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RADIO MANUAL

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The RADIO MANUAL

A Comprehensive Treatise on Radio Telephone Reception, With Helpful Hints for the Beginner and Constructive Suggestions for the Experimenter

Including Diagrams of the Armstrong Super-Regenerator, Flewelling and Various Forms of Reflex Sets

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General Outline of Radio Manual

General description nf types of receiving sets.

Crystal Sets
- How operated.
- Range.
- How to make.
- Selection of parts for crystal sets.
- Effect of wire sizes.
- Importance of sensitive crystals.
- Advantage of crystal sets.

Discussion of Vacuum Tube Action

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Buying the Radio Set

Simple Suggestions That Will Help the Beginner Select the Most Desirable Receiver From the Bewildering Array That Confronts Him.

IF, as has been variously reported, there are upward of two and one-half million radio enthusiasts in this country, then the simple, fundamental questinn, "What kind of a receiving set should I buy?" has been asked at least that number nf times. In fact, it is probahle that the same question has been asked repeatedly hy each neophyte hefore he could gather snfficient conrage to take the initial plunge. For it is a difficult question to answer, and out of ten persons to whom it is addressed there will be on the average four contradicting replies. With this preamble, which more or less will excuse the apparently contradicting statements to be made, the following paragraphs will attempt to simplify the selection of the first set for the man, woman or child who has yet to go through this interesting experience.

There are two general classes of radio receiving equipments. The classification is made according to the type of detector utilized in the outfit, namely crystal or vacnum tube, and while some receivers with crystal detectors have and are selling at higher prices than some brands of sets with vacuum tube detectors, the crystal set is nsually considered the cheaper and simpler.

The simplest receiving set that could be employed would consist of a collector wire called an aerial or antenna, a small coil of wire wound on a pasteboard or other insulating tube, a piece of lead ore, called galena, a telephone receiver and a connection to a handy cold water pipe. Such an array of equipment could be purchased complete fnr $2, but its ability as a receiver of radiophone broadcasts is not considerahle. Even with an antenna of high quality this set would be useless if installed in a locality more than ten miles from a broadcasting station. At this distance the signals, if heard, would be exceedingly weak.

In another particular—that of interference from both broadcasting and code stations—this ultra-simple crystal set has its outstanding drawhacks. Though the broadcasts were heard satisfactorily, the lack of selectivity which is inherent in the apparatus would permit the intermittent dots and dashes of amateur and commercial code stations to interrupt the music and speech. Moreover, it is probable that more than one broadcasting station would be heard simultaneously, thus destroying the programmes of each.

How to Select the Receiving Set.

In order to form some basis on which the prospective purchaser of a radio set may hase his selection, let an imaginary instance be conceived. Brown—the man's name—lives fifty miles from a city, such as Chicago or New York, where there are several broadcasting stations of high power. He has heard about radio from his friends and has decided that he mnst get a set for himself and family. But as usual each of his friends has an idea of his own. Jones uses a crystal set and hears two stations more or less regularly. He paid $18 for the complete outfit, including enough wire for an antenna 150 feet long and 40 feet high.

"Buy a set like mine," says Jones. "You'll hear the two best stations around here. You won't have to buy a storage battery or dry cells. There are no tubes to burn out."

Adams, his next door neighbor, is a man of means. And now, after gradual progressive stages, he is sporting a four tube receiver that is a "Rolls Royce" when compared to the "flivver" crystal set of Jones.

"Don't put your money in a cheap set," he tells Brown. "That's the way I started and now the set is gathering dust in the attic. A radio set is no good unless you can reach out two or three hundred miles every night and pick the station you want to hear. If you want to go at it right, pay out your good money for a good set. Pay $250 if necessary."

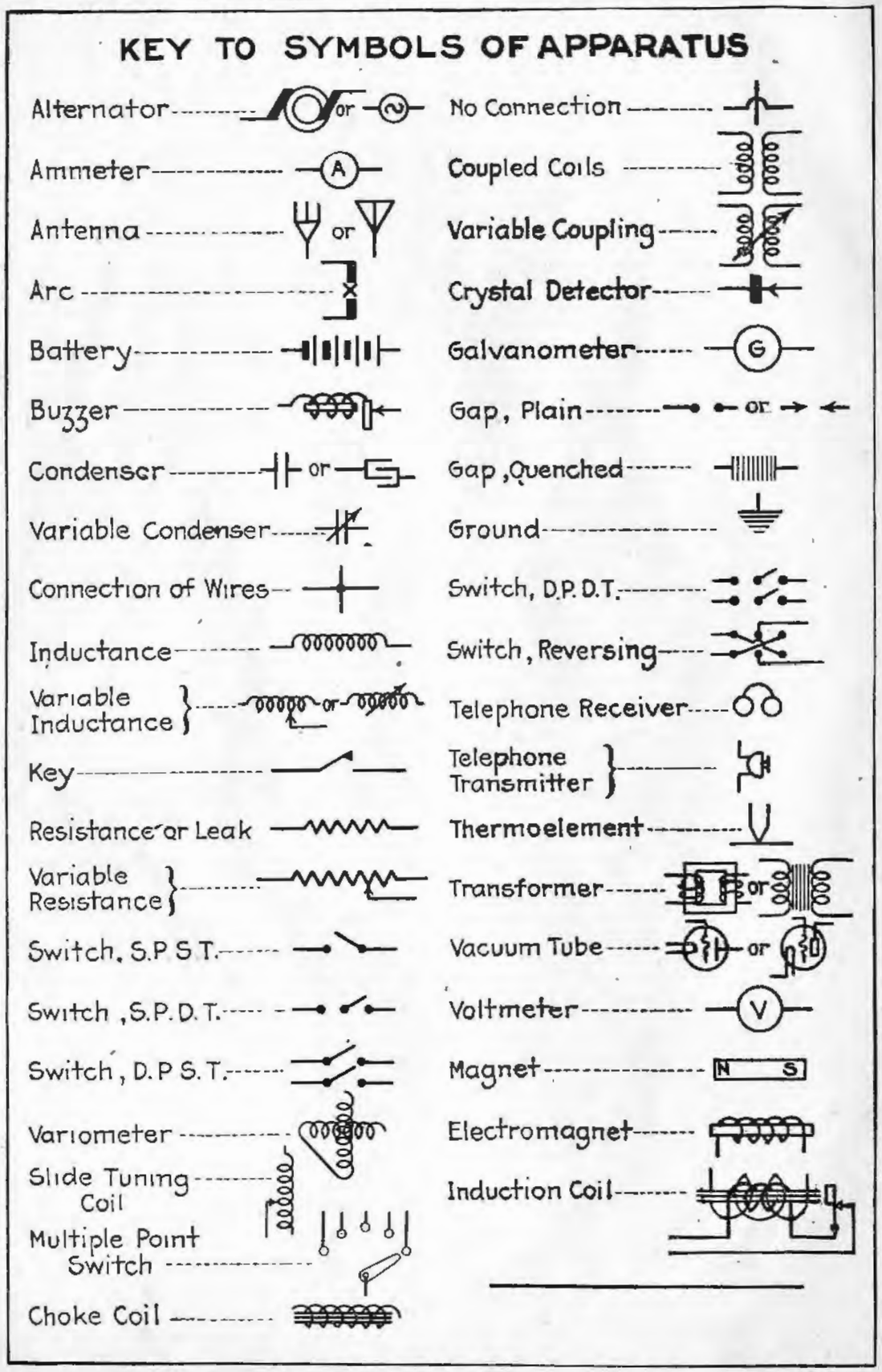
And lastly, as an exponent of the middle course, is Brown's lodge friend Burrows. Burrows was given a single tube receiver by an appreciative relative and since its coming has paid nut only a few pennies for upkeep. His set is operated from dry cells and so far he has nsed the set two or three evenings a week for four months and it seems to work as well as ever. He hears the city stations loud and clear, and one night—he always relates this accomplishment whenever his friends commence their radio fanning bee—one night he happened to be listening in around midnight when, lo and behold, he heard a man's voice saying, "This is Station WBAP, Fort Worth, Texas."

"Eight hundred and fifty-six miles by air line," he adds, "and with a single tube, too."

Is it any wonder that Brown is radio perplexed? One friend recommends the $18 outfit and the other the $250 set.

If the bewildered man could talk with a broadminded, unbiased radio expert this wnuld be the gist of the talk:

How much do you want to spend on a radio set? Yes, I know you want to spend as much as is neces-



sary to get a good outfit. But how much could you put out right now without missing it? Do you want to spend $250, as Jones did? Nn? Well, would $100 be ton much? Still a little high? All right, let's compromise on $65. Fine. Now listen to me.

The Handy Man Can Build His Set.

If you were a mechanic or were handy with tools, could read simple drawings and follow instructions that must of necessity be semi-technical, you could build your own set from purchased parts. The completed set would be twice as extensive in scope as a purchused set for the same money. Not twice as good; I don't want you to get that idea. It might not be half as good. 'Twould all depeod on the degree of skill you used in assembling and selecting the parts. What I mean is that with the $65 you could buy a receiving set having one vacuum tube, batteries, head 'phones, and antenna material, while for the same amoont expended in parts ynu could assemble a set consisting of two vacnum tubes, the same batteries and antenna wire, and so forth. A two tube set, you know, is better for distance and for loudness. The second tube magnifies, or, as they say in the trade, amplifies the sound as it comes from the first tube.

But I know you have not had the training that would make it advisable for you to assemble a receiver of this type. So you should buy one complete.

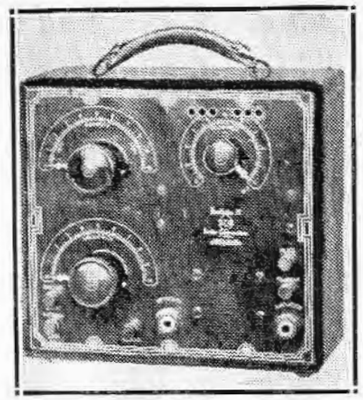
With $65 to spend, you should forget all about the crystal type of receiver. A vacuum tube set is your goal.

Best Receivers Are the Simplest.

Suppose you get out among the shops and see the radio sets on display. For one thing you will be surprised at the wide range of prices for what seems to you to be identical sets. The similarity is the same as is found in the clothing industry. There are suits of wool and suits of shoddy. To the man in the street there appears to be no difference between the two goods. But time and wear soon differentiate between them.

The "all-wool" radio sets are usually the simplest in construction and design. Skilled engineers have "cut" them until all non-essentials have been eliminated. Cnmplete contrnl is secured with the minimum number of knobs and dials.

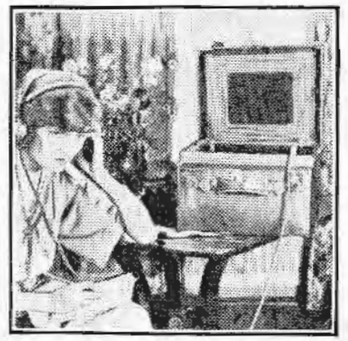
The "shoddy" set, on the other hand, is more apt to be housed in a



One of the Newer Sets. Flashlight Batteries Operate the Tubes.

beautiful cahinet and eqnipped with more dials than the switchboard of a submarine. If anything, this type of set is liable to be the larger of the two. for its builders koow that the few extra dollars spent on a larger panel and a slightly larger cabinet make an infinitely better im pression on the newcomer.

The "all-wool" set can be taken home, connected to an antenna and ground and made to work, merely by following the few instructions that come with it. Six months later the



A Self-Contained Set. The Loop of Wire in the Top of the Cover Is the Antenna.

set will still be working, even better if anything.

The "shoddy" set gives no trouble as far as fundamental connections are concerned but when it comes to operating it——.

The beginner finds that the multiplicity of dials is terrifying. After a sound is finally heard in the 'phones the poor man is at a total loss as to bis next move. Five or more dials coofront him. Which shall he turn! He takes a chance, reaches for one of them, twists it ever so slightly—a hiss, a squeal, a cluck and the sounds disappear. Whatever he does from that point on hrings no results, so he tnrns everything off and starts again from zero.

Finally if through sheer persistence he brings in a statioo so that it is mnre or less plain he discovers that the slightest movement of his hand or bndy distorts the sounds into squeals of divergent pitches. And any radio man—beginner or expert—will tell you that there is mighty little enjoyment in listening to a concert while holding the hands and hody in a rigid pusition.

Perhaps this little story will emphasize the importance of making sure that a radio receiving set is a good one. It also emphasizes the advantage of paying a hit more for the same kind of set in order to get one which is fool-proof.

To get back to that $65 which is waiting to be spent for a receiver. In company with an expert the prospective owner goes to a radio shop and finds that he can buy a single-tube receiving set complete with a pair of head 'phones and all the necessary batteries for $40. The set has two or perhaps three controls. This price includes a hundred feet of stranded copper wire, some beavily insulated wire, several porcelain insulafors and a funny looking device, called a lightning arrester.

The expert explains that this receiving set uses a vacuum tube which has a filament lighted by an ordinary dry cell—the kind of battery that rings the door bell at home. This feature makes it unnecessary to buy a bulky and expensive storage battery.

The Ideal Set Contains a Loud Speaker.

With only $40 spent there remains a balance of $25. If the buyer is a family man there is only one answer to this riddle, viz.: use the money to buy a second pair of head-phones. A loud speaker cannot, as a rule, be operated from a receiving set having only one vacuum tube, hence if there is more than one person in the family there will be frequent calls for two sets of 'phones. Two sets can

be attached to a single receiver without reducing the strength of the signals or affecting the tone.

In the preceding paragraph a statement was made concerning the use of a loud speaker on a radio receiver. The ideal set, it should be mentioned here, incorporates a loud speaker. In the beginoing the head 'phones are satisfactory enough, but as tbe first novelty wears off there will come a desire for a loud speaker. Head 'phones require the listeners to sit near the set and cnnversation is impossible.

Providing that the owuer lives within 25 miles of a powerful broadcasting station, a loud speaker may be used on a receiver comprising two bulbs, that is, a detector bulb and a second bulb to amplify the detecting sounds. But for geueral purposes and to use the loud speaker on stations a hundred or more miles away, two amplifying bulbs are advisable.

Because nf the foregoing facts there are few receiving sets made with two bulbs. After the single bulb set comes the three-tube set.

The three-tube nutfit may consist of vacuum tubes that are nperated from a storage battery or the three tnbes may all be of the dry cell type, with one dry cell attached tu each tube.

The tbree-tube receiver is an exceptionally good one for the average installation. If the unit is well designed, this set when used with an nutside antenna should enable the owner after a little experience to hear on the loud speaker all broadcasting stations within 100 miles and on the 'phones all stations within 1,000 miles.

In the majority of three-tube sets provision is made for the use of either one, two nr three tubes according to the strength of signals desired. The change from one to the other combination is effected by the simple insertion of a small plug much like that used by the telephone operator on a telephone switchboard. Some sets are even arranged so that the insertion of the plug automatically extinguishes the vacuum tubes that are not in use.

At first thought it may seem strange that the amplification of signals is not continued beyond the two amplifying tubes. The novice may wonder why this strengthening of signals is not continued by adding tubes until even the weakest station, perhaps those clear across the continent, is brought in at loud speaker volume.

The answer is simple. These amplifying tubes are not specialists in their field. They refuse to be selective. They amplify everything that comes along. And not only that, but frequently they amplify undesirable sounds in greater proportion than broadcast sounds.

Then again the tubes themselves are not silent in operation. In the very act of amplifying the suunds they produce other sounds which are then passed on to the following tubes, where they are further amplified along with the vncal and instrumental sounds which originated in the detector tube.

Amplification Limited to Two Stages.

It has beeu found through extensive trials that two stages of amplification after the detectur are the limit. Beyond thut the foreign sounds begin to predominate and drown out the musical notes.

This amplification by the two tubes which follow the detector does not represent the ultimate limit in the magnification of radio signals. By the system of "radio frequency amplification" tbe electrical impulses as they enter the receiving set may be amplified many times before they strike the detector. This form nf high frequency amplification may be continued through two to five or even ten or more stages. Unfortunately, however, this method of amplification is not so efficient nor so productive of increased volnme as the "audio frequency amplification." The limitation is presented by the design of vacuum tubes. As this limiting feature is studied and the tubes are improved the use of radio frequency amplificatinn will increase. And as the amplification increases, the efficiency of the set will increase, local stations will be received with greater volume on fewer tubes and distant stations now too weak to be heard will come in as loud as local stations do now.

Use of Radio Frequency Amplification.

During the last year the number of receiving sets using one or more stages of radio frequency amplification in conjunction with one or two stages of audio frequency amplification has iocreased. It is this type of set which now will be discussed.

In general the use of a single stage of radio frequency amplification is not considered warruuted by the results obtained. This is due to the fact that when radio frequency is employed it is seldom advisable to utilize the regenerative feature. That is, since the effect produced in a circuit by regeneration clashes with the action of the same circuit when radio frequency is being employed, the regeneration must be eliminated. But the increase in signal strength with one stage of radio frequency amplification is not quite equal to that obtained with regeneration. Therefore, say experts, why drop oue tbing to utilize auother which is not so satisfactory?

But this objection dnes not hold in every instance. The single step nf radio frequency amplification will help but little ou local stations, but it will assist greatly nn signals from distant stations or o" weak impulses from nearby stations. This last oamed feature comes in handily when an outside antenna is not possible. In such cases a loup of wire containing uhout ninety feet of conductor arranged in the form of a square will absorb so little energy that the detector—a sluggish individual—will neglect to catch it. But if a stage of radio frequency is interposed between the autenna and the detector this anemic energy will be magnified nnd made virile enough to operate the detector.

There are excellent receiving sets on the market using one stage of radio frequeucy amplification, a detector and two or three stages of uudio frequency amplification. The cost cumplete with tubes and batteries varies from $125 tn $200.

Reflex Receivers Build Up Energy.

Still another type of receiver is the reflex receiver, so called because of the fact that the energy from the antenna does not pass in progressive stages from detector through the audio frequency amplifiers, but instead is passed back and forth from one stage to those preceding it. By so doing a greater amplification is possible without additional tubes, since each tube is amplifying at both radio and audio frequencies.

As would be expected, the successful operation of a reflex receiver depends on the exact and proper adjustment of the apparatus in each separate circuit.

The Aerial and the Ground

How to Select the Proper Type and Location—How to Arrange for Stringing the Wires and Installing the Precautionary Measures Demanded by Insurance Companies.

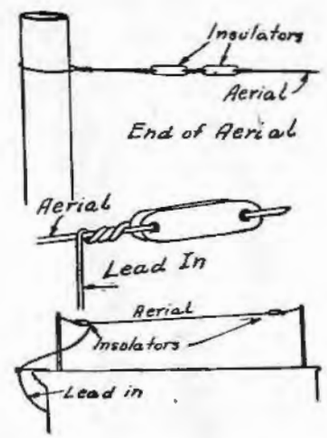
The problem of the antenna, once a serious one, is no longer such a determining factor in radiophone reception. Better methods of transmission, higher power at the transmitting stations, and more efficient receivers have made of the antenna one of the lesser parts of a receiving set.

There was a time when the antenna had tn be as high as possible if any kind of receiving was to be done. But now, in the phrasing nf the times, "anything goes." An outside aerial works best and will give the lnudest signals, but if the radin enthusiast lives in an apartment bnuse with no access to the roof or in a crowded section of the city or town where a stretch of wire is out of the question, be may still enjoy radiu broadcasts, not only of local stations but from distant stations as well, merely by utilizing one of the other forms of antenna.

The ideal antenna still remains as of old: a single wire as high as possible and as long as the wave length will permit.

The length of tbe anteuna is determined by the shortest wave length to be received. In broadcasting circles this is now about 250 meters. To work efficiently tbe natural wave length of the antenna should be something less thau this figure. Roughly, the fundamental wave length of any single wire antenna can be figured by multiplying its length—to which must be added the length of the lead-iu wire and that of tbe ground connection—by the number 1.4. This will give the result in meters. Thus, if the lengths of antenna, lead-in and ground combine to give 100 feet, the wave length would be 140 meters. Therefore it can be seen that the very longest antenna must not have a length greater than 175 feet. Usually this means that the main portion of the antenna cannot be greater than 125 feet in length.

If it is possible to set up an outside antenna a few simple rules should



Construction of the Aerial.

be followed: Keep the wire away from trees. If a tree is used for one end-support arrange the wire with a rope su that it hangs free and clear of the branches.

Erect Antenna Free of Trees and Wires.

Never run an antenna under or over other wires. One of the wires may break and drop across the other, causing an unknown amount of damage.

If electric light wires are near the antenna it is best—but not absolutely essential—to place the antenna wire at right angles to the other. If this is not done the receiving set is apt to hum continually, due to magnetic induction.

Choice of wire for the antenna need not be a serious problem. Almost any kind will do. Eveu iron wire has been known to make a workable aerial. Stranded copper wire is best, copper clad is next and solid copper the easiest to obtain. Any size from No. 14 to No. 18 will do. No. 16 is ideal, because of its ample surface and its medium weight. No. 14 will give more surface and is stronger, but its weight is against it, while No. 18 is so small that a wind storm is apt to rupture it. If the wire is insulated so much the better. The insulation is helpful rather than harmful, except in so far as it adds to the weight.

The antenna should be insulated at its ends with special insulators. Usually these are of porcelain or of a fibrous texture. Ordinary cleats or knobs such as are used in wiring the house are suitable for this work. When placing the antenna end in a tree arrange to have the iusulator well away from the branches, otherwise its exact positinn is immaterial.

After the antenna comes the lead-in. This is another wire similar in size and composition to the main wire. To make the connectiou between the two scrape a place bare on the maio wire and bare one end of the lead-in. Twist the lead-in tightly around the main wire at least ten times. Make a neat and effective job of it by arranging each turn close beside the preceding turn. When completed solder if possible. A hot soldering iron heated over the gas stove and rushed out to the antenna before it cools will do the work. Otherwise a blow torch is necessary. Place a little soldering flux or paste on the joint, hold the iron beneath the joint, and touch tbe strip of solder to the wire as it is heated.

If it is not possible to solder the joint, wrap it tightly with tinfoil and then cover thoroughly with several layers of electricians' insulating tape. This will be effective for several months.

A still better way to arrange for the solderless lead-in is to make the antenna and lead-in in one piece. This merely means that the conductor should be run through an insulator at tbe house end, tied around the insulator with a short piece of wire to prevent a back and forth movement, which would eventually cut through the copper by friction, and then carry the wire directly to the lightning protector.

There is always some discussion

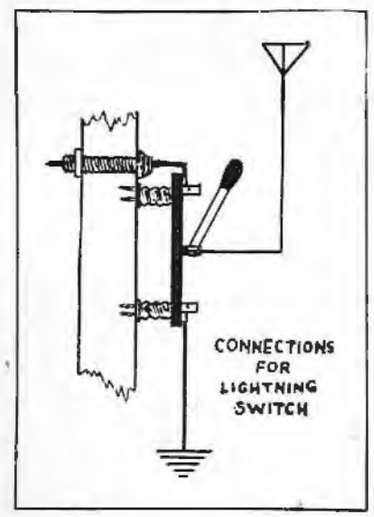
as to the best type of antenna to use; that is, whether it should be perfectly flat, whether it should slope up or down, and whether it should be pointed in any particular direction. In reality the best type of antenna for radiophone reception is the one that is easiest to erect. An antenna that is 35 feet high at its farthest end and 15 feet high at its lowest end will be no better nor worse than one which is 35 feet high along its entire length.

As for direction, this is another subject that allows considerable leeway. Certain types of antenna are directional, but this directional effect refers more to the minimum signal than the maximum signal strength. If there is a navy station near by it would be best to place the antenna so that it runs at right angles with the compass direction of this station.

Lightning Protector Belongs on the Outside.

But the beginner should not think that he is to gain greater signal strength by pointing his wire at a particular station. That station would be received with the same approximate strength if the antenna were to be pointed 60 degrees away from the straight line connecting the receiver with the transmitter.

In connecting the lead-in to the antenna, if the two are separate,



follow out the same idea. Make the connection where it is handiest. If this point is 20 feet away from the near-end make it there. The only effect will be to reduce the fundamental wave length slightly, which is a benefit rather than a handicap.

Every outside antenna should have a lightning protector, not to take care of direct lighting strokes, but to drain the antenna of accumulated charges that appear there winter and

How the Antenna Wire Is Connected to the Insulator.

summer. Insurance companies require this protection and good sense demands it. The cost is little and the self-satisfaction is immense. Buy one that has been approved by the Board of Fire Underwriters. The announcement will be found on the outside of the box and also on the arrester. Put it up according to specifications and forget that there ever was such a thing as lightning. You won't need to be told to keep away from the receiving set during a thunder storm. The noises that then will be present are the best assurance that you will shun it at such times.

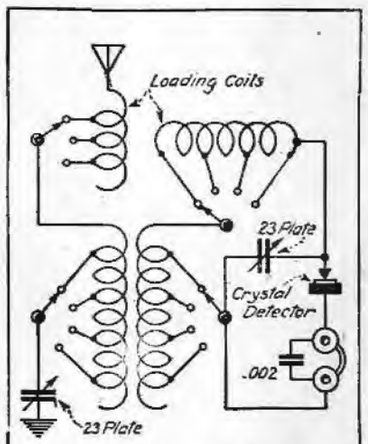
If the radio man lives in a thickly populated and built-up section he is permitted to place this protector inside the house, but it is by far the best policy to place it on the outside if it is in any way possible to do so. Build a small box, cover the top and sides with tar paper or oilcloth, and place the protector inside. Bring the lead-in to the box and carry a wire from the proper binding post on the protector straight down to the ground. The best ground for this purpose is a pipe 6 feet long driven into the earth with the wire from the protector securely soldered to it. This ground wire should be at least No. 4 in size.

Bring another wire from the lightning protector in through a porcelain tube into the house. The hole for this tube may be drilled straight through the clapboards or siding or it may be bored through the window casing. The hole should slope upwards so that water from the wire will not drain in through the tubing. This is the wire which leads to the antenna post on the receiving set.

Ground Wire Should Be Short as Possible.

From the ground binding post of the set carry a wire about No. 14 in size to the nearest and best ground. This will probably be a cold water pipe. But if the nearest cold water pipe is 20 feet or more away and there is a steam or hot water radiator nearer utilize that. Ordinarily the effectiveness of these heating systems as a ground does not rank with that of a cold water pipe, but the advantages in the latter are overbalanced if the ground wire must be more than 20 feet in length to reach it.

Use heavily insulated wire for the ground and attach it to the pipe in the same manner as the lead-in was attached to the aerial. A ground clamp, purchasable at any electrical store, will simplify the ground connection.



Higher Wave Lengths Are Reached by Adding Leading Coils.

Keep away from gas pipes as grounds. Too often there is an insulating bushing near the gas meter which prevents the gas pipe from being a real "ground."

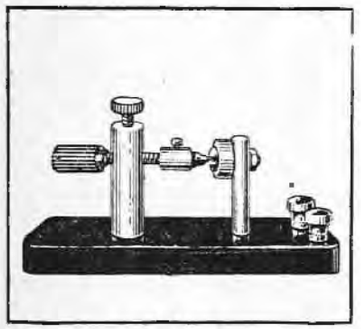
The Crystal Set

How the Simplest Receiving Set Operates, When It Should Be Used, and How a Workable Outfit Can Be Made at Home With a Few Tools.

In entering upon the radiophone as a hobby, the beginner is confronted with a tremendous problem in the choice of apparatus. He may buy the parts and build his own receiving set and transmitter; he may buy the separate pieces of apparatus, all finished and ready to be connected with other instruments to form a complete set; or he may buy a complete receiving set and sending set wired ready to be used.

If the average beginner is only interested in radiophone receiving service and does not care to be troubled with even an elementary knowledge of radio, then by all means the simplest type of radio apparatus is urged. In that event it is well to purchase a complete receiving set already wired and as compact and self-contained as possible. Such a set need only be connected to the aerial and ground for immediate results.

If the layman wishes to do a little experimenting and thereby master slowly the theory and data of radio it will be well for him to purchase separate radio units, each one com-



The Perikon Detector Consists of Two Minerals in Contact.

plete in itself, but arranged to permit its use with other units.

Some manufacturers to-day offer the parts for a complete receiving set, thus facilitating the work of the man who builds his own receiver.

Radiophone service of the present is available to every one provided with some suitable receiver. All that is necessary is an aerial, which for this purpose may be a single wire elevated twenty or more feet off the ground and extending about 100 feet. The use of this aerial or antenna is to absorb the energy in the transmitted radio wave, concentrate

The Galena Crystal Requires a Fine Contact Wire.

it and redirect it into the receiving apparatus. The aerial upon being erected should never be longer than 150 feet. There is no advantage in running a longer wire, for the simple reason that the wave lengths of radiophone stations lie between 285 and 492 meters and it is best to have the natural period of the aerial as near as possible to the average of these values.

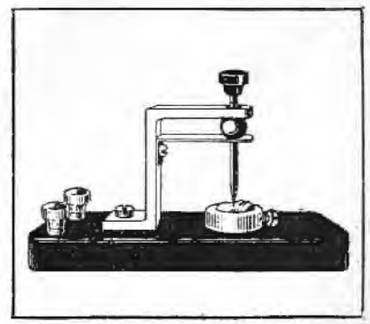
Should the aerial be longer than 150 feet it will be necessary to insert a variable condenser in series with the antenna to lower the wave length of the aerial. This oftimes decreases the efficiency of the set.

When placing the aerial in position the ends should be well insulated by attaching small antenna insulators a few feet from the extremities. A well insulated aerial will exhibit a great gain in efficiency, especially when seeking stations at long distance.

Aside from this simple aerial a ground connection is essential. In cities or towns an excellent ground connection can be made with water and steam pipes. The best means for making this connection is through the use of a standard ground clamp, which can be purchased from any electrical or radio shop for a few cents. In homes where a meter measures the water the meter should be short-circuited, as shown in the sketch, using heavy wire, about No. 4. Should there happen to be other water pipes near where the first ground is made, it would be advisable to connect them all with copper wires or strips. This would increase the efficiency of the ground.

Under certain circumstances it is not an easy task to find a good ground, especially in rural districts. One form can be made by taking an old wash boiler and soldering the ground wire to one of the handles or sides. The boiler should then be sunk a few feet in the ground or, better still, lowered into an abandoned well. Should it happen that none of these grounds can be utilized there is the cistern or water pump in the yard to which the ground wire can be soldered.

As will be explained in detail further on, the receiving set to use de-



Carborundum Works Best With a Stiff Point.

pends entirely on the distance between the receiving station and the broadcasting station. Thus, within a twenty-five mile range a simple crystal receiving set will do. Beyond this range and up to seventy-five miles a better receiving set, with storage battery or dry cells to oper-

ate the vacuum tube detector which replaces the crystal detector used for shorter ranges. It must be understood that crystals are good only for a range of approximately twenty-five miles.

After erecting the aerial and securing a good ground the next step is to consider the receiving equipment. The simplest receiving set comprises a crystal detector and telephones. The detector is a device which changes the frequency of the incoming waves from radio frequency to audio frequency, so that it may be heard in the telephone receivers. While the crystal detector is far more sensitive than the earlier forms of detectors employed during the pioneer days of radio, it is not nearly as efficient as the vacuum tube, which is explained at another place in the Manual further on. However, the crystal detector is inexpensive and may be used with the simplest equipment. Another advantage is that with most of the crystals used to-day no batteries are required.

The simplest receiver, therefore, consists of a ground and antenna connected to a crystal detector and a pair of head telephones in parallel. At short distance from a powerful broadcasting station this outfit is satisfactory, but where two or more stations are in operation some means must be added whereby the receiver can be made selective or, as the act is described, tuned.

There are several methods of tuning devices now in use. One of these is the inductance coil, which consists of fifty or more turns of wire wound in a single layer on a solid tube, three or four inches in diameter, and provided with some means for varying the number of turns of wire which are to be used.

A method of varying the number of turns is a sliding contact which moves over a path scraped bare along the turns of wire. The adjacent wires must, of course, be insulated from each other and the proper contact afforded between slider and wire.

Making the Tuning Coil for Crystal Sets.

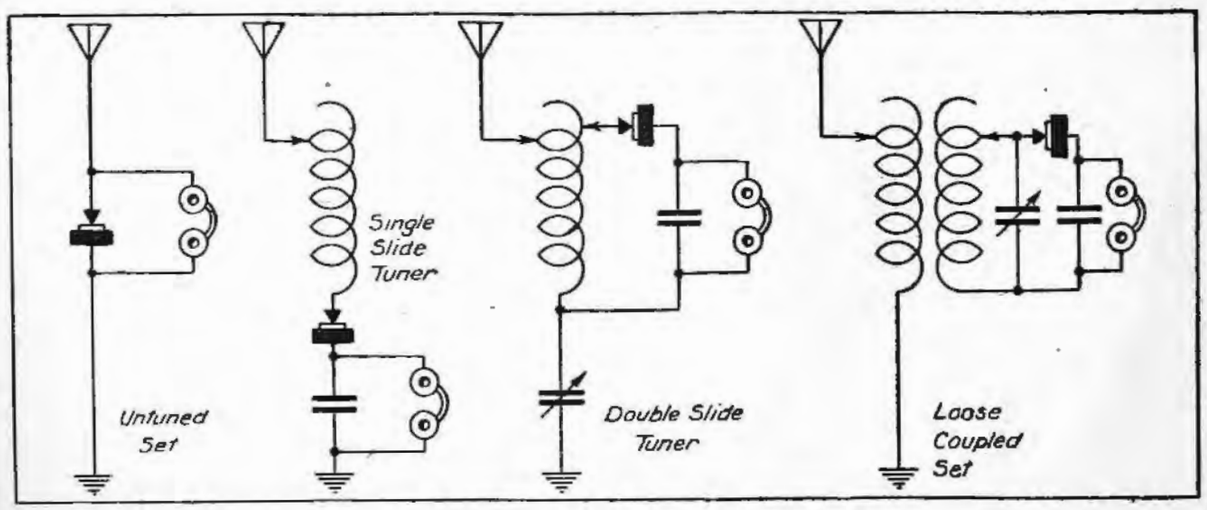
In constructing the tuning coil first secure a cardboard tube about three inches in diameter and eight inches long. The cartons containing cracker dust or oatmeal are quite suitable. Next purchase about one-half pound of number 22 single cotton covered wire and two pieces of wood five inches square and one-half inch thick, the latter being needed for the end supports.

Buy two brass rods, one quarter inch square by nine inches long, and two sliders to fit the rods. Secure also one one-eighth inch round brass rod nine and one-half inches long, threaded for a short distance at both ends and fitted with nuts. Four binding posts and four round head brass wood screws complete the list of necessary parts.

The insulating tube is first given a coat of high grade shellac. When this becomes "tacky," the wire should be wound on. Begin one-half inch from the end and wind on the wire evenly until a point is reached one-half inch from the other end. Another thin coat of shellac will hold the wire in place. Find the exact centre of the end pieces and with a compass draw a circle equal to the inside diameter of the tube. Within the bounds of this circle on both ends fit a crosspiece. Drill one one-eighth inch hole in the two corners of each end piece. In these holes fit the binding posts, the posts projecting from the side opposite to that occupied by the cross pieces.

Now put the ends on the coil, insert the one-eighth inch brass rod through the centre holes and screw up the nuts until the coil and the ends make a firm unit. Connect the right hand end of the coil to binding post G and also connect post G with post 2. Drill one-eighth inch holes one quarter inch from each end of the slider rods. Put the sliders on the rods. Fasten one slider on the top and one on the side of the coil. Connect the top slider rod with binding post marked A and the slide rod with post 1. The instrument is now complete. Its function is to adjust the wave length of your set to the wave length of the transmitting station. By moving the sliders, thereby adding to or subtracting from the number of turns of wire in the circuit, the inductance, which is one of the wave length determining factors, is accordingly increased or diminished. This tuning coil will give a wave length range from 200 meters to about 600 meters.

Two sliders on the coil will permit greater selectivity; in fact, the tuner then operates like an auto transformer, the turns between the aerial slider and the ground end of the coil considered as the primary and the turns from the ground end of the coil to the other end of the slider considered as the secondary. Sometimes a variable condenser connected in the ground lead will be found to sharpen the tuning.

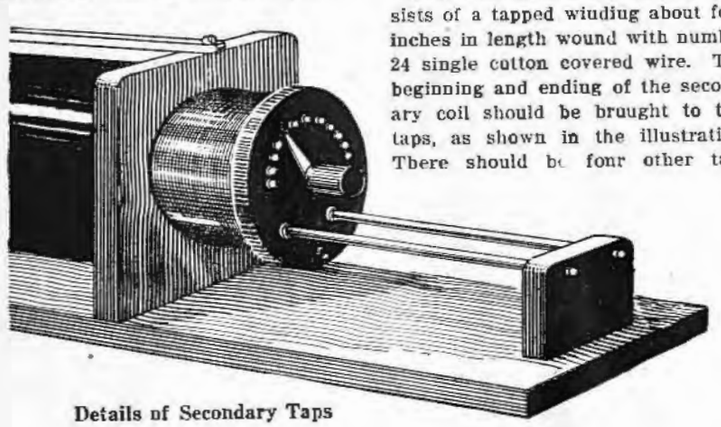


Four Familiar Forms of Tuning Units for Crystal Sets.

Still greater selectivity in tuning may be obtained by using a loose coupler or variocoupler.

Principle and Construction of Loose Coupler.

Although a little more complex in construction than the tuning coil, the loose coupler is superior to it in many ways. Finer tuning and closer coupling is possible. This means greater selectivity and less interference from powerful stations. Signals are somewhat stronger because of this selectivity.



Details of Secondary Taps

The loose coupler may be classed as an improved type of tuning coil. It has two windings, primary and secondary. The primary or outer coil is usually wound on a cardboard or composition tubing with a large sized wire, while the secondary is wound on a smaller tube with the smaller wire. The secondary is designed so that it can slide in and out of the larger tube or primary.

Constructing the Loose Coupler.

In constructing the loose coupler two tubes will be needed, one large one for the primary, and one smaller one for the secondary. If a piece of composition tubing is handy it is much better. A piece of tubing measuring four inches in diameter and about eight inches long will be needed. A tube which will fit inside of this tube with a clearance of about one-fourth or one-half inch will then be needed for the secondary.

Both primary and secondary tubes should first receive a good coat of shellac. The primary tube is wound with one layer of number 22 single cotton covered wire for about six inches of the primary tube, leaving a clearance of about one inch at either end. A thin coat of shellac will serve to hold the winding in place.

White or orange shellac can be used if thinned down with a little wood alcohol.

The winding of the secondary consists of a tapped winding about four inches in length wound with number 24 single cotton covered wire. The beginning and ending of the secondary coil should be brought to two taps, as shown in the illustration. There should be four other taps taken from points in between the two taps mentioned.

Method of Tapping the Coupler

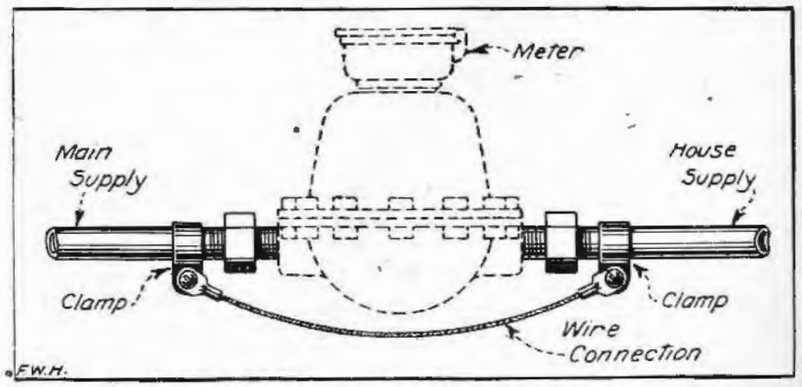
Taps are taken from the secondary in a different manner than usual. Instead of bringing the tap out on the surface of the tube, a hole is punched at the point of tapping and a loop of the wire is forced inside of tube and drawn out for about six inches. The loop is then twisted and the winding continued for another half inch, when the tapping is repeated. The reason for the manœuvre is that the secondary must slide inside the primary tube, and outside taps would be useless, since they would rub against the inside of the primary tube. There is another reason. The end of the secondary tubing is fitted with a wooden head carrying a knob and switch points connected to the tapped sections. It is more convenient to bring the taps to this head from the inside than from the outside of the tube. Two binding posts make connection with two flexible leads. There are two brass rods for the secondary tube to slide on. The primary is, of course, suitably mounted on end pieces and provided with a rod and slider. Two rods and sliders can be used, although there is but slight advantage in so doing.

Winding the Tubes.

One thing that must be watched when winding the tubes is the direction of the winding. The two coils should be wound in the same direction. The wires should travel as though the winding was carried out on one coil and the tube cut in two later on.

Description of the Variocoupler

The feature of the variocoupler is the employment of the rotor for the secondary in place of the sliding coil. The rotor, which is ball shaped, is mounted so that it can be revolved through ninety degrees to change the coupling between the primary and secondary winding. This acts the same as withdrawing the secondary from the primary, as was done in the loose coupler. Saving in space, together with simplicity of mechanical construction, are gained by this method of varying the coupling between the coils. It is not necessary to tap the secondary coil, as the in-



A Loop of Wire Around the Meter Will Improve the "Ground."

ductance is varied by other means, as will be later described.

The primary consists of a tube of insulating material approximately four inches in diameter and five inches long. It is wound with sixty turns of number 22 single cotton covered wire, in one even layer. The winding is then tapped off on the 1-10-20-30-40 and 50th turn. They are tapped off from one to the tenth turn. This then will give six taps of ten turns each and ten single taps. The tapping is carried out diagonally along the tube to make it easier to carry connections from the primary to the taps on the panel.

A quarter-inch hole is drilled through the primary tube for the secondary shaft bearing. This hole should be one-half inch from the top.

Making the Secondary of the Variocoupler.

A three-inch rotor ball should be purchased from a radio shop. If one cannot get a three-inch rotor ball a piece of insulating tubing one and one-half inches long and of such diameter as to allow it to rotate freely within the primary tube will suffice. On this should be wound forty to fifty turns of number 22 or 24 single cotton-covered magnet wire. A quarter-inch shaft is then inserted through the hole in the primary and then through the centre of the secondary tube and fastened with lock nuts. The shaft projects through the hole in the primary and a knob and dial fastened to the shaft end. Connections from the secondary winding is made by pieces of flexible cord twisted about the shaft. Enough slack should be left in the pigtail to allow the secondary to rotate freely inside of the primary through a 180 degree angle.

Selection of Parts for Crystal Sets.

If no provision is made for tuning, a receiving set must perforce be of a low order of efficiency. Furthermore, all signals come in at the same time if several transmitters happen to be working in the immediate vicinity. By providing the simplest kind of tuniug device the efficiency of the crystal receiver is immediately improved.

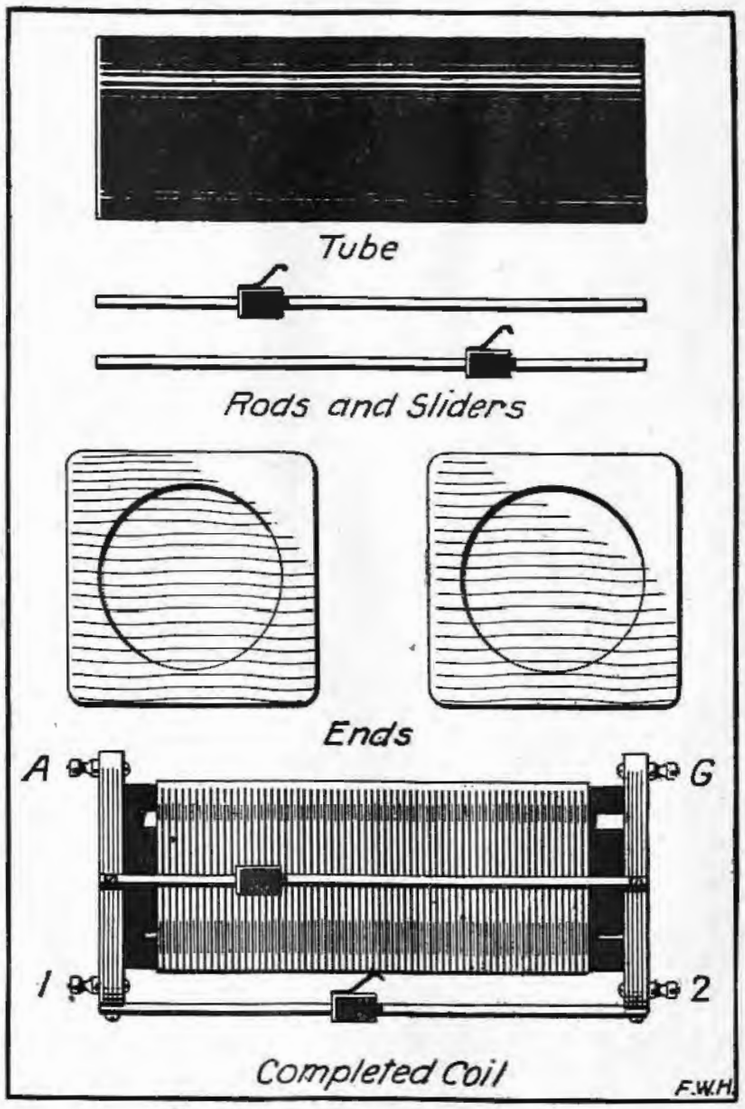
There are several types of tuning devices, most of which were described in the previous pages. We have explained the one- and two-slide tuning coils and the inductive coupled receivers employing the loose coupler or variocoupler. Most crystal sets are of the direct cnupled type, with the sliding arrangement on the tuning coil.

There is still another element other than inductance which is used to vary the wave length. This is capacity. Capacity is supplied by an instrument called a condenser. The condenser may be either fixed or variable.

Various forms of variable condensers are available, some with movable and fixed plates hinged so that one set of plates is moved toward or away from the other set of plates. When a condenser is placed in series with a coil of wire the wave length is reduced, and when placed in shunt or parallel to the coil, the wave length is increased in proportion to the amount of capacity used. The value of the condenser lies in the fine adjustment of which it is capable.

A crystal detector ordinarily consists of a mineral crystal, set in a suitable cup or clamping device. Contact is made with the crystal by means of a short piece of springy steel or bronze wire. The crystal is set in an easily fusible alloy, such as Woods metal.

The operation of the crystal detector is based upon its uni-directional or one-way conductivity. If the wire or catwhisker be brought into contact with an appropriate spot on the surface of the crystal, the high frequency currents will traverse the



Detail View of Parts of Loose Coupler.

device in one direction far more easy than in the other.

A good crystal will have many sensitive spots, whereas a poor sample will contain relatively few.

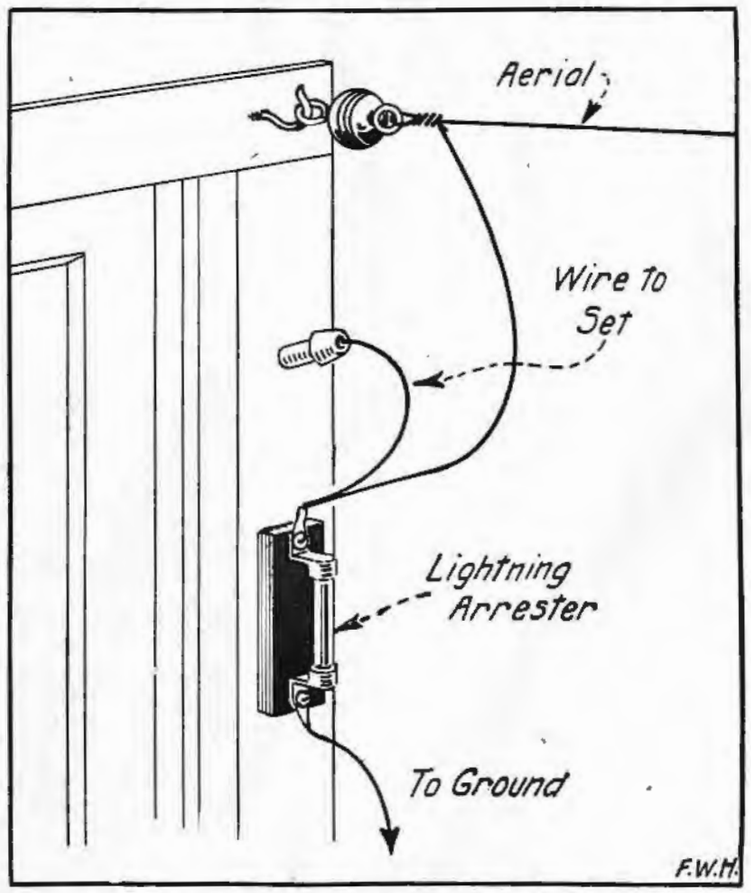
There are many crystals used for receiving radiophone signals. The principal ones are galena, silicon, carborundum, zincite-boroite, iron pyrites and copper pyrites. Some of these minerals need an external battery for best action, but the majority do not. Of the different crystals used galena or lead sulphide is probably the most common. It requires no battery current whatsoever and requires only a needle-point adjustment. When using this mineral cleanse the surface once a month with a slight application of alcohol. This liquid carries away the grease spots received from the fingers. A better method is to keep the crystal covered in an airtight case.

Testing for Sensitivity in Crystal.

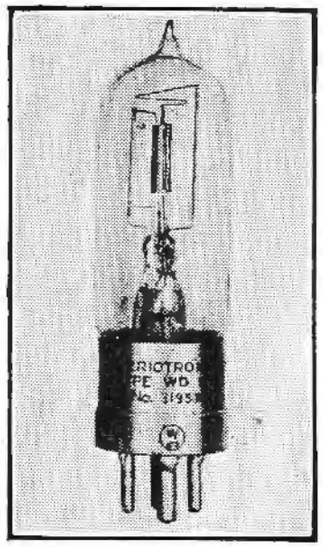
For those desirous of making sure of their crystal detector adjustment it is best to use what is known as "the buzzer test." This calls for a small buzzer, such as used in bell circuits. The buzzer is connected in the nsual manner with a push button and one cell of dry battery, bnt a wire is brought ont from one side of the buzzer interrupter to the ground connection of the receiving set. When the buzzer is operated the electro-magnetic waves given off by the buzzer interrupter are impressed on the receiving set and the detector can be adjusted for sensitiveness in the same manner as though the operator were searching for a transmitting station.

A schematic diagram shows the method of connecting the test buzzer to any crystal receiver.

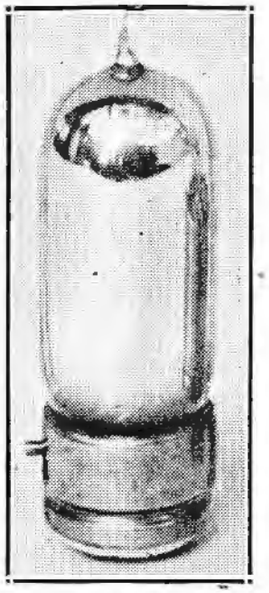
Crystals lose their sensitiveness easily, due to jars or to powerful signals from a nearby station. Whenever a crystal is affected by these signals the tuning coils should be loosely coupled. If this is done the spot on the crystal will remain sensitive for a greater length of time.



A Lightning Arrester on the Outside Is Generally Preferred.



WD11



UV199

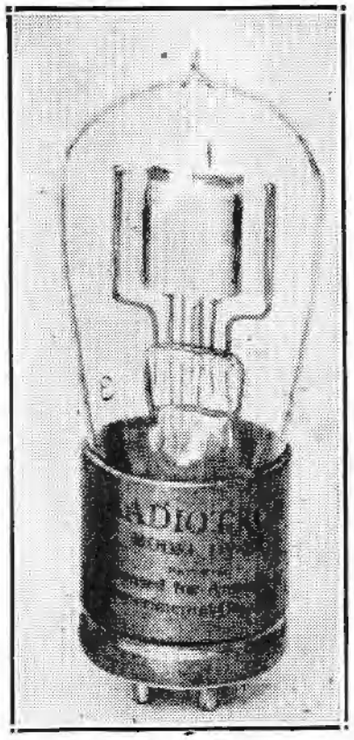
UV200—
Requires a 6-volt storage battery.
Takes 22 volts on the plate.
Consumes one ampere of current.
Used only as a detector.

UV201—
Requires a 6-volt storage battery.
Takes up to 150 volts on the plate.
Consumes one ampere of current.
Primarily an amplifier, but used also as a detector.

UV201A—
Requires either a storage battery or four dry cells.
Takes up to 200 volts on the plate.
Consumes only one-quarter ampere.
Primarily an amplifier, but is also a sensitive detector.

UV199
Requires three dry cells.
Takes up to 80 volts on the plate.
Consumes .06 ampere of current.
A good detector and amplifier. Particularly good as a radio frequency amplifier.

WD11
Requires one dry cell.
Consumes one-quarter ampere.
Takes up to 120 volts on the plate.
An excellent detector and radio frequency amplifier.
The WD12 is the same tube as the WD11 except the former is supplied with a standard base.



UV200

The Three Principal Forms of Vacuum Tubes Used in Receiving Sets.

The Vacuum Tube

A Simple Explanation of Its Early Development From the Original Two-Element Tube and a Discussion of the Modern Three-Element Tube.

To go into the most minute action of a vacuum tube would require more space than a treatise of this nature allows. Moreover, such treatment would be unwarranted, for when the experimenter arrives at the point where he must acquire an intimate knowledge of the fundamentals of a three-element tube he would naturally seek one of the comprehensive books on the subject. The most that can be expected in these few pages is a skeleton outline of the action which takes place within the little glass tube when used as a detector and as an amplifier. For although there is no outward change when the same tube is made to operate as a detector or amplifier, the operations themselves are entirely independent, otherwise it would be impossible for a tube to function in the circuit known as regenerative. Reflex action also would be impossible and much of the flexibility associated with the vacuum tube would be missing.

When a minute fibre of metal or other resistance material, such as the filament in an electric bulb, is heated to incandescence, millions of little charges of electricity fly away from the boiling surface. These electrons are negative. Now the terms positive and negative when applied to any electrical action are to a certain extent merely arbitrary. But, as will be remembered from early experiments with horseshoe magnets, any metal that is charged with negative electricity will be attracted by the positive pole of the magnet and vice versa.

If a sheet of metal is now placed around the glass tube in which the filament glows—the plate may be either inside or outside—and if this sheet is connected to a small dry battery in such a way that the positive end of the battery is nearest the sheet of metal, the negative electrons will be attracted away from the glowing filament at an even greater rate.

The filament in this experiment corresponds to the filament of a vacuum tube and the metal sheet to the plate of the tube. This combination was first discovered by Thomas Edison and has since been known as the Edison effect. A little later and independently, Professor Fleming in England noticed the same action while experimenting on wireless telegraph detectors. He immediately recognized the value of the phenomenon for the detection of radio signals and patented the device known as the Fleming valve. For several years the Fleming valve with its filament and plate was considered the most sensitive detector known. Even to-day, now that the patents on the Fleming valve have expired, firms are making them, a little better and a little more sensitive, and selling them to radio telephone fans to take the place of crystal detector. The valve, however, is seldom an improvement over the crystal detector and has the added disadvantage of requiring a battery to operate it.

One of the most ardent experimenters with the Fleming valve on this side of the Atlantic was Dr. Lee De Forest. After hundreds of experiments looking toward a further improvement in the valve to adapt it to radio, Dr. De Forest finally stumbled on the one improvement that has accomplished more for wireless and radiotelephony than any single invention, not excepting the epochal Armstrong regenerative patent. Dr. De Forest retained the filament and the plate and in addition inserted a third element which he termed the grid.

Heretofore the Fleming valve acted only as a rectifier, due to the fact that current passed in one direction from the plate to the filament with greater ease than from the filament to the plate. Thus the oscillating come-and-go waves of the entering signals were retarded when the direction of movement was in one direction and accelerated when the movement was reversed.

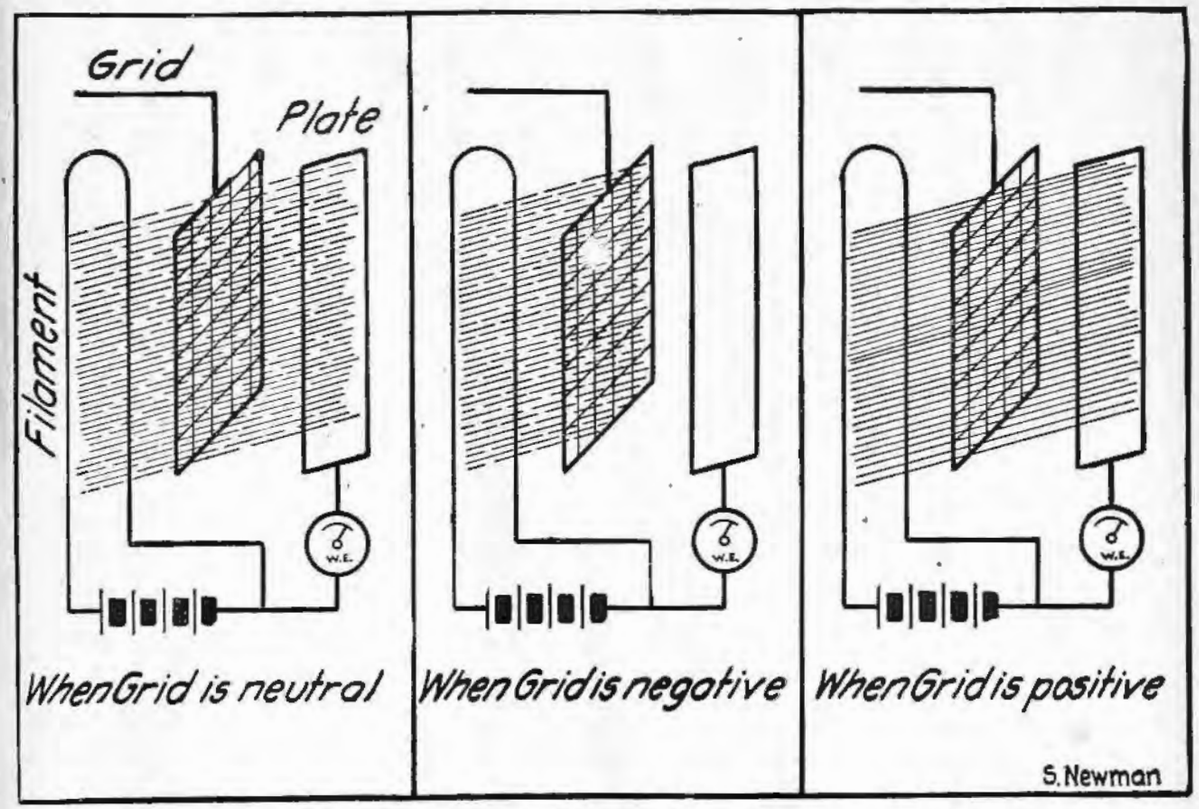
But the insertion of the grid changed the action of the tube completely. The incoming energy—the signal waves—were brought in on the grid. The plate and the filament formed a secondary circuit which operated normally independent of the grid circuit. But the grid, being placed between the filament and the plate, had the last say in the matter of electron transportation.

In this respect the grid can be considered as an all-powerful gatekeeper. When the gate opened, the electrons were free to travel from the filament to the plate, the intensity of this movement depending entirely on the degree of opening of the gate. When the gate shut against the flood of minute charges, not a single electron could find its way by the barrier.

It should not be understood that this gate action is mechanical. The action is far too rapid for that. The checking was accomplished through the effect of electrical charges placed on the grid by the energy from the antenna.

As mentioned in a previous paragraph, a positive charge attracts a negative but repels another positive. Remembering this, it is not difficult to understand the action which takes place within a vacuum tube whose grid is connected to an antenna, whose plate is connected to a battery and whose filament is lighted in order to produce electrons.

Suppose that at the start there is no energy in the antenna. The electrons fly off the filament and to the plate in a steady unwavering stream. The grid is merely a screen through which they pass without trouble. But along comes a series of transmitted waves to the antenna. These waves set up other waves in the receiving set. These oscillations, as they are called because they pass first from antenna to ground and then from ground to antenna at a tremendous rate, pass on to the grid. First the grid is subjected to a positive wave, a fraction later to a negative wave.



This Diagram Illustrates the Three Conditions of the Vacuum Tube.

When the grid is made positive the electroos from the filament are drawn at an increased rate through the grid to the filament. It is mnch as if the electrons were runoing a gantlet, but instead of being impeded as they pass down the laoe they are given slight added pushes which iocrease their speed.

But now, an instant later, the grid is negative, and the action is entirely altered. Negative repels negative; they abhor one another. So the negative charge on the grid acts as a traffic policeman with a "stop" sign. The electron flow is cut off iostantly, the degree of stoppage depending on the intensity of the negative charge. An instant later the grid is ngain positive and the electrons go their merry way.

During this time something must have happened in the wire which connects the plate witli the battery. It is in this circuit that the 'phones are placed. If we had been listening during the experiments just outlined the various phases of action of the vacuum tube would have been evident through the change in sounds.

As long as waves were not striking the antenna, the current through the plate circuit—which also means through the 'phones—was constant. It did not vary. But as snon as those little impulses from the antenna passed down the wire to the grid the placid current in this plate circnit was thrown into the wildest excitement. Each time the slightest change was brought about the action was made evident in the 'phones by a movement of the thin diaphragm, and this 'phone diaphragm movement coincided exactly with the variation in the waves striking the aotenoa. Thus if these waves formed a message in dots and dashes the 'phones reproduced them. If the incoming wuves were part of a radio 'phone concert the 'phones reproduced the sound of the human throat or that of the musical instruments with absnlute precision.

Different Types of Vacuum Tubes.

When the radiophone was in its infancy in 1920 those interested in the new form of entertaiument had but two types of vacuum tubes from which to make a selection. These were denoted by the terms UV200 and UV201. Each tube performed a particular kind of work. The UV200 was and is mainly a detector tube and is unsatisfactory as ao amplifier. The UV201 is primarily an amplifying tube, although popular with some experimenters as a detector.

The two tubes are identical in appearance; the only difference in construction lies in the fact that the UV201 is evacuated to a high degree, while the UV200 is sealed off while a small volume of gas remains in it. The UV201 is called a "hard" tube and the UV200 a "soft" tube. These terms merely indicate the degree of vacuum within the bulbs.

Because of the gas which remains in the UV200, the tube requires a much more delicate control to operate its action properly. Moreover, unless adjusted to the exact operating point, the tube is either insensitive to the iocoming signals or is noisy nnd harsh and distorts the sounds.

When the UV201 is utilized as a detector its control is less delicate, but it does not compare with the soft tube in sensitivity.

Both of these tubes require a source of current with a potential or voltage of 6 volts. This means that a storage battery must accompany each set, and a storage battery

requires some method for recharging it. In addition to these drawbacks is that of bulkiness. A storage battery, with its many lead plates, must of necessity be heavy and bulky. This precludes the use of the two tubes mentioned with any type of light weight, portable receiving set.

Engineers Design Tube for Dry Cells.

Engineers early recognized this fault and concentrated their efforts on the design and perfection of a vacuum tube which could draw its current from a dry cell. Finally the first dry cell tube, called the WD11, was placed on the market.

The WD11 was slightly smaller than the UV200 and 201. Instead of requiring a potential of 6 volts it could be operated satisfactorily on a single dry cell having a potential of only 1½ volts. The filament of the dry cell tube consisted of a fine metal wire coated with radioactive material which made it unnecessary to heat the filament to incandescence in order to provide the proper emissinn of electrons. Thus the WD11 was operated with a current consnmption of ¼ of an ampere, compared with the 1.1 ampere of the first tubes.

Naturally when these tubes became available the radio public became curiuus as to their real possibilities. Being smaller than the UV200, there was a demand to know if the WD11 would do all that the larger tubes would do. Were they sensitive detectors, or were they suitable only for amplifying purposes?

It was stated at the time that the smaller dry cell tube would do all that the larger tubes would do. They were excellent detectors and efficient amplifiers. But since that time experience with a quantity of the tubes indicates that the dry cell tube is not quite as good as the average 6-volt UV200, either as a detector or as an amplifier. Some experts have stated that it is only 80 per cent. as good. Others have said that the tube lost but 10 per cent. in efficiency through its change in design. At any rate it is probable that the advantage to be gained through the use of a dry cell in place of the storage battery more than compensates for the possible loss of even as much as 20 per cent.

As amplifiers the WD11 tubes have been found to vary widely. Some operate perfectly in both the first and second stages of the amplifier. Others refuse to amplify properly in the second stage unless the voltage on the grid of that tube is made negative by the addition of a small supplementary battery called the "C" battery.

At first the WD11 tube was supplied with a very special form of base for the express purpose of preventing the accidental placing of the low voltage tube in the higher voltage socket adapted to the 6-volt tubes. The manufacturers felt that the sudden appearance of the dry cell tube on the market before the radio public had been properly educated in its application would result in the destruction of many tubes and the consequent dissatisfaction of thousands of beginners.

Special Socket Prevents Tube Destruction.

But lately the firms making the tube have concluded that radio fans can understand the difference between the tube for storage batteries and the tube for dry cells, and accordingly are supplying the same tube with a standard base arranged so that the tube may be inserted into any standard socket. To distinguish the two tubes the newer tube is given the name of the WD12. And it should be understood here that, except for this one feature of the alteration in the base, there is no difference whatsoever in the tubes.

One other point has evidently bothered the radio public concerning these tubes. Thousands have asked, "Is the same tube used as either detector or amplifier?" The answer to this is in the affirmative. The WD tubes are "hard" tubes, but they are extremely sensitive detectors.

Within the last few months two other tubes have appeared on the horizon and both are now being seized upon and put to work. The first to arrive was a companion to the UV tubes and was given the name of the UV201A.

The UV201A is a 5-volt tube, but requires so little current that it can be operated from the proper number of dry cells. Since each dry cell delivers only 1½ volts, four such cells should be connected in series to supply the required potential. But the current drawn by the tube is no more than that taken by the WD11 and 12, hence one set of four dry cells should last for 500 to 1,000 hours of actual operation.

The UV201A is an excellent detector and an unusually good amplifier. In time it is expected that this tube will replace the UV201, since it performs better and more economically than the latter.

When the 201A is used in a circuit either as detector or amplifier the resistance of the rheostat which controls the current should be increased from the nnrmal 6 ohms to 30 ohms. Either the rheostat with the lower resistance must be replaced with one having five times the resistance or a permanent resistance of 24 or 25 ohms must be connected in series with the main rheostat.

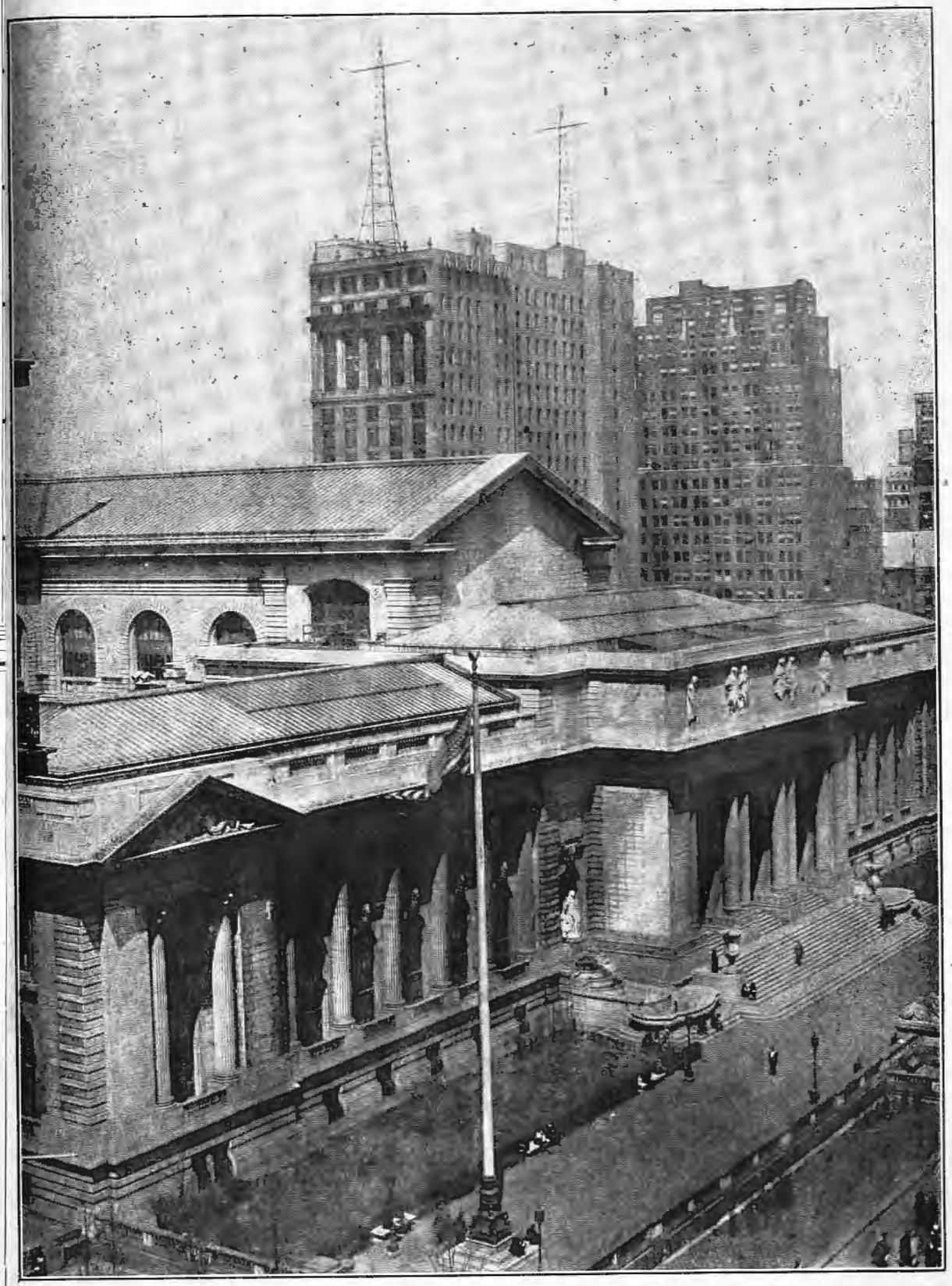
Because of the high potentiul which can be applied to the plates of these tubes the amplification can be carried to a higher value than with either the WD11 or the UV20 tubes.

The second of the new arrivals in tubedom is the UV199, a semi-"peanut tube." A "peanut tube" is the name given to a tube specially designed during the war for compact sets, but never released for public consumption. The UV199 is the nearest commercial approach to the real "peanut tube" that has been developed.

This tube is only 1¼ inches in diameter and 3 inches high. The style of contacts on its base requires its use in a special socket, although adapters are now available by which it may be made to fit the standard socket.

The UV199, like the 201A, is an exceedingly good detector and amplifier. It requires a potential of 3 volts and consumes but .06 of an ampere, or aboat one-fourth of that consumed by the WD11 and the UV201A. Because of this low current demand the UV199 can be operated from a set of three flashlight cells. It is probable that these cells would supply the needed current for several weeks, while three ordinary size dry cells would operate the filament of the tube for six months or a year. The principal advantage in the use of the flashlight cells is that the tube then becomes suitable for the most compact of portable sets. The batteries can be included within the cabinet without increasing its bulk or its weight.

This small semi-peanut tube has also been found to be unusually well adapted to receiving circuits involving the amplification of currents at radio frequencies, but this particular subject will be dealt with more fully under that general heading.



WJZ and WJY Transmit Simultaneously From This Antenna

Standard Receivers

Although Less Spectacular in Performance, the Simple Regenerative Set Still Leads the More Radical Types in Popularity and Ease of Construction.

Radio receivers are usually distinguished by the type of circuit employed in their construction. There is the single-circuit, double-circuit, three-circuit and four-circuit receiver. Sometimes the difference between them is made even more distinct by specifying them as inductively or capacitatively coupled, as the case may be.

These various receivers will be treated individually at their proper places in the Radio Manual.

At this time only the single circuit set will be described at length.

This is perhaps the simplest receiver to build, although not always the easiest to operate. It is, however, an excellent outfit for the beginner to start on, particularly if the separate parts are to be assembled into a complete set.

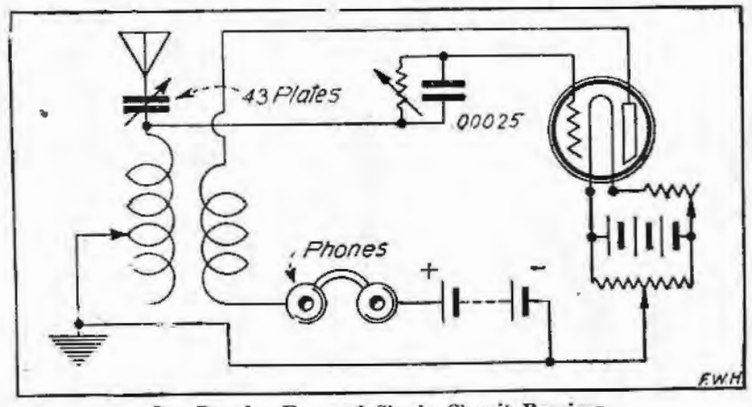
Commencing in a logical order, the construction of the antenna comes first. All that is necessary is a single wire elevated thirty or more feet off the ground and running not longer than one hundred feet. With a much longer wire it becomes necessary to insert a condenser in series with the aerial, which reduces its efficiency. More complete data on the erection of an antenna will be found under that heading in the table of contents.

Next to the aerial is the need of a good ground. This may be obtained through a connection to the steam radiator or cold water pipe. In making this connection scrape a clean place on the pipe with a file, bind a dozen or more turns of the wire around this spot, twist the wire tightly and drop solder on the turns. A better way is to use a ground-clamp around the pipe at the place where the scale has been removed.

Parts Required to Construct This Simple Set.

In order to keep down both size and cost the set has been simplified to the last degree. Most of the tuning can be done with the variable condenser. A variocoupler is used as the inductance, with the wire-wound rotating ball arranged to produce regeneration. With these parts and a vacuum tube and socket the set may be inserted in a cabinet to fit, the combination producing a receiver that is attractive and workable.

The actual parts needed for this set are listed below. The aerial should consist of one hundred feet of stranded copper aerial wire, one forty-three-plate variable condenser, one one hundred and eighty-degree variocoupler, a vacuum tube detector, a tube socket with necessary grid leak and condenser, a rheostat, a twenty-two-volt B-battery and the proper A-battery. The 'phones should be at least of two thousand ohms resistance.



One Popular Form of Single Circuit Receiver.

Constructional Details of the 180° Varicoupler.

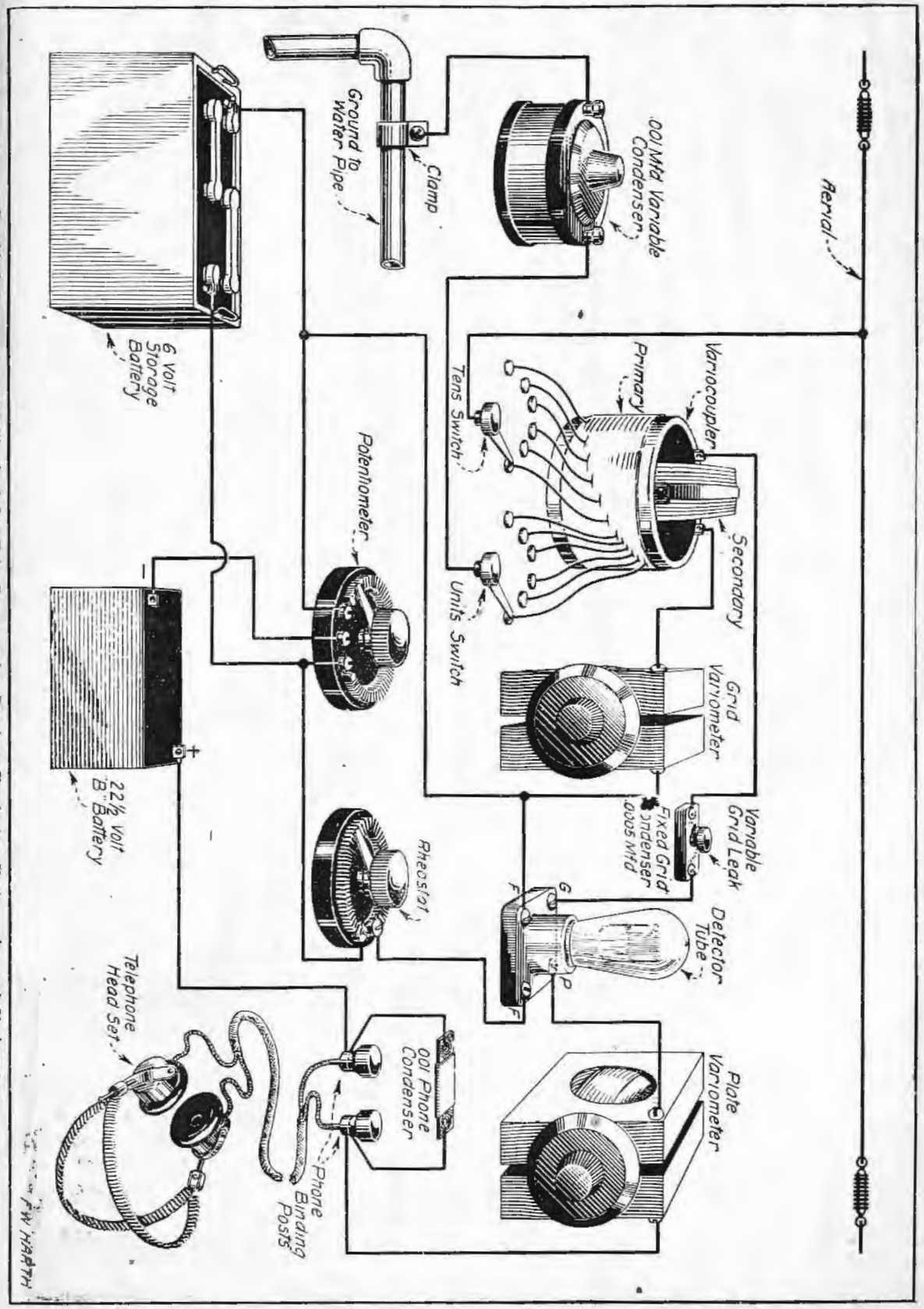
This piece of apparatus is really the heart of the whole receiver, and its selection therefore should be made with care. It is best to secure one which is made of tubing of high insulating quality, as this material will not absorb moisture. See that the coupler is ruggedly made, so that the wires will not loosen when assembling the set. Study the connections to get an intimate idea of the relationship of the parts. Purchase a tube that has a known reputation and one that can be used as a detector tube. In this case the UV 200 is suggested, provided a storage battery is to be available. If dry cells are to be the source nf supply, the UV 199, WD 11 or WD 12 is recommended.

It is mainly a matter of taste in the selection of the remainder of material. The most important part of the tube socket is the four-spring strips on the bottom of the socket. These should make firm contact with the four legs of the tube.

Two dials are needed, one for the condenser and the other for the rotor ball. The rheostat should make a positive contact throughout its range and should revolve easily without jerks. A switch arm with some contact points and a few binding posts complete the list of necessary materials for tuning the complete set.

The three specific claims made for this somewbat unusual adaptation of familiar circuits are simplicity, selectivity, and efficiency. It is a very simple arrangement—one glance at the diagram or the wiring of a complete set would satisfy the most skeptical on that point.

The input tuning is effected by an ordinary variocoupler and a .00025 microfarad variable condenser. All

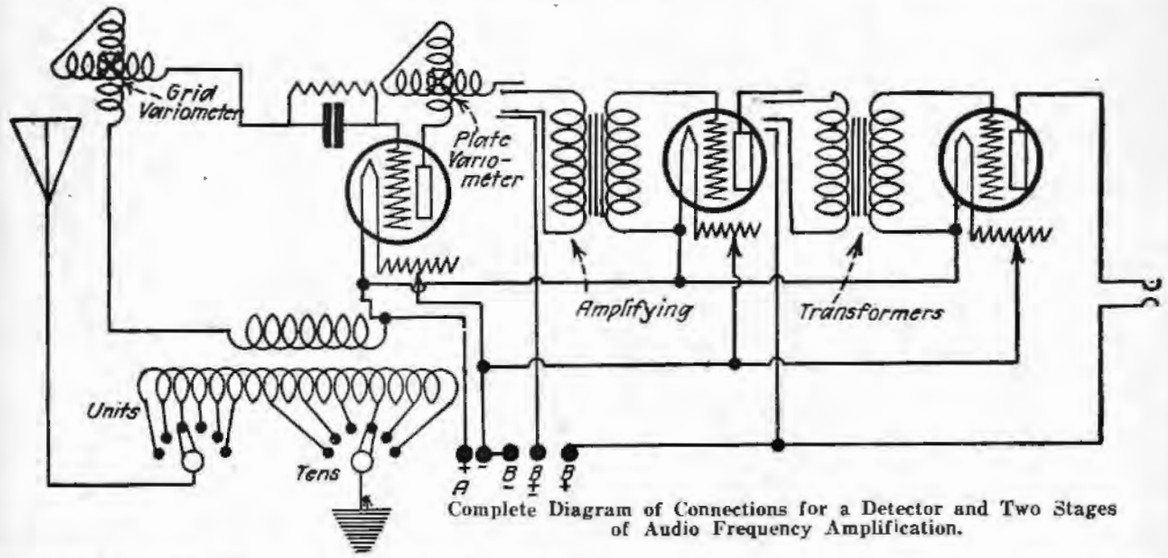


Graphical Arrangements of Standard One-Tube Regenerative Receiver Employing Variocoupler and Variometers.

the other details in the circuit are the same as that required in any other single-tube regenerative type; that is, grid leak and condenser, plate and filament batteries, vacuum tube, tube socket, and 'phones.

The connection on the aerial side of the variocoupler stator is the peculiar feature in the circuit. At the maximum, there are only six turns actually in the aerial to ground circuit. A four-point switch is used to vary this number in steps of one, two, four, and six respectively. These six coils are actually a part of the stator windings and by induction produce in the turns across the grid and filament the voltage which produces the signal in the 'phones.

The connection is known as the direct or conductive type of coupling and the operation is analogous to that of an auto-transformer. The rotor of the variocoupler is used as a tickler for producing regeneration in the usual manner. A feature of this particular circuit which causes it to differ from other single-circuit receivers lies in the fact that it does not reradiate unless the natural period of the aerial is exactly the same as the wave length that is being received. Such a combination is extremely rare. A condenser with only a small maximum capacity must be used in the primary circuit in order to secure the best results in tuning; a large condenser will make adjustments difficult. It is also advisable to use a well-constructed variocoupler that will allow 180 degrees change in the inductive coupling.



Complete Diagram of Connections for a Detector and Two Stages of Audio Frequency Amplification.

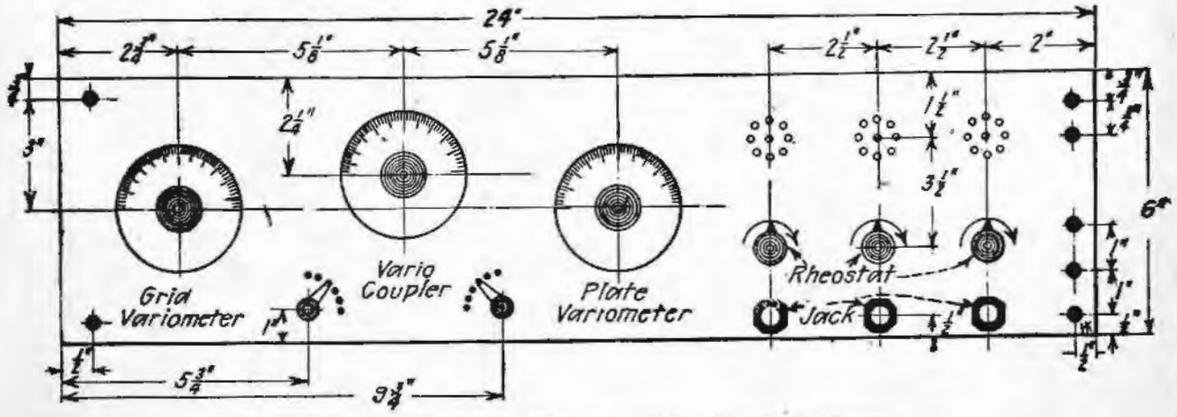
Regenerative Circuit of the Inductive Type.

Regenerative receivers with inductive feedback arrangements of the tickler coil, as explained previously, are in common use at many amateur stations. Another method of obtaining regeneration action which does not require coils is through the use of condensers as in the circuit known as the Eaton oscillator.

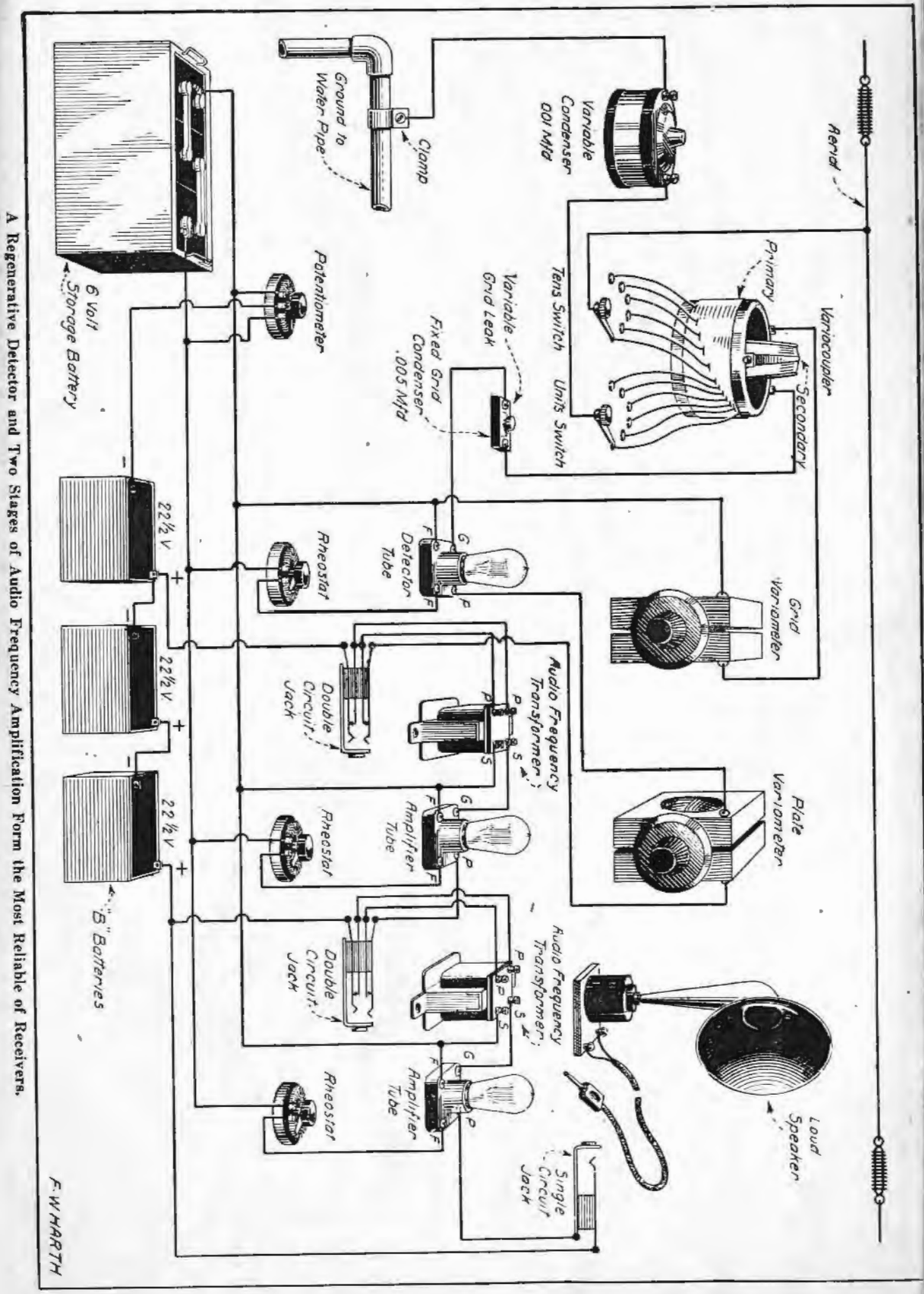
The diagram illustrates one way in which the Eaton oscillator may be incorporated into a receiving set of two units. One unit contains the tuning elements and the other the vacuum tube apparatus.

The Eaton oscillator, which consists essentially of two condensers in series is incorporated in the unit containing the tuning device which is of the loose coupler or variocoupler type. A secondary shunt condenser of the variable air type is also mounted in this unit to assist in tuning the secondary circuit.

The unit at the right contains a vacuum tube detector of the usual type with a lead running directly from the plate to a binding post which is strapped across to one side of the secondary circuit. The other side of the secoudary circuit connects to the grid condenser (C4) which may be of the variable air type. A



Panel Layout Suggested for Variocoupler-Variometer Receiver.



bridging condenser (BC) is connected from the plate to negative side of the filament battery. This condenser has an approximate capacity of .002 mfds.

The condensers C1 and C2 constitute the oscillator or feedback portion of the circuit, while the condenser (BC) is important in the adjustment of the system for the reception of damped or undamped waves. For receiving damped waves, condenser (BC) is set at maximum, while for undamped waves it is adjusted to minimum. The circuit may be operated without employing the bridging condenser (BC), but spark signals will not be received with their normal characteristic tone.

In operation a certain amount of the plate potential is fed back and impressed upon the grid by the condensers C1 and C2, which form a capacity feedback in contrast to the inductive arrangement usually employed.

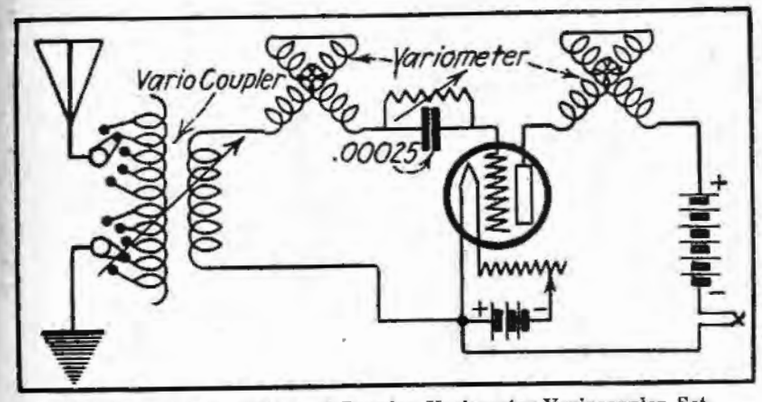


Diagram of Connections of Popular Variometer-Variocoupler Set.

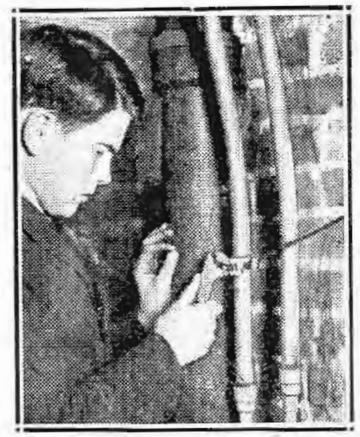
The circuit may be applied to any loose coupler or variocoupler and tube detector without materially changing the circuits or dismounting the apparatus. The condensers C1 and C2 are two fixed condensers in connected series across the secondary terminals, with the grid on one side and the filament in the middle with the plate on the other side.

While not particularly adapted to short wave work it has been possible to get down to 200 meters with this device. Good regeneration is obtained up to several thousand meters. A receiver of this type is comparatively simple to operate.

So far we have spoken about regeneration when referring to the vacuum tube when used as a detector. With crystal receivers regeneration is impossible.

The detector tube requires careful adjustment of the plate battery for best results. As a matter of fact, there are no two tubes possessing the same characteristics either in the filament current or the plate voltage.

It is very easy to make adjustments on the filament, since the rheostat gives fine control of the current. A vernier is even better for proper filament control. One form of these vernier rheostats has an extra arm built on the same shaft as the regular arm, but travelling over a single wire tightened around the body of the instrument. This enables the operator to regulate the filament temperature very closely.



A Ground Clamp Simplifies the Ground Wire Problem.

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Modern Receiving Sets

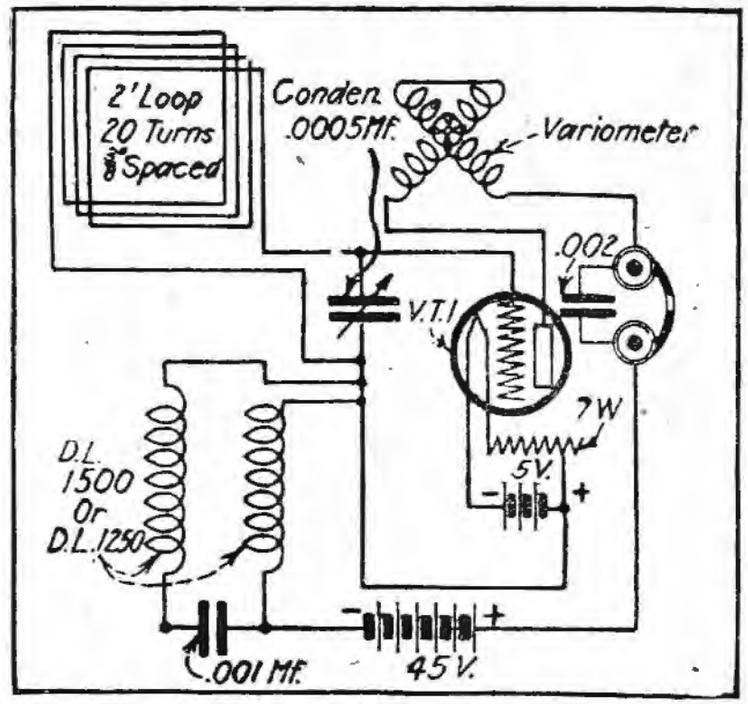
The Armstrong Super-Regenerative Receiver and Others Similar to It Based on the Same General Idea—Future Outfits May Be Developed From One of These Forms.

Unless scores of pages were available for the purpose, it would be far from feasible to attempt to explain in any detail whatsoever the electrical fundamentals of the super-regenerative circuit. Using electrical terms the explanation is not a difficult matter, but unless the reader happens to be an engineer versed in the theory of alternating currents the task is both impossible and inadvisable.

Any user of a regenerative receiver knows that when the tickler or variometer knob is moved just so far and the signals increased in strength to a certain point, a limit is reached after which farther regeneration distorts the sounds and creates a hissing noise which obliterates all that the distortion does not affect.

Met by this limiting factor early in his experiments with the simple regenerative set which he invented, Major Edwin H. Armstrong for years sought a method to eliminate this limit so that regeneration could be carried further, and stronger signals secured, without the addition of other tubes. He finally succeeded in developing what he termed the "super-regenerator." By the arrangement of certain circuits he was able to make the vacuum tube oscillate at a frequency which had a certain relation to the incoming oscillation of the energy waves. This new arrangement did not prevent the vacuum tube from starting to hiss or oscillate when the limit of regeneration was reached, but it did effectually prevent the generation of continuous oscillations. That is, as soon as the set commenced to oscillate a local action blocked it for an instant. Then the incoming signal registered an instant before the oscillations recommenced, but again the local action blocked it, thus making it possible to carry regeneration far beyond the critical point.

As would be expected, if the idea is reasoned out, there is a hum or whining sound that is always present



An Excellent One Tube Super-Regenerator.

in super-regeuerative sets, unless extensive means are taken to filter it out. This whine is of such a high pitch, however, that it is soon lost in the broadcast sounds and is not objectionable.

Because of the principle upon which it is based the super-regenerative set is fundamentally a short wave local receiver. Its efficiency decreases rapidly as the wave length is increased. The shorter the wave the more efficient it is. Likewise on distant stations the set does not compare in sensitiveness with the more common simple regenerative sets.

Multi-Tube Super-Sets Are Preferable.

The most desirable forms of super-regenerative sets incorporate three tubes, one being used as an oscillator, one as a detector, and the third as an audio frequency amplifier. There are single-tube super-regenerative sets, but it will be understood that it is much more difficult to adjust the three circuits when one tube is acting as a combined generator, detector, and amplifier than when each of these functions is being carried out by a single tube.

In the paragraphs that follow directions are given for the construction of a workable one tube super-regenerator. In view of what has just been said concerning the added difficulty to be encountered in making what is known as a "flivver" super-regenerator, it may seem strange that this is the only one to be described in this manual. The selection is made for one reason—available space. It seemed to the editors to be a better procedure to treat a smaller set more fully than to skim over the general details of a more extensive outfit. And the re-

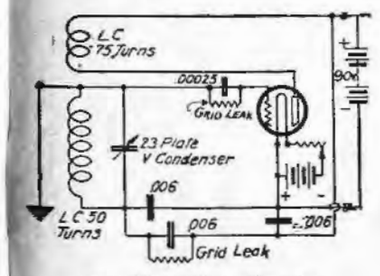
ceiver pictured is a most successful one. with a minimum of parts and of critical adjustments. As a matter of fact, its adjustments are but two, a variometer to control the regeneration and the condenser for close tuning.

With a 20-inch loop this receiver should do remarkable work on stations within fifty miles and on powerful stations within twenty-five miles should amplify sounds sufficiently to operate a loud speaker.

For the vacation trip this small compact set will add greatly to the pleasure to be derived. A list of all the necessary parts is given: One .0005 variable condenser type; one DL1,250 honeycomb coil; one DL1,500 honeycomb coil; one .001 fixed condenser; one .002 fixed 'phone condenser; 45-volt plate battery; one variometer; VT 1-vacuum tube, better knowu as the J tube; one rheostat; three dry batteries, and the necessary hardware. In laying out the variometer and the condenser the builder uay have to place extension shafts on the present shafts in order to mount the instruments away from panel.

Nine small flashlight batteries should be purchased and soldered together. This would give about 40 volts. When soldering the connections together a wad of tape should be rolled around the dry cells, merely as a support to hold them together.

The source used to supply the necessary filament current to the tube is a dry battery, three cells giving



The Flewelling Circuit.

enough voltage to hold out for at least two days' entertainment. Should the set be used at home where a storage battery is available it would be a great advantage to the experimenter if this source of power could be used. Dry cell batteries are only intended for nse when the set is actnally on the road.

Secure a piece of composition panel 8x14 inches, measure off the necessary dimensions as supplied in the accompanying sketch. Drill the necessary holes, bevelling off the ends of the panel in order to make a snug fit when the panel is mounted in the cabinet.

The variometer should be purchased complete. By doing this better results will be secured. A purchased variometer is far more efficient than a home-made one, and as only one tube is to be used every little advantage must be taken into consideration to get results. The variometer should be mounted on the right of the panel, ample room being allowed in order to secure the DL-1,250 above this. After the variometer has been securely fastened to panel place the DL1,250 honeycnmb coil in a position above the varinmeter so that it lies horizontally, say about one-half inch above. The DL coil can be secured by using a small piece of composition panel strip and brass bracket as shown in the photograph.

The vacuum tube socket in this case is mounted in the centre of the panel toward the base of it. A good vacnum tube socket should be purchased, especially one made of high grade cumposition.

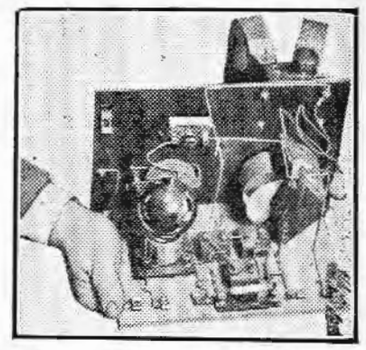
The condenser should be mounted on two strips of panel measuring 4 inches long, ½ inch wide, and about ¼ inch thick. A piece of brass sheeting measuring 4¾x3½ inches should be neatly fastened by screws to the strips. On tup of this, in its proper location, is mounted the condenser.

This second honeycomb coil is mounted underneath the condenser instead of on top, as in the case of the variometer. Ample room will be found for it. It should be secured in the same manner as the other coil. In placing the two coils either can be used in either place, but where a DL1,250 is used a 1,500 must be used in the corresponding space.

The loop aerial used in conjunction with this portable set measures 2 feet square. Two strips of composition panel were used. The strips measured ¾ inch square. A groove was made every half inch to hnld the wire. When clamping both strips an other piece 5 inches square was used, and clamped as shown in photograph. The conductor was No. 20 silk-covered wire wound to twenty turns. Two terminals are brought down to make connection with the binding post at the tnp nf cabinet.

The cahinet for this set measures 8x14 inches. The purchase of the panel is advised, since the construction of a cabinet ready-made is far better than the builder can turn it out himself. The cabinet itself should be fitted witn a cover.

To listen in, turn up the rheostat until the tube shows a fair brilliancy. Never allow the filament to burn brightly, as it may mean the destruction of the tube. Adjust the condenser dial to the wave length desired. Turn variometer handle for proper amplification, and finally turn the loop to increase the volume.


Rear of Cnmpleted Flewelling.

One of the most interesting of receivers embodying in some degree the fundamentals of the super-regenerative set is the Flewelling. As in the case of the Armstrong the details of the action are much too complicated and obscure for this treatise, bnt fortunately the details of construction are such that any one with a knack of following suggestions may build an outfit that should prove satisfactory.

Flewelling Set Obviates Large Coils.

The principal feature of the Flewelling circuit is the bank of three condensers and the critical grid leaks. The other materials needed are two honeycomb coils, a DL50 and a DL75, a 23-plate vernier condenser, a hard vacuum tube such as the WD11, the 201A, or the VT2, about 90 volts of B battery and a suitable A battery for the particular tube used. A two-coil mounting should be provided in order that the coupling between the two duolaterals may easily be varied. Some experimenters, it shnuld be stated here, have obtained excellent resnlts by substituing a variocoupler for these two coils. If this is done the number of turns on the secondary must be increased by about 100 per cent. Since the number of turns already on the rotnr varies with the make of instrument, the use of a var-

locoupler frequently calls for considerable experimentation before the correct turns are found.

The three condensers in the bank have a capacity each of .006mfd. Only first-grade mica condensers should be used here. Paper condensers are apt to be punctured by the high frequency currents they must withstand, and when this happens it is difficult to lay the trouble at their door unless very special testing apparatus is employed. So to play safe it is far more economical to buy the better grade first.

The Flewelling set will work with either antenna or ground, with both or with neither. Usually it will work best with a good antenna or a good ground, hence if either one is available plans should be made to utilize it. Reception without antenna and ground is possible, but except in certain well-balanced receivers the results are unsatisfactory.

The DL 50 coil is both primary and secondary with the 23-plate vernier condenser directly across it for tuning purposes. The DL 75 is the tickler coil and is inserted in the plate circuit. The position of the condensers is best showo by the diagram. This wiring diagram should be followed in every detail.

As mentioned previonsly, the grid leaks are exceedingly critical, particularly the one across the bank of condensers. In selecting the leak care should be taken that the instrument used has the most gradual of adjustments. The figures noted on the drawings are the values that have been found most suitable by a number of radio fans who have built the set.

Steps to Take in Operating the Flewelling.

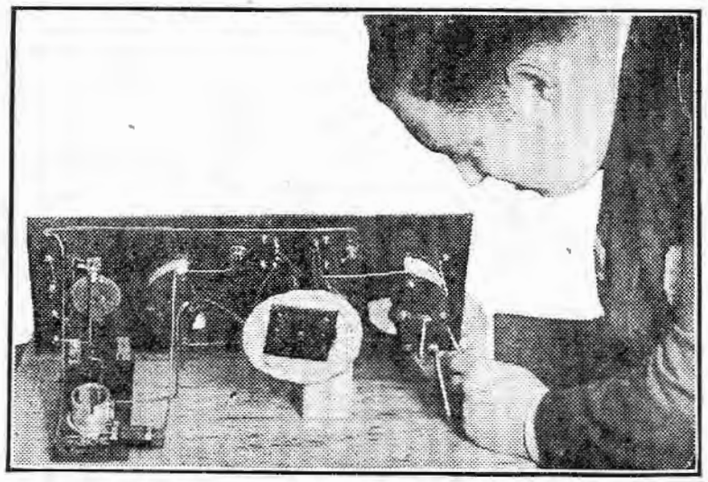
The first step is to place the two dnolateral coils close together. Set the twenty-three-plate condenser so that the movable platns are half way in mesh. Place the phones just forward of the ears, so that the sudden start of the oscillations when the tube is lighted will not affect the ear drums. Then light the tube. Immediately the phnnes should indicate the presence of the "Flewelling whistle." If no sound results, adjust the two grid leaks either simultaneously or singly until a noise is heard. It may even be found necessary to vary the condenser slightly at the same time. If connections are followed and all parts are perfect one or more of these moves should result in the generation of oscillations by the tube. When these start the next move is to loosen the coupling between the two coils. "Loosening the coupling" means to separate them.

As this is done it is probable that the tone of the whistle will change gradually, growing higher. If the whistle breaks and stops before a broadcast statioo is brought in, bring the coils together again, alter the position of the condenser slightly and try again. At some point the stations will be heard. Their presence will first be denoted by the familiar "whisp," as in any regenerative set. Once the lucation of the station has been found it should be easily tuned in hy means of the condenser and the vernier.

When the station is tuned in clearly it is possible that the whistle is still so loud that the sounds are smothered. To clear up the whistle alter the grid leaks slightly until the pitch of the whistle becomes so high as to be negligible.

While some remarkable distance records have been scored with the Flewelling, it, like the Armstrong, is essentially for local work. High amplification is gained by increasing the plate voltage, the limit of this voltage being determined by the type of tube used. With a WD11 tube this is reached at about 135 volts, with a 201A at about 200 volts and with the VT2 at 250 volts.

One disagreeable property of the Flewelling circuit is the presence of an exorbitant amount of stray capacity. This bothersome feature cannot be entirely eliminated perhaps, but it can be reduced to a point where operatioo is made easier by shielding the inside of the panel with a copper sheet. This bit of work might as well be done while the set is being assembled, because it is certain that later on the user will find it absolutely necessary and the labor in taking down a set after once getting it in working order is not to be disposed of lightly.



Rear view of the popular Reinartz circuit, known for its selectivity.

Reflex Receivers

Theory of These New and Sensitive Sets, With Suggestions on the Selection of Parts and the Construction of One- and Two-Tube Outfits.

One of the remarkable developments of this epoch-muking year is the so-called reflex system of reception. This circuit causes the same amplifying tubes tn act as magnifiers of radio and audio frequencies without interference in such a manner that three tubes do the work of six or two tubes do the work of four.

A reflex amplifier can be made from a single electron tube and crystal detector, the single tube serving both as a radio frequency and as an audio frequency amplifier. If it is desired to have sufficient amplification to operate a loud speaker it is usually necessary to add two stages of audio frequency amplification. In a reflex circuit this is accomplished by three tnhes. The first two tubes serve as radio amplifiers and also as audio amplifiers. The third tube acts as the detectnr tube.

A Workable Single Tube Reflex Circuit.

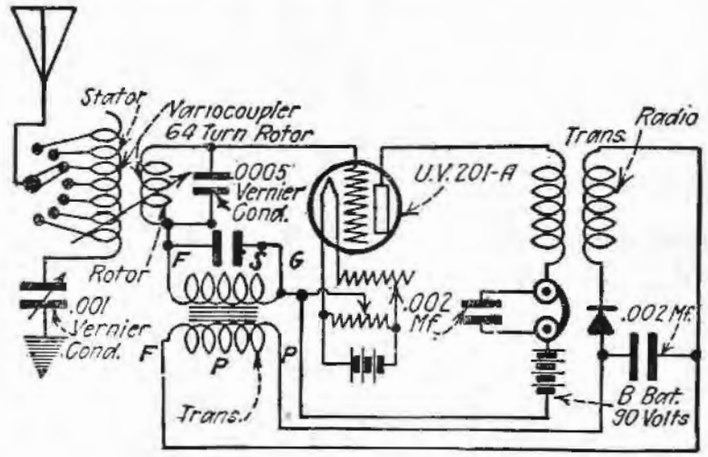
The circuit ahout to he described is very simple and can be made up by the heginner at a small cost. The idea of this simple set is to make use of the tube for both functions, as previously explained. The incoming oscillations are amplified at radiu frequency by the vacuum tube and then passed on through the radio frequency transformer to the crystal detector circuit, where they are rectified and changed to audio frequency oscillation.

These oscillations are then fed back into the tube only to be again amplified by the tube, whence the amplified signals are then passed on to the detector tube. Thus it can be seen that with one tube we have what is generally accomplished with two in other circuits.

Besides these advantages there are two other outstanding features of note. The circuit is quiet in operation, inasmuch as there are no tube noises. This is of extreme importance on very weak signals. Last, but not least, the circuit brings back the crystal detector, which makes possible u distortionless rectifying circuit.

A circuit shown is a one-tube reflex with crystal detector. If this set is made up, the builder should see that the leads are kept short and direct, thus making the set much more efficient.

One tube that works particularly well with the reflex is the new U.V.201-A. The WD11 or WD12 does not seem to produce results, for the simple reason that the plate of the tube will not stand up under the plate load. The small "N" tube, if available, would be a tube from which some results could be expected. The main point, however, is to see that the tube has sufficient plate to stand up under plate voltages recommended for the set.



A One-Tube Reflex Receiver.

How to Operate the One-Tube Reflex.

To operate this outfit the catwhisker should be in contact with the crystal. Turn on the filament, lighting the tube gradually. Continue turning the rheostat until a screeching or rumbling sound is heard in the head telephones. This noise may be stopped by adjusting the secondary variable condenser and the secondary of the rotor. The condenser in the aerial is optional. The fan who is considering the conversion of his crystal set into a vacuum tube set should study this circuit, for he may still use his crystal detector to good advantage. The only additional items needed in changing over that of the plain tube circuit is the use of two transformers and the crystal detector.

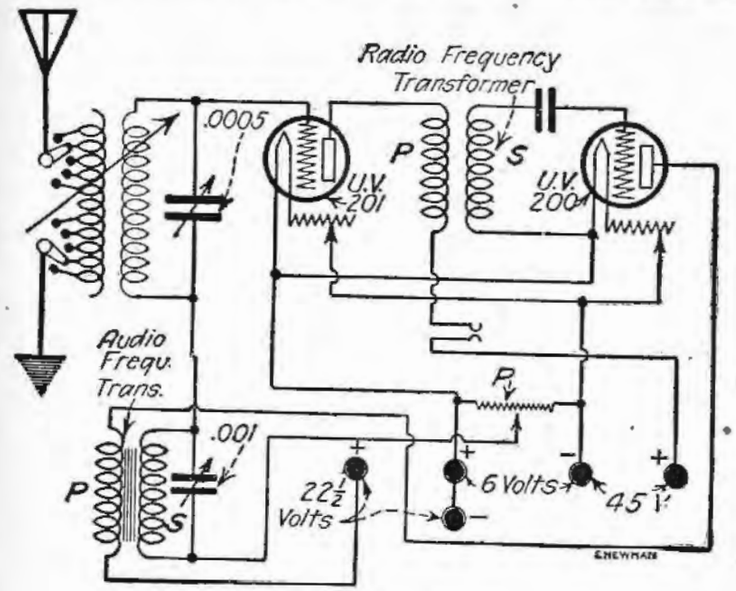
A final word about purchasing apparatus. Do not be influenced entirely by price. Pick out merchandise that is trademarked and that has a reputable manufacturer's name, together with proper research facilities behind it. In radio work we deal with such minute electrical impulses that the best should be the rule rather than the exception. A little additinnal outlay will well repay the builder by superior and consistent results.

Construction of a Two-Tube Reflex Set.

The two-tube set is the equivalent of two stages of audio frequency amplification and two stages of radio frequency amplification. Using this set with a loop antenna, the fan will find that the signals come in clear and strong with a fairly good range.

The only additional feature is the use of a by-pass condenser across the secondary of the audio frequency transformer.

In the two-tnbe reflex circuit shown, the tubes act as radio frequency amplifiers for the purpose of building up the incoming signal, to be later rectified hy means of the crystal or vacnum tube detectur. The entire receiver can be enclosed in a compact case and made to operate successfully on a lnop aerial.



A Twn-Tube Reflex Receiver.

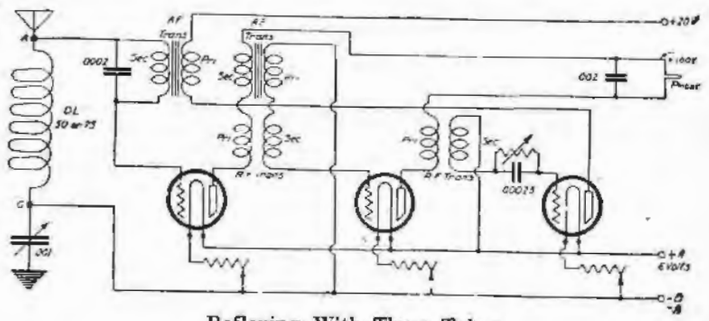
In the actual application of this circuit there are several difficulties that have to be overcome. The tubes, for instance, must be coupled for both radio and audio frequency circuits, but in placing an audio frequency amplifying transforuer in a circuit in which radio frequency currents are flowing the windings of the secondary act as a choke coil and prevent the radio frequency currents from passing.

To overcome this a condenser is sbunted around the secondary windings of the audio frequency transformer, unless the secondary winding of the audio frequency transformer has a sufficiently high distributed capacity to make its impedance low. The American-made tube has a high internal capacity which is bad for R. F. amplification.

The amateur attempting to build reflex sets should not employ regeneratinn, fnr once the tube starts oscillating the whole set may become paralyzed, due to the tubes becoming choked.

The by-pass condenser will be found of great value to the experimenter and constructor, especially when inserted around head telephones or loud-speaking devices. If this by-pass condenser is left out of the circuit around the head telephones the 'phones have a tendency tu act as a chuke coil. These small by-pass condensers, which are of .002 mfd. capacity, are essential, and no reflex circuit will function satisfactorily unless they are properly placed in the circuit. They must also be of the correct value.

There are various ways in which coupling may be employed. For the shorter waves the coupling may cnnsist of an ordinary choke coil, radio frequency transformer, or a tuned impedance. Due to the fact that we are most interested in the 360-meter to 492-meter wave lengths of the various broadcasting stations, we must give nur attention to that wave.



Reflexing With Three Tubes.

The coupling used to the best advantage on these short waves is that of the transformer. It eliminates tube nuises and allows the circuit to operate quietly.

Using the crystal detector brings us back to the old days when such detectors were in power. The crystal is used in the reflex to great advantage. It eliminates the noises from the tubes and batteries and make the set distortionless. These gains offset the loss in signal strength.

A loop aerial is recommended with the reflex circuit, but an outside aerial will function as well. Of course, the inherent tube noises and atmospheric static noises will be greatly eliminated if the loop is used.

Potential of B Battery Is Important Factor.

The two-tube circuit differs slightly from the one-tube set in that it uses a tube as a means of detection. The plate voltage of this set depends on whether a hard or soft tube is used. A soft tube is recommended, but in such a case a vernier rheostat must be employed in the circuit. When constructing such sets extreme care should be taken in the wiring, keeping all wires that run parallel as far apart as possible, and making sure that there is no chance for a short circuit. If further amplification of the signals is desired the batteries of the amplifier should be separated from those of the circuit proper.

If amplifier tubes are used in all three stages the B battery should he regulated so that the proper voltage is applied to the respective plates. This is accomplished by experiment. Usually between 40 and 70 volts are found best for the plates of the tubes, and sometimes as high as 125 volts. In the diagram the plate current is indicated as 1,000 volts, but the real

value is obtained only by experiments.

In the actual application of this circuit there are several difficulties to be overcome. The tubes, fur instance, must be coupled for both radio and audio frequency circuits, but in placing an audio frequency amplifying transformer in a circuit in which radio frequency currents are flowing the windings of the secondary act as a choke coil and prevent the radio frequency currents frnm passing. To overcome this result a condenser is shunted around the secondary of the audio frequency transformer, unless, as sometimes happens, the secondary winding of the audio frequency transformer bas a sufficiently high distributed capacity to make its impedance low.

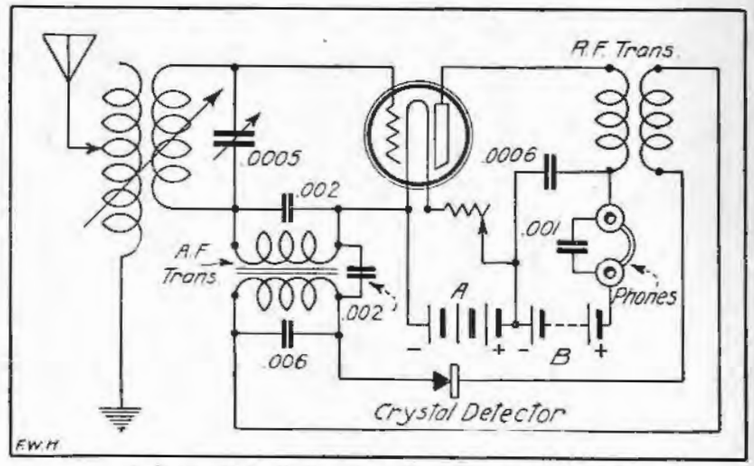
If the UV201A is used the builder should purchase a 25-ohm rheostat, in order to control the tnbes properly.

Different tubes have a decided effect on the set as a whole and if not prnperly considered the whole circuit may be a total failure. Many radin frequency transformers in combination with various audio frequency transformers have been tried out.

With this set either aerial or loop may be used. The loop is recommended and the one used successfully with this set was wound on a frame with fourteen turns spaced three-eighths of an inch apart, the outer turn having a diameter of 23 inches. Number 20 wire, either cotton covered or bare, can be used to make up the loop.

When the amateur begins to tune in for DX stations he will hear considerable howling, which can be easily eliminated. Some of this howling can be easly reduced by regulating the filament rheostat. Careful adjustment of the filament voltage of the second amplifier tube and detector will be found to be the critical adjustments.

It will be noted that for stations of the 360-meter class the detector filament will require more current than for some of the 455- and 492-meter stations. The variable grid leak also is an important factor. The 'phones are placed across the plus or positive side of the 100-volt line and the primary side of the radio frequency transformer in the second tnbe amplifier. The coil used for the inductance in the set is a DL50 or 75 with a .001 mfd. variable condenser in series when the aerial and ground are used as means of antenna.



A Single Tube Reflex That Has Proved Its Worth.

If the loop aerial is used it will sometimes tend to make the tnbes "spill over." Should the tube oscillate too much, reduce the value of the capacities in the condensers that are in shunt to the secondaries of the andio frequency transformers. In using the UV201A amplifying tubes it will be found that most of the tuning will be done with the condenser and filament rheostat.

The Storage Battery

Its Design, Formation, and Construction, With Suitable Hints to Be Followed in Testing the Cells for Condition and Arranging for the Proper Recharging of Depleted Cells.

A storage battery is an essential with receiving sets incorporating certain types of vacuum tubes. These tubes—namely the UV200, UV201, VT1, and VT2—require such a high current for heating the filament to full brilliancy that some high capacity source of electricity must be utilized. This is best supplied by the storage battery.

The oldest type of storage battery is made up of lead cells. There are two classes of lead cells, the classification being based on the method of forming the active plates. One of these methods has the active material of the positive plates formed directly on the surface of the plates, an invention attributed to M. Plante. The other is called the "Faure" type and has the active material applied to the surface of the plates in the form of a paste.

The Plante type cell is considered heavier and stronger than the Faure type, and possesses greater durability when subjected to severe working conditions. Since the Faure type of cell is not so heavy for a given output it is usually adopted for use in vehicles.

To Illustrate the Principle of Plate-Formation.

If two clean lead strips are placed in a solution of dilute sulphuric acid and their unimmersed ends connected with a galvanometer or sensitive voltmeter no deflection is noticeable. If a current from a primary cell or from any direct current source be allowed to pass from one strip to the other through the acid solution for a few minutes, and the circuit then broken and the strips again connected to the sensitive voltmeter, a movement of the meter will be noted. By observing the portions of the lead strips immersed in the solution it will be seen that one strip has undergone no change while the other has become coated with a brownish film. This brownish coated film is peroxide of lead formed by the action of the electric current. The two lead strips are now dissimilar and act exactly as a primary cell.

The plates which make up these small cells of electrical energy are

(Photo by K. & H.)

The hydrometer shows the condition of the storage battery.

constructed chiefly of lead. The plates are generally cast and the pores filled with oxides whose component parts are varied, one combination producing what is known as the positive and another the negative plate.

The positive plate consists of minium, 70 per cent.; litharge, 8 per cent.; graphite, 12 per cent., and white of eggs, 10 per cent., the latter ingredient acting as a binder. For the negative plates the litharge is 95 per cent., the remaining 5 per cent. consisting of finely divided asbestos fibre or powdered porcelain.

The plates are made in various sizes, depending upon the capacity called for, capacity in turn being figured on size and area of plate, and the number of groups of plates assembled. When a cell is ready for assembly an even number of positive plates are connected together by a strap, preferably burned on by heat and an uneven nomber of negative plates attached in the same manner to another strap. It must be remembered that there is always one more negative plate than positive.

The electrolyte commonly used in lead storage batteries consists of a mixture of chemically pure acid, sulphuric acid, and pure distilled water. The acid should be made from sulphur and not from pyrites. The acid mixture is usually designated by its specific gravity, I. e., its weight compared with an equal volume of water. One pint of pure water weighs approximately 1 pound, while a pint of pure concentrated sulphuric acid weighs 1.835 pounds and is alluded to as eighteen thirty-five acid. The proper acid electrolyte is one having a specific gravity of about 1.225 at ordinary temperatures when the cells are fully charged. The final specific gravity on discharge should not fall below 1.185.

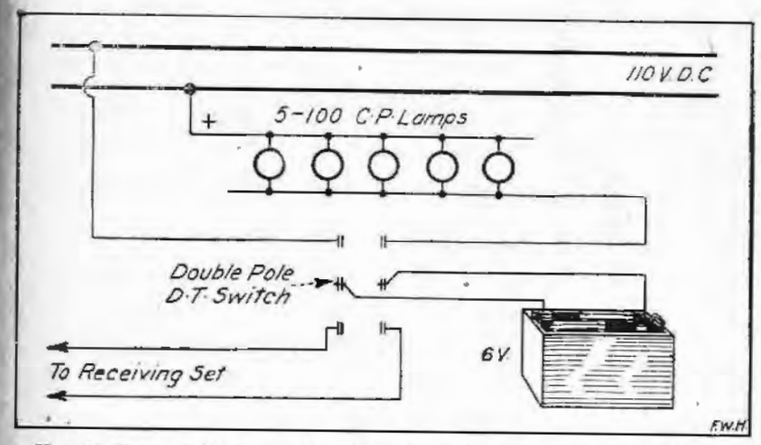
In mixing the acid and water to make the electrolyte, the water should first be put into a glazed earthware jar and the acid slowly added in a very fine stream to prevent excessive production of heat and possible explosion. Never pour the water onto the acid. While mixing the acid with the water stir gently with a glass rod. Just after being mixed, the electrolyte is hot and has a lower specific gravity than when cold. The final adjustment of the specific gravity may be made by adding a small quantity of pure water to the cooled solution.

The electromotive force and internal resistance depend largely on the density of the acid electrolyte. The greater the density the greater the E. M. F., while the specific resistance of diluted sulphuric acid is least at a specific gravity of about 1.260 and increases or decreases from this value.

The voltage of a lead cell when

fully charged is about 2.5 volts and should never be allowed to fall below 1.8 on discharge.

Storage batteries are rated in ampere-hours. The ampere-hour rating means that the battery will deliver a certain number of amperes for a certain number of hours. Take a 40-ampere-hour battery. This battery will deliver 1 ampere for 40 hours or 5 amperes for 8 hours. The higher the ampere-hour rating the longer the battery will go without charging.



How to Connect the Parts for Charging a Battery From D. C. Lines.

Storage Battery Capacity Rated in Ampere-Hours.

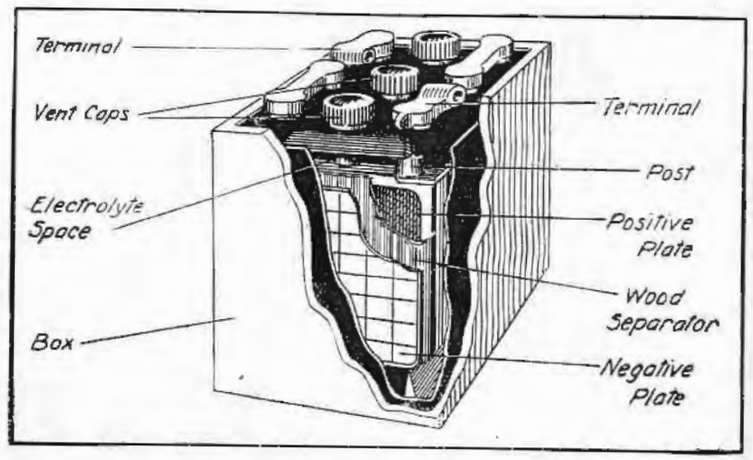
If a vacuum tube detector alone is being used, a 40-ampere-hour battery is sufficient. If amplifiers are employed an 80- or even a 110-ampere battery is more suitable. Vacuum tubes of the standard type require about 1 ampere each, so that an 80-ampere battery should operate a receiving set of 3 tubes for about 25 hours, after which the battery must be recharged.

There are a number of ways to gauge the condition of a battery when it is discharged. They are the voltmeter process, the ampere-hour meter process, and by the use of what is called a hydrometer. Without any of these instruments it is possible to judge the condition of a cell by applying it to the filament of the tubes. Should they decline to light up brilliantly when the full voltage of the battery is impressed, it is an indication that the battery needs charging.

However, the most useful instrument to note the condition of a cell or battery is a hydrometer. This is a glass tube containing a graduated scale marked 1.000 to 1.300 on paper within and the lower part of the tube being enlarged to about twice its diameter. This base contains lead shot or some heavy substance that will cause it to stand upright as it sinks in the electrolyte. The hydrometer may be placed in the solution where the cells have open tops, but usually the solution is drawn up into the chamber of a syringe which contains the hydrometer. The hydrometer syringe is a convenient device for testing the density of the acid. By slightly compressing the bulb and inserting the slender tube through the vent hole in the cover of the cell sufficient acid may be drawn up to float the hydrometer within the large glass tube and the reading made at once. The acid is returned to the cell by again compressing the bulb and the reading of the next cell taken. Should the hydrometer show a reading of less than 1.180 the battery should be placed on charge.

After the storage battery has been in use for a short time its voltage becomes less than when first put into service and it becomes necessary to recharge the battery. The recharging may be done from direct current wires or from alternating current mains if some form of rectifying device is employed to convert the alternating current into direct current.

All vent caps should be removed from the batteries while charging. Distilled water should be used. Always keep the plates covered with water at least ½ inch over their tops. See that the polarities of the batteries are correctly right to that of the charger. See that the charger is connected up properly to the source of supply. The battery should



Storage batteries consist of alternating sets of positive and negative plates spaced in each instance by an insulating separator and surrounded on all sides by a solution of sulphuric acid called the electrolyte. In building a battery the positive and negative plates are punched or drawn in the form of grids and, plastered with a pasty mixture of oxides of lead. They are then given a long charge from a source of direct current which "forms" the plates. This term means that the oxides on the positive plates are further oxidized and changed into lead eroxide, a brown chemical. The current acts in the opposite manner on the negative plate and reduces the degree of oxidation, thereby changing the original lead oxide to the dull gray "spongy lead."

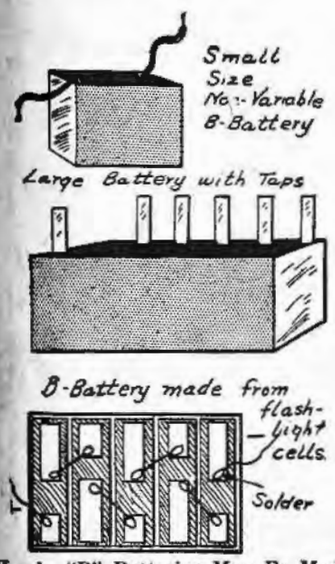
In the storage batteries used for radio all the positive plates in one cell are connected together and all the negative plates. Then the positive plates from one cell are connected by metal strips to the negative plates of the next cell, and so on through the three cells.

placed and kept on charge until the reading of the electrolyte shows at least 1.225 or more on the hydrometer. Frequent readings should be taken while the battery is on charge.

An attempt should never be made to light the filaments of the set while the batteries are being charged. If this is done the tubes will be destroyed. When the battery is fully charged shut off the power and disconnect the battery from the charger. Care should be taken that the vent holes are closed up and the battery thoroughly cleaned. A little attention in keeping the battery clean will maintain its condition, thereby preventing short circuit from any material that may find its way in and around the terminals of the cells.

When connecting up the battery to the set see that the terminals are cleaned off. Use a small piece of sand paper. It may be noticed from time to time, as the battery is used, that the terminals show signs of a white deposit called "sulphation." A small amount of vaseline or petroleum placed about the terminals will tend to keep sulphation at a minimum.

For those who have direct current in their homes, a battery charger is



Handy "B" Batteries May Be Made From Flashlight Cells.

not needed. As indicated in the sketch, four or five lamps properly connected will suffice to charge the battery in first class condition. The lamps should be about 100 watts each and all connected as shown. The charging current will average between four and five amperes. By removing one lamp, one ampere will be lost from the charging rate. The correct charging amperage is generally marked on the battery by the maker. It is always best to charge the battery at a low rate. Remember, the slower the rate of discharge the longer the battery will last. Do not try to overload a battery nor discharge a battery too quickly.

The following list of don'ts for the storage battery user has been collected from battery experts:

¶Don't charge faster than the rate that will keep the temperature of the liquid below 110 degrees Fahrenheit.

¶Don't use any water except distilled water.

¶Don't let the electrolyte get below the plate.

¶Don't overcharge the cells.

¶Don't let the cells stand idle longer than five weeks without giving them a charge.

¶Don't let dirt or other mineral matter get into the cells.

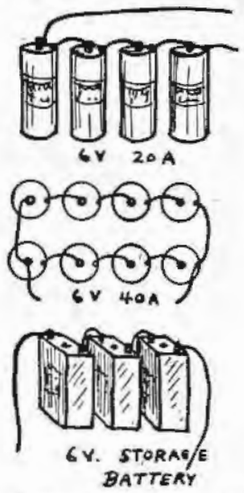
¶Don't charge a battery before removing the caps so gas may escape.

¶Don't light any matches near the battery while it is being charged.

The vacuum tube is said to be the most sensitive electrical device in existence. The slightest electrical charge on the grid controls faithfully and instantly a strong current flowing between the filament and plate. In this manner it becomes possible to control a strong force by a weak force. The vacuum tube can be used for many purposes. It is a rectifier of alternating curreot, that is, it converts alternating current of almost any frequency and of any strength within its capacity into direct current. It also can convert direct current into alternating current of a wide range of frequencies. As stated previously it makes possible the control of a powerful current by a weak current. This feature is the basis of the amplifier. When the weak current from the detector is impressed on the amplifier tube a current several times as powerful is produced in the second tube, giving a much louder response in the telephone receiver.

Radio receiving sets employing vacuum tubes either for detector or amplifier must be equipped with some sort of battery for supplying them with a high voltage. This battery is called the B-battery to distinguish it from the other battery which lights the filament and is known as the A-battery. The proper voltage of the B-battery is about twenty-two volts.

The operator of a set should be sure that both batteries are connected correctly, for if the B-battery happens to become connected to the



Series Connection (Above) and Parallel Connection (Centre) of Dry Cells.

filament circuit the tube will burn out almost instantly.

There are several different types of B-batteries on the market, most of them satisfactory. The principal requiremeots are to have a battery that will supply a high voltage and a low amperage, since the actual drain on the battery is small. In fact, the B-battery usually succumbs to old age long before the current is consumed by the tube. The B-battery can be placed somewhere on a shelf at the back of the set and forgotten for several months.

"B" Battery Needed to Supply Higher Voltage to Tubes.

The first type of B-battery to be considered is the small size, which delivers about twenty-two volts. These little batteries are good enough for ordinary work, but in some sets it is desirable to vary the voltage from the B-battery and in such a case as this it is best to secure one which is supplied with taps so that the voltage may be varied. The amateur may find that his particular vacuum tube will work the best with only twelve to eighteen volts on the plate, but as the battery gets older the voltage will need to be raised.

A little wrinkle in battery use may interest amateurs or novices.

instead of buying large B-batteries go to any electrical store and purchase a number of small flashlight batteries. They are usually sold in a box containing five, but the supply is unlimited. Leave the batteries in the box or build a special box for them and connect them all in series with short pieces of wire, aided by a little solder. There are two pieces of brass on each of the flashlight batteries. These are the terminals. The long one is the one connected to the zinc of the battery and is the negative pole. The other, or shorter one, is the positive.

In connecting them up leave the first long one for the external connection, then connect the short piece of brass on the first cell to the long piece on the second cell. Keep this up until all the batteries are connected together. It will be found that a short lead will be left on the other end of the series. Always connect B-batteries in this way. If more batteries are needed for an amplifier simply buy several additional boxes of the batteries and proceed to connect them in the same way.

If the voltage must be varied take a small battery clip or spring clip and solder a piece of wire to it. It is then a simple matter to vary the number of cells in use by moving the clip from electrode to electrode. Remember, though, to place the clip always on the positive side.

A B-battery of this type should last many months before it needs renewing. Even then the operator will be able to pick out the cells that have deteriorated and replace them with new cells, thereby saving the expense of purchasing a whole new B-battery.

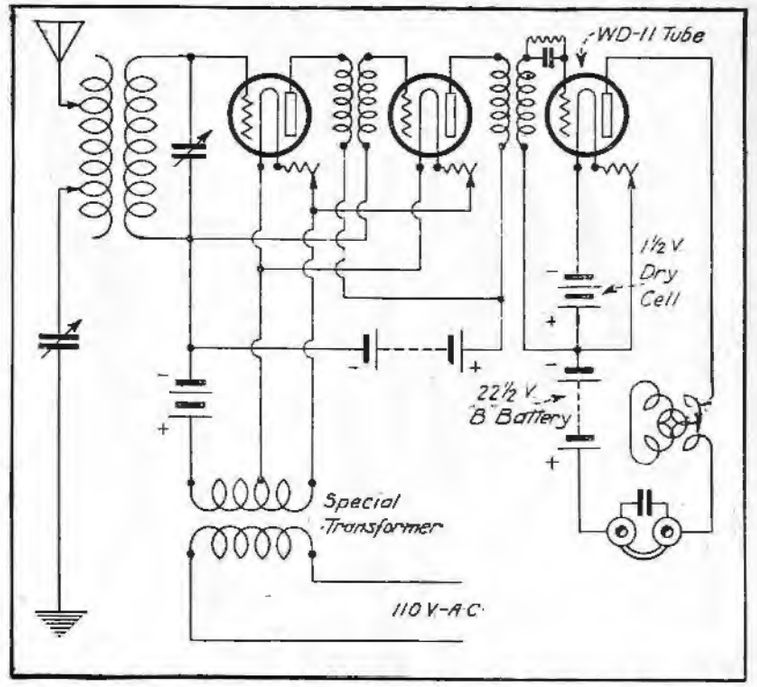
The "A" Battery, or Filament Lighting Battery.

The use of a vacuum tube in a radio receiver involves a battery to supply current for the filament. This is referred to as the A-battery. The A-battery in the case of the more common tubes is a six-volt battery, but the tube known as the WD11 or 12 operates on an ordinary dry cell. Another tube, known as the UV199, operates on two dry cells, while the remainder, or majority, operate on the six-vult storage battery. Should the owner of a radio receiver possess six-volt tubes but desires to use dry cells he may readily do so, but it is inadvisable to begin operation with such an arrangement, as the life of dry cells is limited and it is a matter of a few days only when they will need to be replaced by a new set of dry cells.

If dry cell tubes are used it is advisable to have them connected in parallel in order that their life may be lengthened. To do this connect all the carbon rods, or centre posts, of the dry cells together, and all the outside or zinc posts together. This then makes the outside polarity negative, while the carbon rods, or centre posts, form the positive connections. This mode of connection allows the voltage to remain at one and one-half volts, the correct value for the dry cell tube, but the amperage or life of the battery will be four times that of a single one.

Still, there is nothing that really takes the place of the storage battery for the six-volt tubes. This is especially true when more than one tube is being used, as, for instance, when one or two stages of amplification are added to the detector. The storage battery may be of any standard type, but a battery of large capacity is preferred. A battery in the vicinity of eleven ampere hours is a satisfactory size. Then if a loud speaker is added at a later date the battery will be large enough to handle the added demands.

A storage battery must be recharged after its charge has been consumed. Where a storage battery is employed to light several vacuum tubes the drain on the battery is considerable and a home charging outfit will be found to pay good dividends. The storage battery then may be recharged whenever necessary at a minimum of expense and without losing valuable time.



Filaments of Amplifier Tubes May Be Lighted From A. C. Lines.

House Lighting Current for Filament Supply.

The question: "Why is it not possible to use the house lighting current on the filaments of vacuum tubes?" is frequently asked. The fact of the matter is we are dealing with delicate fluctuations in the tubes. If the filament voltage should vary even in the slightest degree the electronic flow would likewise vary and cause a corresponding noise in the head telephones. Therefore, for absolute quiet in the head telephones it becomes necessary to use a steady, non-varying direct current source, such as the storage battery. The lighting current could be easily cut down to six volts, regardless of whether it be direct or alternating current, but in either case there would be a distinct hum, which, in the head telephones, would drown out the signals. This prevents the use of the lighting current on the detector.

How to Locate Troubles ir Radio Receivers

Whatever the type of receiving set, the first step is to rest out each piece of equipment individually. A small flashlight lamp and battery form a simple testing outfit.

If no sounds are heard in the 'phones, hegin at the lightniog arrester and test each part. With the lamp aod battery across the arrester the lamp should not light. A light indicates a short circuit. Applying the test to the tuning nnit, the lamp should light when the terminals are connected across the primary, and alsu across the secondary. It is a good idea to test out the separate taps on the primary to see that none of the small pigtails have become broken inside the flexible tubing.

When coonected across the condenser, the lamp should not light. If it does, this indicates a defective condenser, whether it be variable or fixed.

The only satisfactory way to test a tube is to take it to some other receiving set known to be in working order and substitute it for one of the tubes in use. A tube with a filament that lights up when connected to a battery is not necessarily a good tube. There is always the possibility of grounds between the elements.

Regeneration and Its Effects

A Brief Talk on the Methods of Obtaining and Controlling This Very Desirable Condition, Together With Working Diagrams.

Three million good and honest American citizens or citizens-soon-to-be are using receiving sets in which regeneration plays an important part. These radio enthusiasts, most of them, know when the set is regenerating. They know how to produce it, but why the effect is made manifest by such insignificant accessories as a simple variometer or even a single slide tuning coil is beyond their ken. As a matter of fact, they don't have to know. It is because of this last statement that this treatise, like many others intended for consumption by the average man, will not attempt to enter into the technicalities of regeneration. Rather, the phenomenon will be described briefly in terms that it is hoped will give a general idea of its cause and effect.

Many receiving sets are now sold which are non-regenerative. But friends of the buyers soon inform them that the sets can he improved by making them regenerative. All that is necessary to bring this about is the insertion of a variometer in a certain pnsition in the plate circuit of the detector tube.

Even after Dr. Lee De Forest developed the three-element tube it was used as a straight rectifier of incoming waves for many years. Peculiar effects were undoubtedly observed originating in the tube under certain circumstances, but no one seems to have studied them until Edwin H. Armstrong, a student at Columbia, while carrying out experiments on tubes and tube circuits, happened to notice that the plate circnit of a tube which he was using as a detector contained something other than rectified currents in the plate circuit. He experimented further and discovered that this plate circuit was carrying high frequency currents in addition to the low frequeocy rectified currents. If this were so, he figured, then by tuning this circuit and allowing the energy to feed back into the secondary circuit of the receiver the incoming signal would be greatly reinforced. He placed a variable tuning coil in the plate circuit, tuned it to resonance and the signals fairly boomed out with their added volume. He had made one of the most astnunding discoveries of the age and one that in later years was tn affect the entire complexion of the radio industry, broadcasting as well as reception.

Small Current in Grid Controls Large Plate Current.

As was stated in the chapter devoted to the fundamental action of the vacuum tube, the presence of a very small amount of energy in the grid of the vacuum tube will control a much larger amount of energy in the plate circuit. If the action of the two circuits is considered as being entirely independent of one another the analogy is much the same as that of the motorman of a trolley car, who by the application of a small amount of force on the air brake handle liberates a large amount of force at the air brake and thereby controls the movement of a car weighing many tons.

In the vacuum tube, which is arranged for possible regeneration, this energy in the plate circuit can be tuned to be in phase or in step with the incoming wave, and thus incrense the initial force or the grid. Of course the complete action is instantaneous, but an idea of the manner of working may be clarified if the following word picture is understood.

For purposes of the example assume that a force of 1 pound is impressed on the grid. Through the amplifying action of the tabe this original force is increased to 4 pounds. This quadrupled force is then arranged to be in step with the first force and is fed back to the grid, where the two forces combine to form a force of 5 pounds. This force of 5 pounds, acting through the tube, is increased to 20 pounds in the plate circuit and so on.

If this seems like perpetual motion the radio fan should not become too enthused since the design factors of the tube themselves soon form a limit beyond which this amplification cannot go. After a certain point in regeneration is reached the tube is set off into oscillations, which means that it is no longer acting as a pure receiver but is also functioning as a transmitter. When this point is reached the signals will lose their real tone and will become mushy and distorted. With code signals this does no harm, but radiophone sounds are made nointelligible.

Regeneration Can Be Secured in Several Ways.

There are several methods of obtaining regeneration. One method has already heen mentioned, that of tuning the plate circuit of the tube with a tuning coil or variometer. Another method makes use of a wire-wound tube called a "tickler," which is placed near the rotating element of the primary tuner or variocoupler. Still another form of feed back is that made possible by a condenser inserted between the grid and plate of the detector tube. This last named method is not usually satisfactnry with the apparatus in the hands of amateurs.

Of all these methods it is probable that the "tickler" form of regeneration is the most satisfactory, although it is not incorporated in receivers so frequently as the tuned plate method, using a variometer to control the regeneration. With the "tickler" it is easier, as a rule, to carry the regeneration to a higher point before the tube breaks into oscillations.

One very satisfactory form of "tickler" is that made by winding forty to fifty turns of wire on a rotor ball similar to that comprising the secondary tuning inductance and placing this "tickler" ball at the opposite end of the wire-wound tube which comprises the primary tuner. Thus the complete tuning accessories are included in one unit with

the primary as the permanent coil, one rotor in one end of the primary as the secondary coil and another rotor in the opposite end of the primary as the "tickler."

In arranging these coils for regenerative circuits it sometimes happens that while the receiver will work the regenerative effect is lacking. This usually may be remedied by switching the connections leading to the two ends of the "tickler" coil.

Variocoupler-Variometer Outfit Is for Short Waves.

The varioconpler two-rotor receiver or the variocoupler-variometer set is suitable only for short waves from 150 to 550 meters. As now covered by regulations, these limits are sufficient to accommodate all broadcasting stations. But for experimenters who feel the urge to listen to the code signals of the powerful transatlantic stations here and in Europe some other form of receiver must be built. With few exceptions this is the honeycomb set.

All parts of a regenerative set utilizing honeycomb or duo-lateral coils instead of couplers for tuning purposes are similar to those using couplers and variometers except for the substitution of these coils themselves and the means for tuning them.

Honeycomb or duolateral coils are coils containing many turns of fine wire wound criss-cross in such a way that the separate turns of wire touch only at certain times and places. In short, this scheme of winding reduces to a minimum what is known as "distributed capacity," a factor that reduces the efficiency and tuning range of tuning coils.

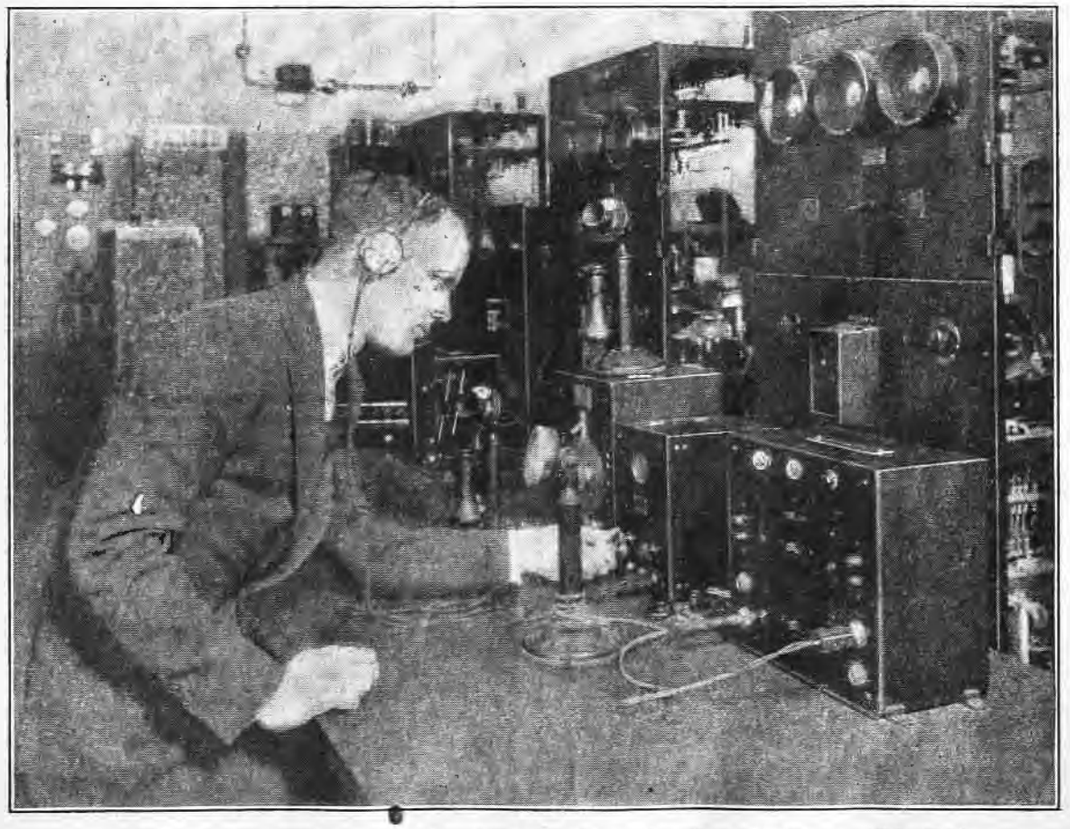
In following out this scheme of winding the inventors were able to compress the enormous inductances needed for long waves into a relatively small space. Thus the old coils for receiving 15,000-meter stations consisted of several thousands of turns of wire wound on a 6- to 8-inch insulating tube, 6 or more feet long. The honeycomb or duolateral coil for this wave length is only 1½ inches thick and 6 inches in diameter.

These coils are seldom tapped, hence it becomes necessary to connect a variable condenser across them to tune the circuit to the desired wave length. The following table suggests the sizes to use for various wave lengths, the size in each instance having been figured for use with a 43-plate variable condenser (capacity .0011) across them. The "tickler" is more frequently employed without this condenser.

TABLE OF HONEYCOMB COIL SIZES FOR ALL WAVE LENGTHS.

Wave Lth.	Primary	Second.	Tickler.
150-350	DL50	DL25	DL50
300-700	DL100	DL50	DL100
450-1,050	DL150	DL100	DL150
850-2,000	DL250	DL150	DL250
1,750-4,000	DL500	DL250	DL500
4,000-8,500	DL1,000	DL500	DL1,000
6,000-12,000	DL1,500	DL1,000	DL1,500
12,000-20,000	DL1,000	DL1,500	DL1,000
16,000-25,000	DL1,500	DL1,500	DL1,500

When a receiver is built with honeycomb tuning coils the same set may be utilized for the reception of broadcasts or of 20,000-meter code signals. All the owner need do is remove the smaller coils from the mounting and replace with the larger coils for the longer wave lengths.



All the Intricate Operations of a Broadcasting Station Are Controlled From This Table.

'Phones and Loud Speakers

Head Sets Are Essential for Crystal Sets and for Weak or Distant Stations, but the Ideal Receiver for the Home Requires a Loud Speaker.

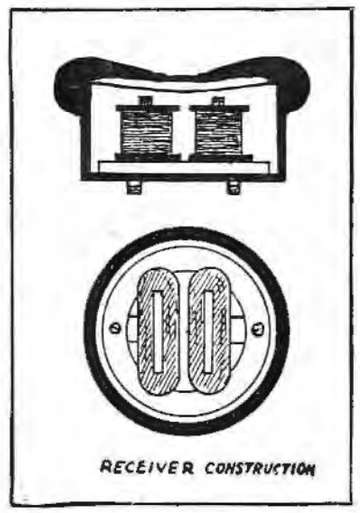
The radio head 'phone has never had the credit it deserves. Without it there is no telling what intricate and supersensitive apparatus would be necessary to take its place and carry out its function of translating the fast-moving impulses of electricity into audible sounds.

The amount of energy picked up by an antenna is so small as to be measurable by only the most sensitive of special indicating instruments. Yet the headphoue, in the case of the crystal receiver, is set into motion by these trains of almost insignificant energy.

A 'phoue consists of several thousands of turns of very fine wire—No. 40 to 44 silk co·ered or enameled—wound carefully on two little spools, through the centre of which run cores of soft iron. Around the outside of the case holding these spools are several circular pieces of somewhat harder iron which have been permanently magnetized.

The spools are placed in the centre of the case in such a position that the tops of the iron cores are slightly below the level of the outside of the case. Then across the top of the case a thin diaphragm of iron is laid.

The permanent magnets hold the diaphragm in a slightly dished position. The electro magnets formed by the wire-wound spools have no effect on the diaphragm until a signal impulse passes through the set. When a high-frequency wave strikes the grid of a vacuum tube the current in the plate circuit, where the 'phones are located, is also made variable, although the changes are



RECEIVER CONSTRUCTION

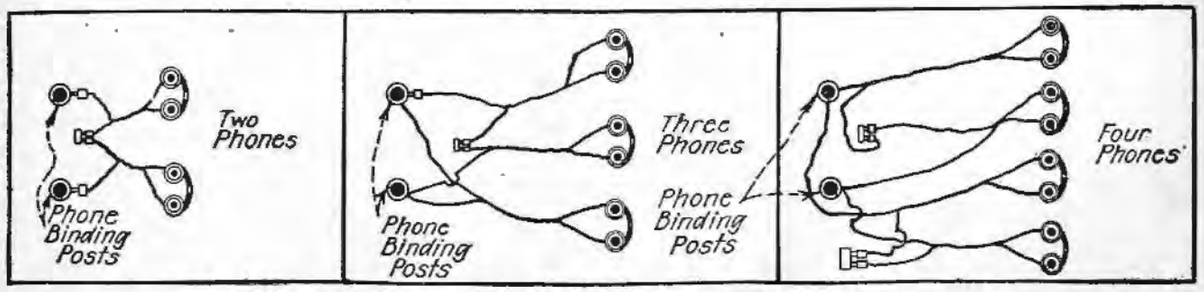
not so rapid as are those of the incoming wave. The windings of the 'phones hold back the actual high-frequency currents in the plate circuit.

When a sound is made with the voice and the sound waves impressed on a telephone transmitter, the shape of the electric impulses sent out over the wire or over the air, as the case may be, assumes the shape of the vocal sound. These waves are not regular in shape, but are a mixture of many odd-shaped waves. As these peculiarly modulated waves strike the grid of the tube they create a disturbance in the 'phone circuit that is practically similar to the words spoken at the transmitter. As these currents pass through the fine winding on the spools a temporary magnetic field is formed. This new magnetism may help or "buck" the magnetism of the permanent circular magnets. When they help, the diaphragm is drawn down with considerable force; when they "buck" the total effect is less than that of the permaoent magnet alone and the diaphragm tends to return to its normal position.

'Phones Should Not Be Bought by Ohms.

In advertisements and store windows 'phones are usually specified according to the number of ohms, such as "2,200 ohms" or "3,000 ohms." The 'phones with higher ohmage are more apt to carry a higher price tag, leadiug the unknowing purchaser to believe that the 'phones are better in proportion to the amount of resistance.

To explain this fact a bit further, the term ohms is merely a measure of resistance. Thus an electric bulb of the type used to light the home may have a resistance of 200 ohms. But no one buys a lamp according



Proper Connections to Follow When Two or More 'Phones Are Connected to One Set.

to the ohmage. In the same way it is unwise to purchase radio 'phones by their resistance. The ohmage may, however, be considered in the case of reputable 'phones, since the increased number of ohms indicates the greater number of "ampere-turns" in the receivers. And ampere-turns are the determining factors which make one receiver better than another.

One ampere of current flowing once around a magnet is one ampere-turn. It makes no differeuce what kind of material the conducting wire is made of. But when a 'phone is specified as having 3,000 ohms, the magnet coils within the case may be wound with a comparatively few turns of some odd kind of wire having a high resistance. Thus there would be few turns in the receiver, although the label would be quite right in stuting the resistance value.

It is understood that the beginner in radio cannot, nor does he want to, bother with these technical terms. For him it is best to buy only those 'phones that are made by reliable firms. The cost will be higher, but the intrinsic value will accompany the cost. If the cost is beyond his financial means, then he should insist on a trial of the 'phones, with aa option of returning them if unsatisfactory.

The crystal set operates best with high-grade 'phones of about 2,300 ohms resistance, but the modern tube set frequently gives best results with 'phones of higher resistance, the value sometimes running as high as 6,000 ohms. For general purposes, however, the reliable makes of 3,000 ohm 'phones are the most suitable for the average receiving set.

The Ideal Receiver Requires a Loud Speaker.

The extension of radiophone entertainment has brought into prominence other types of head 'phones, one in particular having a diaphragm operated by levers terminating in a small iron bar floating in a magnetic field. As this field is varied the bar is moved back and forth. This movement is then magnified through the leverage and the final force exerted on the diaphragm. These receivers produce a greater volume of sound and are known colloquially as "loud talking receivers." These 'phones form the basis of phonograph adapters and are excellent for the purpose. For head sets, however, some of the makes are so heavy as to be uncomfortable, although their increase in volume over other types sometimes compensates for this disadvantage.

Loud Speakers Available in Several Styles.

A receiving set is not complete until it contains a loud speaker. Head 'phones are essential until the detected sounds have been built up through amplification to a point where they are powerful enough to operate the mechanism of a loud speaker. This usually requires at least two stages of amplification. For experimental purposes a head set is superior to any other type of sound translator, but the family receiving set will fail in its ultimate usefulness unless the sounds as delivered from the set are thrown out into the room for all who may be there to hear.

There are several widely differing types of loud speakers. Some of them are nothing more than horns made of tin, white metal, plaster of Paris, wood pulp, or wood strips, to the base of which a loud-speaking receiver is attached. Others are equipped with two horns at the base to which the complete head set may be attached, one 'phone on each horn.

Strictly speaking these devices are not loud speakers, but are merely resouators. They take the souud waves as they issue from the telephone and by resonance increase the volume. The action is like that of a megaphone through which an announcer speaks.

All too often these horns are designed incorrectly or built of wrong materials. They pick up one or more of the sounds from the 'phone and amplify it out of proportion to all other sounds. Conversely, certain sounds will not be amplified at all. This selective resonance produces foreign or "tinny" sounds which have the effect of distorting the speech.

The most satisfactory type of loud speaker is either the one which embodies a special diaphragm built into the throat of the horn or, better still, that type which utilizes a specially designed diaphragm of the amplifying type.

In the first class will be found many exceptionally fine reproducers of the broadcast programmes. These loud speakers require no extra equipment, but are inserted in the output of the receiver just as a pair of 'phones would be placed.

The second class of loud speakers is connected to the output of the receiver, but in addition two leads are taking from the storage battery, for the purpose of supplying the current for the supplementary magnetic field in which the bar of iron floats.

Few suggestions can be given to aid the novice in selecting the loud speaker. There is but one criterion. It is not the price, but the sound. Before buying any loud speaker, the prospective purchaser should be permitted to listen to several types, one after the other, as it is switched into the same receiving set. Even though the set is improperly adjusted, this method provides a comparison which quickly separates the speaker of highest quality from the others.

Loud volume does not always accompany tone. The loud speakers with the sweetest and purest tones are not, as a rule, those which "fill a room with noise." The loud speaker for the home should be selected on the merits of its tone, first, last, and always.

Engineers Are Developing Better Loud Speakers.

No radio or acoustical engineer is so rash as to believe that the ideal loud speaker has been even approached by those now available. The last year has seen some distinct improvement in this line of radio equipment, but there is still much to be desired. It is not a simple problem to amplify the wide range of sounds encountered in radio transmission. These sounds range from the low notes of the bass singer and of the church organ to the high shrill notes of the violin and wind instruments. The perfect loud speaker must amplify these tones, each in its proportion to the others, otherwise strange notes are sure to be introduced.

Radio Frequency Amplification

Higher Amplification, Greater Distance and Finer Selectivity Are Possible With the Proper Application of This Feature.

"Use audio frequency amplification for volume and radio frequency amplification for distance and selectivity." This is the admonition of radio engineers. Thousands have followed the advice without knowing why. An equal number have attempted to apply radio frequency units to receiving sets already in existence with utter failure, due to the fact that their understanding of the devices was meagre.

When a broadcasting station transmits sounds in the furm of waves these waves travel at a high rate of speed, depending on the wave length. Thus a wave with a length of 400 meters occurs with a frequency of 750,000 times a second. A wave of 800 meters occurs at just half this rate. The reason for the use of this high frequency is a technical one and refers to the efficiency of the aerial as a radiator of waves. Its exposition has no place here.

But referring to the section on crystal detectors, it will be recollected that the function of the crystal detector was to change this high frequency of the transmitted wave to the very low frequency at which the human ear will function. The vacuum tube operates as a detector for the same reason.

The frequency at which waves are transmitted is called radio frequency. That at which the waves are heard is called audio frequency.

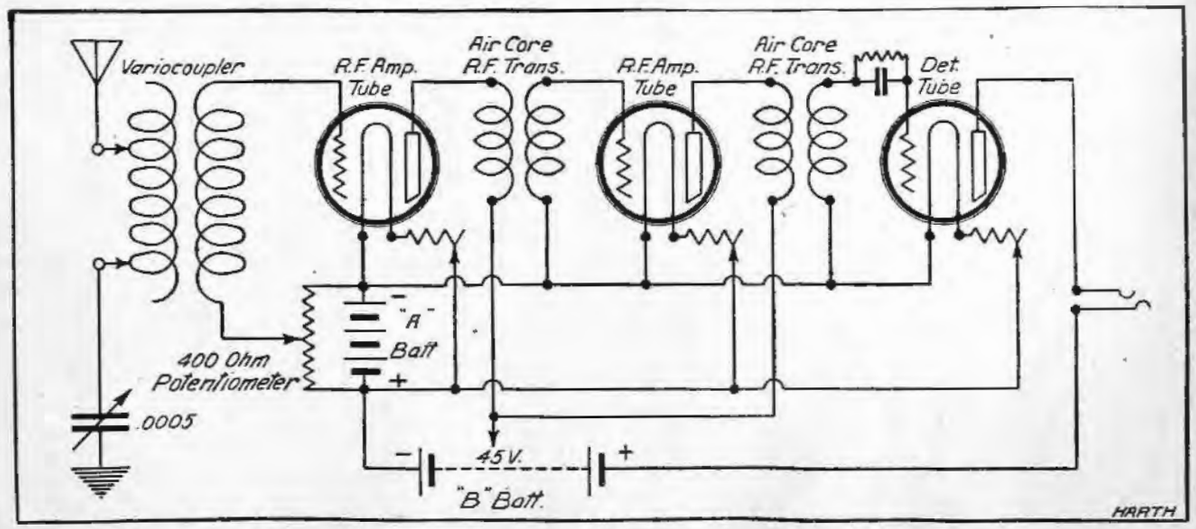
In receiving sets that do not employ radio frequency amplification it is the intentiou of the designer to change the radio frequency waves into similar waves of audio frequency as quickly as pussible. Waves of high frequency are much more difficult to control and keep in their proper path than waves of lower frequency. So as soon as the antenna picks up these waves and leads them down to the tuning unit they are tuned hy means of coils and condonsers, and are then immediately passed into the "slowing down" or detector tube. In this tube—in the case of a 400-meter wave—the waves which were travelling at the rate of 750,000 a second are toned down to a mere 800 to 2,000 a second, for these latter limits are those to which the human ear is sensitive.

But if the slowed-down waves can be amplified, why shouldu't the high-frequency waves be treated likewise? This question occurred to engineers who, after considerable experimenting, found that not only could it be done, but that results obtained were well worth the doing.

How High Frequency Waves Are Amplified.

Rudio frequency amplification means that the infinitesimally weak waves coming in from the antenna are passed through one or more vacuum tube units and given an added push or energy before they are sent through the detector tube. To do this requires the nse of tubes and other devices placed between the tubes, just as transformers are placed between tubes in stages of audio frequency amplification.

In one form of radio frequency amplification utilizing two stages the incoming waves are first tuned with the usual tuning device. They are then passed into a vacuum tube. From the vacuum tube they pass through a specially constructed radio frequency transformer, out of the transformer into a second tube, through the plate of the second tube



How to Connect a Radio Frequency Receiver Using Inter-stage Transformers.

to a second transformer, and from the transformer into the detector tube.

These radio frequency transformers differ considerably from the audio frequency transformers. In the first place, as a usual thing, they are not built over a core of soft iron, although some types do use a metallic core. Furthermore, the windings of the input—called the primary—and the output—called the secondary—usually consist of the same number of turns, whereas in audio frequency transformers the secondary turns are frequently ten times those in the primary.

Several Types of Radio Frequency Amplification.

Radio frequency amplification is obtainable in several widely differing forms. There is the transformer type, sketched in hasty outline above; there is also the resistance coupled type described in one of the diagrams shown in this article, and, thirdly, there is the choke coil type of coupling. For the short waves and corresponding high frequencies with which the radio enthusiast works the transformer type of coupling is by far the more suitable.

The resistance-coupled R. F. amplifiers have the advantage of being equally effective over a wide range of wave lengths, but at any given wave length their effectiveness does not equal a well-designed transformer coupling.

The reactance or choke coil type of coupling is of interest to the experimenter who enjoys the careful manipulation and manifold adjustments required to fit the reactance to the particular stage of amplification and to the wave length being received.

The highest degree of amplification is obtainable with transformers of careful, conservative design. Unfortunately the amount of amplification and the stability of the amplifying tubes do not go hand in hand. One must be sacrificed to feature the other. Hence, the best radio frequency transformer is one which effects a healthy compromise between amplification, minimum distortion, and stability.

It should be mentioned here, however, that due to the characteristics of transformer coupled amplifiers the same transformer cannot be used for all wave lengths. There is usually

Government Radio Publications

The following list of books is reprinted from various official lists because the information contained in them will be found to be valuable in supplementing the data in the RADIO MANUAL. The publications may be secured by mailing the indicated amount to the Superintendent of Documents, Government Printing Office, Washington, D. C. Remittances should be sent in the form of money orders.

Elementary Electricity, Signal Office Training Pamphlet No. 1 ..... 15c

Elementary Principles of Radio Telephony (Radio Communication Pamphlet No. 1) ... 10c

Principles Underlying Radio Communication (600 pages) $1.00

Radio Instruments and Measurements (Technical) 60c

Construction and operation of a simple home made radio receiving outfit (Standards Circular No. 120) 5c

Construction and operation of a variocoupler receiving set with crystal detector (Standards Circular No. 121) 5c

Description and operation of electron tube detector unit for simple radio receiving outfits (Standards Circular No. 133) 10c

List of Commercial and Government Radio Stations 15c

List of Amateur Radio Stations of U. S. 25c

Sources of Elementary Radio Information (Standards Circular No. 122) 5c

In addition to the foregoing publications the Department of Commerce publishes a monthly pamphlet called the Radio Service Bulletin. This Bulletin contains the names and call letters of all new broadcasting stations, all government regulations affecting commercial and amateur stations and general information relating to the entire radio industry. The Radio Service Bulletin will be mailed to any address for 25 cents a year.

one point at which the amplification will be best. Just how wide a band of wave lengths one transformer will accommodate will depend on the design. A transformer with an iron core will cover a wider band than another with an air core. But exceeding care must be used in selecting the iron and arranging the windings with respect to the core, otherwise the amplification will be uneven as the wave changes from a given value.

Radio Frequency Useless With Regeneraton.

Most receiving sets in use to-day employ the regenerative feature. To add radio frequency amplification to these sets requires that the regenerative feature be eliminated, else the intermeshing of frequencies will result in feed backs and beat notes, causing those squeals and hisses for which some outfits are noted. Regeneration in itself is a function of radio frequency currents, hence to combine the two phenomena is only wishing for trouble.

But regeneration, if properly controlled, means the life of the detector unit. To drop it means that one tube will do only one-third the work possible with regeneration. Hence, if the receiver is to be rearranged to include radio frequency units, it is useless to think of utilizing fewer than two stages of radio frequency.

If regeneration is omitted, the loss is not quite fully made up with one stage of radio frequency. With two stages of radio frequency the loss is compensated for, and in addition the amplification is increased. But the employment of radio frequency stages has the advantage of providing a filter circuit through which extraneous noises and other wave lengths can penetrate only with difficulty. This tends to provide sharper tuning and greater selectivity.

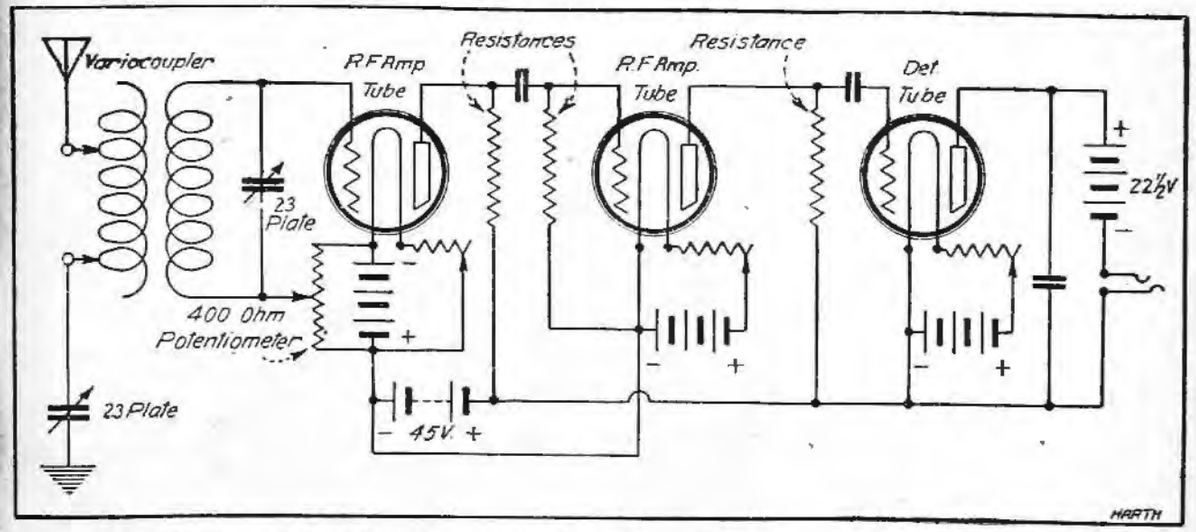
Radio Frequency Efficient in DX Work.

In one department of radiophone broadcasting radio frequency amplification is in a class by itself. This is the reception of distant stations. Without radio frequency amplification the detector will detect only those impulses that are sufficiently virile to actuate the circuits of which the tube is the nucleus. Thus many signals that are too weak pass through the detector tube without causing any effect in the 'phone receivers.

When radio frequency units are present, these puny waves are built up through the two or more stages to a point where they exert a sufficiently powerful force on the grid circuit to cause a sizable change in the plate circuit and in the 'phones. Thus with R. F. the signals from distant stations can be brought in loud and clear enough to be recognized.

In arranging radio frequency units the various leads should be shortened to a minimum and should not be allowed to run together for any distance. The greatest enemy of successful R. F. amplification is the presence of capacity, and wires running parallel are fruitful sources of this deterrent. For the same reason switches should not be used except when essential. It is not a good idea to install switches to cut in or out the radio frequency units, for the reason that the mechanism of the change-over switch and the wires leading to it are prolific sources of capacity.

If one will stop for an instant and consider the substance he is dealing with, it will be evident that plugs and jacks are useless in the radio frequency side of the receiver. The impulses then are still at the high inaudible frequencies and the insertion of a jack would reveal nothing.



Radio Frequency Amplification Utilizing the Reactance Form of Coupling Between Stages.

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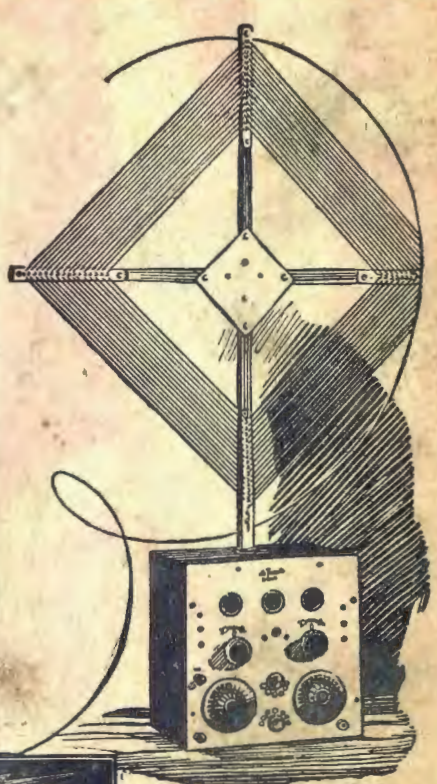

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