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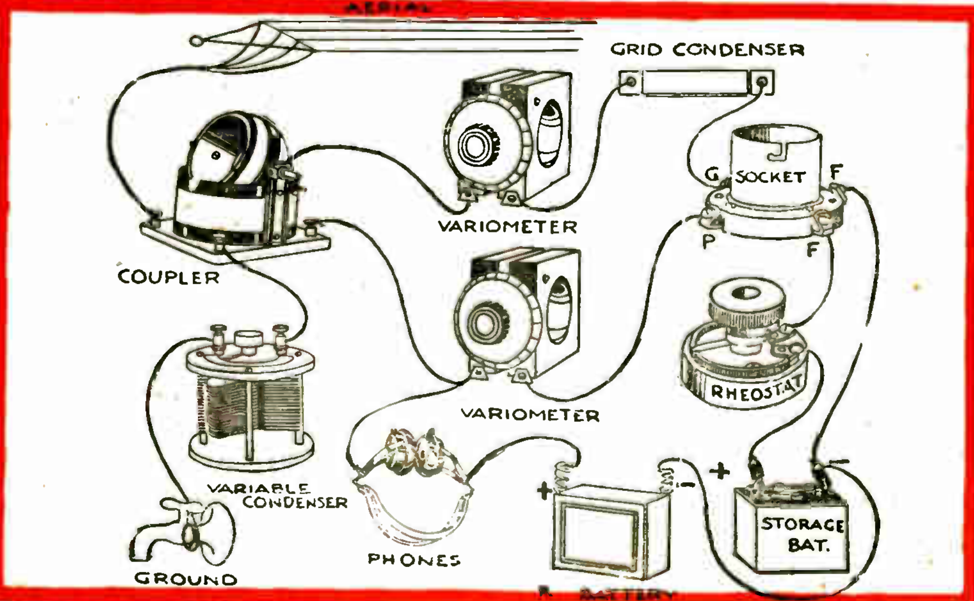
THE "REGENERATIVE" CIRCUIT

E-Z RADIO

VOL. I NUMBER III



By Henry M. Neely

E-Z COMPANY, Inc.
[illegible] CHESTNUT STREET
PHILADELPHIA

RADIO BUSINESS IS CLEANING HOUSE

There has been a big slump in the radio business during the past two months. Most manufacturers and dealers are blaming it on the summer and saying that people are not staying indoors these warm evenings even to listen to broadcast concerts and that static and bad carrying qualities of summer ether serve to make the fans postpone their radio enthusiasm until the better times of the autumn.

That's all probably true. But there are a lot of people who have quit because they have been badly stung. That's a brutal way of putting it but it's the truth. They have bought for cheapness rather than quality; they have let the store salesman talk them into buying loud speaking horns to hook to crystal sets and all that sort of thing.

Every young fellow who has had any service in an electrical concern—whether it be as salesman or bookkeeper or office boy, has branched out into building sets for all his neighbors and charging them regular standard-line prices—and the sets won't work. Of course not. How could they? The boys who built them probably don't really know the difference between audio and radio frequency or between a micro-henry and a pound and a half of beef liver for the cat.

The present slump is going to drive out of business most of the fly-by-night concerns who started on a shoestring—and borrowed that. And that will be the best thing in the world for the public and the legitimate manufacturers and dealers.

Just a word to you who are thinking of entering this fascinating game. Don't buy stuff unless it is stamped with a name that has a reputation behind it. That kind of stuff costs money, you may say. It doesn't—not in the long run.

Next fall you'll be able to depend more on what you see in the stores. The grab-it-and-beat-it brothers will be gone far away from here and no one will mourn but their creditors.

This slump is the best thing that could have happened for radio. It's a house cleaning—and house cleaning isn't pleasant but things do look nice and bright and comfy afterward, don't they?

Meanwhile, if you are puzzled about what to buy, write to me. I'll recommend the stuff that I have personally put to severe test and found good. If you want me to, I'll buy it for you and have it shipped to you at regular prices—no charge for my services. Address—

HENRY M. NEELY,
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E-Z RADIO

BY

HENRY M. NEELY

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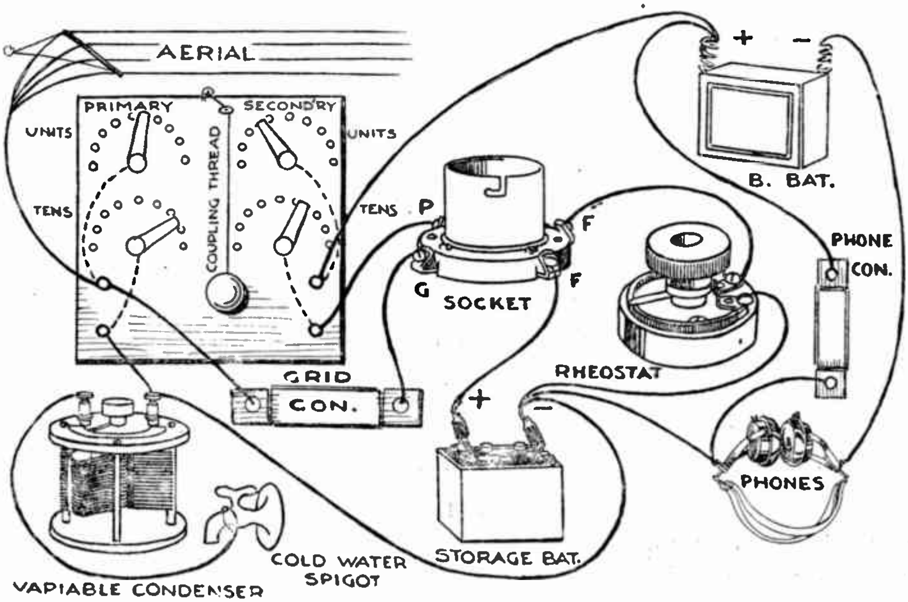
With this, the July issue, E-Z RADIO increases from 32 pages to 40.



A CORRECTION AND AN APOLOGY

About a week after the June issue had gone out to the public, with all of us feeling rather proud of it as a complete and helpful little book, I began to get letters from readers telling me that they had tried the spiderweb and audion bulb hook-up given in the frontispiece but that they couldn't get it to work.

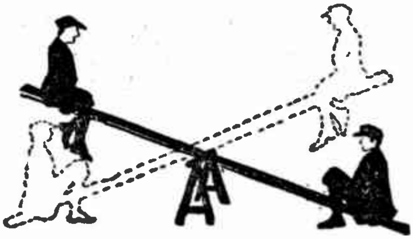
I had used that same circuit so often and so satisfactorily that I couldn't understand it, until one New York man wrote from Baltimore that it was "bunk," like all the rest of the radio stuff of today, and that the plate circuit was incomplete.

I looked over the circuit and checked it up connection by connection. And I found, very much to my chagrin, that the New York man was right. The artist had left out just one little line about an inch long, going from the minus side of the storage battery to the side of the phones nearest to it. You see, I place the blame on the artist but, unfortunately, it's my business to check up these drawings and so I really cannot side-step the responsibility. The fault is entirely mine and I apologize. If I didn't own a half interest in the magazine, I'd probably be fired.

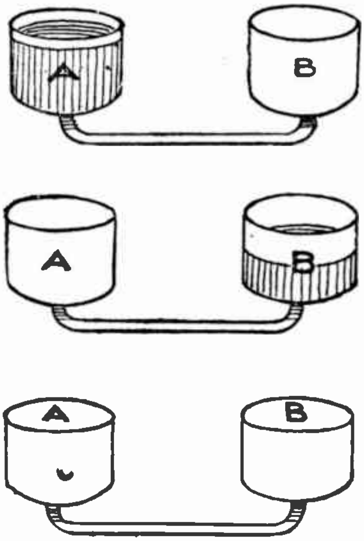
I am printing above the circuit as it should be. I'll guarantee that it will work this way.

But I want to make one request of all readers. Please dig out your June issue and draw this line in. You never can tell into whose hands back issues will fall in the future and I'm extremely anxious not to have anyone else misled by this mistake.

THE CONDENSER IS A FAST LITTLE WORKER



How a condenser acts. Keep the idea of a seesaw in mind and also the idea of the two tanks as explained in the article.



Whenever you calmly turn the knob of your variable condenser you unconsciously accomplish marvels that are almost beyond the power of the human imagination to comprehend. The condenser is a regular little miracle worker.

Let us see if we can get some idea of what goes on between the plates of this little wonder. It isn't really necessary to understand the workings of it to operate your set, but condensers play such an important part in both transmission and reception of radio concerts that it is interesting to know what they do.

In the illustration you will see a picture of two boys on a see-saw. I want you to keep this see-saw idea in mind all the time you are considering condensers for they are see-saws of electrical energy working up and down or back and forth with such unbelievable rapidity that it is almost staggering to consider it.

On some wave lengths this electrical see-saw will swing 3,000,000 times in one second!

Let us, in imagination, apply this see-saw thought to two water tanks arranged like A and B in the other pictures, with a pipe connecting them. And, as we did in a previous talk, let's imagine that we have some arrangement which, when tank A gets full, opens the entire bottom at once and lets the whole contents rush through the pipe and fill tank B. And tank B, as soon as it is full, opens and the water rushes back into tank A.

Now we will assume that the leakage lets some of the water escape and, in time, the tanks will be only half full. And finally there will be no water left.

Right here the water illustration ceases to be good unless we can imagine some sort of arrangement by which, when the A tank first opens, an automatic arrangement permits both tanks to open afterward without being full.

That is, it must be of such a nature that they can keep opening and shutting until the water is all gone.

That is the way a condenser works.

In radio we work with what we call alternating current. Electricity, as everybody knows, is of two kinds—positive and negative. In alternating currents we have first a positive current, then a negative, then a positive and so on. In the ordinary house-lighting system these changes take place usually about sixty times a second. In radio, as I have said, they may work up as fast as 3,000,000 times a second.

It is very difficult to explain just what it is that a condenser stores up. It isn't exactly electricity. It is a form of energy that is produced by electricity and that, when released, creates electricity. The alternate plates of a condenser, have, of course, no electrical connection. That is, an electric current will not flow through them. One half of the plates are charged with positive electricity and the other half with negative and this difference in what we call "potential" creates a strain in the ether between the plates.

When this strain becomes too great it overflows its bounds and sends a current of electricity swinging around the circuit. The remarkable thing is that, until this overflow point is reached, there is such a resistance in the circuit that it prevents the current from flowing, but once the resistance is broken down it does not build up again until the currents have died out.

These currents swing like the sea-saw or like the water in our supposititious tanks. If one section of the condenser plates are originally charged with negative electricity, the discharge swings the current the opposite way and they next become charged with positive. Again the current swings and they become negative and so on until the swing of the current dies down and there is no longer sufficient difference in potential to cause a discharge.

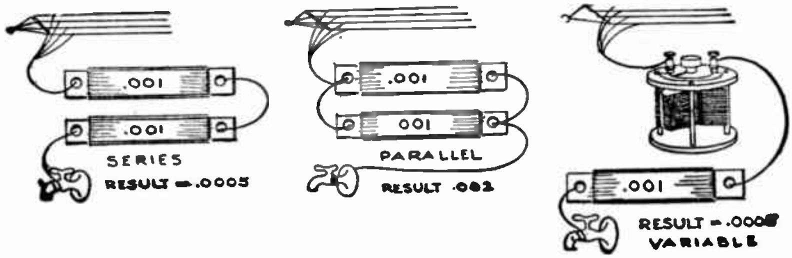
When you strike a tuning fork it vibrates violently for a while, but the resistance of the air soon makes it die down. If you start a pendulum swinging it will gradually die down. So with these discharges from the plates of a condenser.

Only don't forget the amazing fact that they swing from one to three million times a second, depending on the wave length of the signals employed.

SOME WAYS OF USING CONDENSERS

You have learned that a condenser is a tank in which we store up energy to make electric currents in our radio set. Now it is wise to consider, for a few moments, some of the ways in which we can use condensers to get various effects.

When we store up water in tanks, we measure it in gallons and quarts and pints and gills. We are so accustomed to speaking of those measurements that it never occurs to us that there is anything difficult in the names. But try to get a Frenchman or an Italian to learn to speak in terms of gallons and quarts, and you will see that there are other people who do not consider the terms so simple.



If you don't happen to have condensers of the exact capacity called for in a certain hook-up, two or three of those you have can be arranged together to give you the desired capacity. This picture shows how it is done

You must consider yourself an Italian or a Frenchman now and that you are learning to think in new terms of measurements. For various aspects of electrical and magnetic energy are measured in various ways and they all have different names.

We say that 500 gallons is the capacity of a tank. We also speak of the capacity of a condenser, which is the storage tank of the radio set. But we do not measure this capacity in gallons. We measure it in units that scientists call farads. You need not bother to know just how much of what a farad is. Mighty few of us could really give an intelligible definition of it. But the farad is the unit of measure of the capacity of a condenser—of its ability to store up energy before it overflows and sends electric currents rushing through the wires.

But the farad is too big a measure to use with the small condensers employed in radio apparatus. We use a subdivision of the farad called the micro-farad, which means one one-thousandth of a farad. And the amounts of energy which we use in radio condensers are so small that, even speaking in terms of micro-farads, we use a decimal point and a couple of ciphers before getting down to numbers.

Your 43 plate variable condenser stores up, at its greatest capacity, only one one-thousandth of a micro-farad. In other words, its capacity is one one-thousandth of one one-thousandth of a farad.

The word micro-farad is usually abbreviated mfd. And, when you write down the capacity of your 43 plate condenser, you write it .001 mfd. which is spoken of among "hard boiled hams" as "double-oh one." Your 23 plate condenser has only half that capacity so we write it .0005 and call it, in talking about it, "triple-oh five."

In the illustration, there are shown some ways of "hooking up" two condensers to get different capacities. In some diagrams printed in the radio magazines, you will see that you are to use a .0005 condenser. Perhaps you have none of this capacity but have two of those neat little thirty-five-cent .001 condensers known as "phone condensers." If you hook them up in what we call "series," you will make the total capacity of the two just half what one is. In other words, your two .001 condensers will take the place of one .0005 condenser.

"Series," as shown in the illustration, is like driving two horses tandem—one ahead of the other.

If you follow an imaginary radio impulse from the aerial down in the illustration, you will see that it must first pass through one condenser and then through the other to reach the ground, as represented by the spigot.

Now suppose your diagram called for a condenser of .002 micro-farads. You would take your two .001's and join them as shown in the second part of the illustration. This is called "parallel." The radio energy comes down from the aerial, goes into both condensers at once and comes out of the other end of both at once and so to the spigot. Hooking up condensers in parallel adds the two capacities.

You might think from this that two condensers in series would just make the capacity half, but this is so only when they are of the same capacity individually.

A series of condensers has a total capacity that is not very hard to figure, but it involves a mathematical formula that we won't go into in these articles.

The third illustration is just a suggestion for the man who has a .001 variable condenser — the 43 plate kind—and finds he has a diagram which calls for a 23 plate one. He can simply take one of his fixed condensers and put it in series with his 43 plate and the result is a very fair imitation of a 23 plate condenser, or .0005 variable.

And, if you have a 23 plate and need a 45 plate, hook up your 23 plate with a .0005 grid condenser, according to the middle diagram, and you have a fair substitute for a 43 plate variable.

It's a wise thing to have several .001 phone condensers because you can make almost any combination out of them that you want to. And hooking up your 43 or 23 plate variable with them makes them also satisfactorily variable.

A SALT BOX VARIOMETER

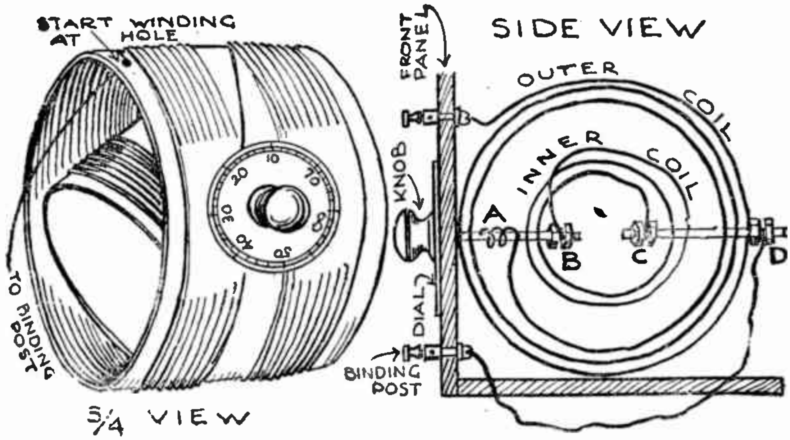
Every beginner in radio, who starts out with a crystal receiver and then graduates to a bulb, using his loose coupler or his spiderweb coils for the "single-circuit" hook-up, which we have already given, longs for the time when he can afford the regular "short wave regenerative" set, with two variometers.

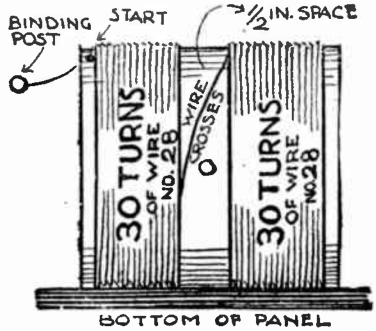
But variometers cost money. The cheapest really good ones cost at least $5 each and he needs two of them. And it isn't every amateur who feels like passing out a $10 bill for apparatus before he knows he is going to like it.

As we have said before, this standard short-wave regenerative hook-up is about the best there is for getting broadcast concerts. But it's also the hardest to work. It will exhaust the patience of most amateurs and they will give up in disgust, but, if they persevere and learn the six or eight adjustments, they will find they have an extremely sensitive set and one by which they can tune out virtually all interference.

In these little talks, we have taken up all of the apparatus necessary except the variometers. You can use a regular vario-coupler or else the one we built of two spiderweb coils mounted with a knob and thread to raise and lower one from the other. I prefer the spider webs.

The variometer shown in the illustration is the easiest one for





FRONT VIEW

This is the best way to wind a home-made variometer. Don't use the solid shaft usually recommended. Use two machine screws or two brass bolts as shown. Start the outer winding at the binding post, carry it around the two sections of the outer coil and solder it to the shaft at A. Pass the next wire through a pin hole in the inner tube and solder it at B, wind the two sections of the inner coil and solder the end at C. Then bring a wire from the soldered connection at D to the other binding post on the panel. In this way you avoid a lot of loose wire that gets in the way when you turn the inner coil for tuning

the beginner to build. It is not nearly so efficient as the bought ones, but there isn't one amateu in a thousand — even the most skilled in tool craft — who can wind one like the factories turn out. If you have the money to spare, by all means buy two standard variometers. If not, you can make two like the one illustrated and you'll get remarkably good results on them.

I built my two out of a salt box and a paper mailing tube. The salt box has an outside diameter of 3⅝ inches. One salt box is more than big enough for the two variometers. I use pieces a little more than 2¼ inches wide.

The mailing tube I use with this is 2¼ inches outside diameter. I use a piece about 2¼ inches wide. That just lets the piece of mailing tube turn all the way around inside the sàlt box when it is mounted. You need not use tubes of these exact dimensions. The object is to have them, so that the smaller will turn inside the larger.

Most writers advocate putting a shaft all the way through both tubes. I find it much better to use the method in the illustration. I use two ordinary machine screws (preferably brass, of course), two inches long and any thickness that is handy. If they are passed through the holes in the tubes as the pictures show, and the nuts screwed up tight, they make an excellent shaft and by this method, also act as separate conductors of the electric current.

Use No. 24 to 28 cotton-covered wire for the windings. The two tubes are wound in two sections, as you can see, but these windings are continuous—that is, you carry the wire right across the open space when you have finished the first section, and go on with the second. The open space is simply to give room for the shafts.

There are thirty turns of wire in each of the four sections. This makes a total of sixty on the outer tube and sixty on the inner. In starting, leave a good length of loose end. This will later attach to one of the binding posts on the panel. When the sixty turns on the outer coil are wound, fasten the last turn and the first and each of the inside ones with a drop of good glue. Then bring the end of the last turn inside the tube so that you can solder the end to the front shaft when you mount it.

The loose end of the first turn of the inner tube will be soldered to this same shaft. You wind these inner sixty turns in two sections, fastening them here and there with a drop of glue and the loose end of the last turn will be soldered to the rear shaft. Another separate piece of wire will be soldered to the end of this shaft and will lead to the second binding post on the panel.

If you will now in imagination follow the electric current you will find it will enter through the first binding post, go all around the outer coil, enter the front shaft and go into the winding of the inner coil, come out to the rear shaft and through it to the second binding post.

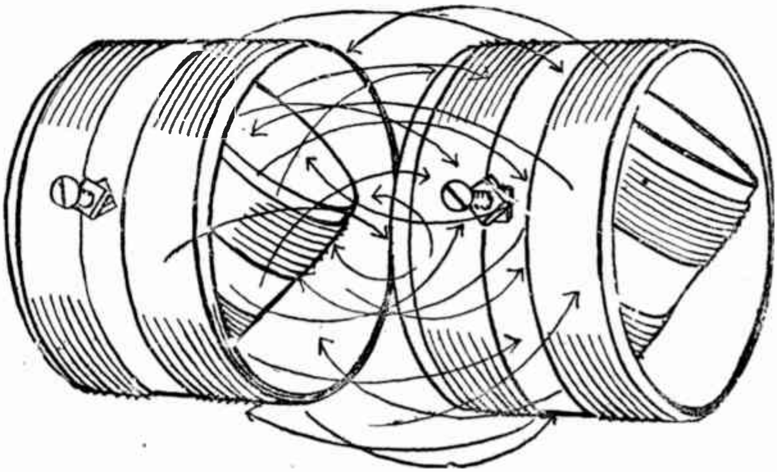
VARIOMETERS ARE DELICATE INSTRUMENTS

You may think it is quite a waste of space when you build the two variometers that have been described, to mount each one in its own six by six-inch panel. It leaves a lot of room on each side that you don't like to see vacant.

But that room isn't vacant. Whenever a current of electricity swings with very rapid changes from one direction to another around a coil of wire, it causes a great commotion in the atmosphere around the coil. You have seen an ordinary horseshoe magnet brought near to a compass or to a pile of iron filings. And you have seen the compass needle dance a turkey trot and the iron filings do a regular shimmy without any direct contact between them and the ends of the magnet.

Your variometer becomes a magnet the minute you send currents of electricity through the wires, alternating with inconceivable rapidity as radio currents do. And, as the currents alternate, so does the magnetism which is caused all around the coil.

When a current starts, it sends out a wave of magnetism around the coil; when it stops, the wave



This shows the wrong method of placing two variometers near each other and in the same positions. The arrows give an indication of the way that the magnetism which surges around one, when currents flow, interferes with the other

of magnetism collapses and falls back. When the current swings through in the opposite direction, another different wave goes out through the ether and when that current stops that wave collapses and falls back. Now, there is a very peculiar thing about waves of invisible magnetism like this. If you have a wired circuit in such a position that any part of any wire is within this wave which the first coil sends out, the wave of magnetism will create or induce a current of actual electricity in the other circuit. It will make a current in one direction when the wave is sent out and a current in the opposite direction when the wave of magnetism collapses and falls back.

Consequently, if you put two variometers close together, as shown in the illustration, the waves of magnetism from one (the area through which these waves are felt is called the "magnetic field") will create currents of electricity in the other, and these currents will affect the currents which the signals are making in that coil. It is even possible that the currents may be in such a relation to each other that the induced current will swing in just the opposite direction from the signal curent and oppose it so much that it will not be audible in the phones.

And then, again, when you turn the inside coil (known as the "rotor") of one so as to get the proper magnetic influence from the outside coil (known as the "stator"), the magnetism from the other variometer may reach them both and totally destroy the effect you want.

Variometers placed parallel and near to each other like those shown in the picture have most remarkable effects upon each other and one of the most common of these effects is a constant and deafening howling in the phones that makes it impossible to hear any signals at all.

If these instruments are so delicate, you may wonder why we use them at all. The answer is very easy. They do two important things: they increase the strength of signals and, perhaps most important, they are so delicate in adjustment that, when used properly, they enable us to tune out one signal and hear another plainly, even when both signals are on the same wave length and the one we want to hear is farther away or is weaker than the one we want to tune out.

As I have said, the types shown here are not nearly so efficient as the manufactured ones in which the "stator" is wound on the inside of a form to fit over a ball and the "rotor" is wound around this ball. That kind of winding brings both layers of wire so close together that they almost touch, and this is a great advantage in many ways.

But these home-made ones will give you some needed practice in handling variometers and they are surprisingly efficient. With two home-wound spider web coils as a coupler and with two of these home-wound variometers, and with only one bulb, I regularly hear Pittsburgh, 370 miles away, and Newark, about seventy miles away, and I have no difficulty in tuning either one out to receive the other. And I can eliminate the five stations in and about Philadelphia so that I do not even hear them faintly while listening to either KDKA or WJZ. And, conversely, I can tune out those two and listen to any one of the five at will.

The hook-up which I use is given in the next article.

THE "SHORT WAVE REGENERATIVE CIRCUIT"

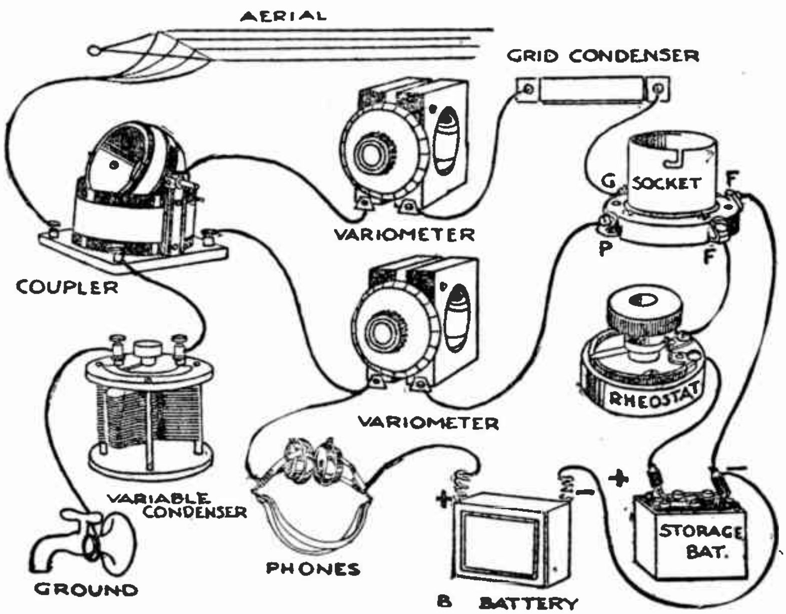
In every radio magazine you pick up you see a great deal about the superiority of the "short-wave regenerative" circuit for receiving the broadcast concerts. You may wonder why it is that so few of the manufacturers of sets now on the market advertise that they use this circuit. The answer is that they don't use it. If they did nine beginners out of ten would get disgusted with radio and quit.

That isn't because there is anything the matter with the circuit. There's nothing the matter with the main switchboard in the principal power station of the trolley company, but you wouldn't advise a novice in electricity to monkey with the switches.

This set, with its two variometers, is about as delicate and hard to manage as anything that can be imagined. At first you get the impression that all it can do is howl and squeal and whistle and "fry." Then, after a few nights of discouragement, you hear the sound of a voice and you quickly turn something to improve it, and it is gone. And, like swimming, you fuss around and are about ready to give up when suddenly you find yourself swimming and after that you don't have much trouble.

If you are through building all the six by six units we have described in these lessons we will "hook the set up," as we "hams" say, and see what it does. But first, have you pasted tin foil or copper foil on the backs of the panels of the units where we recommended it? If not you'd better do it, for you will have a sad time otherwise.

I have already said that the human body is a great condenser, quite as powerful as the beautiful



Here is the hook-up for the famous "short wave regenerative receiver," the best hook-up for getting the concerts but the most difficult to manage. The article explains the change necessary if you have taps and switches on your vario-coupler

forty-three-plate variable that you have bought. With many hook-ups, when you reach out your hand and turn a knob until you hear a signal the way you want it, you are including this human condenser in the circuit without knowing it, and, when you take your hand away, removing the condenser, your signal disappears or the set begins to howl.

In the illustration I am showing the hook-up as applied to the regular manufactured apparatus which you buy in any store. Some time ago I gave a list of apparatus and prices, totaling $58 as approximate for the best circuit that could be used. This was the one I had in mind.

Let me say here that the illustration does not show the usual taps and switches on the vario-coupler. If you use them (and you should) the aerial hooks to the shaft of one switch blade and the variable condenser to the shaft of the other. If you have unit taps on your coupler, you won't need the variable condenser.

You'll probably be bothered by body capacity with these instruments if you have bought them. If you are you will have to arrange some sort of "body capacity ground," as it is called. If you are mounting them in a cabinet paste tinfoil all over the back of the panel and the inside of the bottom and sides, cutting it away wherever you have to make connections, except at the "ground" binding post. See that the tinfoil has good contact with this post and it will then carry off the body capacity and divert it to the ground so that it will not affect the set so seriously.

If you aren't mounting the instruments you had better stand each of them on a piece of cardboard on which you have pasted tinfoil. But be very careful that no metal parts touch the foil or your set may not work at all. Or you can paste a piece of paper over the tinfoil.

Now get a number of ordinary paper clips—the kind made of steel wire—and solder two on the two ends of a number of pieces of wire. The number and length will depend on how you are arranging your apparatus.

The idea is to slide one clip over the cardboard so that it makes good contact with the tinfoil and slide the clip on the other end of the wire to the tinfoil under the next instrument. In this way you must connect the tinfoil under all the instruments in the same line and the other end of the line goes to the ground binding post on your variable condenser, if you use one, or if you don't, to the ground binding post on your variocoupler. The object is to see that all these pieces of tinfoil are connected to the ground wire somewhere.

This is a nuisance, I know, but it isn't one-tenth the nuisance that body capacity is. And this hook-up is hard enough for the novice to operate without any extra troubles thrown in.

The thing that makes this a difficult set is the number of different adjustments and each of them is critical. You have the primary switch, the coupling, the secondary switch (on some forms of coupler) the variable condenser, the two variometers and the rheostat which controls the brilliancy of the filament light. And this rheostat adjustment is important, for, if you are the least bit too bright in your filament, your signals will be distorted and you will get annoying noises in your phones.

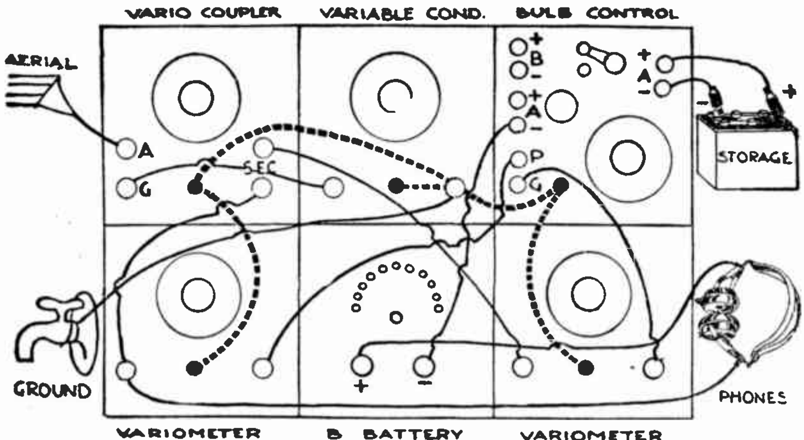
With this set you've simply got to be dogged and obstinate and keep at it until you learn to handle it. And then you'll have an outfit that will compare favorably with anything that anybody can get and you are ready to put on two stages of amplification and a loud-speaking horn.

PUTTING THESE "UNITS" TOGETHER

If you have been building all of those six-by-six-inch units that I have been recommending in these articles, you can now put together a "short wave regenerative" set and you will see what a neat-looking bit of radio apparatus they make. And you will also realize how convenient this system is when you come to wiring up your set.

First, the dotted line represents the wiring for the "body capacity ground." You may think I have been over-emphasizing this body capacity business, but just hook up the set and try to work it without a body capacity ground and you'll change your mind.

I don't mean to say that it can't be done. But it's a nuisance. If you haven't cared to go to the trouble of "backing" all your panels with tinfoil, you'll have to use what a friend of mine always refers to as a "magic wand." This is simply a stick of thin, but stiff, wood about eighteen inches



Here's the "short wave regenerative" hook-up as used with the "unit" method of building advocated in past issues of E-Z RADIO. Six of the units fit together and give the appearance of a complete cabinet. Best of this system is that, if you want to try other hook-ups, it's easy to take apart and put together another way. The dotted line is the wiring of the "body capacity ground"

long on the end of which you wind a tip of insulating tape or rubber or anything that has considerable friction to it. This wand is to turn the various dials and so make the adjustments necessary to receive signals.

Not long ago I saw in one of the radio magazines that the same thing could be done with a long lead pencil, but I never was able to make it work. The lead in the pencil seemed to make itself a part of the condenser which the human body is and I found this "body-capacity" effect just as bad with the pencil as without.

The wand, however, does the trick. But it is a great nuisance and it is frequently very difficult to make a fine adjustment with a stick the length necessary to overcome this capacity. And with this hook up you will often find an adjustment only the width of a pencil line will make the difference between good and bad reception.

As the units are arranged in the illustration, you will notice that the variocoupler and the two variometers are placed as far apart as possible. This is to keep them outside of the influence of each other's "magnetic fields," which I have already explained. The variometers, built in this unit system, would probably be far enough apart even if the units were next to each other, but in radio, as in everything else, it's better to be safe than sorry.

There is no set way of going about operating this hook-up. To a very large extent, it is simply a case of hunt around until you find the signal you are after. Then, on succeeding evenings, you can usually find it somewhere around the same adjustment—but not always.

Of course, the first thing to do is to find your desired wave length roughly on the variocoupler. This is done by varying the number of turns of wire you use in the coils of the variocoupler and at the same time varying the coupling. The coupling is varied, as already explained, by rotating the ball back and forth if you are using the standard variocoupler, by raising or lowering the top coil if you are using our home-made spider-web coupler and, if you are using an old-fashioned loose coupler, by pulling the inner coil out of the larger one or pushing it in. Personally, I have had very little success with a loose coupler with this hook-up. The adjustments necessary are too fine. I have been able to hear the speech and music fairly loudly, but have never been able to "clear it up" so as to make it really satisfactorily distinct. I much prefer the home-made spider webs to any other kind of coupler, and by the knob and thread which I have described, you can get the very finest kind of adjustments of the coupling.

Be careful of the brightness of your filament in using this hook-up. If your phones are noisy, try less current. If that doesn't stop the noise, use the same amount of current and see if altering the setting of one or the other of the variometers won't stop it.

When you hear the first faint sound of the broadcast, get it as clear as you can with the coupling and condenser (if you are using one) and then try slowly and carefully altering the setting of the two variometers. Try the rheostat again, too, every now and then. And if you have mounted and tapped the forty-five-volt "B" battery as I have advised, try a little more or less current from that.

That, unfortunately, is all I can tell you about operating this set. It is a matter of sticking at it until you master it.

THE "EDISON EFFECT" MADE ALL THIS POSSIBLE

Radio would not seem half so complicated to the average boy or man if it were not for the scientist's love of big words. It sometimes seems as if he deliberately hunted around to find the longest possible name for the smallest possible object.

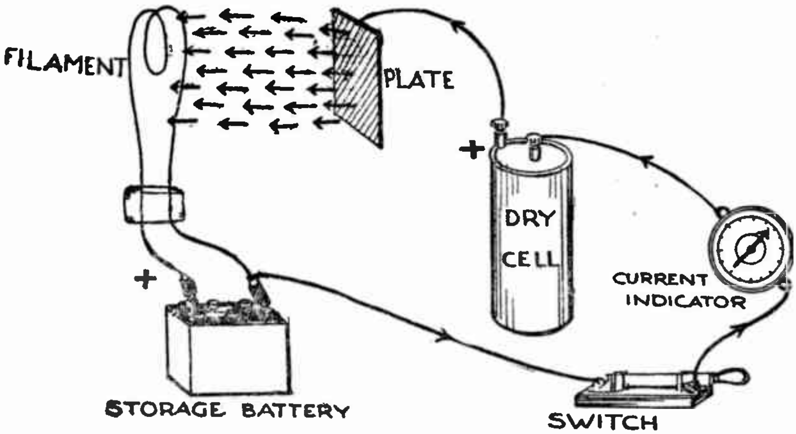
Today we are going to meet the smallest thing in the world and learn how it is that this little thing which is so tiny that it has never been seen by man even with the most powerful microscope is responsible for all this radio craze, and when you come right down to it, really runs the most powerful machinery that it is possible for man to build.

The tiny mite's name is electron.

You have all heard of molecules and atoms. Once upon a time scientists thought that the molecule was the smallest possible subdivision of matter. Then they began to see that something was happening inside of the molecule and, after long and careful study of it, they discovered that each molecule was made up of a great many still smaller things to which they gave the name of atoms.

Then, for a number of years, they went ahead on the theory that nothing could be smaller than an atom. They even made a close study of all the substances that we know and computed the weight of one single atom of each substance.

They took the extremely thin



EDISON EFFECT

This illustration shows what is known as the "Edison effect." When the filament is lighted the measuring instrument between the switch and the dry cell proves whether a current is flowing from the plate across the open space to the filament. The current will flow when the plate is connected to the positive post of the dry cell, but not when it is connected with the negative post

gas known as hydrogen and used the weight of an atom of hydrogen as standard, just as we use the pound as a standard of weight for things in everyday life. They count the weight of an atom of hydrogen as 1 and they print in their text books lists of various substances with the figure after them which indicates how heavy they are compared with this atom of hydrogen. Thus the "atomic weight" of hydrogen is 1 and that of lead is 206.4. A table of atomic weights of this kind gives the scientist quite a clear idea of any substance he may be discussing.

Now the atom itself is so indescribably tiny that even our microscopes will not show it to us and all the things that are known about it are the results of deductions made from long and complicated experiments and mathematical formulae. So, for a long while, everybody was satisfied that scientists had found the very smallest thing that matter could be divided into even in theory.

But now the atom is found to be quite big in comparison with the still smaller particles which compose it. These particles are known as electrons. Scientists now believe that the atom has a center or nucleus of some kind surrounded by these tiny electrons.

Perhaps you will wonder what this lesson in physics has to do with radio. The answer is very simple. It is the electron which makes possible the "Aladdin's lamp" of science which we call the audion bulb. It is in fact the electron which runs our telephone and telegraph system, our trolley cars and the huge electric plants that are developing millions of horsepower every hour in the big steam and hydraulic systems all over the world.

It was the study of the earliest type of electric light made by Edison which first gave scientists the suspicion that such a thing as the electron existed. You have all seen the dark yellowish brown deposit which gathers on the inside of an old electric light after it has been used a long time. It is believed that most of this brownish color is caused by a bombardment by millions and millions of electrons shot out by the white heat of the filament.

Edison, in his experiments, once enclosed a plate of cold metal inside a bulb with the filament and connected the plate by wire with an ordinary battery. He lighted the filament and his experiments proved a very remarkable thing which nobody was able to explain for many years afterward.

Everybody knows, of course, that a current of electricity of moderate power will not jump across a space between two conductors. According to this well known fact, no current of electricity should have flowed from the plate to the filament in his experiment. And, when he had the negative side of his battery connected to the plate, no current did flow.

But when he connected the positive side of the battery to the plate he was astonished to find that, when he lighted the filament, his measuring instruments showed a very decided current flowing across the open space from the plate to the filament and, when he turned off the electricity in the filament the current from the plate stopped flowing across in spite of the fact that the plate was still connected to the positive side of the battery.

This proved that the lighting of the filament, in some way, made this space between the filament and the plate a good conductor of electricity, providing the electricity were what we call positive but not if it were negative.

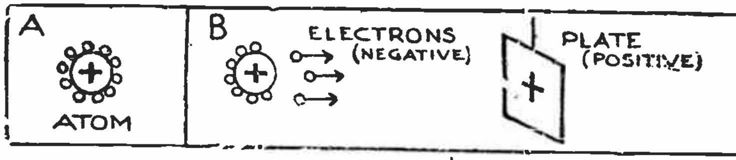
Scientists who heard about this called it "the Edison effect." It was not until many years afterward that it was studied separately and began the career that has produced the marvels of radio as we know them today.

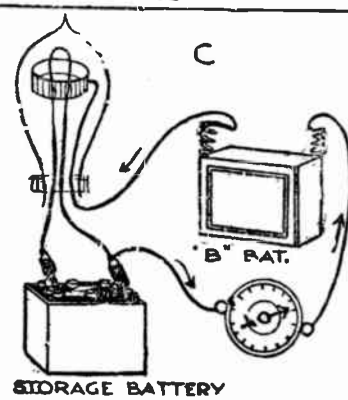
HOW FLEMING USED THE "EDISON EFFECT"

In the last article we talked about the part that the tiny little mite known as the electron plays in radio work. When Edison discovered that something or other took place inside his electric bulb when he lighted the filament and that this something, whatever it was, furnished a good conducting path across the space between the plate and the filament when the plate was charged with positive electricity, but not when it was charged with negative, he was too busy with other matters to hunt for an explanation, but some years later when the telephone companies were seeking means of carrying the human voice across the continent and when wireless companies were hunting some method of extreme delicacy for receiving weak signals, they began studying this "Edison effect," and the results have been remarkable.

Briefly, the conclusion arrived at is this:

The atom is not by any means the smallest subdivision of matter. According to the theory now held, the atom is a group of infinitely small particles. In the





A, in the above illustration, gives a rough idea of what an atom is. It shows a nucleus, containing a charge of positive electricity, surrounded by a number of electrons, each containing a negative charge and placed in such number that the negative exactly equals the positive. B shows the atom disrupted by the heat when the filament of the electric light is lighted. The positive electricity on the nearby plate attracts and captures the negative electrons thus liberated. Below is the bulb devised by Fleming with the plate made in the form of a ring around the filament and the flow of electrons causes a flow of the electricity in the circuit containing the measuring instrument, the "B" battery and the plate

center is the largest of a group which is called the nucleus. This nucleus is surrounded by a number of still smaller particles which we call electrons. The atom, in other words, is built much like a blackberry, the nucleus being the center of the blackberry and the electrons being the little berries around it, only the atom is as much smaller than the blackberry as the blackberry is smaller than the entire earth.

Scientists now believe that, in its natural state, this nucleus contains a certain charge of positive electricity and that each electron contains a charge of negative electricity. In fact, it would be more nearly accurate to say that an electron IS a charge of negative electricity rather than a particle of matter.

This conception of the atom assumes that the positive charge of the nucleus exactly equals the total negative charges of the electrons attached to it and consequently as these two charges exactly equal each other the atom itself is without measurable electricity. If we were to take away some of the electrons there would then remain a larger positive charge than a negative charge or if we were to add electrons to it there would then be a larger negative charge than positive charge. When this is done we call the atom an ion, either positive or negative—but you needn't worry about that because we are concerned only with electrons and they are always negative.

The heat that is caused when the filament of an electric light is lighted disrupts the atoms of which it is composed. A certain number of electrons are released and expelled.

Now we know from our school books that positive electricity will attract negative, but will repel positive. In other words, like repels like, but attracts that which is unlike. Consequently, when the plate inside the bulb is charged with positive electricity it will attract these negative electrons which are being expelled by the filament.

There are two ways of explaining what takes place after that, but whichever one you prefer, the result is the same; the electrons permit a distinct current of electricity to flow from the dry cell to the plate and apparently across the open space from the plate to the filament.

One explanation is that the electrons themselves form a path and that the positive electricity flows across this path in the opposite direction from which the electrons are flowing much as Richard Barthelmess carried the unconscious girl up stream across the down-flowing blocks of ice in that marvelous scene in "Way Down East."

The other explanation is that each electron, as it strikes the plate, combines with a tiny charge of positive electricity and that when there are enough electrons to equal the positive charge they simply neutralize each other and become nothing. This would mean that there was really no positive charge flowing across the space, but it would cause a current to flow through the battery circuit because the dry cell would constantly be called upon to furnish more positive electricity to meet the demands of the negative electrons landing upon the plate and neutralizing the positive charge that was there.

We are not concerned here with the academic discussion of which of these theories is correct; all we are interested in is the important fact that these electrons do, in some manner, cause current to flow in the dry cell circuit, and if we put a pair of telephones in the place of the measuring instrument shown in the illustration we can hear this current flowing and that is what we want in radio.

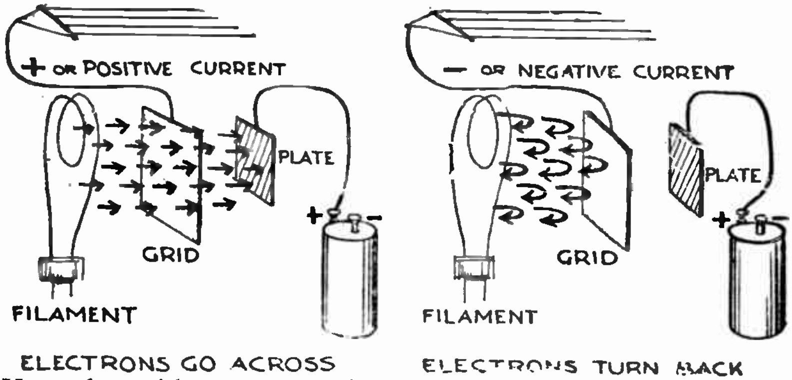
HOW DE FOREST MADE THE MODERN AUDION BULB

We have already seen the action that takes place inside an electric light bulb which has in it a plate of metal charged with positive electricity. This positive charge draws negative electrons across the space and causes a current to flow in the circuit in which we have our telephones.

Fleming used this principle in a bulb which he devised and in which he constructed the plate in the form of a ring or hoop around the filament. By this method he was able to capture the electrons which were being sent out in all directions by the heat of the electric light.

We have shown that this current flows only when the plate contains a charge of positive electricity. If it is charged with negative electricity, the electrons are repelled because like electricity repels like and attracts unlike.

Dr. Lee DeForest made an improvement on this valve and this improvement is what has made our modern radio broadcasting possible.



How the grid acts as a trigger in an audion valve. To the left a positive current is received by the grid from the aerial and the negative electrons are drawn from the filament and captured by the positive plate, thus causing a flow of current in the telephone. To the right the grid has received a negative charge from the aerial and this repels the negative electrons and sends them back to the filament before they can be captured by the positive plate. Consequently no electric charge affects the telephone

DeForest's idea was to introduce between the plate and the filament an element which he called a "grid." This grid, in practice, may take any one of a number of forms. It can be made of mesh like a fish net or piece of mosquito netting, or it can be made of straight bars like the gridiron marked out on a football field or like the skillet in which the cook broils chops.

Now let us see what the advantage of this grid is.

In the Fleming type of valve or bulb—the same thing is meant by both names—it took a comparatively strong charge of current to make it function. What we want to accomplish is to have the current strike the telephone all in one direction. In other words, it must be a succession of positive charges or a succession of negative charges, but not positive and negative alternating as rapidly as they do in radio work. And as the radio signals received by aerials are extremely weak, it was desirable to devise an apparatus more sensitive than the Fleming type of bulb.

DeForest places the grid around the filament and very close to it. He connects this grid to the aerial so that the incoming radio signals go directly to the grid. The grid is between the filament and plate.

Bear in mind the fact that the plate which is connected to our dry cell, or "B" battery, is always positively charged, and this positive charge will flow across to the filament as soon as the space between is sufficiently filled with negative electrons.

DeForest's grid acts as the trigger which releases or stops the flow of electrons to the plate.

Radio signals, as we know, come in the form of what we call alternating current—that is, the electricity caused by them is first positive, then negative, then positive again and negative again, and so on, the alternations coming so rapidly that a telephone diaphragm cannot work fast enough to respond to them. So what we want to do is to eliminate the negative currents entirely and send only the positive currents into the telephone.

When a positive alternation reaches the grid in a DeForest bulb it at once attracts the negative electrons constantly thrown out by the hot filament and brings them out to where the positive charge on the plate can easily capture them, and so the space between plate and filament is filled with electrons which permit the dry cell current to work the telephones.

Now the next alternation which we get from the aerial to the grid is negative. We know that negative repels negative, and as the electrons are all negative the negative charge in the grid repels them and sends them back to the filament before the positive charge on the plate can capture them.

Consequently no current flows from the plate to the filament when the grid is negative and no impulse affects the telephones.

But, you may say, the positive charge on the plate is so much stronger than the weak negative charge on the grid that it ought to capture the electrons in spite of the negative grid.

This natural difficulty is overcome by placing the grid very much nearer the filament than the plate is. You know that light becomes much weaker the further you are away from it. In other words, if you get a certain amount of light from a lamp two feet away from it and then move four feet away from it you do not get one-half the amount of light, but only one-quarter. The power of the electric attraction varies in this way, and by means of placing the grid in a certain relation to filament and plate the trigger action of the grid is made effective and it passes electrons only when it receives a positive charge from the aerial and shuts off the flow of elecrtons when it receives a negative charge.

THE AUDION BULB AMPLIFIES SIGNALS

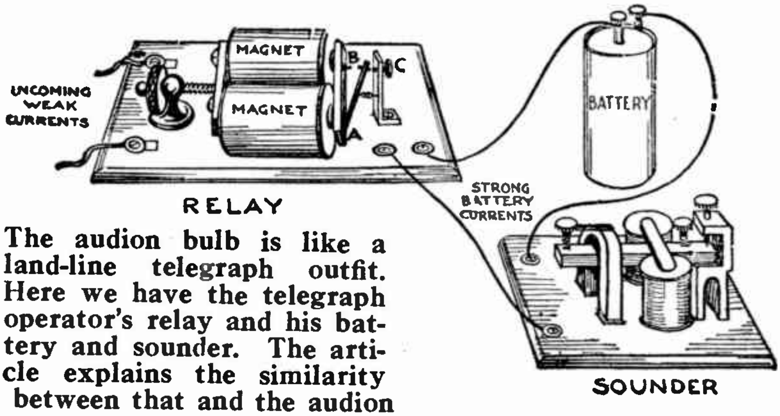
Now that we have seen how the audion bulb, as developed by Fleming and DeForest, acts as a traffic cop in a one-way street and permits electric currents to strike the telephones in one direction only, let us turn our attention to another and even more valuable ability which this Aladdin's lamp possesses.

This is the ability to receive extremely weak currents from the aerial and deliver them to the telephones thirty or more times as strong as when they were received.

First let us take a well-known instrument to illustrate this effect. This instrument is the relay used in ordinary land line telegraphy.

The illustration shows this relay hooked up to the sounder and dry cell battery.

In each telegraph station there is a set of these batteries connected to the sounder and delivering so strong a current that the sounder will be raised or lowered with such a powerful pull that its impact can be heard all over a large room. It is not the electric current sent from the distant station that makes this loud sound.



The audion bulb is like a land-line telegraph outfit. Here we have the telegraph operator's relay and his battery and sounder. The article explains the similarity between that and the audion bulb

That current does not come in strong enough to operate the sounder. It is the strong batteries under the operator's table that do this and the weak signals that come in from the distant station merely work a delicate trigger which controls the current from these batteries.

The illustration shows the relay first. The currents sent from the distant station may start from that station quite strong, but the resistance offered by the many miles of wire over which they travel weakens them, and they may arrive at the relay so feeble as not even to make a visible spark if the two ends of the wire are touched together.

The principal part of the relay is the two coils seen mounted in the middle of it. We have already learned that when electricity travels around a coil of this kind through a great many turns of wire it creates magnetism and even a very feeble current if sent a good many hundred times around a core of soft iron will make this iron a magnet, much like the horseshoe magnets that you buy in the toy shops, and this magnet will be strong enough to attract a small piece of metal if placed near it.

You will see in the picture the little metallic trigger marked B. There is a little spring that holds it back against the post marked C. While it is in this position no current flows from the battery. When the trigger is pressed against the coils it then makes contact with a metal point there and the current of the battery flows from the battery through that point down the trigger, and along the wire connection and so to the sounder, and permits the strong battery current to operate the sounder.

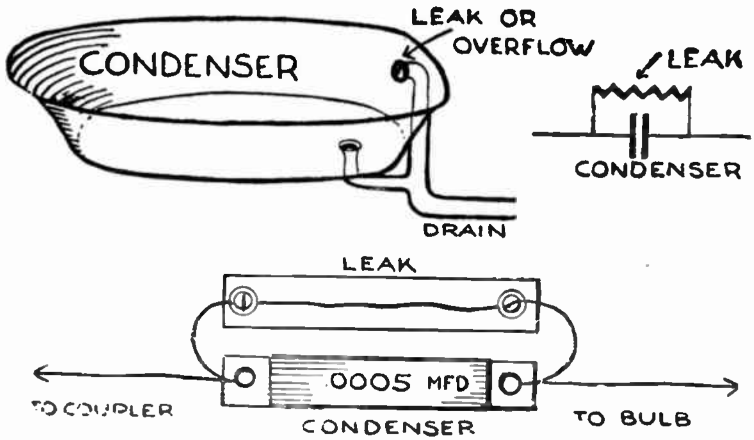
Thus when a feeble current comes into the relay it causes the coils to become magnets; these magnets draw the trigger over to them and as soon as it touches the metallic contact point the strong battery current operates the sounder. All this, of course, is done instantaneously because electricity travels at the tremendous rate of nearly 187,000 miles in a single second.

And, as soon as the incoming feeble current stops, the coils cease to be magnets, and the spring pulls the trigger back away from the contact point, thus stopping the flow of current from the battery.

It is in just this way that the feeble currents which we receive in our aerials govern the very strong currents of our "B" batteries which operate the telephones. These currents from the aerial, weak as they are, assist or stop the flow of electrons from the hot filament to the plate. It is only when these electrons flow that the powerful currents from the "B" batttery can operate the telephone.

The electrons inside the bulb are like the trigger of the telegraph relay. The grid which receives the weak aerial currents is like the two coils of wire which become magnets when the incoming feeble currents flow around them. The current from the "B" battery is the same as the current from the batteries under the operator's table, and, instead of the sounder of the telegraph outfit, we have our head telephones.

THE GRID CONDENSER AND GRID LEAK



The grid condenser and grid leak might be likened to a bathtub as explained in the accompanying article. To the right you have the symbol used in electrical diagrams to indicate the grid condenser and grid leak. The two vertical lines placed near together, but not touching, always indicate a condenser. The saw-toothed line above it always indicates what is known as a resistance—something that opposes the flow of electricity, but will allow a certain amount of it to pass. Below is a picture showing how a grid condenser and grid leak are hooked up on a home-made set

For a man who started out with the promise not to be too technical, it strikes me that I am getting you into rather deep water with this series of talks on the audion bulb and how it works. But there is one consolation about it; you can operate your set without knowing these things and so you can skip this particular part if you want to.

But if you do you will miss half the enjoyment of radio. The more you understand of what goes on inside your set the more fully you will get the romantic appeal of the marvels of this new science, and, incidentally you will get a better idea of just what to do when you hear funny sounds in your phone which would completely puzzle a man who didn't know what caused them. These sounds will frequently interfere with the reception of the broadcasts and it is only by understanding them that you will be able to eliminate them with any degree of certainty.

Most beginners seem to be very much puzzled by the term "grid leak. They don't know what it is and they don't know what it does and yet they know they have to have it.

Well, a grid leak is an extremely simple thing. Make a pencil mark about an inch and a half long on a piece of cardboard and you will have a grid leak.

In our talk on condensers we learned that a condenser is a little apparatus which has the ability to store up electrical energy and discharge it all at once. You have seen in all the radio shops neat little pieces of apparatus marked "grid condenser" and you may have wondered why such a cheap little thing, costing only 35 cents if you buy it, or requiring only the tinfoil and piece of wax paper from a package of cigarettes if you make it, should be so important.

Cheap as it is, simple as it is to make, you could not hear the signals through an audion bulb without it.

You already know that the signals received in your aerial come in the form of alternating current — that is, electricity caused by them in your receiving set is first positive, then negative, then positive and again negative, and so on.

But these alternations come with such inconceivable rapidity that the human ear would not be capable of hearing them even if the diaphragm of the telephone could vibrate so fast—which it cannot. When an amateur is sending on a 200-meter wave length, these alternations take place about three million times in a single second. When a broadcasting station is sending on a 360-meter wave length, the alternations will be above a million and a half times a second.

Now the human ear cannot make us conscious of vibrations faster than 20,000 times a second and even these vibrations are too fast for most ears and are certainly too rapid to work the comparatively heavy and stiff diaphragm of a telephone. The best response between telephone and human ear is with alternations of about 1000 a second.

It is easy to see then that something must be done to reduce 3,000,000 vibrations to 1000 vibrations. The cigarette tinfoil and the lead pencil mark will do it.

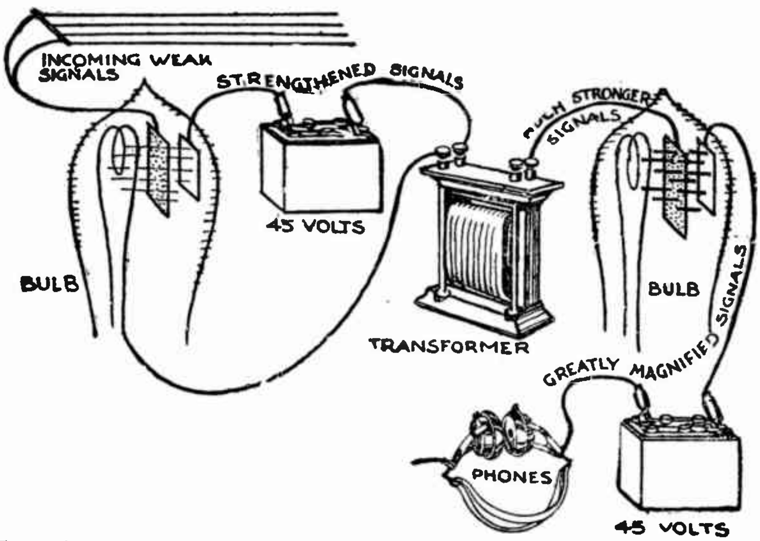
The little condenser which we place between the aerial and the grid of our bulb stores up a great many of these tremendously fast oscillations. When the condenser gets chock full of them, they leak out and there is just enough lead in the pencil mark to permit them to leak across and get to the grid.

The pencil mark also has such a resistance that the current is not strong enough to leak across until the condenser is chock full. And the condenser is so designed that it will get chock full and the currents leak across just about 1000 times a second. In that way the trigger of electrons inside the bulb is worked 1000 times a second and the "B" battery current operates the telephone diaphragm at that speed, which is just what we want.

You might compare the grid condenser and grid leak to an ordinary bathtub. You turn the water on and it flows until it reaches the drain and when it gets at that height it flows out. In this same way the electrical energy piles up in the condenser until it reaches a certain strength and then it flows across the lead in the pencil mark, only, instead of flowing slowly as the bathtub does, it empties itself all at once.

Let me say in closing that some bulbs do not seem to require grid leaks. I have lately been using A-P and Radiotron 201 (both amplifiers) as detectors and I have had excellent results whether I used the leak or not.

HOW THE AMPLIFYING BULB WORKS



Here is a detector and one stage of amplification. The incoming weak currents are multiplied in the detector valve, are again multiplied by the transformer and still further multiplied by the action of the second valve

Everybody who is installing a radio set wants one or two stages of "amplification." They know that they cannot operate a loud-speaking horn or phonograph attachment without building up the strength of their signals to such an extent that they will be unpleasantly loud in the ordinary head telephones. And so the "two-stage amplifier" is so much in demand that many companies are putting out neat little cabinets containing the detector bulb and the two amplifying bulbs with the rest of the necessary apparatus inclosed.

If you understand the operation of the ordinary audion bulb, it is a perfectly simple matter to understand the operation of an amplifying unit.

We have learned, in our studies of the audion bulb, that comparatively weak currents of electricity that come in from the aerial and are transferred to the grid inside the bulb act as a trigger which alternately releases and stops the strong currents of the "B" battery in the head telephones.

Now suppose we take these greatly strengthened signals and, instead of sending them into the telephones. send them into the grid of another specially designed bulb. Again they will operate a still more powerful trigger and deliver to us added electrical strength from another "B" battery.

If we take this added strength and put it into a pair of phones we are using what we call "one stage of amplification."

If, instead of using the phones at this stage, we take this amplification and transfer it to the grid of still another bulb we get a yet more powerful trigger effect which permits us to add the current of another "B" battery to our signals. That would be two stages of amplification. And so we can build up until we finally receive signals several thousand times as strong as those which come in through the aerial.

This strengthening effect is further added to in practice by the use of what we call "amplifying transformers."

We will not now go into an explanation of how a transformer works. It will be sufficient to know that you can put a comparatively weak alternating current into one coil of a transformer and it will come out from the other coil with its strength multiplied a great many times.

And so in amplification we keep multiplying and multiplying the strength of the weak currents brought down to us by our aerial.

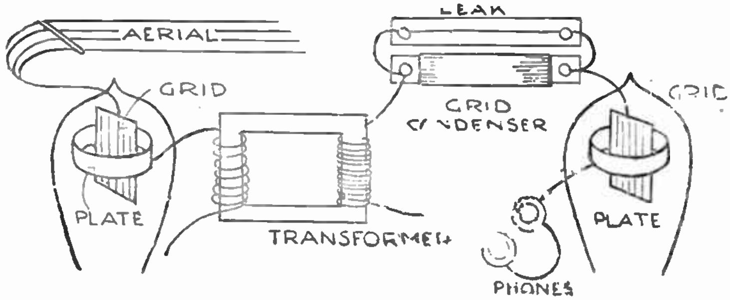
First the audion detecttor multiplies the current by means of its trigger action. It is again multiplied by the first transformer and sent into the first amplifying bulb. Here it is again multiplied by the trigger action of the bulb and again multiplied by the second transformer, which sends it into the second amplifying bulb where the trigger action still further multiplies it.

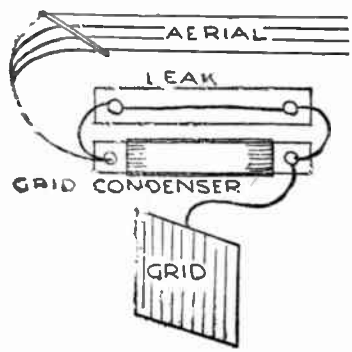
And so we can keep on building up until we get a dozen or more stages of amplification. This would be sufficient to make the sound of a fly's footsteps audible all over a large auditorium, but I do not advise any beginner to attempt to operate a dozen stages of amplification unless he desires to head himself for the insane asylum. In fact, I do not advise the beginner to attempt amplification at all until he has thoroughly mastered the operation of the detector bulb alone. Amplification, unless done by a skilled man, means the distortion of sounds and this distortion can be so bad that it would make Farrar's singing of "Butterfly" sound like the wailings of a melancholy cow.

Beginners have rushed wildly into the market for two-stage amplifying apparatus since this craze started and the consequence is that a lot of people are becoming disgusted with radio when they should merely be disgusted with themselves for attempting to handle delicate apparatus which is far beyond the ability of a beginner.

Don't be impatient for amplifiers and loud speakers. You won't get satisfaction from them until you have learned to master the moods and mysteries of your detector bulb.

THERE ARE TWO KINDS OF AMPLIFICATION





The difference between audio and radio frequency. In the lower picture electric vibrations up to several million times a second come in through the aerial and are divided by the condenser and leak into about one thousand groups a second. This latter is what we call audio frequency. In the upper illustration, the vibrations are carried directly to the grid, are strengthened by the plate, and, still vibrating too fast to be audible, go through the transformer. They come out further strengthened and are then strong enough to operate the condenser and grid which chop them up into audio frequency groups

Whenever I pick up a radio magazine I find myself very much in sympathy with the average beginner who is trying to get an idea of what kind of apparatus to get for his receiving set. The magazines bury him under such a deluge of technical terms that I sometimes wonder how he gets out at all.

Almost everybody who installs a radio receiving set dreams of the day when he can put on a loud speaking horn or one of those attachments which makes the music come right out of his phonograph just as though he had a record playing. He knows, however, that this result cannot be achieved with a crystal detector and that, if he is using an audion bulb, he will in most cases have to have extra bulbs, which are known as amplifiers and which serve to increase the strength of the signals so much that the addition of a horn will make them sound all through the house.

Knowing that he needs amplifiers he turns to his radio magazine and, in nine cases out of ten, he finds himself plunged into a puzzling discussion of the relative merits of "audio" and "radio" frequency amplification. Naturally he doesn't know what this is all about. He is under the impression that amplifiers are amplifiers, and when he finds that there is a difference, he is inclined to be discouraged.

But he need not be. In most cases the amateur will find audio frequency the best for him to handle and whenever he sees transformers advertised he can be fairly sure that they are audio frequency, because if they were radio frequency, the advertiser would be sure to boast about it.

The difference between the two, however, is really very easy to understand. Let us spend a few minutes today studying this difference and then the discussions in the radio magazines will mean something to us.

Everybody knows by this time that wireless work is carried on by means of extremely rapid vibrations of electric energy. The rapidity of these vibrations governs the difference between these two forms of amplification.

Radio waves are made so fast that, in the signals sent from broadcasting stations, there are nearly a million swings back and forth in a single second. This is much too rapid to work the diaphragm of the telephone and, even if the diaphragm did respond, the mechanism of the human ear is not capable of translating them into sound.

When we get to a frequency of ten thousand a second or more we are beyond the power of the average ear. Signals which vibrate faster tnan that are not audible—they cannot be heard and therefore are not of "audio frequency." So we class vibrations above ten thousand as "radio frequency."

To turn a radio frequency current into an audio frequency one, we insert the grid condenser and grid leak. Those two instruments, as we pointed out some time ago, store up a quantity of the current and release it about a thousand times a second and so we get one thousand groups of pulsations and the ear can respond readily to this number. In other words, the vibrations are of radio frequency when they come from the aerial, but the condenser and leak turn them into audio frequency groups.

Naturally the signals as received must be of a certain strength or else they will not be able to fill the condenser and overflow through the leak. It is here that radio frequency amplification becomes valuable. Let us see how it works.

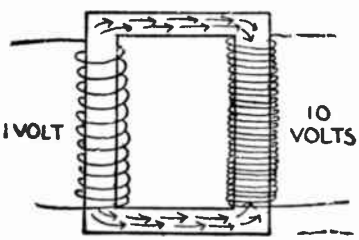
The extremely rapid vibrations that come in from the aerial are carried at once to the grid inside the audion bulb. Here, by means of the trigger action, their strength is greatly multiplied by the "B" battery and the plate and they are sent into a transformer which is especially designed for vibrations of radio frequency. They come out of this transformer still further multiplied and then strong enough to fill the condenser and leak across and so become audible in the phones.

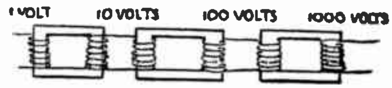
As a general proposition, all the average beginner need know is that, if he can receive signals strong enough to be heard clearly in the phones with a detector bulb only, two stages of audio frequency amplification will work a loud speaking horn satisfactorily for him.

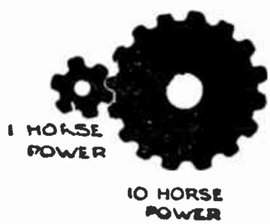
If, however, he wants to hear a station so far away that its signals are not audible with a detector bulb alone, he had better put a stage of radio frequency ahead of his detector and one or two stages of audio frequency after it. If the station he desires to hear is especially far away it will be better to have two stages of radio frequency ahead of the detector. The only safe way to tell is to insert radio frequency until the signals come in fairly distinctly in the phones when the phones are hooked to the detector.

Audio frequency transformers will not give good results with radio frequency currents. You must use specially designed radio frequency transformers and they must be built to operate on the particular wave length you want to hear, for their range of usefulness is very limited.

WHAT AN "AMPLIFYING TRANSFORMER" IS







The sketch on the left, as explained in the accompanying article, gives a rough idea of how a transformer increases a current of one volt to ten volts. The upper sketch on the right shows how a series of transformers might increase one volt to 1000 volts. The use of the two gear wheels is explained in the text

Anybody who has ever used a claw hammer to pull a nail out of a piece of board or has used a long pry to lift a heavy weight has employed the principle of the amplifying transformer.

All of the gears in your automobile are amplifying transformers. The belt which is run from a small motor around the big wheel on the shaft in a mill to run the machinery is an amplifying transformer.

All of these mechanical devices are used to turn a comparatively small amount of power into a much greater amount. So, in electricity, we use amplifying transformers to take currents of small voltage and turn them into currents of much higher voltage.

The spark coil on a gasoline motor is an amplifying transformer which takes the six volts from your battery and turns it into a current of several thousand volts which will cause a spark to jump across the points of the plug and so ignite the gas.

This last bit of mechanism can

accomplish this marvel because it works with alternating currents only a comparatively few times a second. But when we work with currents which change several million times a second, as they do in radio, we introduce a lot of complications which it is not necessary to go into here, but which make it impossible to increase strength in this enormous ratio. These complications act as a brake on the current when we get beyond a few thousand alternations a second.

Calculating the exact construction of an efficient amplifying transformer for radio is no job for a novice and so it is only necessary to have a general idea of what these transformers accomplish and then buy any one of the good makes on the market and hook it up to your set if you are going to use an amplifying bulb.

If you will look at the left-hand picture in the illustration you can get a general idea of how a transformer works. The square framework is supposed to be of iron or steel. We assume that we have an alternating current of one volt coming in through the wire at the left-hand side and going around the turns on one side of the "core," as we call the frame.

Each time the current swings from positive to negative or back it sends out through the core a strong wave of magnetism. This is done in spite of the fact that the wire of both coils is insulated, but we have already learned that while there are substances through which electricity will not pass, magnetism will flow readily through any substance that we know of.

This magnetism then, starting from the first coil, goes around the core and cuts through the insulated wire of the coil on the right-hand side of the framework. This, through one of the remarkable phenomena of radio, causes an actual current of electricity to flow in the wire of the second coil, although this wire has no electrical connection with the first coil, but is thoroughly insulated from it. We say that this second current is "induced" by the first, and the process is what we call "induction."

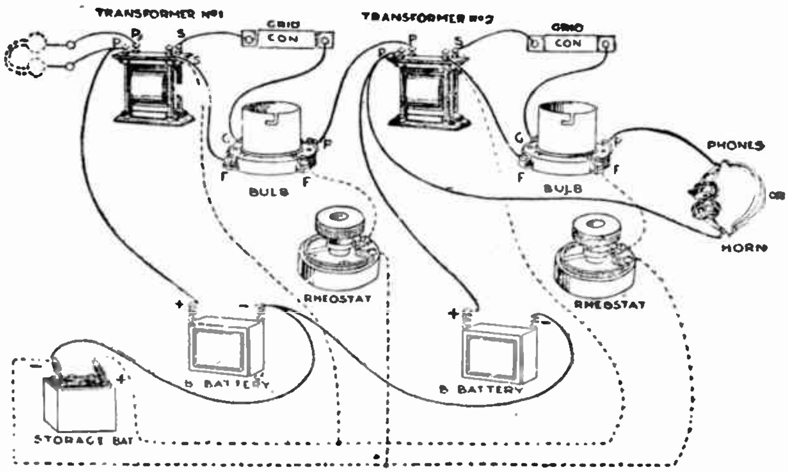
If the number of turns in the second coil is the same as in the first coil, the second current will have approximately the same voltage as the first. If the second coil has twice the number of turns, the current will be approximately twice the first current, and so on.

The amplifying transformers generally used in radio work have about five or six times the number of turns in the second coil as they have in the first. A greater proportion than this has drawbacks which make it undesirable. This is for what we call "audio-frequency." We also use what we call "radio-frequency," but we will not bother about that now.

It is a law of mechanics that if you design an apparatus which increases one element of motion it will have to decrease another element. This can be illustrated by the two gear wheels in the illustration. The small one is supposed to have one horsepower impressed upon its shaft, and if the proportions of the wheels are correctly designed we can deliver ten horsepower or any other horsepower which we desire to the shaft of the second one. But when we increase power in this way we sacrifice speed. So if we wish to reverse the process and make the big wheel turn the small one we will gain speed but sacrifice power.

We can have the same thing illustrated in electricity. A "step-up" transformer increases volts, but reduces amperes. A "step-down" transformer reverses the process.

"TWO STAGES OF AMPLIFICATION"



Here is the simplest hook-up for two stages of amplification. The use of the two grid condensers is optional. They are not really necessary

Before this radio craze swept the whole country the amateur who had a little home-made tuner with a crystal detector and could receive the mystic dots and dashes was looked upon with envy by people who had none.

Then came the audion bulb, with its marvels of making radio speech sound human and the amateur with the crystal graduated to a detector bulb and the novice with nothing graduated to a crystal. Now we have all moved up one step further. The amateur who knows anything about radio at all is no longer satisfied with the detector tube that he once thought so wonderful; he will talk nothing but "two stages of amplification."

The man who has a crystal is dreaming of the day when he can get a bulb with the great point in view all the time of some day arriving at this two stages of amplification.

Anybody who has hooked up a set with an audion bulb detector will find no difficulty in adding this two stages of amplification—providing he has the necessary money. The two stages can be added directly to any of the regular regenerative hook-ups by following the simple diagram which accompanies this article.

In this picture the phones shown in dotted lines are the phones used with the detector bulb alone. In adding the amplifiers you remove those phones and hook up those binding posts to the bindng posts marked B and P on the first transformer. You can use the same storage battery to light all three filaments, but you will have to have another "B" battery to add to the one you use with the detector. The "B" battery shown on the left hand side of the illustration next to the storage battery is the one you already have.

The dotted lines going from the storage battery show the wires that go to light the filaments. I have made them dotted simply to emphasize the distinction between them and the other wires. Many hook-ups for two stages of amplification use the one rheostat to control the brilliancy of both amplifying bulbs, but I have found it invariably best to put in separate rheostats for individual control.

Let us see now what we will need and what we will have to spend to add two stages of amplification to our present regenerative hook-up. The prices which I give are average and you may have to pay more or less, according to the make of apparatus you use:

2 amplifying bulbs	@	$6.50	$13.00
2 transformers	@	5.00	10.00
2 grid condensers	@	.35	.70
2 sockets	@	1.00	2.00
2 Vernier rheostats	@	1.50	3.00
1 45-volt "B" battery (tapped)			3.50
Total			$32.20

The diagram shows where the phones are connected on the second stage of amplification. With powerful transmitting stations within twenty-five miles of you these two stages should give signals so loud as to be uncomfortable with the phones on. Even at much greater distances than that you should get very strong signals and should be able to insert a horn or one of those phonograph attachments in the place where the phones are shown here.

Most people who go to the expense of amplification like to use what is known as the "plug-and-jack" system. In this, the phone cords are attached to a round plug and there are three "jacks" with holes in them to receive this round plug. One of these jacks would be in the place where the dotted line phones are shown on the left and the other would be in the place where the phones are shown on the right. You will notice that the right-hand phones are connected on one side to the plate of the socket and the other side to the plus of the "B" battery through one binding post set on the transformer. Imagine the same arrangement attached to the first amplifying tube and transformer and the place where the phones would be is where you would have your third jack.

The method of tuning then is very simple. You plug your phones into the first jack and tune your circuit until you get best response on the detector tube alone. Then you plug your phones into the second jack and adjust the rheostat and "B" battery until you get maximum strength.

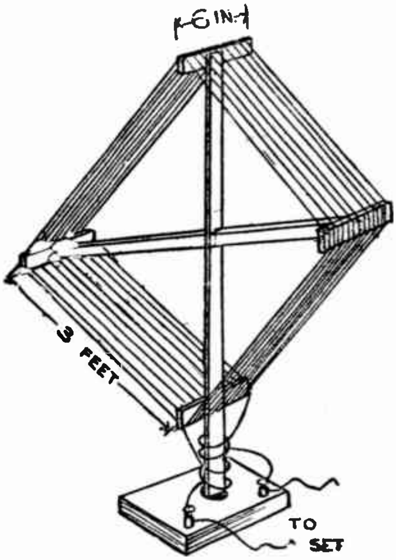
I would almost say that this plug-and-jack system is essential to satisfactory manipulation of a two-stage amplifier.

The reason for this is that you are adding a number of problematical elements all at once and if there is trouble you can, by this method of tuning each bulb separately, determine whether the trouble is in the detector circuit, the first amplifier or the second amplifier.

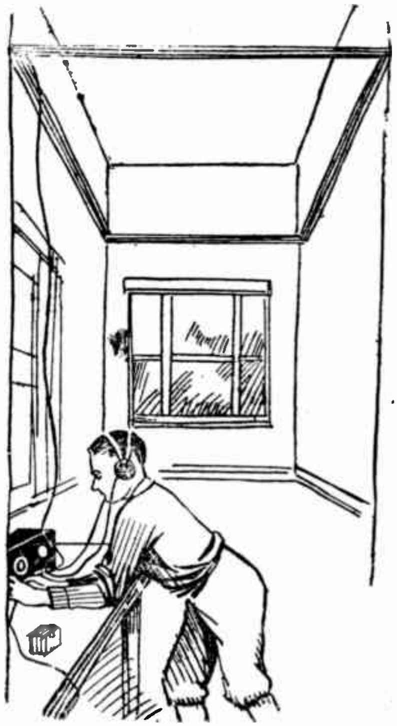
But we will later show the plug-and-jack connections as applied to this hook-up, so you had better wait until then before trying to insert them yourself unless you can find some one in your favorite radio store to show you exactly how to do it.

Meanwhile you'll find this hook-up very satisfactory, as it stands.

THE USE OF INDOOR AERIALS



LOOP AERIAL



To the left is the loop aerial described in the accompanying article. The picture on the right shows an indoor aerial made by winding a long piece of wire around the picture molding of a room, the wires being spaced about an inch apart. This makes a good aerial, but not by any means as efficient as one placed outdoors. The number of turns required for an aerial of this kind can be told only by experience, but it is best to start with something like 150 to 200 feet of wire altogether. One end of the wire is made fast to the ceiling and the lower end is brought directly to the receiving set, and the set then has the ordinary ground wire

The melancholy days of radio are upon us. Even in the wintertime the interference caused by the constantly growing number of broadcasting stations is hard enough to tune out. But now and for the rest of the summer we are confronted with a very different and more pernicious kind of interference and one that cannot be tuned out, if we are using the accepted type of aerial outdoors.

This interference is "static," the discharge of powerful electric currents in the atmosphere. Static is a giant radio spark, but it is produced without any of the fine adjusting devices of our modern transmitting stations, and it has no respect for the wave-length regulations of the United States or any other government.

When a discharge of electricity shoots across the atmosphere some dozens of miles above the earth it uses every wave length known to modern radio and will come crashing in on your phones regardless of your tuning, and if you are using a loud-speaking device there will be evenings during the summer when you could hear the broadcast concerts just as well if you were in a boiler factory. The only thing that I know of that will even partially suppress static is an indoor loop aerial.

So today we are taking up the question of the loop, not only for the benefit of the sufferers from static, but for those who live in cities under such conditions that they are not permitted to put up outdoor aerials.

First, let it be thoroughly understood that the loop aerial is not by any means as efficient as an outdoor aerial. My own experience with loops suggests as a comparison that a loop aerial with an audion bulb and with the best hook-up possible will get about the same response in the telephones as will a crystal detector with a good outdoor aerial placed in the same station.

If, therefore, you are in such a situation that an outdoor aerial and a crystal would just barely bring the concerts to you in your phones you will know that if you use a loop aerial you will most certainly have to use an audion bulb and at least one step of amplification to get satisfactory results. But the fact remains that it is possible by adding the necessary amplifying bulbs to get very good satisfaction with an aerial that you can stand on the floor beside your set and that the loop also removes most of the complicated and expensive regulations of the fire underwriters with regard to wiring, lead-in, lightning arresters and switches and grounds.

The only regulations you need worry about with a loop are those covering the storage battery, and we have already described them.

The usual form of loop is like the picture on the left of the illustration with this article. As a matter of fact, it can be round or square or hexagon, but this square form is the easiest to make and is quite efficient.

For a loop built in this way with dimensions three feet on each side and six inches wide, eight or ten turns of wire will be all that you require. Your regular aerial wire will do for this or you can use a good insulated wire not less than about No. 20 gauge. The wire is wound in a continuous spiral around the loop and the two ends are made fast to the binding posts shown on the stand.

You need not adhere to the dimensions given or to the number of turns. Personally I like to put about twenty-four turns on such a loop, the turns spaced a quarter of an inch apart. I use a bare wire, insulated by tape wherever it touches the frame. Instead of connecting the ends of this wire to the binding posts I make them fast to the frame and use two short pieces of wire for the binding posts, the ends of these wires being soldered to spring clips, which when you press two parts together open their saw-tooth jaws, and when you let go allow these jaws to grasp firmly whatever is in between. I don't know what you call these clips, but they are the same things our grandfathers used on their suspenders.

With these two jaws I can of course clip any number of turns into the aerial whenever I want and receive different wave lengths from 200 to 800.

The great advantage of the loop aerial, if you are in a city where there are a number of broadcasting stations, is that the loop receives only when one corner of it is pointed directly at the waves coming from the sending station. This ability of the loop is used by the government in its radio compass stations.

If you are in a city with four or five broadcasting stations you will hear the one at which one corner of this loop is pointed, and those which are off at an angle of 15 degrees or more will either come in so faintly as not to bother you or will not come in at all. Those which are at right angles to the loop will be completely suppressed.

If, however, you are directly between two stations the loop will respond to both of them equally well because each station will have one of the corners of the loop pointed directly to it. It then becomes a question of your skill in tuning with the receiving set.

This ability of the loop—what is called its "directional properties"—is of great assistance in static season because the static which originates in the parts of the sky not pointed at by either corner of the loop will be minimized or suppressed. It is therefore well worth while if you are the fortunate possessor of a bank account large enough to permit it, to add two stages of amplification to your set, take down your outdoor aerial entirely and use a loop.

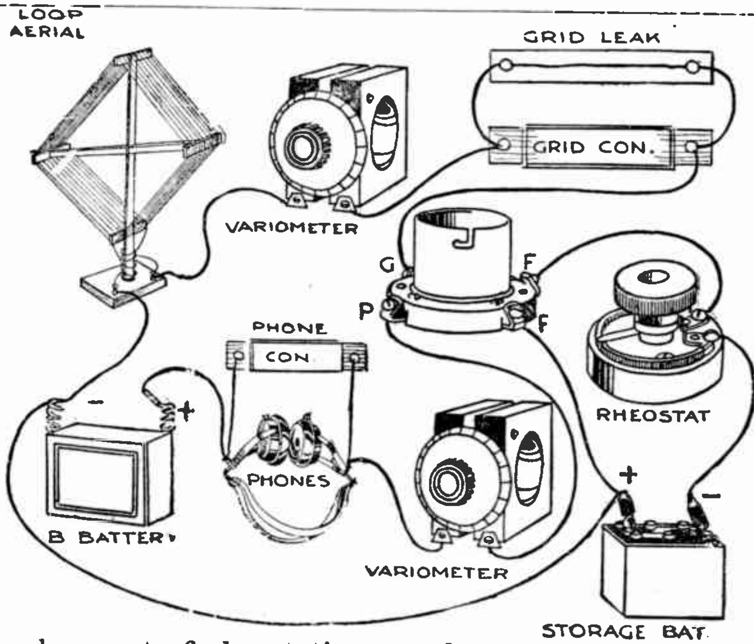
A HOOK-UP FOR THE INDOOR LOOP AERIAL

As a general proposition, it may be said that it is virtually useless to attempt to use a loop with a crystal detector. There have been instances where this has been done, but it is usually through either extremely close proximity to a powerful sending station or to a combination of lucky conditions not often to be found.

There are almost as many different hook-ups for a loop aerial as there are for an outdoor one. The arrangement given in the accompanying diagram is not so simple as some others, but I have personally had more satisfaction with it and am therefore taking it up first.

The diagram very clearly indicates how the various parts of the apparatus are to be connected, so that it will not require any further explanation.

You must not forget in using a loop of this kind that it has very decided "directional properties." Your set will respond only when one corner is pointed in the direction from which the signals are coming. If you have many tin roofs about you or buildings with steel framework they are likely to deflect these waves to such an extent that you may have to point the loop almost due north to get a station that is west of you.



The only way to find a station with this hook-up is to begin by pointing one corner of the loop in the general direction of the station and twist your variometer knobs back and forth several times. If this gives no response turn the corner of the loop four or five inches one way or the other, and try various adjustments of the variometer knobs again.

It is only by feeling around in this way that you will be able to get your signals.

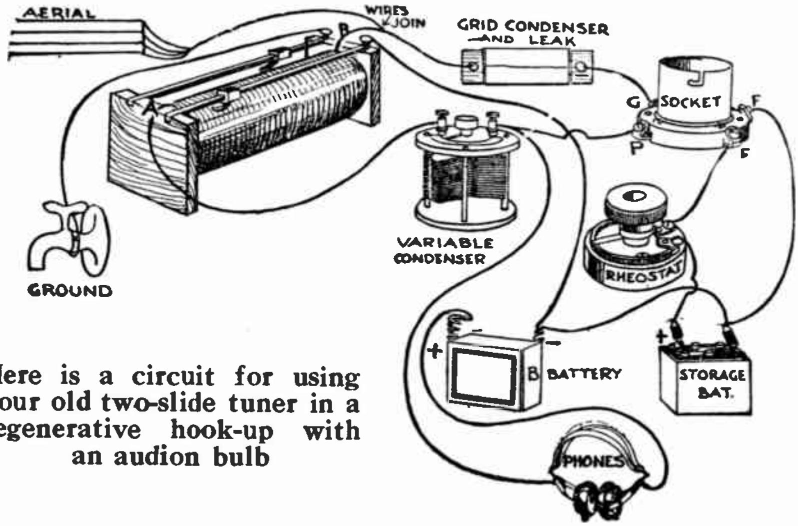
You will probably find a loop of this kind quite sensitive to "body capacity"—that is, to the influence of your own hand and arm, which act as an extra condenser in the circuit when you reach out to turn a knob or the loop. When you take your hand away, after tuning in the signal, you unconsciously remove this condenser and the signal disappears.

I have found it necessary to adjust this circuit by means of a stick of wood about eighteen inches long with the end wrapped around with insulating tape, not because it insulates, but because it is sticky and makes it more easy to turn the variometers or the loop.

If, in spite of all the adjustments you make, you fail to get signals, it may be that your wave length is too short. If that is the case you can lengthen it by adding one or two extra turns of wire to the loop or by using a variable condenser with one binding post wired to one binding post on the loop and the other binding post of the condenser wired to the other binding post of the loop.

USE THAT OLD TWO-SLIDE TUNING COIL

Thousands of boys and men who became interested in wireless telegraphy in the early days made or bought the old-fashioned two-slide tuning coil. This, for the benefit of the newcomers, is simply one long continuous coil of wire wound around a cylinder.



Here is a circuit for using your old two-slide tuner in a regenerative hook-up with an audion bulb

The insulation is removed all along the coil in a straight line, and over this bare-wire line or path two little metal strips can be slid along two rods. As they slide they make contact with the wires over which they pass and the current flows from the wire through the blade or strip along the metal rod on which it slides and so to the binding posts and the receiving set.

This was the best of the home-made devices in the old days, and it was the cheapest of the good devices which the manufacturer turned out.

Most of us wanted "loose couplers" with one coil (the secondary), sliding in and out of the other (the primary). We thought it was necessary to have a primary and secondary, and indeed it was. But when we used the old two-slide tuner we really had both primary and secondary without knowing it, unless we had gone rather far in the study of the then infant science.

The part of the coil included between het aerial connection and the ground connection was the primary; the other was the secondary. It was what the high-brow radio scientists called "conductive coupling—though unscientific readers need not worry about that.

In spite of these high-sounding words the simple fact that we are leading up to is that the old two-slide tuner can be taken down from the garret, the dust brushed off and it can be hooked up to the modern audion bulb so as to give mighty good results as a "regenerative" set and you can get the broadcast concerts on it just about as well as with any of the simple single-circuit hook-ups.

The old tuner, when used with the audion, is not, though, a single-circuit arrangement. It is better.

You have all seen, in the stores, those attractive little mountings that use three coils—either the neat honeycomb coils or the spider web. One coil is used as the primary, one as the secondary, and one as the "tickler." As we have already learned in these talks, the primary is the coil through which the received currents flow from the aerial to the ground, these in turn "induce" or create currents in the secondary, though the two coils have no real connection, and the "tickler" takes the strong electricity from the "B" battery and makes it boost up and strengthen the "induced" currents in the secondary.

This three-coil hook-up is a very popular one, but is likely to be expensive. The two-slide tuner, as used in the illustration, becomes all three coils at once and will do just about anything that the three-coil arrangements will do.

The first part of the coil, between the aerial and the grounded slider, is the primary; the part between the two sliders is the secondary, and the part between the second slider and the connection to the variable condenser becomes the tickler. You can tune the first two parts by moving the sliders, but that leaves the third part, or tickler, fixed, so we put in the variable condenser to tune that and to keep the "B" battery from short-circuiting itself as it would do if the condenser were not there.

The usual two-slide tuner has a binding post for each slider, and one for the ground wire. In this circuit you must make one more connection at the end opposite the ground connection. You can solder the end of a wire there as indicated. Or if the construction of your tuner admits it, you can bend a strip of brass and screw it to the wooden upright on one end so that the edge of the brass goes down solidly and makes contact with the bare wire on the coil.

In tuning in signals, give a guess at the number of turns on the primary part—on a four-inch diameter coil perhaps twenty or thirty, depending on your aerial. Then use your one hand for the other slider and the other hand for the variable condenser. Slide the slider up toward the first one until you hear a moaning in the phones. Then slowly bring it away, all the time turning the condenser around all the way one way and back again.

Hunting by this method will soon give you a signal, if the wiring is correctly done. And the hook-up is capable of remarkably fine adjustments and a very fair ability to tune out interference.

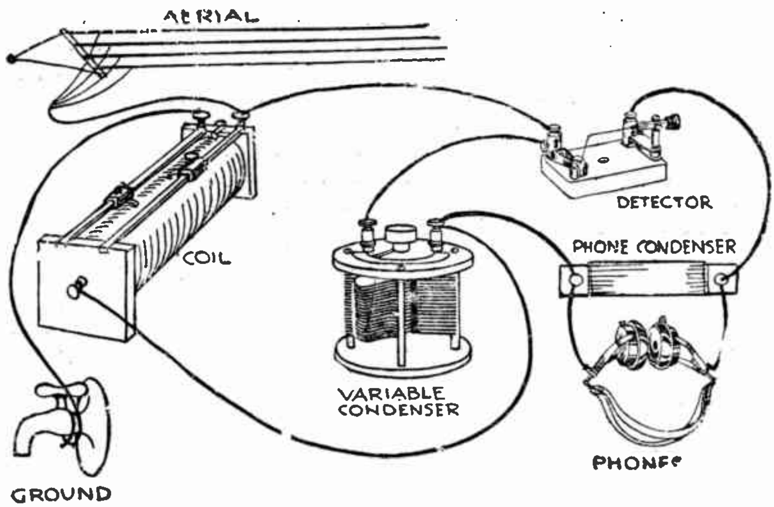
Naturally this hook-up is for audion bulb only and will not do for a crystal detector.

For the benefit of those who have never used a two-slide tuner, and who are not particularly handy with tools, we will soon give directions for building this little instrument, for it is remarkably easy to construct and any boy can make one that will give him the broadcasts and introduce him to the art of tuning.

USE THE TWO-SLIDE TUNER WITH A CRYSTAL

This two-slide tuning coil that we have been talking about does not, of course, necessarily have to be used with an expensive audion bulb. It will give you very excellent results with a good crystal detector if you are within a reasonable distance of a broadcasting station.

The hook-up is simple in the extreme, and the operation very easy. It is, perhaps, the most feasible thing for the beginner to try, and it will give quite a lot



The two-slide tuner in its best hook-up with a crystal detector. The variable condenser is not necessary but makes tuning sharper

of satisfaction, though it isn't by any means the best arrangement. Its cheapness and ease of construction and operation are, however, points in its favor that no other piece of tuning apparatus can beat.

The illustration shows the best arrangement of parts for using the two-slide tuner with a crystal detector. If you haven't been able to afford the luxury of the variable condenser shown, that need not stop you from trying this hook-up. It will function without the condenser, though it will not give such sharp tuning.

However, if you are building your own tuner, there is a way of increasing sharpness without a condenser. That is to build your coil with much smaller diameter and make up for its small diameter by increasing its length. I once built a two-slide tuning coil by winding the wire around an ordinary curtain pole only about two inches in diameter, and I found the tuning quite sharp and satisfactory without a variable condenser.

But there's no doubt about it that a variable condenser is well worth using. Personally I prefer the twenty-three-plate kind to the forty-three in this circuit. It gives a more gradual adjustment and is easier for the novice to use in finding the sharpest point in it.

The diagram is so clear as to make explanations unnecessary. It will be better today to use the space at our disposal by some additional hints on building the tuner. As I have said, a pasteboard oatmeal box or salt box will do, or a cardboard mailing tube can be used. But there's one undeniable disadvantage to all this stuff. It is bound, in time, to shrink with the changes in the weather and your careful wiring will all come loose and probably destroy the usefulness of the coil.

If you have a little money to spend, tubing or formica or bakelite or else of hard rubber makes an ideal outfit.

But by all means the simplest thing to handle and a thing that is just as good as anything else, is a section of an old (or new) rolling pin. This is so easy to saw to fit and to nail the end boards on that it is the obvious thing for the beginner to use. And it won't shrink with the weather and your coil will be just as good ten years from now as it is the day you make it.

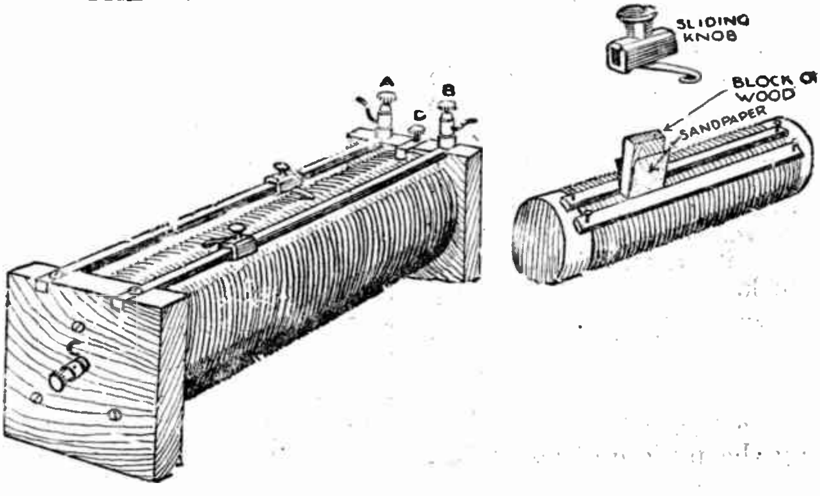
Of course, it's a nice thing to use pretty brass rods to hold your sliders, but it isn't necessary, if you don't want to go to the expense. You can twist a hatpin or a wire paper clip so that it will slide along a wooden skewer, and you can attach the wires from your set directly to this makeshift slider instead of to binding posts. Only, if you use this kind of a substitute, be sure to rig up some means of keeping the ends pressed down to good contact with the bare path along the coil.

I have done this by attaching small weights to the ends of the sliders, just heavy enough to keep good contact. There are a thousand and one things you can do to cheapen this set, and just so long as your contacts are firm you will get the results you are after.

Don't forget, in using this—or any other hook-up with a crystal detector — to provide for your buzzer tester. We have already explained how this is used.

It is the height of folly to use a crystal without having this simple attachment to tell you beyond doubt that your catwhisker is on a sensitive spot on the piece of mineral. If you aren't sure of this, you might fuss around all night with your apparatus — no matter how costly and elaborate it was — and not get a signal, thinking all the time that nobody was sending or that something must have happened to your set.

THE TWO-SLIDE TUNER IS EASY TO BUILD



In the old days of wireless, before we suspected that the sound of the human voice could so easily be sent and received through the ether, we amateurs knew of no coils except those wound around and around a cylinder. These were used in a variety of ways, but the two main kinds were the loose coupler, which is a small cylinder which slides in and out of a larger one, and the single cylinder with the insulation scraped off of a path along the top so that some kind of sliding device could be run along it to make contact with the coil at any part.

The latter type then subdivided in two great classes—the single-slide coil and the two-slide. Some preferred one, some preferred the other. Still others would have nothing but the loose coupler.

Old-time amateurs who gradually dropped out of the game because they never could master the dot-and-dash code (which was the only thing we heard) stowed these tuners away in the dust and debris of the attic and forgot all about them, or else gave them to their sons, who soon put them out of commission.

But broadcasting of music and speech has revived the wireless interest of most of these old-timers and they have wondered if their old tuners would work with the new audion bulbs. As we have already pointed out in these articles, they can all be used. But the best of them, for use with the audion bulb, so far as my own investigation shows, is the two-slide tuner. We have already given the wiring instructions for its adaptation to concert work.

If, however, you are a newcomer in the fascinating game of wireless and you want to install a set as cheaply as possible, you will find a two-slide tuner an extremely cheap piece of apparatus, and it is, perhaps, the easiest to build.

For a tuner of this kind you will find that enameled wire is by all odds the best. Many writers advise silk or cotton-covered wire, but I have found that the silk and cotton unravel and become nuisances in time, even if they are well coated with shellac.

The wire that is insulated with a coating of enamel is very cheap and much easier to work, besides giving much better length of service. Use almost any size, from No. 30 to No. 20. Smaller and larger sizes can be used, but it is best to get wire somewhere around No. 24 or thereabouts.

The tube should be from three and a half to four inches in outside diameter. It can be as much smaller as you like, but the smaller it is the longer it must be. Figure on a four-inch tube about six or seven inches long as standard. If you get it larger you are going to sacrifice sharpness of tuning.

The illustration makes the simple connections quite clear. You will notice an extra connection screwed onto the end between the two slider binding posts. This is just a blade of brass or copper or tin that goes over and makes permanent contact to the last turn of wire at this end. The diagram in the previous article shows how this is connected for an audion bulb.

The illustration on the side shows the best method for removing the enamel along the path of the sliders. Fold a piece of fine sandpaper over a block of wood and, with the slide rods as guides, sandpaper off the enamel until the wires show shiny and bright. But don't rub so hard that you will dig down into the wires and permit two adjacent ones to touch. The enamel should be removed from the tops of the wires only so that, when you look closely, you will see that they are still separated by some enamel in between them.

MAKE YOUR FILES COMPLETE

You will probably find in this issue of E-Z RADIO some article which will make you wish you had the back issue in which the subject was first taken up. This is inevitable in a magazine dealing with a technical subject such as radio. The various issues will build up and expand upon the foundations laid in previous issues.

There is only one way to make your reading on such a subject thoroughly satisfactory. That is to get every issue of the magazine and save them all.

This, the July issue, is the third of E-Z RADIO. You can get the May and June issues by sending twenty cents for each to our publication office.

Then write your name and address on a slip of paper, fold it around a one dollar bill and send it for a six months subscription to start with the August number. Or send two dollars for a whole year.

You'll find each issue increasingly interesting and valuable. We will take up such subjects as indoor and loop aerials with complete dimensions and data and operating directions, the results of experiments Mr. Neely has been conducting ever since last winter. You will find simple and complete directions for handling amplification, both radio and audio-frequency. You will find full instructions for building the new three-spiderweb-coil mount which Mr. Neely has recently devised and which is accomplishing wonderful things in the E-Z Experimental Station at Delanco, N. J.

Subscribe now and be sure not to miss any of this.

E-Z RADIO,

608 Chestnut St.,

Philadelphia.

YOUR PROBLEMS SOLVED FOR YOU

Mr. Neely's offer, made last month, to answer all radio questions from readers of E-Z RADIO brought a veritable flood of letters but they have been taken care of. It was interesting to see the variety of the questions asked. Boys who had only a few dollars to spend wrote asking what they could do with their limited capital. Men to whom price seemed to mean nothing wrote asking Mr. Neely to recommend or buy for them complete outfits.

Within the limits of human possibility, this free service will continue. Any reader of E-Z RADIO is entirely at liberty to write Mr. Neely whether it is to get a hook-up for some special lot of apparatus or to seek the free shopping service we have offered.

When writing, kindly enclose a stamped, self-addressed envelope for reply. Address—

HENRY M. NEELY,
E-Z Experimental Station,
Delanco, N. J.