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HOW TO READ RADIO DIAGRAMS

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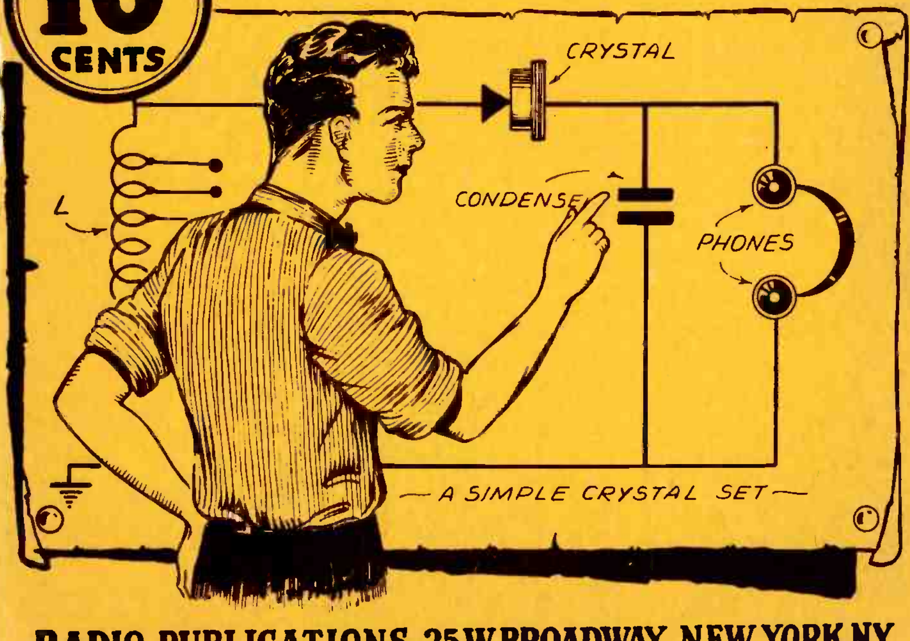
BY Robert Eichberg



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INTRODUCTION

IF you are the average beginner in radio, you prefer picture diagrams to the schematic diagrams, which use symbols. The symbols are unfamiliar to you and, therefore, bewildering. But when, after two or three hours' study, you have learned to understand the symbols, you will find schematic diagrams far simpler to read and easier to trace than the pictorial diagrams, with their confusing mazes of wiring.

Symbols are really the short-hand of radio. With a few simple lines, they can show any unit used in radio work. Not only that, but they lend themselves to better arrangement, and more clearly show the relationship between various parts. Charts of many of the most frequently employed symbols are given on the following seven pages.

In each of the charts, the name and derivation of each symbol is shown. wherever possible. For example, the curlicue which symbolises a coil can be traced to the turns of wire which comprise a coil; the Audio Frequency Transformer symbol shows two such windings in relation to a core; etc.

Numerous simple diagrams of simple radio circuits are also shown. To familiarize you with schematic (symbolic) circuits, each has below it the corresponding picture diagram. As an aid to learning to read the schematics, it is suggested that you lay a piece of paper over the picture diagram and the textual explanation which accompanies each drawing.

If you are unable to read it, refer to the picture diagram. The symbols and pictures are in precisely the same position, in so far as possible. Try to read the schematic diagram with the aid of the picture diagram.

After having familiarized yourself with the symbol chart, you should be able to take the point of your pencil and reason out what happens in the circuit. In Figure 2, for example, you should be able to say, "The antenna is connected to one side of the phones and the cat-whisker of the crystal detector. The other side of the phones and the crystal of the detector are connected to ground."

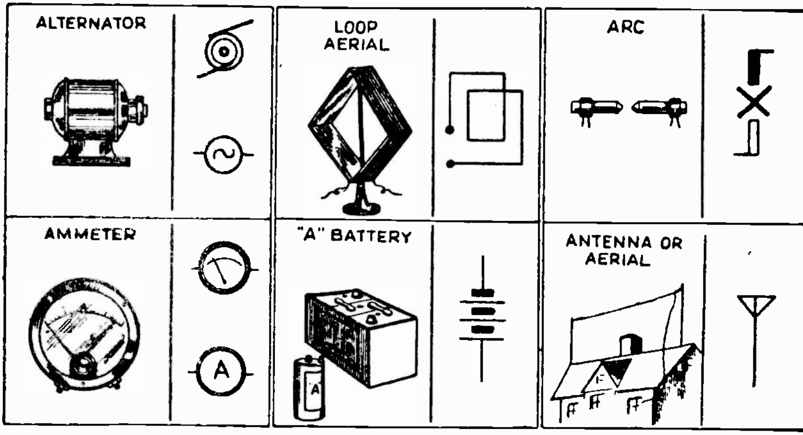
To get the most benefit from the "Explanation" pages, it is suggested that you follow a certain procedure.

First, as has been said, study the symbol charts given in the preceding pages, until you are familiar with the meaning of the most commonly used symbols.

Second, Take some sheets of paper and cover up all of a symbol page except for the symbols themselves. Try to write the name of the part each symbol represents.

Third, take some sheets of paper and cover up all of a symbol page except for the names of the units. Try to draw the symbol for each name given.

Fourth, have someone call off the names to you in no regular order. Draw the symbol for each and write the name of the unit under it. Check and practise as above.



ALTERNATOR—The upper symbol shown is based upon the brushes and slip-rings of an alternating current generator. The lower symbol, much used because it is more easily drawn, has at its center the symbol for alternating current, which indicates the type of current which the generator produces.

AMMETER—While the upper symbol is still used, the lower one is favored by most draftsmen. The letter "A" at its center shows that the instrument represented is an ammeter. Were it a milliammeter, the symbol would show an "MA"; a voltmeter, a "V"; and a millivoltmeter an "MV". Thus each unit is readily identified.

ANTENNA OR AERIAL—The single long line which projects at the bottom of this symbol represents the lead-in wire, while the other two lines which angle upward from it indicate the feeders from an old-fashioned multiwire antenna, represented by the flat line across the top. Though antennas of this sort are no longer widely used for radio reception, the symbol has persisted. It is used to indicate an antenna or aerial irrespective of design.

LOOP AERIAL—Most loop aerials were simply a piece of wire spacewound on a large rectangular frame. Therefore the symbol was a rough representation of this, showing two turns of the loop and a pair of connections.

"A" BATTERY—The symbol repsents a number of cells in series.

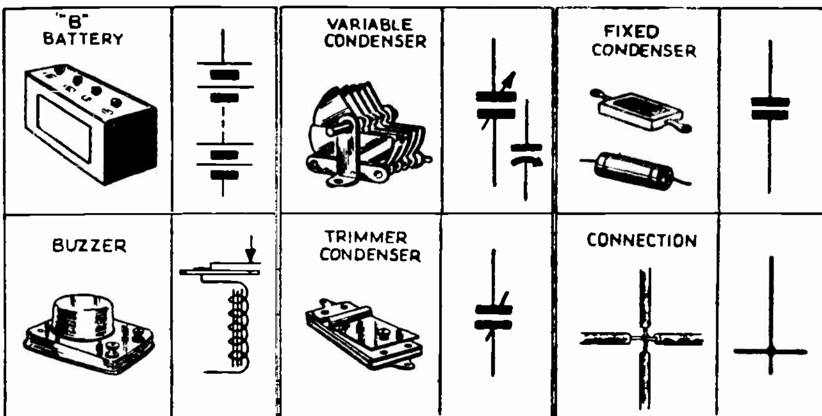
ARC—The arc, much used in the days of spark transmission, was a simple drawing of the two electrodes, with an X, indicating the arc, between them.

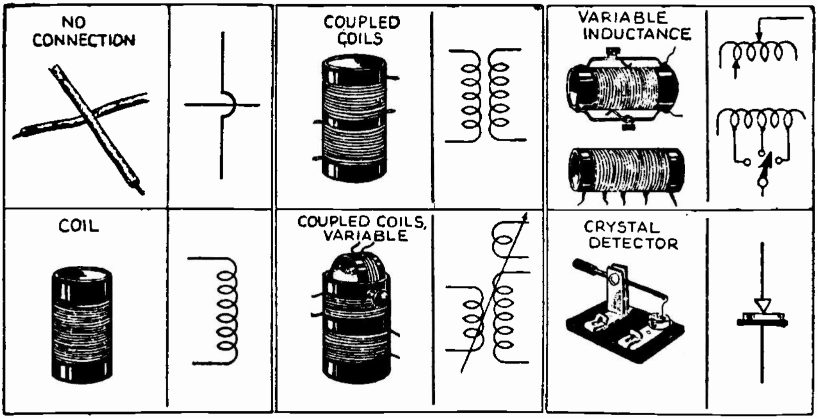
"B" BATTERY—The symbol for the "B" battery is much like that for the "A" battery, except that more cells are shown, for the "A" usually consists of from 1 to 3 cells in series, while the "B" may have from 15 cells (for a 22½-volt battery) to 120 cells (for a 180-volt battery). Each pair of lines means one cell. Not all of these cells are drawn, however, the voltage being indicated by figures.

BUZZER—As a buzzer consists of a winding around an iron core which attracts an arm used to complete the circuit, the symbol shows this arrangement clearly. The parallel lines are the core; the arm makes contact at the little arrow head.

FIXED CONDENSER—No matter whether it is flat, tubular or of any other shape, a fixed condenser consists, essentially, of two metallic plates, with a dielectric (non-conductor) between them. Therefore the symbol shows connections to two plates, with a space between them, to indicate that there is no connection between the plates. The capacity of the condenser is shown by figures.

VARIABLE CONDENSER — Irrespective of its size or shape, a variable condenser consists of two or more metal plates with a dielectric (generally air) between them. The symbol may be much like that for the fixed condenser, with a diagonal arrow added to show variability or, as in the lower symbol, one of the lines may be curved and provided with an arrow head, to show that it is a rotary plate or group of plates.





TRIMMER CONDENSER—A trimmer condenser is variable, but not as widely nor as easily as a standard variable condenser, for its shaft is slotted for a screwdriver instead of being provided with a knob. The decrease in variability is indicated by omitting the head of the arrow.

CONNECTION—When two wires are brought together and a drop of solder applied, the connection looks much as it appears in the symbol.

NO CONNECTION—Sometimes, in drawing a diagram, it is necessary to cross lines over each other. To make it clear that there is no connection between the wires these lines represent, one of them is curved where it crosses the other, to indicate that there is space or insulation between them.

COIL—A coil consists of a number of turns of wire, and the symbol for a coil is therefore nothing more than a line with a number of loops in it, to represent the turns. The inductance of the coil is given in figures; the same symbol is used to indicate a radio-frequency choke coil.

VARIABLE INDUCTANCE—Some coils may have any predetermined number of their coils connected into or out of the circuit at will. This can be done by means of one or more sliders, as shown above, or by means of a number of connections made between various turns and a number of switch taps. A movable metal arm allows the circuit to be made to the desired tap. This is shown in the lower part of the illustration.

COUPLED COILS—Sometimes, as in radio-frequency transformers, it is desired to have two coils so arranged that there is inductive coupling (a form of magnetic linkage without direct connection) between them. When this is done, the coils are placed closely together, as the symbol shows.

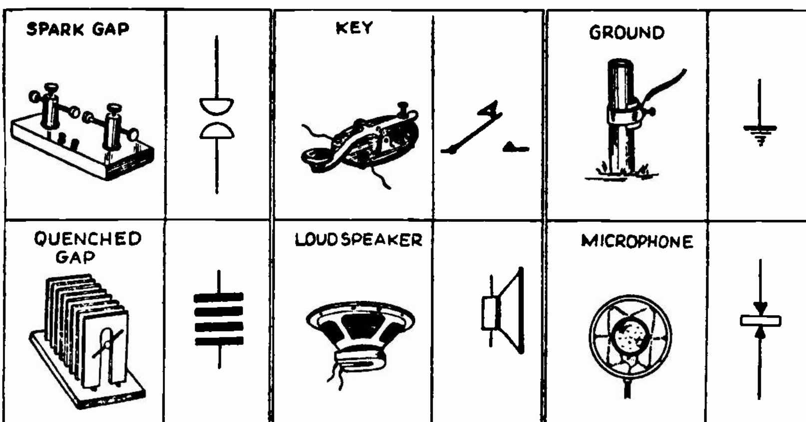
COUPLED COILS, VARIABLE—When the coupling between two coils, the variability is indicated sliding or rotating one of the coils, the variability is indicated by the arrow run diagonally across the symbol, as shown.

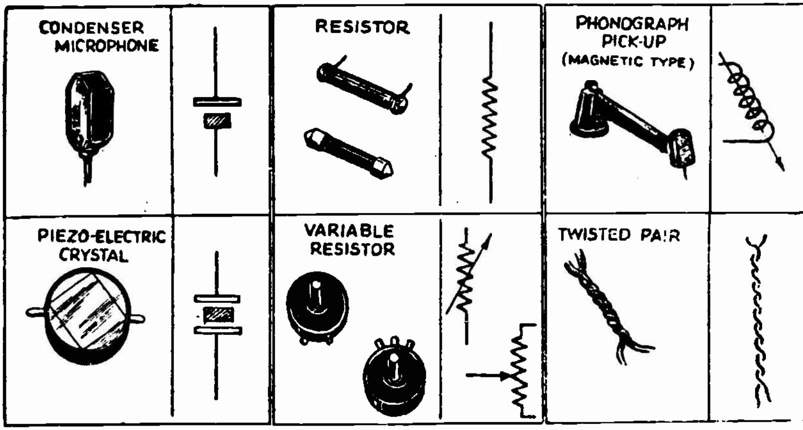
CRYSTAL DETECTOR—This unit generally consists of a mineral crystal used in conjunction with a fine wire "cat's whisker" which is moved about its surface until a sensitive spot is found. The heavy line in the symbol indicates the crystal; the arrow head, the cat's whisker. Even if the cat's whisker is fixed, the symbol remains the same.

SPARK GAP—Once widely used in radio, this is now seldom if ever employed. The symbol merely represents the two electrodes of the gap.

QUENCHED GAP—Like the above, this has virtually faded from the radio picture. It had large plates to cool the gap, and these are indicated in the symbol. It is much like the battery symbol, except that the lines are all of the same thickness.

GROUND — In normal receiving practice, the ground connection may be a water pipe, the frame of a building, a radiator, a pipe driven into moist soil, or anything which makes good contact with moist earth—as do all of the units mentioned. So the symbol is highly simplified. It is merely a little cross-section of a piece of ground, showing a few layers of soil. It is always given the triangular form to make it readily recognizable.





KEY—A key is an easily operated switch, normally in the open position. And that is precisely what the symbol shows.

LOUD SPEAKER—If of the magnetic type, it may be represented simply by a horn, as shown in the schematic illustration. In representing a dynamic speaker, the symbol shows the big field winding, the metal core (parallel lines), and the small voice coil which is attached to the paper cone.

MICROPHONE—The double-button carbon microphone is symbolized by two short, thick points to indicate the carbon buttons, with a long, thin line, representing the diaphragm, between them. For other microphones, see **Transmitter.**

CONDENSER MICROPHONE—A condenser with a thin and a thick plate (much like a battery) may be used to indicate a condenser microphone. Its position in the circuit helps show what it is.

PHONOGRAPH PICK-UP — The magnetic pick-up consists of a coil of wire surrounding an armature to which the needle is attached, as the upper symbol shows. The crystal pick-up has the needle attached to a piezo-electric crystal which is clamped between two contact plates. In each, the arrow head indicates the needle.

PIEZO-ELECTRIC CRYSTAL — Different from the detector crystal, this one generates electricity when subjected to strains. As the symbol indicates, it is clamped between two metal plates. The same symbol sometimes is used for a crystal microphone.

RESISTOR—You can readily understand that, as every conductor offers a certain amount of resistance to the passage of electric current, a longer wire (of the same size and material) offers more resistance than a shorter wire. Therefore the symbol for resistance is the jagged line, which is longer than a straight line would be in reaching from one point to another. The same symbol is used irrespective of the material or design of the resistor, and its resistance is shown in figures.

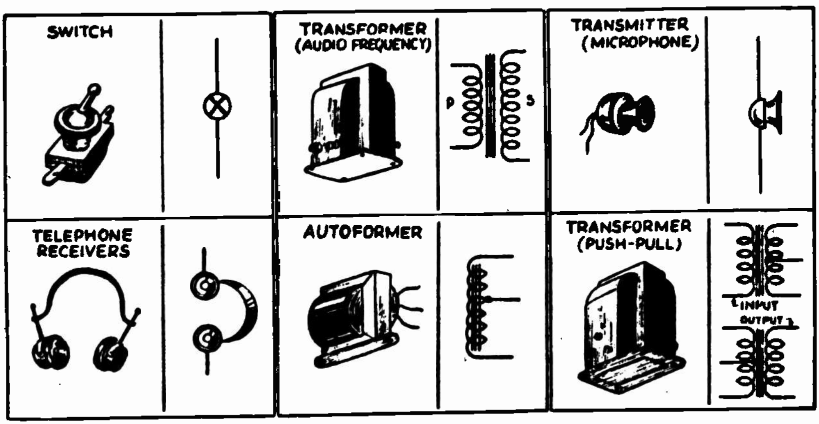
RESISTOR (VARIABLE) — One means of showing that a resistor is variable is by putting an arrow diagonally across it, as shown. But sometimes the resistor is of a particular type. It may be connected at both ends, with a movable contact on the resistance element. This is shown at the lower portion of the illustration. At times this same symbol, with one of the ends unconnected, is used instead of the other symbol, to show an ordinary variable resistor —particularly when the circuit can be opened entirely by moving the arm from the element.

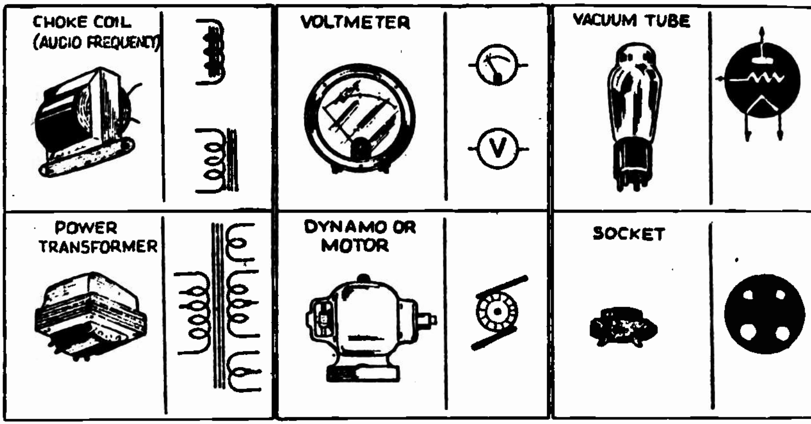
TWISTED PAIR—Twisted wires, often used for lead-ins and for heater connections, are shown merely by a pair of intertwined lines, as in the illustration on the preceding page.

SWITCH—A convenient means of opening or closing a circuit.

TELEPHONE RECEIVERS—This symbol is merely a simplified drawing of a pair of head-phones (the two small circles). The curved line which joins them represents both the head-band and the connection between the phones.

TRANSMITTER (MICROPHONE) This is the diagram most usually used to indicate any type of transmitter or microphone except the double-button carbon type. Let-





tering generally shows whether it indicates a crystal, single-button carbon, dynamic, velocity or capacity microphone. Circuit connections may also indicate this.

TRANSFORMER (AUDIO FREQUENCY)—An audio frequency transformer consists of two coils of wire wound on the same iron core, and this is readily followed in the symbol. There are the two coils, with the parallel lines between them, to represent the core. The primary is distinguished from the secondary by being drawn with fewer turns in many diagrams; in others, the primary is marked "P" and the secondary, "S". Occasionally no special means of distinguishing is used, in which case the primary is the winding connected to the plate circuit of one tube, the secondary being connected to the grid circuit of another.

AUTOFORMER—This is simply a transformer with a single winding, tapped so that one part of it may be used as the primary, the other part as the secondary. The symbol shows this clearly.

TRANSFORMER (POWER) — A transformer designed to handle high voltage and considerable current. Used to step up line voltage in power packs. May have additional step-down windings for filaments of tubes.

TRANSFORMER (PUSH-PULL)—In some circuits, the plate of one tube is used to feed the grids of two tubes connected in "push-pull", and a special type of transformer, with a center-tapped secondary, is used. This push-pull input transformer is shown at the top of the illustration. If the plates of these tubes are to be connected to a loud speaker, a push-pull output transformer,

(Continued on Page 28)

EXPLANATION

You know the symbol for the aerial. Here it is, in Figure 1, connected right to one side of a crystal which "detects" the signals the aerial picks up.

In order to hear these signals, you need a pair of phones, so the other side of the crystal is connected to this unit.

Both sides of the phones must be connected, for best results, so the other side of the phones is connected to ground.

That is really all there is to reading diagrams—you simply have to figure out what has to be done and connect up the units to do it.

Every circuit must be complete; there must NEVER be any "loose ends" in radio.

One of the most important of all circuits is the antenna (or aerial) circuit. This consists of the aerial wire and the ground, and any units connected between them.

Later, in other books, you will learn of circuits which operate without any **apparent** ground connection, but the ground is always there. For example, in electric sets, it may be one side of the electric lighting lines.

Antennas may be anywhere from 25 to 100 feet long; generally speaking, the longer the antenna, the more numerous and stronger the signals you will pick up, you will have more trouble separating one station from another, and you will get more interference and static noises, on the broadcast band.

The phones should be 2,000 ohms or upward; 75 ohm phones, such as are used on telephones, will **not** do.

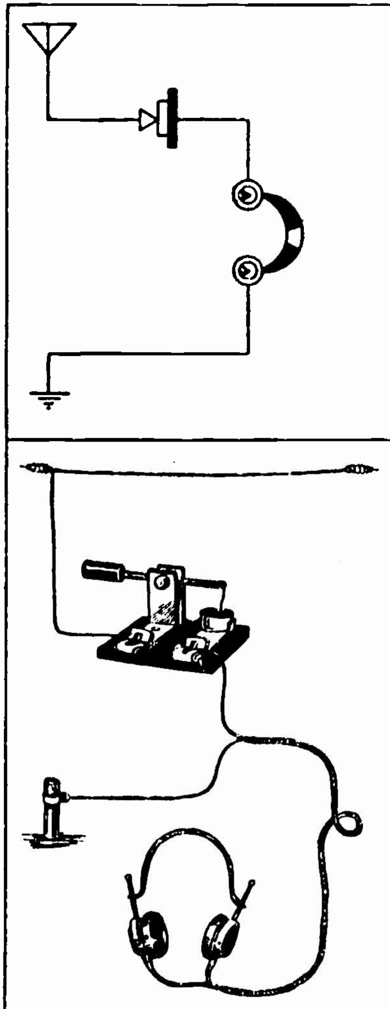


Fig. 1

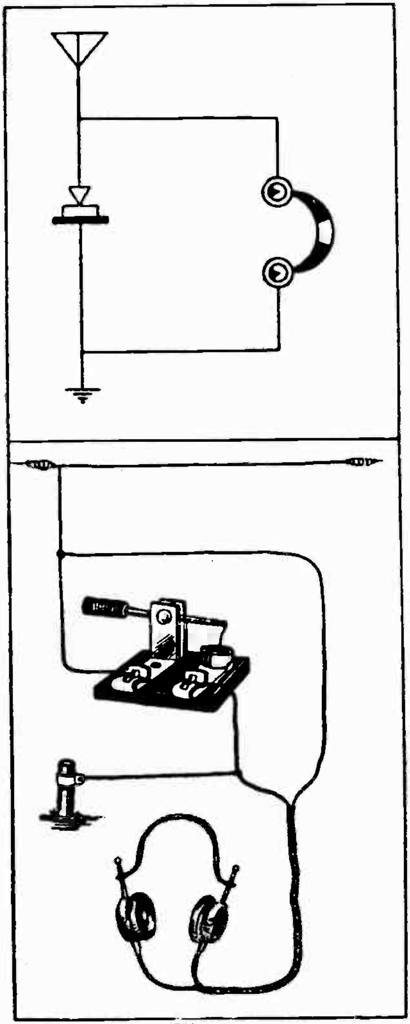


Fig. 2

EXPLANATION

Is the diagram in Figure 2 the same as the preceding one?

True, it has the same parts, but if you inspect it closely, you will see that they are connected differently. It is NOT the same.

In the preceding diagram, the crystal detector and the headphones were **in series**. In the diagram on this page, the crystal detector and head-phones are **in parallel.**

Trace the circuit. The antenna connects to one side of both the crystal and the phones. The other side of the crystal and the phones connect to the ground.

This makes entirely different action take place in the circuit.

To understand this, you must know that a radio wave is alternating current, shaped or "modulated" by a lower ("audio") frequency. In order to work the phones, this radio wave must be rectified or changed into direct current. The detector, whether it is a crystal or a tube, does this.

The crystal offers great resistance to one-half of the radio wave, but passes the other half freely. That is known as "detector action."

In the preceding circuit, half of the wave is retarded, and the other half passes through the crystal and the phones. That is what always happens in **series** circuits of any type — the same current passes through all the units which are connected in series.

In the circuit on this page, the half of the wave that passes through the crystal goes directly to ground; nearly all of the half that is retarded passes through the phones.

EXPLANATION

What have we in Figure 3? A new element — a fixed condenser — added to the circuit of Figure 1.

No device made by man is perfect. Therefore, some of the radio frequency current gets by the detector. The phones offer a great deal of opposition to the passage of radio frequency currents, and this makes the circuit work less perfectly than we would wish.

But currents of this sort, though they do not pass freely through coils of many turns of fine wire (such as the windings of a phone or a pair of phones) do pass very easily through condensers.

For this reason the condenser has been added. It affords a free path for the radio frequency currents and, equally important, it keeps them from passing through the phones.

They would not injure the phones in any way, but they would make reception weaker, for one-half of the alternating current radio wave would tend to cancel out the other half. It would not cancel it completely, because the half that leaked through the detector would be much weaker than the half that passed easily through the detector, but it would make reception poorer. The condenser takes care of it.

You will see that the condenser is marked ".001 mfd." That is the measure of its capacity — what laymen call "its size." Sometimes a condenser of greater or lesser capacity will work better, depending upon the phones and crystal used. Experiment — trying one condenser after another — will show which works best.

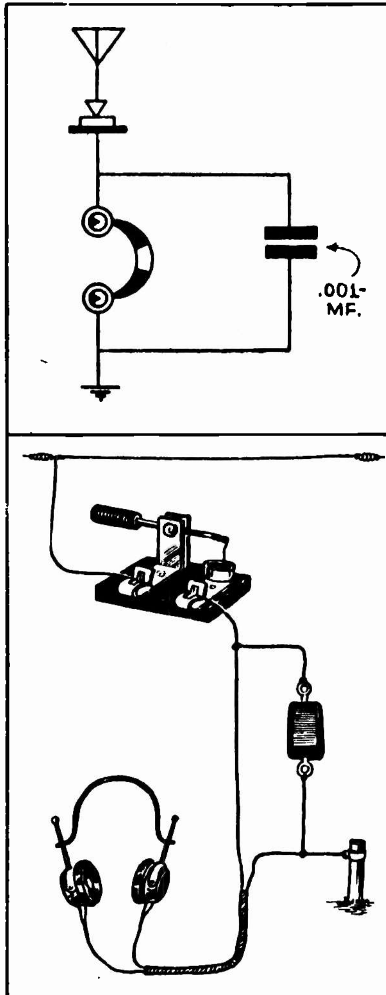


Fig. 3

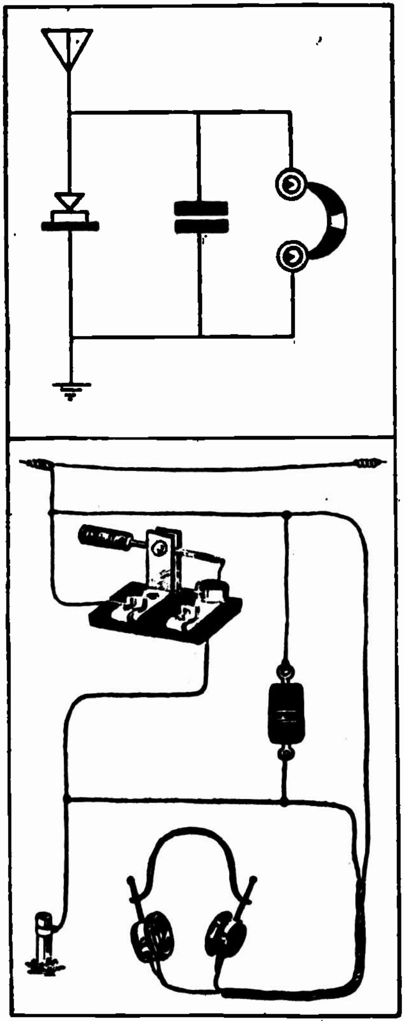


Fig. 4

EXPLANATION

The diagram, Figure 4, is wrong. A mistake has been put into it deliberately. Do you see what it is?

True, it is the circuit of Figure 2, with a condenser added as in Figure 3, but there is something different.

The condenser is across the crystal as well as across the phones. Remember what you read about parallel circuits when studying the explanation of Figure 2.

In this circuit, the radio frequency currents would not only be bypassed around the phone, but around the crystal as well, at least in part. For that reason the crystal could not function as perfectly as though the condenser were not there, though one station might be heard.

TUNED CIRCUITS

All of the circuits given thus far have been untuned circuits. That is, they will pick up any signals which reach their antennas, but will be efficient only on a wave which happens to be of approximately the same length as the antenna. If two radio waves are being received at the same time, the circuits given cannot be adjusted to cut one signal out so that the other can be heard in comfort.

A tuned circuit is needed to adjust the receiving circuit to resonance with the various stations' waves. This is done most simply by adding a coil of wire in series with the aerial; the more turns of wire that are added, other things being equal, the longer the wave-lengths which will be received.

EXPLANATION

Do you recognize this circuit in Figure 5?

Just as Figure 3 was developed from Figure 1, so the circuit on this page is developed from Figure 3. It is the same as Figure 3 except that an extra unit has been added.

This new unit is a single-slide tuner, connected between the antenna and the crystal. It could have been connected between the phones and the ground instead, but the results are usually (although not always) better when it is connected as shown.

A single-slide tuner is simply a coil of wire with a slider arranged to be movable along it, to make contact with any of the turns of the coil. By moving the slider, more or fewer of the turns can be connected in the circuit, at will.

When making a tuner that employs sliders, it is easiest to use an insulated wire. Enameled wire is perfectly satisfactory and costs less than cotton covered or silk covered. When the coil is made, the insulation must be scraped off the wire where the slider touches it. This can be done easily with a piece of sandpaper held over the end of a finger and rubbed back and forth along the coil, following the path the slider will take.

The coil can be wound on an empty oatmeal box. Put on about 150 turns of No. 22 wire. Wind the turns close together if you use an insulated wire; if you use a wire that is not insulated, you will have to leave a tiny space between each turn so that the wire does not short circuit. This is hard to do neatly.

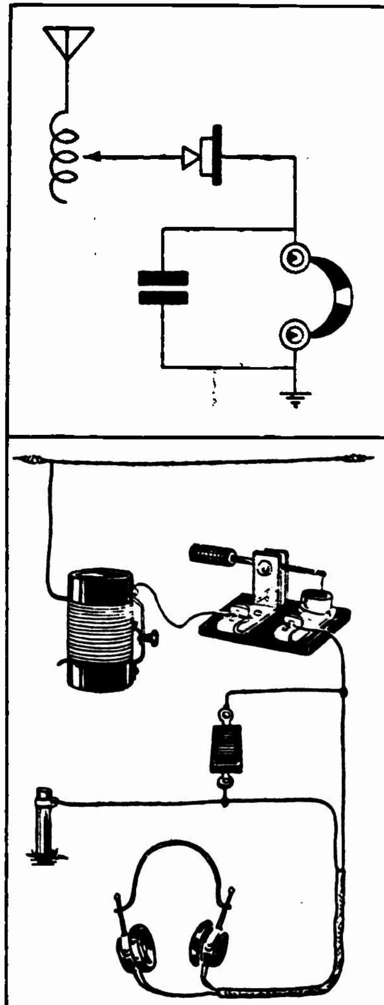


Fig. 5

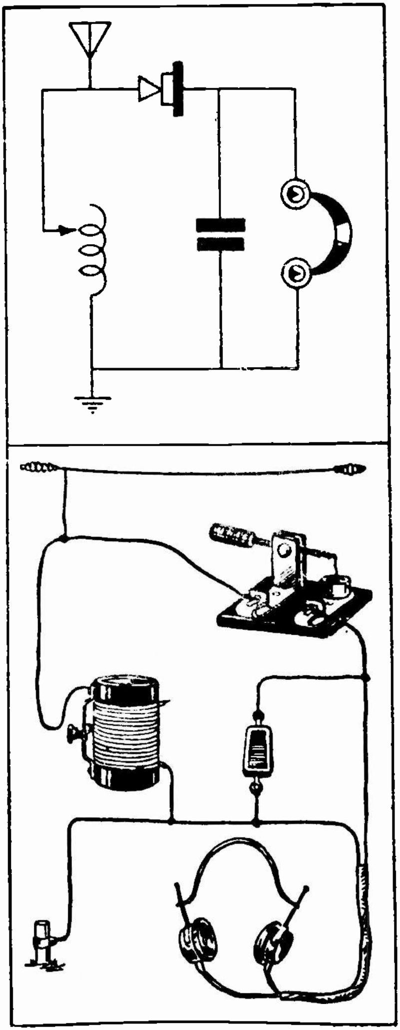


Fig. 6

EXPLANATION

In Figure 6, we have something a little different.

If the coil were omitted, this diagram would be exactly the same as the one shown in Figure 3. But the coil is connected between the aerial and ground. It is in parallel with the detector-phone circuit, and thus is actually a part of the circuit.

There is a fact called "resonance". When a circuit is in resonance with an incoming wave, the natural frequency (or wavelength) of the circuit is the same as that of the wave being received, and the result is that the signal is received strongly. Moving the slider along the coil permits the circuit to be brought to resonance, just as in Figure 5.

Another explanation of this action is that when the coil is correctly tuned by means of the slider, it offers a very high resistance to the passage of the one particular wave to which it is tuned, and but little resistance to all other waves. Thus the wave which is wanted is forced to go through the crystal and phones, while the others flow through the coil to the ground and therefore do not interfere.

The second explanation is easier to understand, and while it means much the same as the first one, is not quite so accurate technically and therefore is less commonly used. However, it may give the reader a clearer understanding of the action of the circuit.

Resonance is one of the parts of radio which is often difficult for the beginner to understand, and it is beyond the scope of this volume.

EXPLANATION

Except for one detail, Figure 7 is the same as Figure 6. Instead of a slide tuner, it has a tapped coil.

The tapped coil can be easily mounted, because the connections to the various turns can be made to switch points inserted through the panel, and used together with a switch arm.

By tapping the coil correctly, any desired number of turns may be connected into the circuit—but not every turn has to be tapped. If this were not possible, a 100-turn coil would need 100 taps, and this would be extremely inconvenient. Only 19 taps are needed to use from 1 to 100 turns of a 100 turn coil.

In winding the coil, make one turn of the wire, then twist a little piece of the wire so it stands up from the coil, and wind the next turn, twisting a loop on it in the same way. Do this on each of the first ten turns. Then wind nine turns in the regular way, make a little loop on the 20th, nine more regular turns and the 30th turn with a loop in it, and so forth, for the rest of the coil, tapping each tenth turn.

Connect the first ten taps (the ones on every turn) to one group of switch points, which will be contacted by one switch arm. Connect the other nine taps (the ones on every tenth turn) to a second group of switch points, to be contacted by a second switch arm. Make your rough tuning adjustments with the second switch, the fine adjustments with the first switch. If you number the switch points, you can make a record of where every station is tuned in.

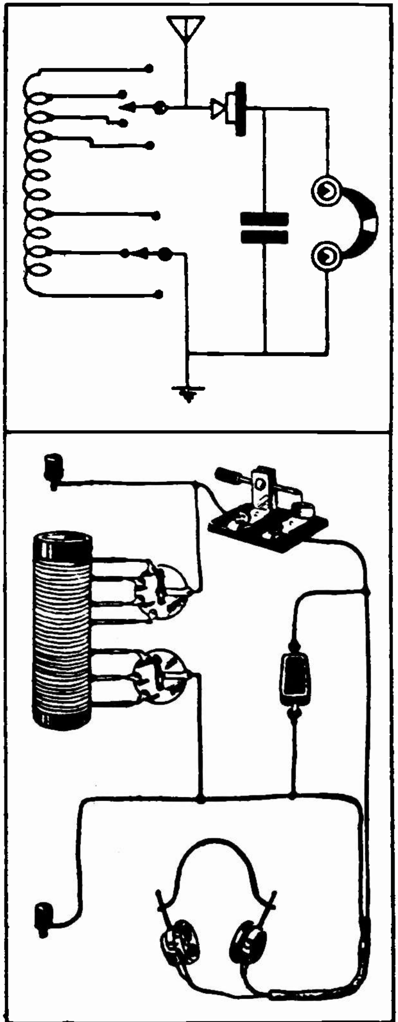


Fig. 7

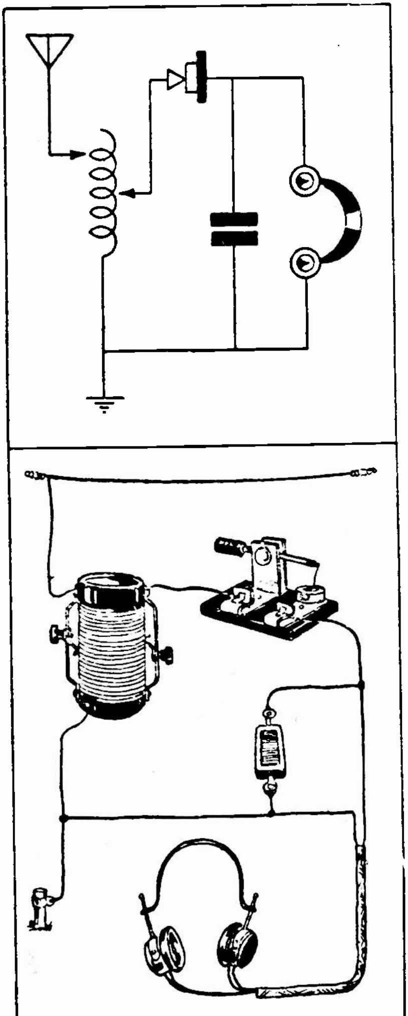


Fig. 8

EXPLANATION

Notice the similarity between Figure 8 and Figure 6.

A two-slide tuner has replaced the single-slide tuner.

One end of the coil is connected to ground; the antenna connects to one slider and the detector to the other. In Figure 6, the detector was connected directly to the antenna, and when the slider tuned the antenna circuit, it also tuned the detector circuit. Now these two circuits may be tuned separately, each by means of the slider to which it is connected.

This will give appreciably better results than the single-slide tuner, because each circuit can be tuned separately, instead of a compromise reached. The single-slide tuner simply tunes to a point which is between the best tuning of the detector circuit and the best tuning of the antenna circuit.

A tuner of this sort is made exactly the same as a single-slide tuner, with but one exception. This is that there are two rods, each with its slider. It is connected as shown in the figure on this page.

At first one might think that the two sliders could be mounted on the same rod, but this is not so. The reason is that for some stations the antenna slider will have to be nearer the end of the coil and that for other stations the detector slider will have to be nearer the end of the coil. If they were on the same rod, this could not be done without stopping to change connections—a great nuisance.

The two-slide tuner is used in most of the so-called "long distance" crystal sets.

EXPLANATION

Here is something new again! Figure 9 shows the first two-circuit set which has been presented in these pages. All the others have been single-circuit diagrams, for the antenna circuit was coupled directly to the detector circuit.

In this circuit, however, you will see that there are two coils instead of one. The two coils together form a radio-frequency transformer of sorts. The antenna and ground are connected to the primary, which is inside the secondary. The detector-secondary, which may be a simple single-slide tuner but which is more easily made as a tapped coil, as shown.

Notice the arrow running through the two coils. That, as you have learned, indicates that the coupling between the primary and secondary can be varied at will. This is usually done by winding the primary on a smaller form, which fits inside the secondary and mounted on a shaft which can be rotated by means of a knob.

This circuit is a great improvement over those previously given, for although it does not make the set more sensitive than the one given in Figure 8, it makes it far more selective. In other words, it helps the listener tune-out unwanted stations.

Not only does it make it possible for the antenna circuit and the detector circuit to be tuned perfectly; it also enables the listener to decrease the amount of energy fed from the antenna circuit to the detector circuit. Thus, when two sta-

(Continued on Page 31)

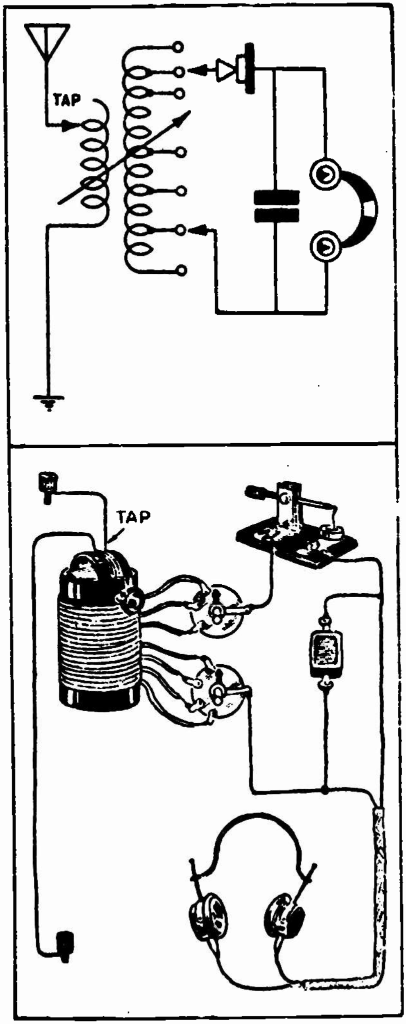


Fig. 9

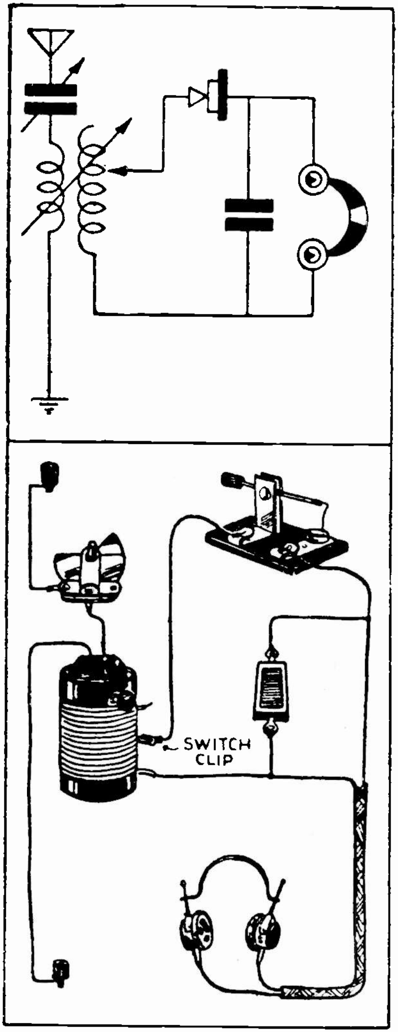


Fig. 10

EXPLANATION

Here, too, is a new element entering the circuit; it is the variable condenser. It is connected between the aerial and the antenna coil, and is used to tune the antenna circuit, as seen in Figure 10.

Coils with sliders or with taps are more of a bother to tune, for the slider must be pushed back and forth, or if a tapped coil is used, two switches must be manipulated. Nor are coils of these types as efficient as might be desired, for there are losses of energy due to currents set up in the turns which are cut out of the circuit.

Putting a condenser in series with the circuit is the electrical equivalent of taking some turns off the coil. Using a smaller condenser has the effect of taking off more turns than using a larger condenser. Therefore the use of a variable condenser permits the user to secure the effect of taking off a fraction of a turn, a complete turn, a few turns, or a large number of turns, simply by twisting the condenser shaft to move the plates in and out of mesh.

Better yet, with the slider or with the tapped coil, every adjustment meant changing the coil by one complete turn. There are no such steps in the adjustment of the variable condenser—the variation is smooth and gradual instead of being in steps. The user can secure the effects of removing 1/10 of a turn, or 15¾ turns with equal ease. As a result, the circuit can be tuned more accurately than with taps or sliders.

Like fixed condensers, variable condensers are rated as to capacity

(Continued on Page 24)

EXPLANATION

As you see in Figure 11, another variable condenser has been added to the circuit, to tune the secondary coil. A condenser in parallel with a coil acts in precisely the opposite way that a condenser in series does. That is, as the capacity is increased, this acts like adding more turns.

Now, in this circuit, no taps or sliders at all are needed to tune the antenna circuit or the detector circuit. They are brought to resonance with the incoming wave by means of the condensers.

Circuits of this sort are seldom used with crystal detectors, for variable condensers are not as cheap as sliders or switches. They are, however, used in vacuum tube circuits, which will be considered next.

Before going on to vacuum tube circuits, however, review Figures 1 to 11, inclusive. Be sure that you understand how connections are made between units, and the functions of the various units you have studied thus far.

Every tuned radio circuit has capacity and inductance. A coil is an inductance, and even if there is no condenser used with it, some little "distributed capacity" exists between the turns of the coil.

Even in the circuit of Figures 1 and 2, where no condensers or coils are used, inductance and capacity exist—the former, in the windings of the phones; the latter between aerial and ground, and in the wiring of the set, particularly in the phone cords.

Remember that there must be inductance and capacity in all the circuits which follow.

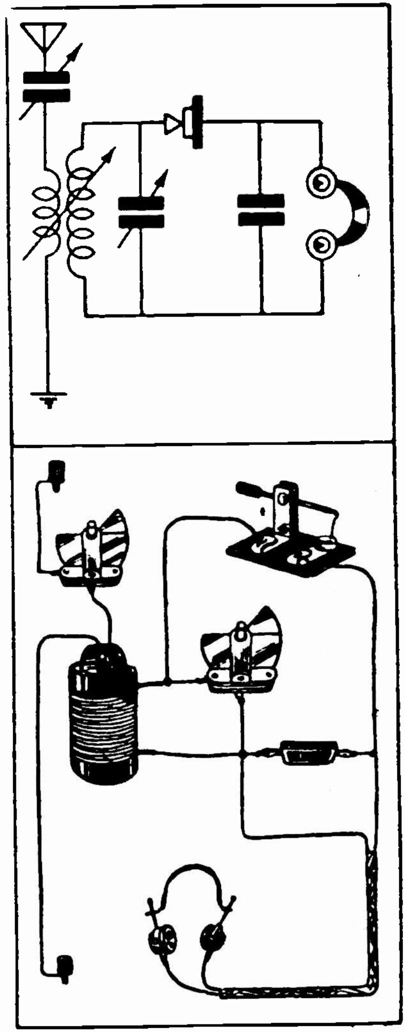


Fig. 11

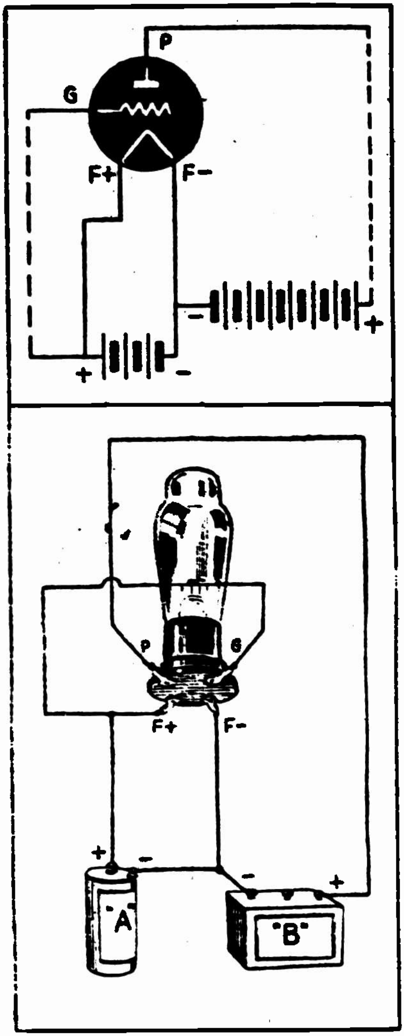


Fig. 12

EXPLANATION

You recognize the symbol, Figure 12, for a simple three-element vacuum tube, which contains grid, filament and plate.

Connected to this tube are two batteries—the "A" battery to provide current to heat the filament; the "B" battery to supply voltage and current to the plate circuit.

The filament is a wire which is so treated that it emits a cloud of electrons when it is heated by the passage of current from the "A" battery. The electrical charge of electrons is said to be negative.

It is a fact that unlike charges of electricity attract each other. Therefore the electrons are attracted by the plate which, as you see, is connected to the positive end of the "B" battery.

An explanation of how and why current flows in the plate circuit would be long, and technically beyond the scope of this book. However, you can believe that electricity from the "B" battery flows through the filament, from the filament to the plate, from the plate through any coils or resistances which may be between the plate and the battery, and back to the battery. The circuit just described is the external plate circuit.

There is another equally important circuit in the tube—the grid circuit. The electrons from the filament must pass through the grid to reach the plate, and some of them are attracted to the grid. These must flow back to the filament through any coils or resistors in the external grid circuit.

The third circuit is the filament

(Continued on Page 26)

EXPLANATION

You are not expected to understand this diagram thoroughly, for you will never build a set of the sort shown in Figure 13. It uses a special type of detector which is called a "diode" as it has but two elements instead of the three just described.

It is given for a special purpose, for it is virtually the link between the crystal detector and the three-element vacuum tube described upon the preceding page.

Diodes came out before three-element tubes and, as the latter were far more efficient, were soon discontinued. But a few years ago, they came back strong in certain circuits (such as for use as second detector in superheterodynes with automatic volume control). However, they are never used today in the circuit shown on this page.

In this circuit, the tube functions as a simple rectifier or detector. Notice how similar the secondary circuit is to that given in Figure 11. Except for the fact that it has a two-element tube instead of a crystal, and that the antenna and ground are directly connected, it is the same.

Compare this diode tube, which has only plate and filament, to the three-element tube shown in Figure 12. The grid, added by Dr. Lee de Forest, is what really put radio on the map. That little grid acts as a valve. When the incoming wave gives it a negative charge, it retards the electron flow from filament to plate; when it is given a positive charge it accelerates the flow of electrons from filament to

(Continued on Page 25)

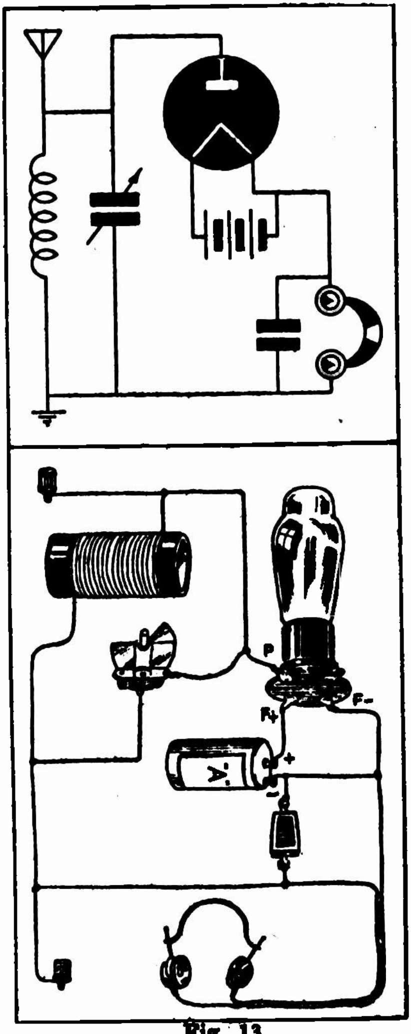


Fig. 13

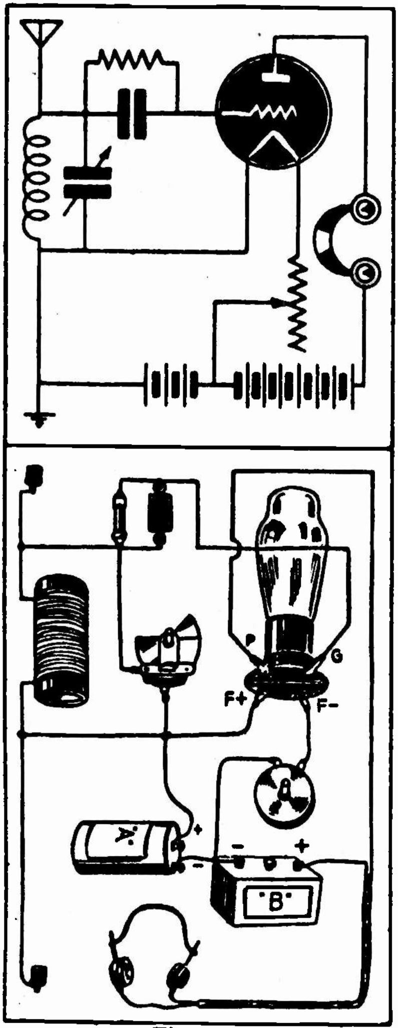


Fig. 14

EXPLANATION

Figure 14 presents the simplest of standard tube circuits. Compare it to the one given in Figure 13.

Also refer back to Figure 12 and the explanation thereof, you will see that the tuning unit and an additional resistance and fixed condenser have been added to the tuning units (coil and variable condenser) in the grid circuit. You will also notice that the headphones have been added to the plate circuit. And a variable resistance has been put into the filament circuit, as was explained.

The resistor (usually from 2,000-000 to 6,000,000 ohms—or, more simply, 2 to 6 megohms) completes the grid circuit, allowing the electrons to leak slowly back to the filament. But this resistor, which passes the direct current of electrons, offers tremendous resistance to the passage of the high-frequency alternating currents which are the radio waves, and it is these radio waves which must reach the grid in order to make the tube operate.

As you were told in the explanation of Figure 3, the high-frequency currents flow easily through a condenser. For this reason, a fixed condenser (generally .00025 mfd.) is connected in parallel with the resistor. The condenser is called a grid condenser, and the resistor is called a grid leak, from their uses. As you read in the explanation of Figure 2, these elements are connected in parallel.

Direct currents cannot flow through condensers, so the grid leak is used to afford a path for the electrons; alternating currents can,

(Continued on Page 29)

EXPLANATION

Figure 15 shows the same set as that presented in Figure 14, but with a great improvement added. This new feature is regeneration, and the set shown is known as a single-circuit regenerative set.

As you were told in the explanation of Figure 3, some of the radio frequency wave escapes past the detector. Up until this circuit, such currents have been by-passed to ground by means of a fixed condenser across the phones, and the energy wasted. This circuit no longer wastes the energy.

Notice the coil between the plate of the tube and the phones. It is a radio-frequency choke coil, and offers high resistance to radio frequency currents, though it permits the detected audio-frequency part of the signal and the plate current from the battery to pass without appreciable hindrance.

The radio-frequency currents, impeded by the choke, have to go somewhere and, as you have been told, they pass through condensers. Therefore, a variable condenser is placed between the plate and the grid coil. The radio-frequency currents are thus caused to flow through this coil again. This has the effect of reducing the resistance of the grid circuit, and making the set far more efficient.

The more the plates of the feed-back condenser, controlling this action, are in mesh, the more the effect of the R. F. (radio frequency) currents, because the condenser's capacity is increased.

A fixed condenser cannot be used for this purpose because if the capacity is too low, there is not enough feed-back, and if its capacity is too high, there is too much feed-back and the set howls or whistles.

In fact, it becomes a transmitter when it whistles, and if a key is connected between the tuning coil and the ground, it can be used to send signals in Continental or Morse code.

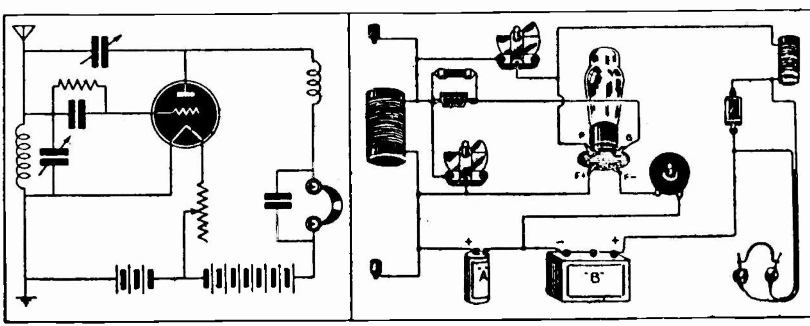


Fig. 15

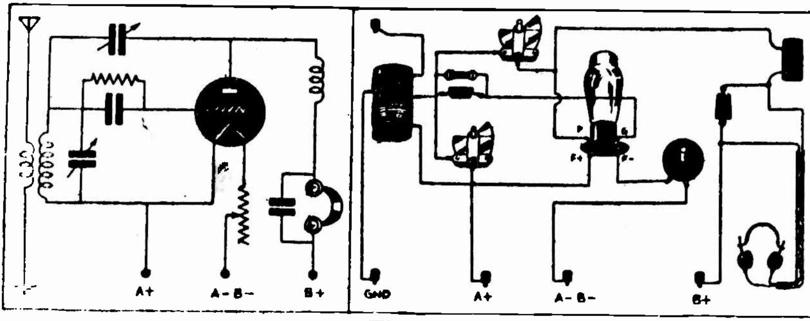


Fig. 16

EXPLANATION

One of the greatest drawbacks of the set shown in Figure 15 was the fact that every time it was carelessly tuned, it howled, and that these howls (caused by electrical oscillations in the tube) radiated and could be heard for blocks. This ruined reception for everyone trying to listen-in in the same area as the set.

Another of the set's disadvantages was its inability to tune very sharply. Two powerful or nearby stations, broadcasting on almost the same frequency (i.e., wave-length) would interfere with each other; their signals could not be separated.

To overcome these difficulties, the circuit was developed as indicated in Figure 16, on this page. An antenna coil and a grid coil replace the single tuning coil that was used in the preceding circuit, and this new two-coil unit was called a two-circuit tuner. It has, as you see, a coil in the antenna circuit and a separate coil in the grid circuit.

These two coils are wound on the same form, and are separated by a fraction of an inch. The greater their separation, the more sharply the set will tune, and the less it will radiate; but if they are too far apart, the set becomes less sensitive and loses volume.

Heretofore, we have always tuned the coils in the set, but this circuit makes use of an untuned antenna coil, which serves merely to transfer energy from the antenna to the grid circuit. It has comparatively few turns; if the grid coil is, say, 120 turns on a 2-inch form, the antenna coil will have only from 5 to 15 turns.

A set of this sort is remarkably efficient, and this circuit is the basis of many sensitive short-wave sets in use today. It can be built at a cost for parts of less than $5.00.

(Continued from Page 18)

in microfarads. In the case of the variable condenser, the capacity given is the capacity with the plates completely meshed. It is decreased as the plates are brought out of mesh.

EXPLANATION

The three-circuit regenerative set, shown in Figure 17, operates in much the same way as the two-circuit set of Figure 16.

Notice, however, that there is this difference: The choke coil and feed-back condenser are omitted. Instead there is an additional coil, known as the tickler, which serves the same purpose. The plate current, together with its R. F. component, must pass through the tickler coil to get from the plate to the battery.

As you have already learned, when alternating current is flowing through one coil, it induces (i.e. sets up) a like current in another coil placed close to it. That is how energy is transferred from the antenna coil to the grid coil. In exactly the same way, the R.F. in the plate circuit is fed back to the grid circuit by means of the tickler coil.

The amount of feed-back is controlled by having the tickler coil mounted on a shaft which can be rotated by means of a knob. There is the greatest amount of inductive coupling (transfer of electrical energy) between the tickler coil and grid coil when the two coils are in the same direction; this coupling is decreased more and more as the tickler is turned from this position. The tickler is usually wound on a smaller coil than the grid coil, so that it can fit partly inside it, and has from ¼ to ¾ as many turns of wire.

NOTE ON TUBE FILAMENTS

The detector grid returns shown in these diagrams are connected to the positive side of the tube filaments ("A"+). Such connections are used with the —01A, 27, 30, 56, 76 and other tubes. The grid returns of —00A tubes are made to the negative side of the filaments ("A"—).

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plate. When the degree of the positive or negative charge maintained on it is increased or decreased, similar action takes place.

You will understand this better when you have studied the next diagram, Figure 14.

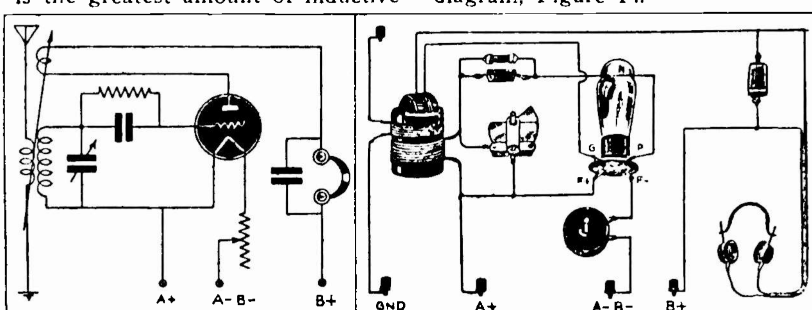

Fig. 17

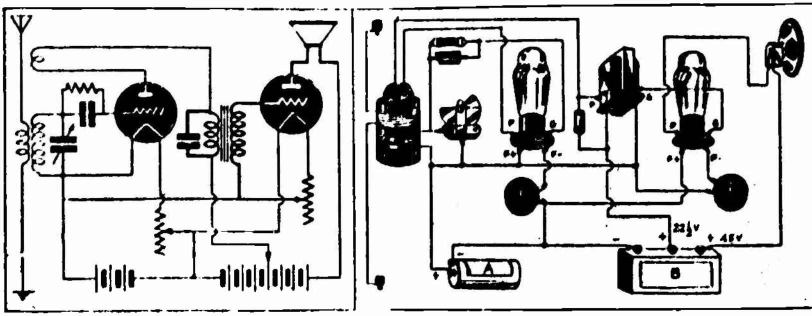

Fig. 18

EXPLANATION

Here, in Figure 18, is the circuit just described, but with an important addition—a stage of audio-frequency amplification.

Adding this stage does not make the set any more sensitive or selective; it makes it louder. While the preceding sets will work headphones with good volume, they are not loud enough to operate a loud speaker. The addition of a stage of A.F. (audio-frequency) amplification will permit a speaker to be operated at low volume; two stages will give ample volume for any home, as you will be told later.

The phones are no longer in the detector plate circuit; instead there is the primary of an A.F. transformer which is by-passed with a small fixed condenser to afford a path for the R.F. to slip by without passing through the condenser windings, just as the phones were.

The secondary of this transformer is the grid coil of the audio stage. As there is no need to detect in this stage, the grid leak and grid condenser, used in the detector stage, are omitted.

The plate circuit of this A.F. stage is completed through a loud speaker or, if you prefer, a pair of phones. No by-pass condenser is needed across the A.F. stage's output.

One thing you must notice carefully is the way in which the grid circuit of this stage is completed. The return, instead of being to the positive filament lead (i.e., wire) which is the correct grid return for most detector tubes, is made to the negative filament lead. This is necessary in all A.F. amplifier tubes.

This can be done by connecting them to the negative side of the filament in single-stage amplifiers, but two-stage amplifiers, handling stronger signals, need a greater negative grid bias.

(Continued from Page 20)

circuit, consisting simply of the filament, the "A" battery, and any resistor that may be in series with them to regulate the filament temperature and thus the emission of the electrons.

EXPLANATION

Figure 19 shows a two-stage audio amplifier connected to the tuner and detector of Figure 17. This circuit will work a loud speaker with perfectly satisfactory volume, and good tone.

It has several features not previouslv discussed.

First, you will notice, it makes use of "C" batteries—that is, batteries in the grid circuits—of the amplifier tubes. These are drawn just as are "A" and "B" batteries; their use in the circuit marks them as "C" batteries.

The positive terminal of the "C" battery is always connected to the filament circuit, just as is the negative terminal of the "B" battery. You will also notice how the "B" and "C" batteries are tapped to provide the correct "B" voltages for detector, first audio and second audio plates, and the correct "C" voltages for the two audio stages.

Normally, higher "B" and "C" voltages are used on the second audio stage than on the first, for this second tube must handle a greatly amplified signal, and requires more power. In fact, special power tubes, such as the 20, 31, 33, 112-A and others give best tone when used in the output stage.

While the volume can be controlled by adjusting the filament rheostats (variable resistors in the filament circuits) or the tickler coil, this is not the best method. A far better volume control is the resistor R connected across the secondary of the first A.F. transformer. Moving the slider-arm along this resistor reduces the volume the more nearly it approaches the grid end of the resistor. There is practically full volume when the arm is at the "C" battery end of the resistor.

Another feature of this circuit is the output choke. The plate current of a power tube is so great that it might damage the windings of the loud speaker. It is therefore caused to flow through the A.F. choke connected in the plate circuit of the last tube. This choke passes the

(Continued on Page 32)

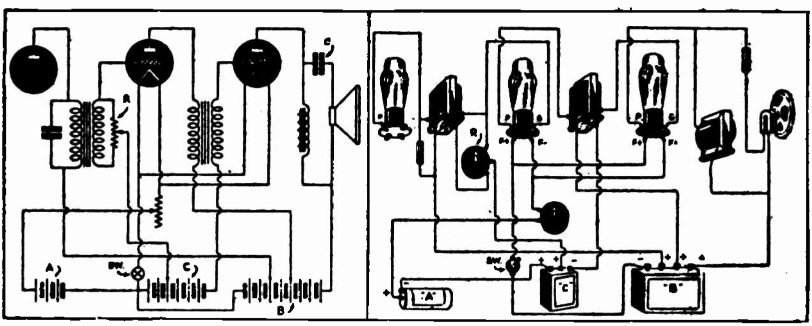

Fig. 19

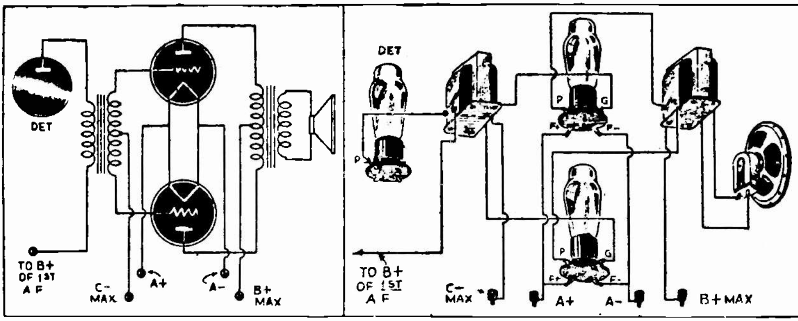

Fig. 20

EXPLANATION

Figure 20 represents a stage of push-pull amplification, as used in an audio output stage. It can be used in place of the last stage shown in the preceding diagram, Figure 19.

It makes use of two tubes for a single audio amplifier stage. They are connected into the circuit by means of special push-pull transformers. The push-pull input transformer has a center-tapped secondary; the push-pull output transformer, a center-tapped primary.

When the transformers are connected as shown, a negative bias is kept on the grids of both tubes in the push-pull stage, and a positive bias on their plates. But when the signal impresses a more negative charge on one grid, it makes the other less negative, and vice versa. Thus one tube is "pushing" while the other is "pulling" the signal.

The output of such a stage is far greater than that of the same two tubes with their grids connected together and their plates connected together would be.

(Continued from Page 8)

shown in the lower part of the illustration, is used. Its primary is center-tapped. Between two push-pull stages, an inter-stage push-pull transformer, with both primary and secondary center-tapped, is used.

CHOKE COIL (AUDIO FREQUENCY) — Either of the two symbols shown may be used to designate this unit, for each shows that the coil is wound upon an iron core. If this is not immediately clear, refer to **Coil** and **Transformer, Audio Frequency.** The choke differs from the audio frequency transformer in that it has but a single winding.

VOLTMETER — See the explanation given for **Ammeter.**

DYNAMO or MOTOR—This symbol represents two brushes touching the commutator of a D.C. generator, or a motor.

(Continued on Page 30)

EXPLANATION

Another type of amplifier is seen in Figure 21. This is a resistance coupled amplifier. It does not use transformers, as did those previously discussed, but employs fixed resistors in the plate and grid circuits of the tubes, as shown.

Although its accepted name is "resistance coupled" it would be more accurate to call it condenser coupled, for the true coupling is through the fixed condensers which couple the plate of each tube to the grid of the next.

As you have gathered, when a signal is flowing through an amplifier, its audio component is a pulsation which acts much like an alternating current. The plate resistors offer opposition to the passage of these pulsations, which are impressed upon the condensers (known as coupling condensers, but more often as blocking condensers) and thus are conveyed along to the grids of the following tubes.

The tonal quality it is possible to secure through resistance coupling is far better than that obtainable through the use of cheap or even most moderately priced transformers, but the amplification (increase of signal strength) per stage is not so great. Therefore, instead of two stages of transformer coupled, three stages of resistance coupled amplification are needed.

However, resistors and fixed condensers are inexpensive, and there is generally a saving of expense. The plate resistors are 250,000 ohms, the grid resistors 1 to 2 megohms, and the coupling condensers, .006 mfd. to .25 mfd.

An A.F. choke is generally used in the output, as few resistors will carry the current supplied in the plate circuit of the power tube.

(Continued from Page 22)

so the grid condenser affords their path.

The radio waves reaching the grid through this condenser vary the charge on the grid many thousands of times per second. The grid controls the plate current, and thus the signal is heard in the phones. As the plate current is far greater than the radio currents which control it, the signal is more loudly heard.

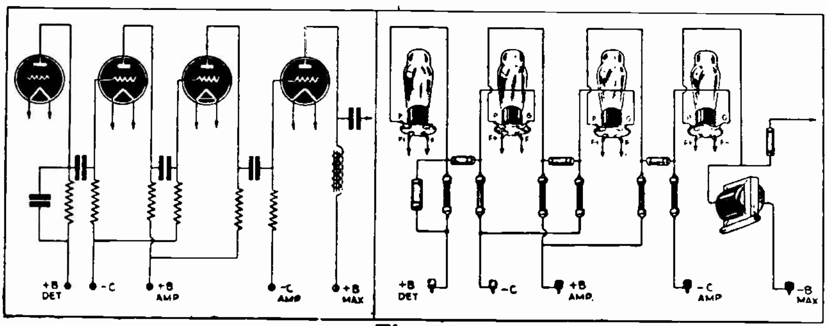

Fig. 21

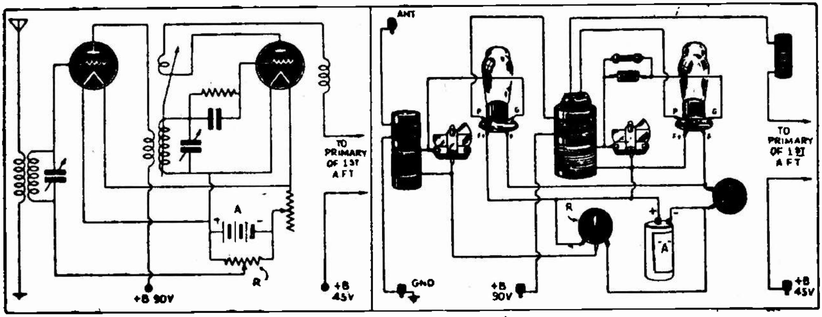

Fig. 22

EXPLANATION

In the few preceding diagrams, we have been considering audio frequency amplifiers. As you were told they do not make the set more sensitive or selective.

The diagram, Figure 22, on this page, shows another type of amplifiers—a radio frequency amplifier—which does add to the set's sensitivity and selectivity.

Refer back to Figure 16. The antenna coil and grid coil used in that circuit are the same as those used in the R.F. stage here. The detector stage (the second tube and its associated units) makes use of a coil assembly similar to the three-circuit tuner of Figure 17, but with a few more turns on its primary. The primary, which was the antenna coil in Figure 17, has become the R.F. (radio frequency) stage's plate coil in Figure 22. Having no grid leak and condenser, the tube does not act as a detector. Certain biassing (not used) could also make it detect.

If a standard three-element tube, such as the 01A, is used in the R.F. stage, there is the problem of giving it the correct grid bias. It will be inefficient if the bias is too positive, and will cause howling noises to come from the phones or loud speaker if it is too negative. Therefore, a potentiometer type of variable resistance may be used, connected as at R in the diagram.

There are many other ways of keeping the R.F. stage from oscillating (the cause of howling), but the best is to use a screen grid tube.

(Continued from Page 28)

VACUUM TUBE — The tube most frequently used in battery circuits has three elements, the filament, grid and plate, and is represented as shown at the top of the illustration. One of the most common tubes for electric (house lighting lines) operation has cathode, grid and plate. The cathode (corresponding to the filament) is heated by a separate part called the heater, which is not considered as an element.

EXPLANATION

Figure 23, herewith, is precisely the same circuit as that of Figure 22, except that a screen-grid (four-element) tube has been substituted for the three-element tube of the earlier diagram.

The added element is the screen grid. The element called the grid in preceding explanations remains the same as heretofore, but its name changes. It is now called the control grid to distinguish it from the screen-grid, for its function is to enable the incoming wave to control the electron flow in the tube.

The addition of the screen grid serves two purposes. It makes it impossible for the tube to oscillate and so eliminates the chance of howling originating in the R.F. stage; it also can be made to amplify the signal much more than can a three-element tube.

Its grid bias may be obtained by connecting the grid return to the negative side of the filament battery, or to a "C" battery, as shown in the illustration. The positive bias applied to the screen grid may be obtained from a tap on the "B" battery which supplies the plates of the tubes in the circuit. You will notice that the voltage applied to the screen grid is lower than that applied to the plate.

The screen grid attracts electrons, too, and some current flows in the screen grid circuit, but as it is an open coil or mesh, and as the plate is at a higher potential, most of the electrons are attracted through the screen grid to the plate.

The screen grid prong is in the position occupied by the grid prong of a three-element tube.

(Continued from Page 17)

tions are heard, and their signals cannot be completely separated, the listener can tune until the wanted station is louder than the unwanted one, and then move the sliding coil of the loose-coupler (as this unit is called) until the unwanted station is no longer heard.

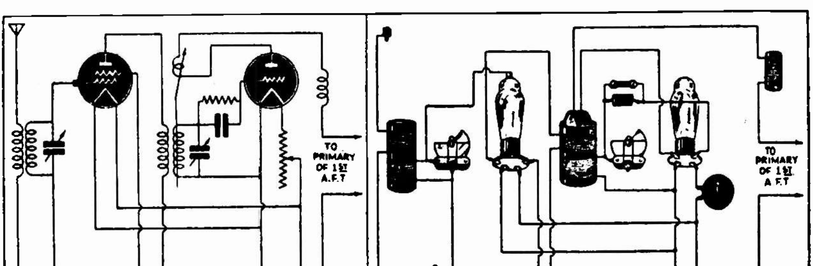

Fig. 23

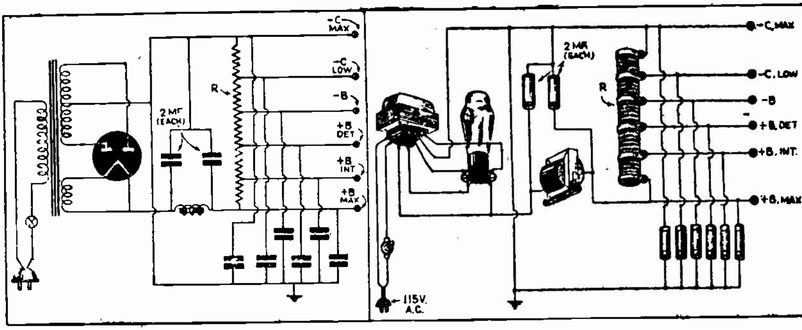

Fig. 24

EXPLANATION

Figure 24 shows a "B" and "C" eliminator or power pack.

The transformer at the left is a power transformer, and its primary is connected to the A.C. electric light lines of the house. It has two secondaries. One of these steps up the voltage to supply "B" and "C" voltage to the set. The other steps the voltage down to heat the filament of the rectifier tube.

In this diagram, a full-wave rectifier is used. It is really just two diodes (See Figure 13) in the same tube and using the same filament for both plates. It enables the power pack to make use of both halves of the alternating current cycle.

The rectifier changes the A.C. to pulsating D.C. — and the set needs smooth D.C. Therefore one or more audio chokes are put in series with the high voltage lead, as shown. In addition, large capacity fixed condensers are connected between the high voltage and low voltage leads, as shown. These condensers may be of any capacity from about 2 mfd. up. The larger they are, the better the filter, and the more it costs.

To get different voltages for the various stages of the set, a voltage divider, R. is used. As it is connected across the lines, it always draws some current through itself, and is therefore often called a "bleeder." This resistor is usually provided with contacts which can be fastened at any desired points, so that the desired voltages may be tapped off. It works much like the potentiometer resistance described in Figure 22.

Other fixed condensers, usually about 1 mfd. are used to by-pass each tap to ground.

(Continued from Page 27)

plate current but impedes the A.F. pulsations, which flow through the large condenser C and the speaker, and so back to the plate circuit.

A switch has also been added in the "A" battery lead, so that the set can be turned on and off without having to readjust the rheostats.

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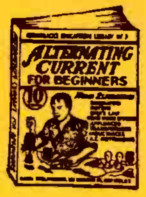
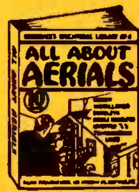


No. 3
Alternating
Current
for Beginners



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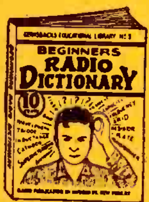

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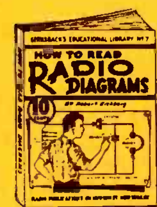

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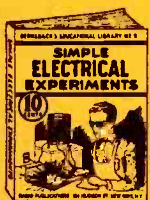

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