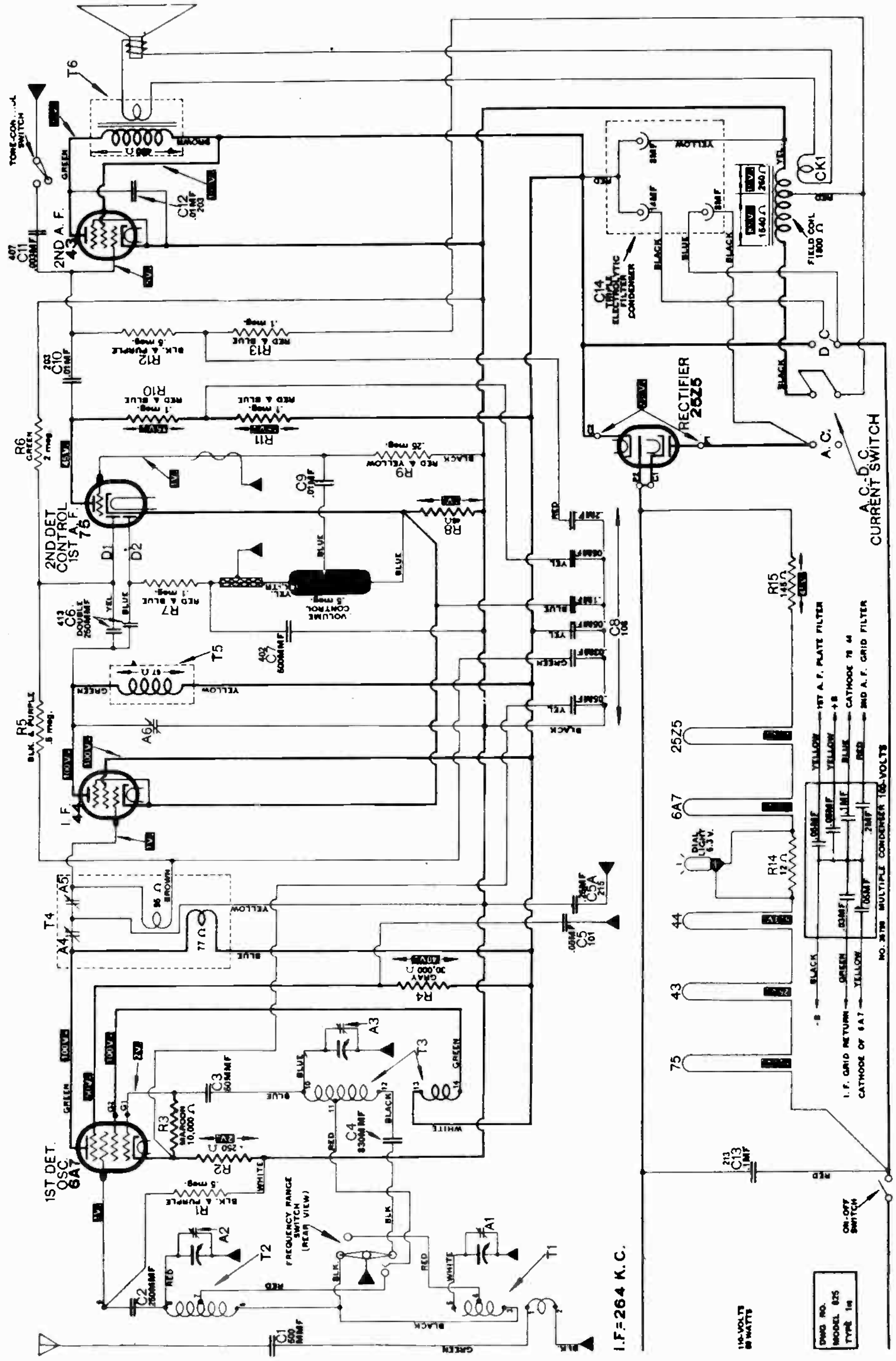
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 825 (A. C.—D. C.)



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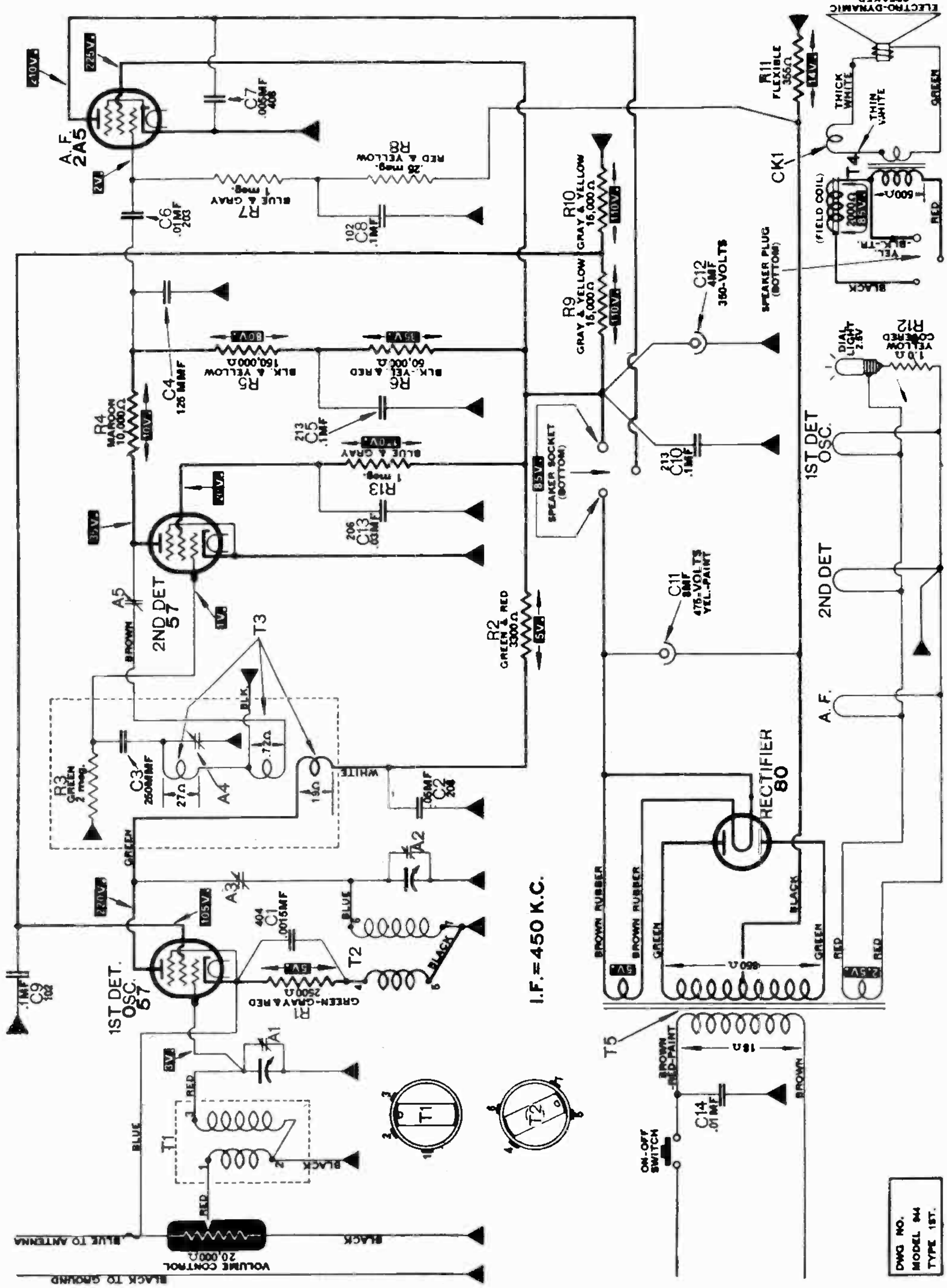
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 944



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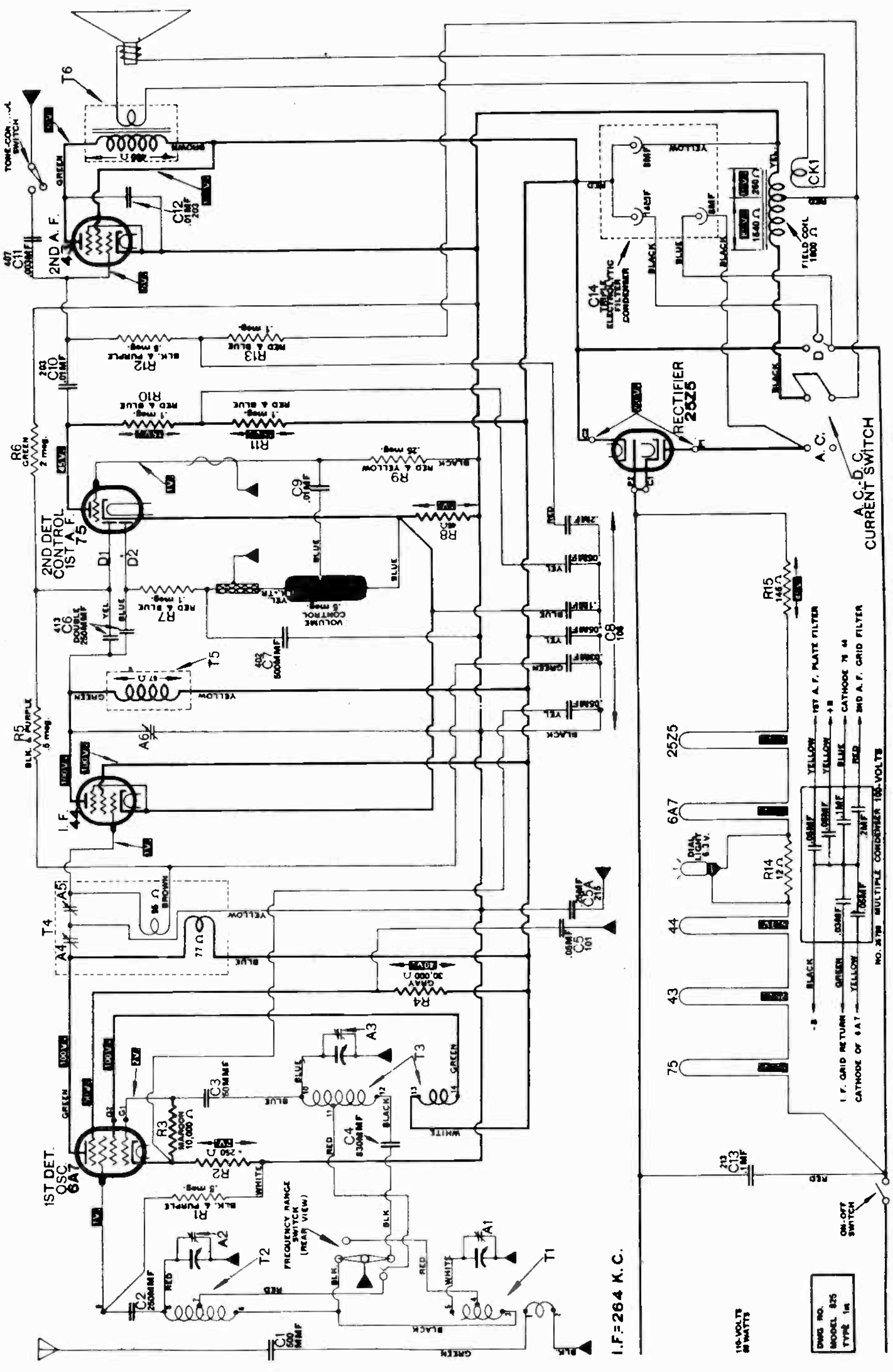
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT



MODEL 825 (A. C.–D. C.)

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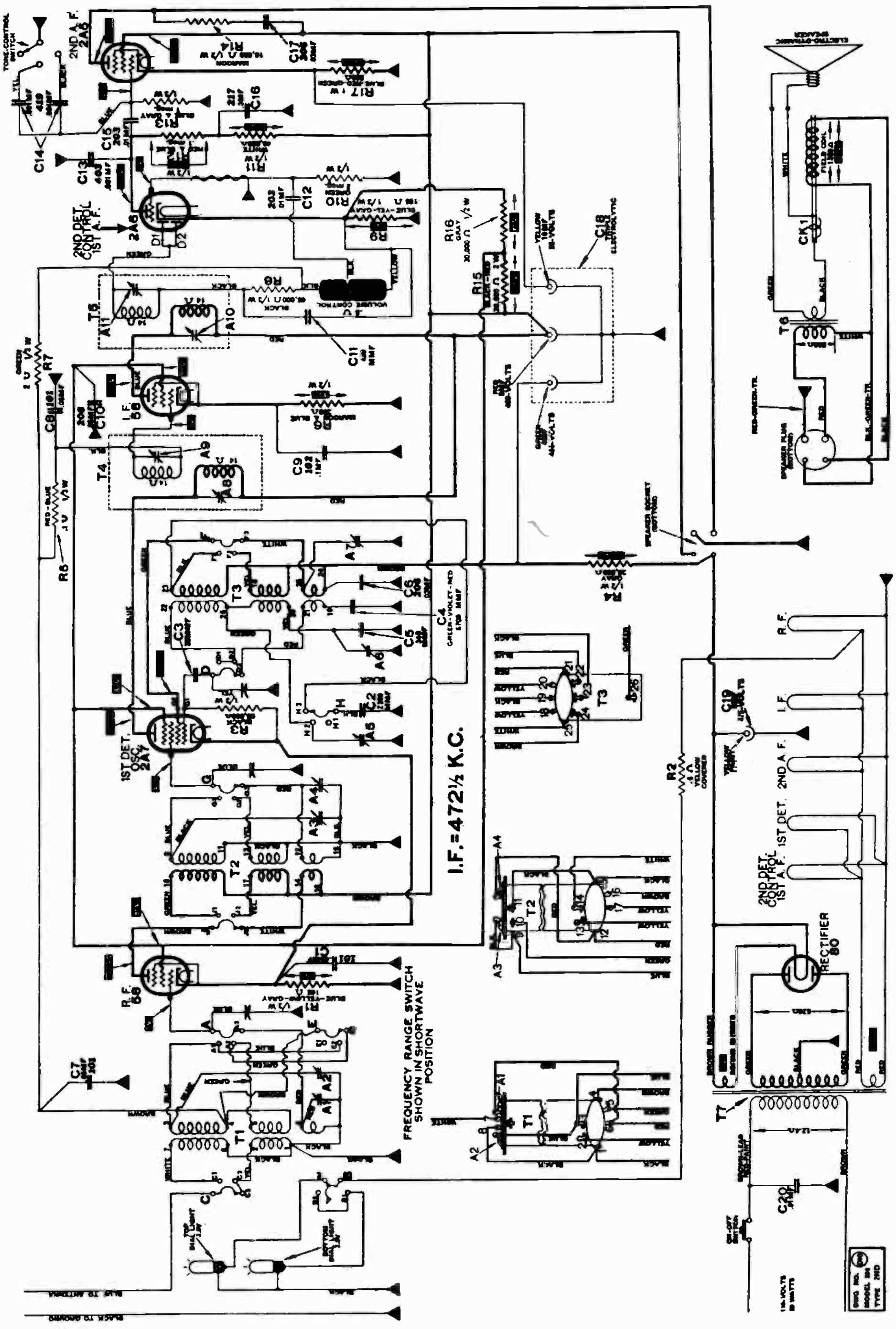
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 206 AND 376 (2nd TYPE)



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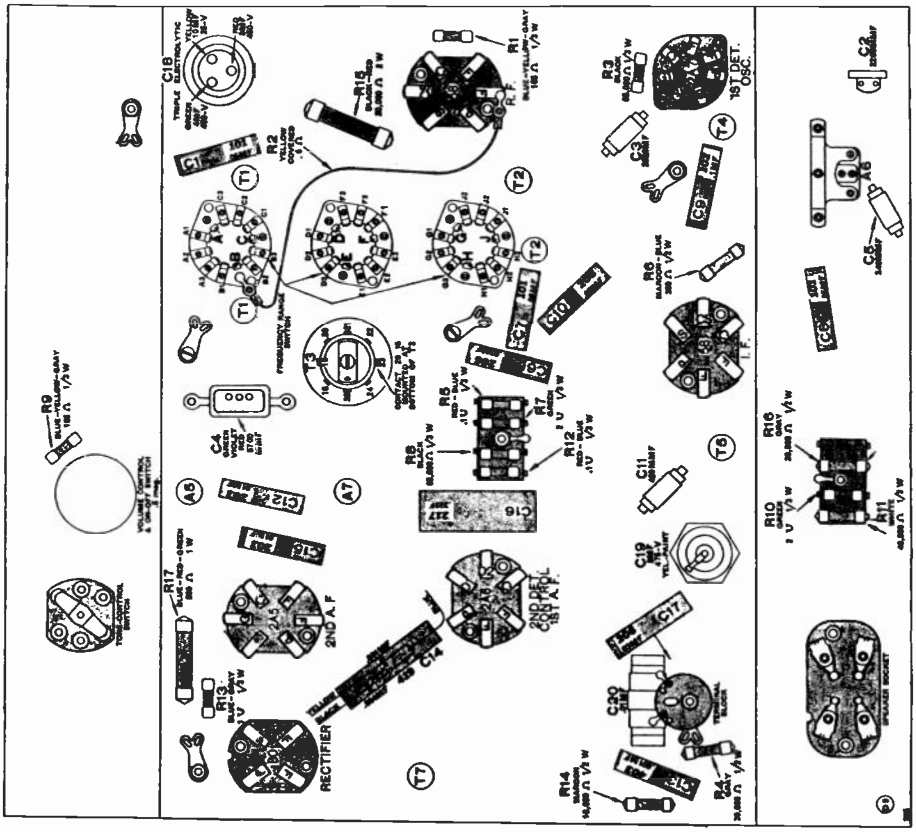
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 206 AND 376 (2nd TYPE)



ADJUSTING TRIMMERS, MODELS 206 AND 376 (2nd Type)

I. F. TRIMMERS.

Connect an I. F. test oscillator to the 1st-detector tube by means of the I. F. coupling unit shown in Fig. 1. Adjust the oscillator to 472½ KC. Use the weakest possible signal that will give a reading on the output meter with the radio volume control on full.

Peak trimmers A11, A10, A9 and A8 for maximum output. Remove the I. F. coupling unit and seal the I. F. trimmers.

DIAL POINTER ADJUSTMENT.

With the variable condenser rotor completely meshed, the dial pointer should be set at 535 KC.

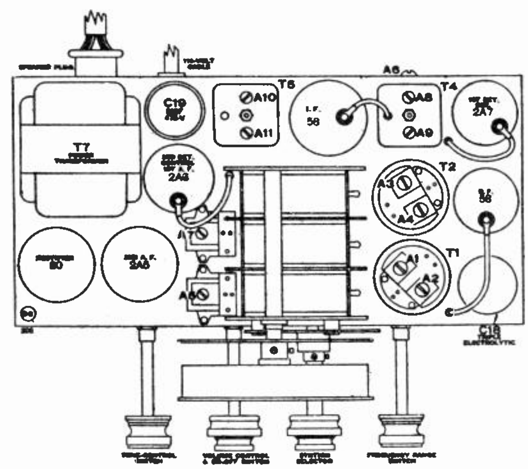
R. F. TRIMMERS.

Connect a suitable R. F. oscillator to the antenna and ground terminals of set.

Broadcast range. Oscillator at 1500 KC and dial pointer at 1500 KC mark, adjust trimmers A5, A2 and A3. Tune oscillator and set to 560. Peak A6. Repeat adjustments on A5 at 1500 KC and A6 at 560 KC if necessary.

Police range. There are no trimmer adjustments for this range.

Short-wave range. With oscillator at 15 MC and set turned to 15 MC, peak trimmers A7, A1 and A4.



R. F. TRIMMERS ON MODELS 206 AND 376.

	Short-Wave Range	Police Range	Broadcast Range
R. F.	A1	None	A2
1st-Detector	A4	None	A3
Oscillator	A7	None	A5
Tracking	None	None	A6

The I. F. trimmers are A8, A9, A10 and A11

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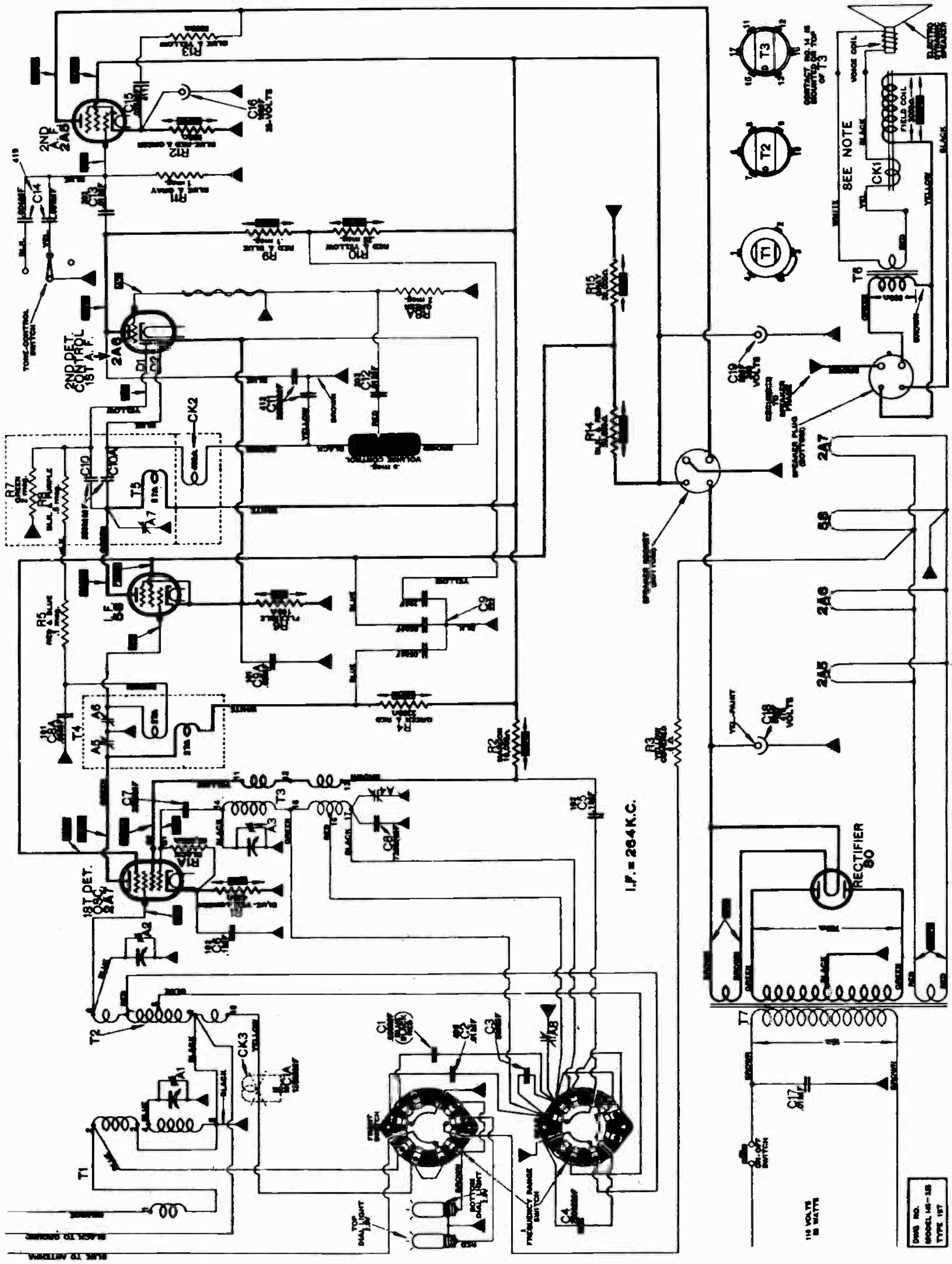
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 145 AND 325



In Model 325 the field coil is 1200 Ω and the voltages throughout are slightly higher than shown in diagram. In later sets C4 is not used, the diode circuit is changed and there are some minor changes in the frequency-switch circuit.

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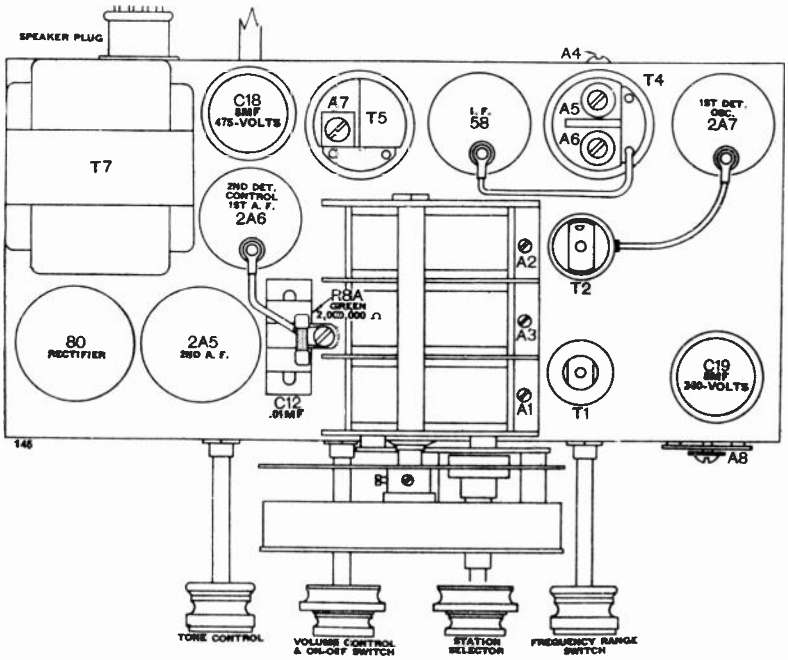
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 145 AND 325

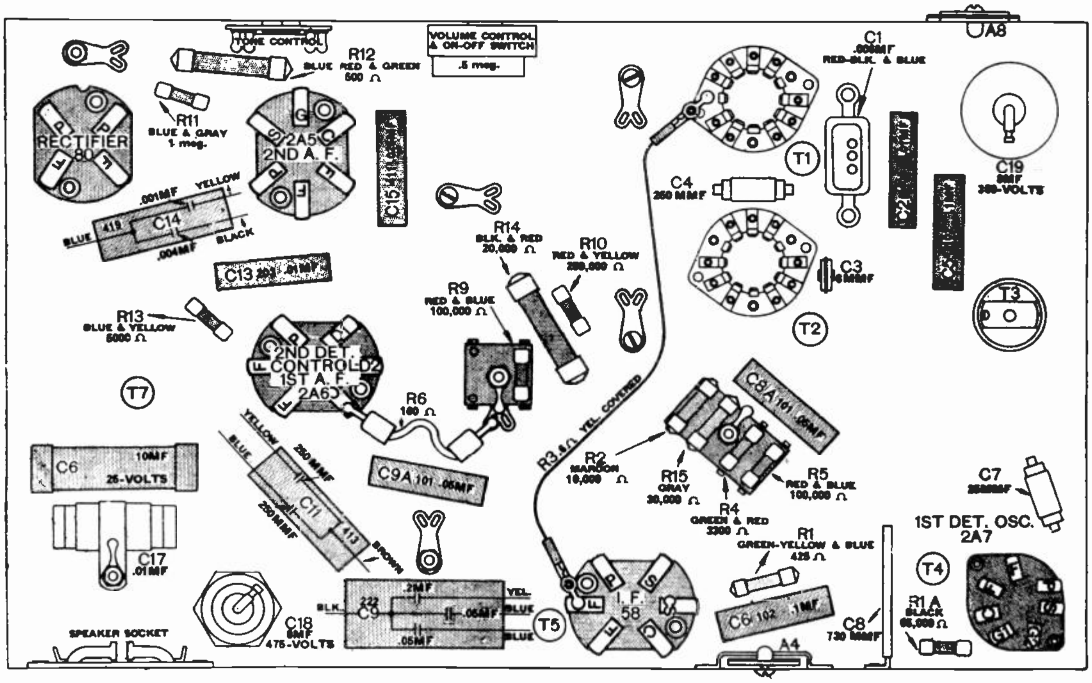
(I. F. = 264 KC.)



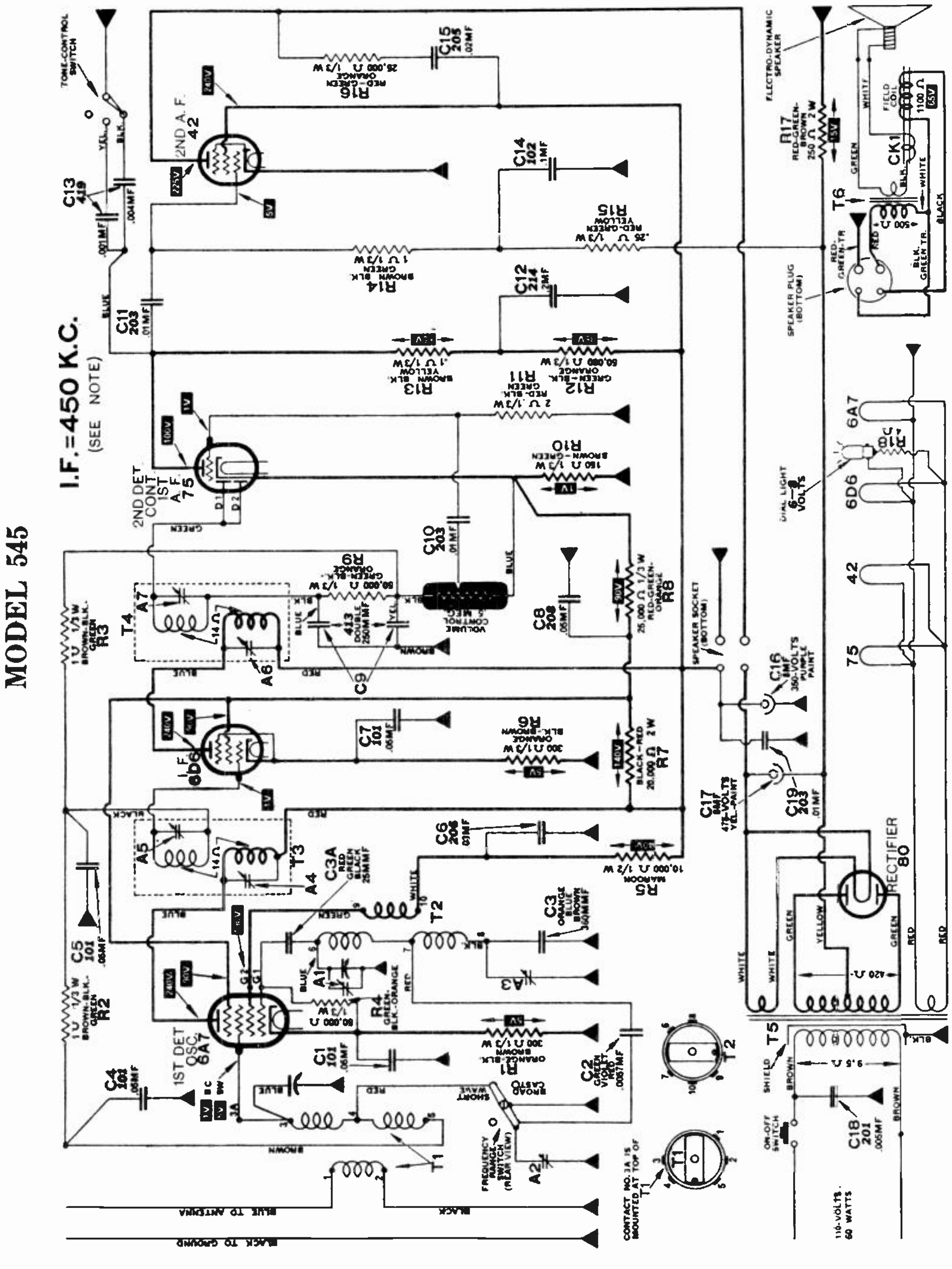
R. F. TRIMMERS ON MODELS 145 AND 325

	Short-Wave Range	Police Range	Broadcast Range
Antenna	None	None	A1
Detector	None	None	A2
Oscillator	A3	None	A8
Tracking	None	None	A4

The I. F. trimmers are A5, A6 and A7.



NATIONAL SCHOOLS Los Angeles, California	COMMERCIAL CIRCUIT DIAGRAM *ATWATER-KENT*

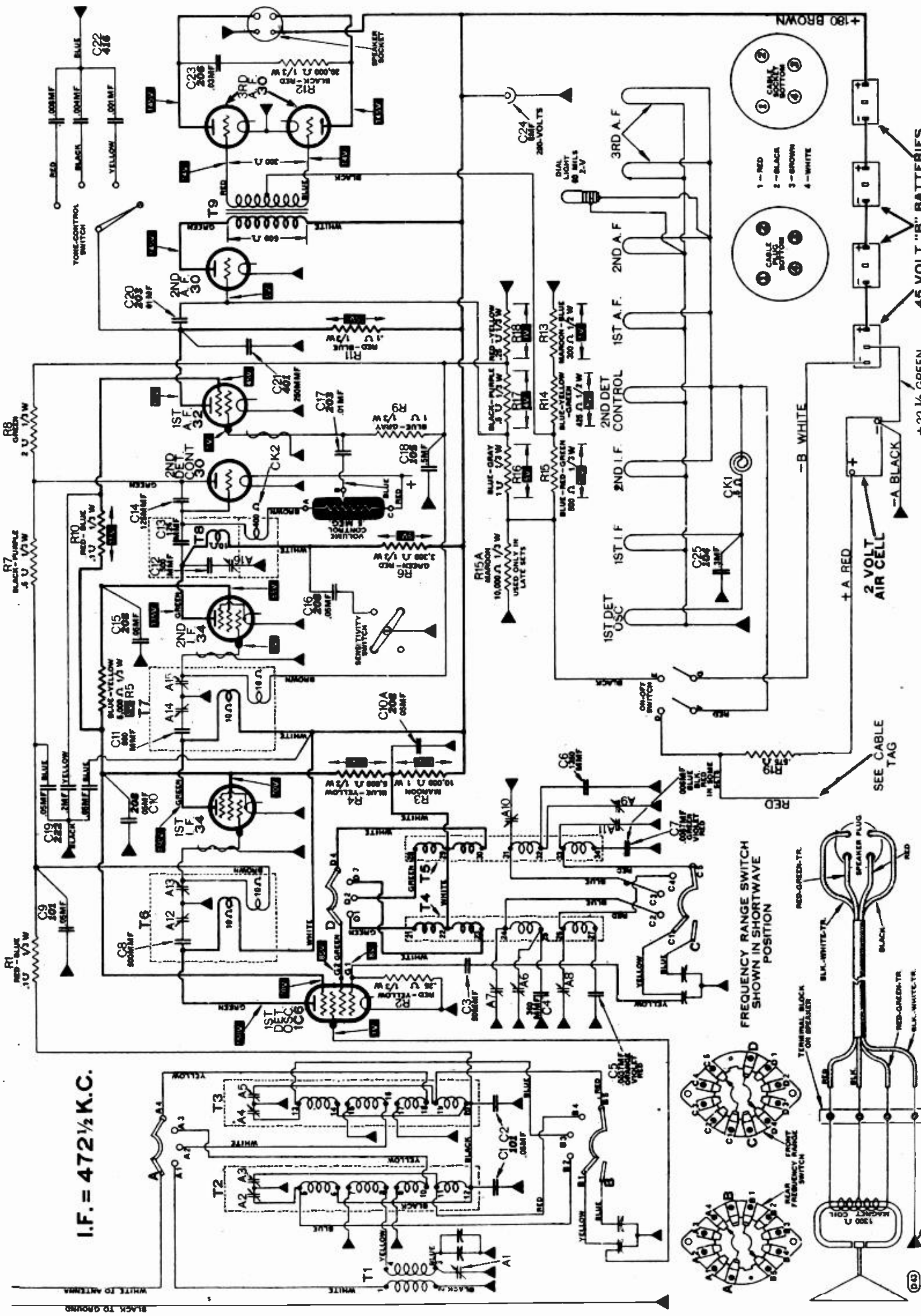


NATIONAL SCHOOLS
Los Angeles, California

COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODELS 768Q and 978Q



An extra tracking condenser (No. 25837, 1100 MMF, brown-brown-red) is connected across C5 in some models.

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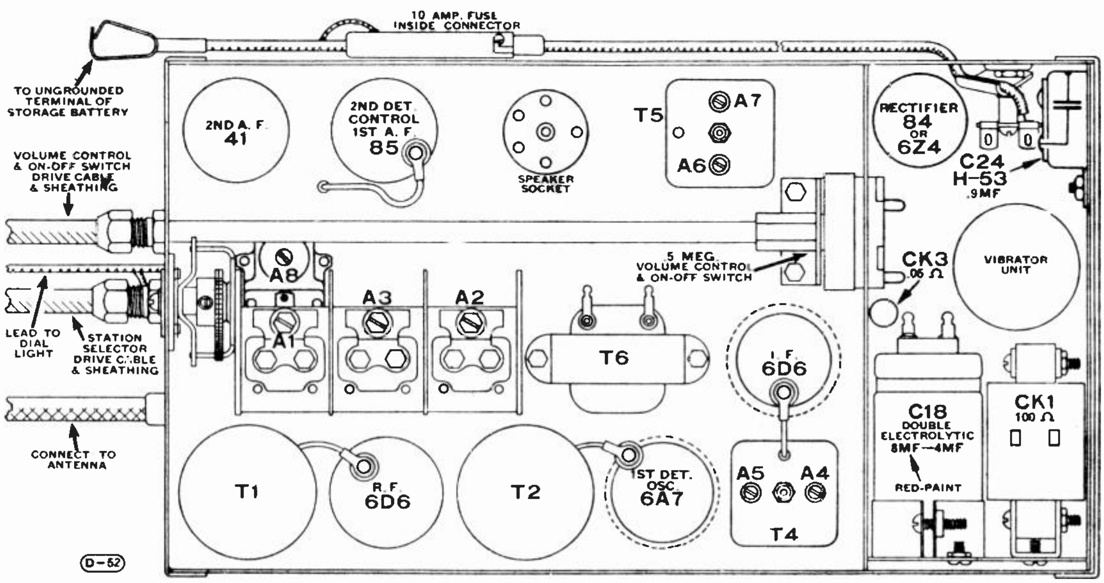
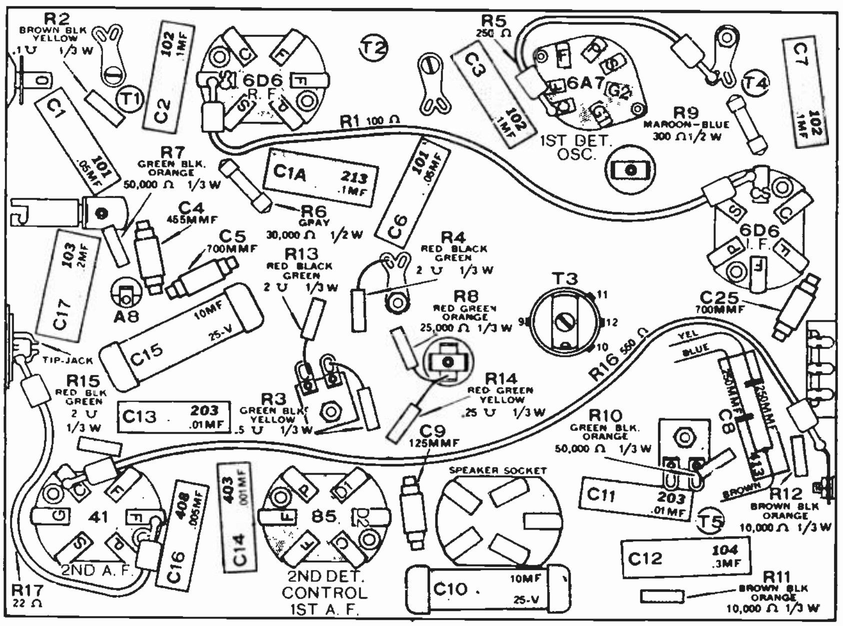
COMMERCIAL CIRCUIT DIAGRAM

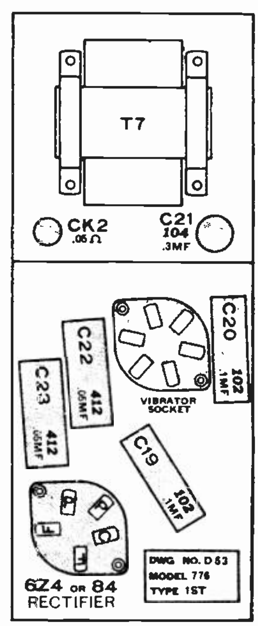
ATWATER-KENT

MODEL 776

TOP VIEW AND CHART







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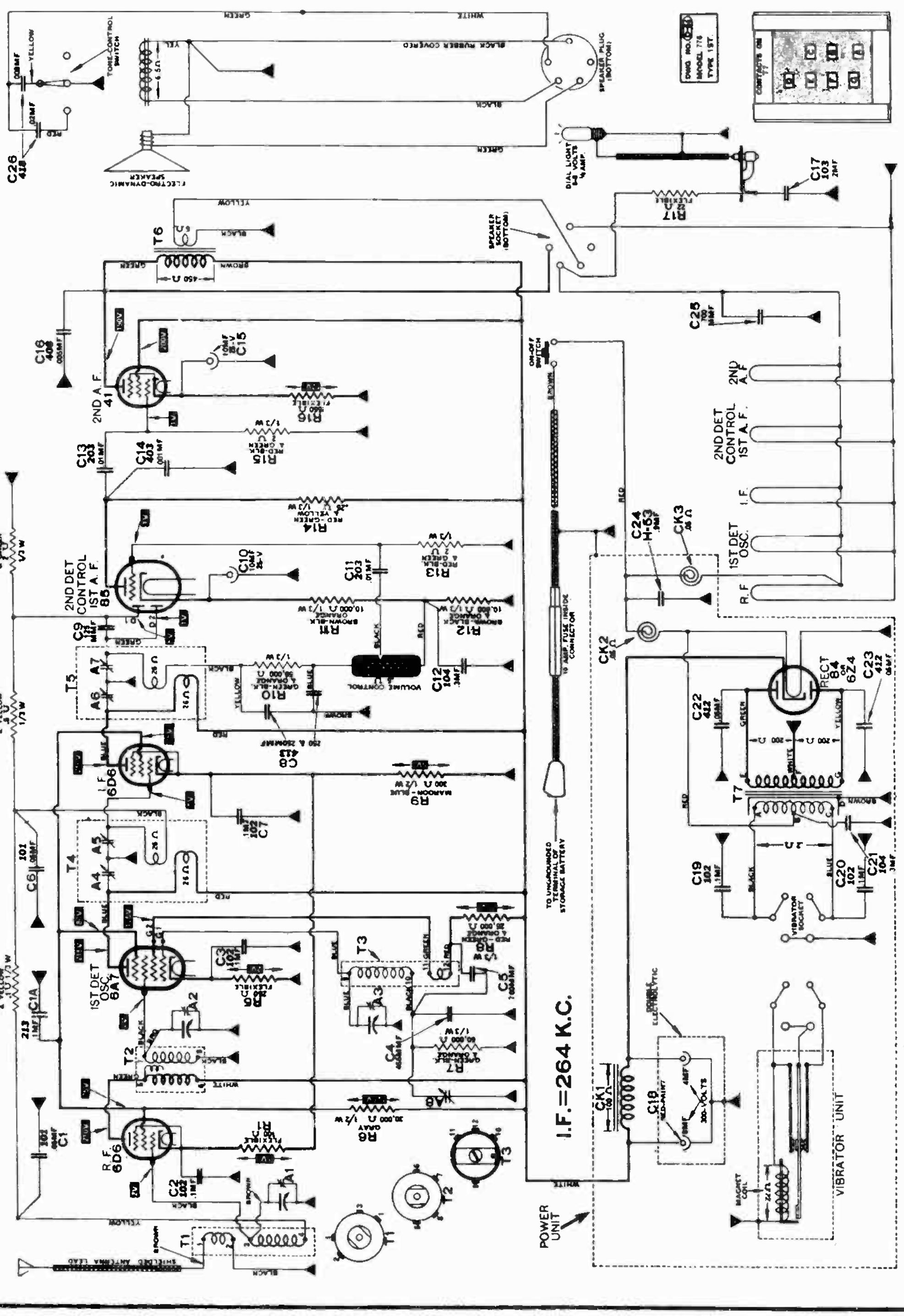
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 776 MOTOR CAR RADIO



In early sets R11 is 5,000 ohms with a drop of 4 volts and R12 is 15,000 ohms with a drop of 10 volts. In late sets these two resistors are each 10,000 ohms and there is approximately 6 volts across each. (At the same time this change was made, the 1st-A. F. plate resistor, R14 was changed from .1 meg. to .25 meg. With the .1 meg. resistor, the drop across it is 55 volts, and the plate voltage is 125. With the .25 meg. resistor, the plate voltage is lower. All voltages are measured with the 250-volt scale of a 1,000-ohm-per-volt voltmeter.)

The voltage across R11 regulates the "squelch" or minimum-signal level at which the 2nd-detector begins to function. The combined voltage across R11 and R12 acts as the bias on the AVC and the 1st-A. F. grid.

Early Model 776 sets do not have tone control, and the "A" filter circuit is slightly different from that shown. C17 in the lower right-hand part of the diagram is .2 MF

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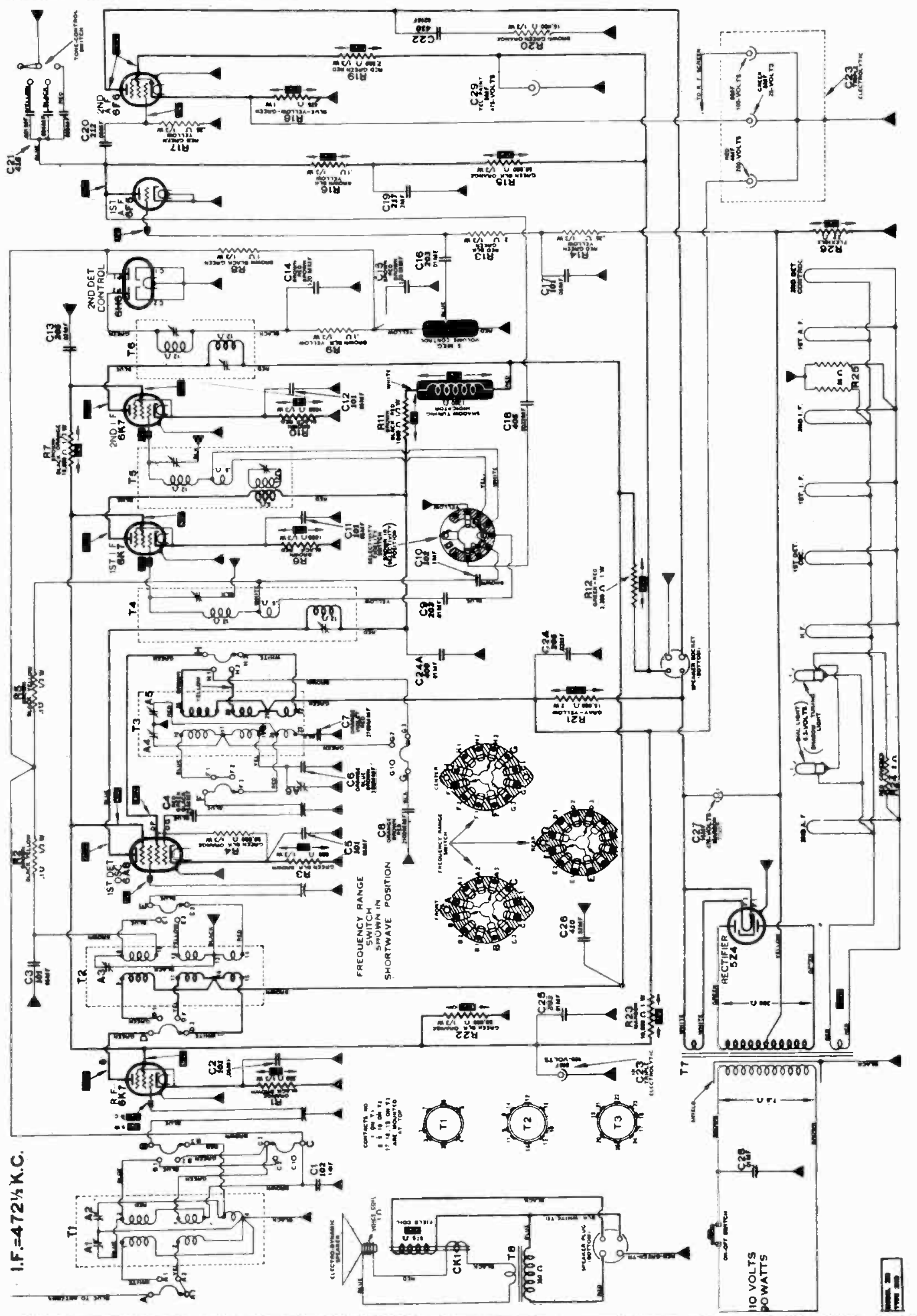
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 328, 2ND TYPE, ABOVE SERIAL No. 6438750



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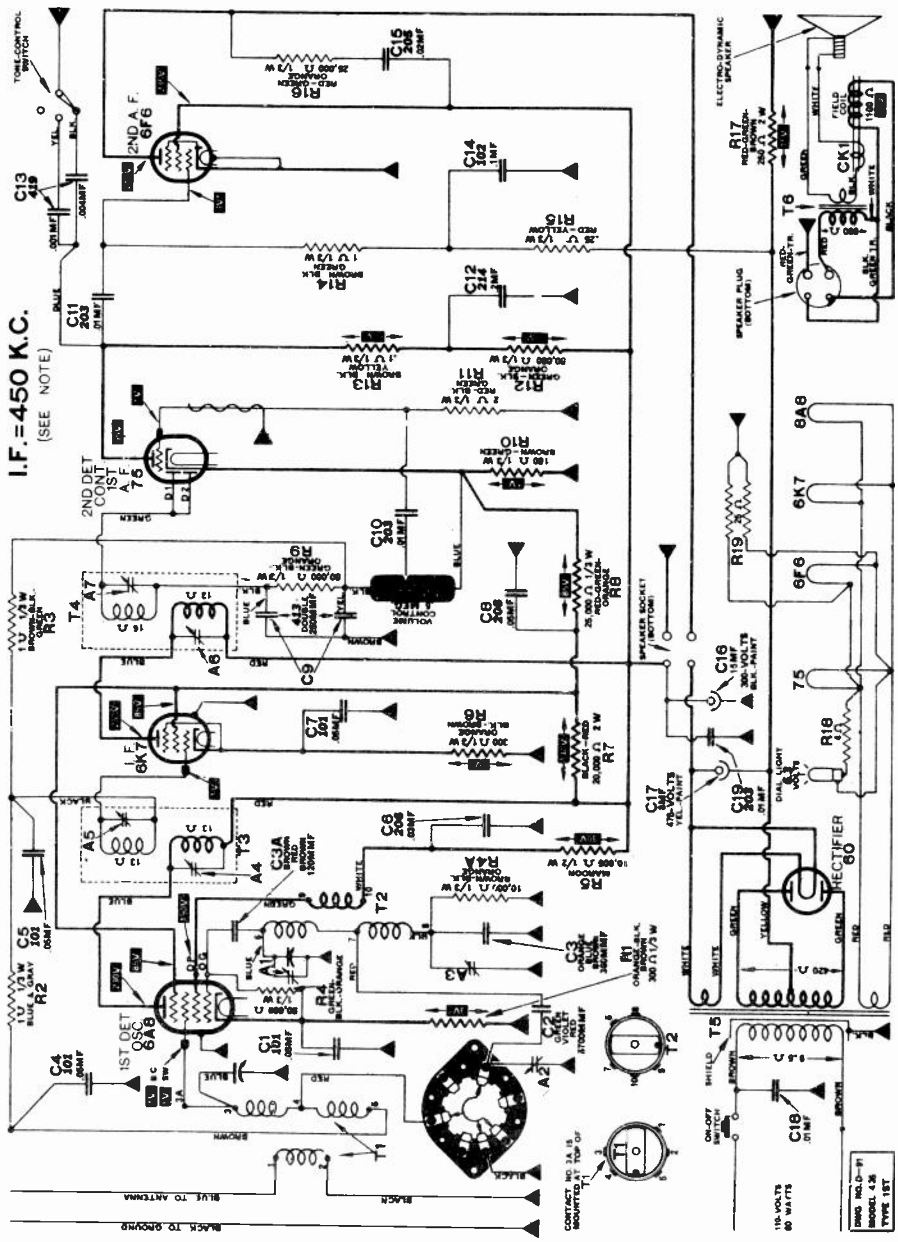
COMMERCIAL CIRCUIT DIAGRAM

ATWATER-KENT

MODEL 435 DIAGRAM (Early Type)



The frequency-range switch is shown in the short-wave position.

The I. F. in some Model 435 sets is 472½ KC and a label to this effect is attached to the rear of the chassis. The I. F. transformers and trimmers, etc., are exactly the same for either 450 or 472½ KC.