THE RADIO AMATEUR'S HANDBOOK

A. FREDERICK COLLINS

The Radio Amateur's Handbook

By A. FREDERICK COLLINS, inventor of the wireless telephone. Fifth edition. Edited by Geo. C. Baxter Rowe, Assistant Editor of the *Radio News*. Profusely illustrated. 437 pages. 8vo.

Interest and progress in radio increase so rapidly that the new thing of today becomes obsolete tomorrow. This, at least, has been true to the present; but indications now foreshadow a standardization of equipment. Mr. Collins's book appeared among the first and has been accepted as an authority; yet at each new printing many minor changes have been found necessary. Now the text has been completely gone over again by a daily writer on radio matters who is in touch with every branch of the field. New features in this edition include new preface, latest regulations of the National Board of Underwriters, latest government regulations for amateurs, supplementary information on radio frequency amplification, tuned radio frequency receivers, loud speakers, A and B battery eliminators, additions to table of frequency and wave lengths, chart of vacuum tubes, and other useful information.

A feature of this book, which has attracted attention from the first, is the number and clarity of its cuts and diagrams. By their aid almost any amateur ought to be able to work out his own radio salvation. It has been the publisher's ambition from the outset to make one of the very best and most complete works on radio procurable—an ambition which this further revision and enlargement aid no little to realize. The book will be found of immediate service to both the amateur and the expert.

Thomas Y. Crowell Company, New York

THE RADIO AMATEUR'S HAND BOOK

A Complete, Authentic and Informative Work on Wireless Telegraphy and Telephony

BY

A. FREDERICK COLLINS

Inventor of the Wireless Telephone 1899; Historian of Wireless 1901–1910; Author of "Wireless Telegraphy" 1905

FIFTH EDITION

REVISED BY

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Assistant Editor of *Radio News*

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BOOKS BY

A. FREDERICK COLLINS

WONDERS OF CHEMISTRY

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THE AMATEUR PHOTOGRAPHER'S HANDBOOK

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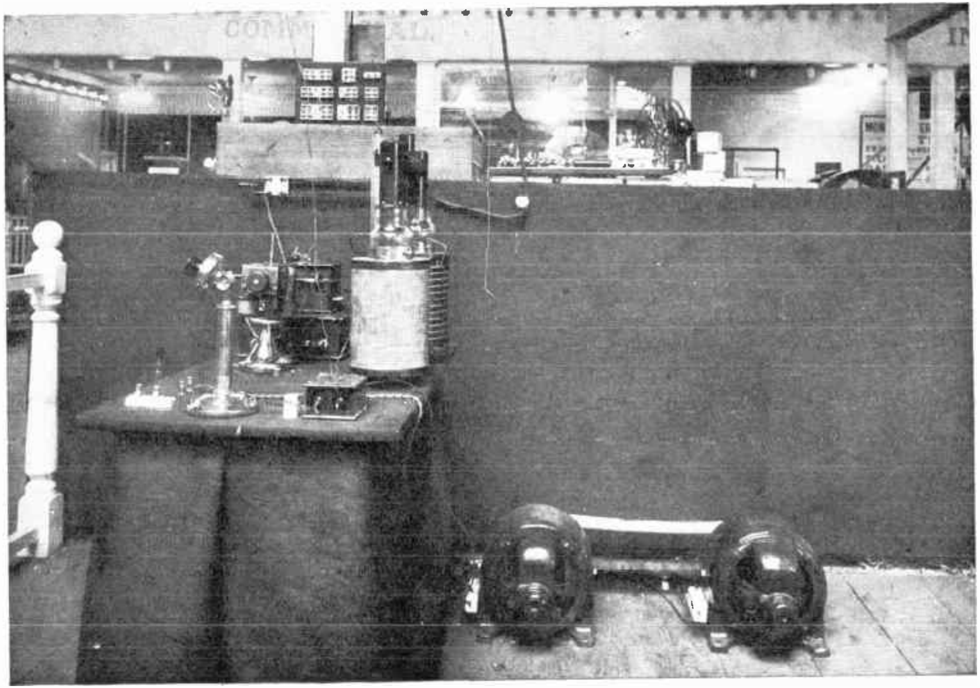


Collins' Wireless Telephone Exhibited at the Madison Square Garden, October, 1908.

PREFACE TO THE FIFTH EDITION

ONLY a year and a half has elapsed since the fourth printing of the Handbook, but in that time progress has been made in the field of radio that was not expected for several years to come. Today it is possible to sit in an office in New York City, remove the receiver from its hook on a telephone and ask the operator to connect you with someone across the Atlantic Ocean in London. Land wires carry the conversation part of the way on both sides of the ocean, but it is radio that spans the thousands of miles between the two countries.

Other phases of radio have kept pace if not outdistanced this feat. In the matter of broadcasting more and more power is being employed, due to the powerful transmitting tubes of 20 and 100 kilowatts. This power and the wave lengths on which stations operate are now under the control of the Federal Radio Commission, which solves the problems that have arisen in an industry so complex as this one. In the realm of reception, in which the majority of people are interested, the most progress has been made in the improvement of apparatus, not many new circuits having appeared.

This being the case, the editor of this edition has only mentioned two circuits that in his opinion are interesting from an experimental viewpoint. Additions have been made, however, to the data on circuits for the transmission and reception of short wave lengths, new audio-frequency amplifiers, loud speakers, socket power units, experiments with light sensitive cells, etc. Also with the advance in the art new phrases have been introduced which are included in the Glossary. The Radio Act of 1927 replaces the former one of 1912 and is given in the Appendix.

In what direction radio will now progress is a difficult matter to predict, but it seems safe to say that with the very rapid advance made in television much will be done along those lines. The U. S. Navy is using radio now to broadcast weather maps to all her ships and aviation fields; radio beacons now guide airplanes through fog and rain, making possible the air mail service between New York and San Francisco, and in the recent transatlantic airplane flights radio played an important role. Chain broadcasting is now a daily occurrence, four networks now covering the entire United States and making the hook-up of about fifty stations possible.

Never before in the history of any country is so much being done for the entertainment of the public at large, and a great amount of credit is due to recent experimenters and inventors who have done so much to make radio what it is today.

G. C. B. R.

July, 1927

INTRODUCTION

Before delving into the mysteries of radio it might be well to give something of its historical background. As in any other branch of science, radio has a history that is indeed intensely interesting, and all the more so from the fact that history is being made daily.

To start at the very beginning of radio—or wireless as it was called in the closing days of the last century—and trace its development down through the few years would be a gigantic task. Yet there are a few names with which every radio amateur should be as familiar as he is with his own.

In 1888 a German, Heinrich Hertz, demonstrated that the spark of an induction coil set up electric oscillations in an open circuit and that the energy thus released was sent out in the form of waves. These electric waves he received at a distance from the induction coil with a device he called a resonator. Two years later Branly of France, followed by Sir Oliver Lodge of England, developed a device called the coherer, which was for the detection of these radio waves. In 1895 the Russian, Popoff, while studying atmospheric electricity, connected his detector to an antenna and ground, thus forming the first receiving set using these two last mentioned features.

A year later, 1896, William Marconi invented the wireless telegraph. His experiments were conducted at Bologna, Italy, where he found that by interrupting the current in the primary of an induction coil he could send dots and dashes in the Morse telegraph code, these being received at a distance of a hundred yards. Marconi was the first to connect an aerial to one side of a spark gap and a ground to the other side of it. He used an induction coil to energize the spark gap, and a telegraph key in the primary circuit to break up the current into signals.

In the last year of the century the author of this book found that the human voice could be transmitted from one point to another without the use of wires, the distance being about three city blocks.

Between the years 1900 and 1905 experiments in wireless were being conducted in all parts of Europe and America and rapid progress was made in methods of detection. G. W. Pickard discovered that certain kinds of metals made excellent detectors and the days of the coherer were over. In the last mentioned year J. A. Fleming, an Englishman, discovered the vacuum tube detector, which consisted of a filament, or hot cathode, and a plate or anode. This device, however, did not come into general use until Lee de Forest in 1906 introduced the third element, the grid, into the tube.

This invention of Dr. de Forest's is perhaps one of the biggest factors in the advance of radio. With the grid in between the filament and the plate to control the electron stream, almost anything at all is possible. Vacuum tubes are not only used in the transmitting and the receiving radio stations, they are responsible for transcontinental telephony by land-lines; they are used in countless scientific instruments performing things thought hitherto impossible; they guard our money in banks; in short, it is safe to say the little glass tube is one of the wonders of the modern world.

Almost as soon as it was possible for one man to talk to another without the aid of wires, experimenters turned their efforts to another important field—that of sight. They believed it possible to see objects at a distance by means of radio, which act was termed television. One of the pioneers in this work was Francis Jenkins of Baltimore, who first showed the moving image of a revolving windmill projected across a room, entirely by means of radio. Further advances were made by engineers of the American Telephone and Telegraph Company, when in the early part of 1927 they sent an image of Secretary of Commerce Herbert Hoover from Washington, D. C., to New York. The experiments of John L. Baird, a Scotchman, in 1926 and 1927, are also worthy of note. He succeeded in transmitting the image of a person sitting in an absolutely dark room so perfectly that it was possible to tell what the person said by the movements of his lips. This was done by radio and the infrared ray, which is just outside of the visible spectrum on the long wave side.

It would be possible to fill page after page with the names of men and the deeds that they have performed in the field of radio, but the amateur is more interested in what he can get personally. The receiving sets of the present year are indeed a far jump ahead of those of

1922. In those days when most of the broadcasting was done on a wave length of 360 meters and the receiving of KDKA in Pittsburgh 500 miles distant was a feat to boast of, the receiving sets had many dials, rheostats, switches and other devices that have almost disappeared from the panel of the modern set. Now with the stations spread over a band from 200 to 550 meters it is possible to sit in your home and listen to stations in any part of the country by merely turning one or two dials. And what is more, these stations are clearly heard on a loud speaker.

This is indeed a wonderful time for anybody to start in the radio game. For the outlay of a very few dollars one can obtain a transmitting set with which he can reach the most distant points of the earth. For instance, when John L. Reinartz was in Greenland, he worked with the Naval Research Laboratory in Washington, D. C., on 16 meters, roughly a distance of 3,500 miles, using about 250 watts. Amateurs all over the world have made remarkable records using one-tenth of this power on the short wave lengths, and anyone can duplicate their feats with a little study and work.

The writer has just a word or two of advice to the beginner in radio. First of all, buy whatever equipment you do not make yourself from reliable stores—but it is to be hoped that you will construct as much as possible. Cheap apparatus never pays in the long run. When constructing a set, before you do anything, understand why you do it and then do the job in a neat workmanlike manner. Slipshod work always means poor and unsatisfactory results. Above all, have patience. Don't expect to get stations a thousand miles distant the first time you light the filaments of your tubes. Learn the whys and wherefores of the different instruments, and you will find radio as delightful to you as it has proved to the many thousands who have become its devoted followers.

CONTENTS

THE RADIO AMATEUR'S HANDBOOK

CHAPTER I

HOW TO BEGIN WIRELESS

In writing this book it is taken for granted that you are: *first,* one of the many millions of persons in the United States who are interested in wireless telegraphy and telephony; *second,* that you would like to install an apparatus in your home, and *third,* that it is all new to you.

Now if you live in a city or town large enough to support an electrical supply store, there you will find the necessary apparatus on sale, and someone who can tell you what you want to know about it and how it works. If you live away from the marts and hives of industry you can send to various makers of wireless apparatus for their catalogues and price-lists and these will give you much useful information. But in either case it is the better plan for you to know before you start in to buy an outfit exactly what apparatus you need to produce the result you have in mind, and this you can gain in easy steps by reading this book.

Kinds of Wireless Systems.—There are two distinct kinds of wireless systems and these are: the *wireless telegraph* system, and the *wireless telephone* system. The difference between the wireless telegraph and the wireless telephone is that the former transmits messages by means of a *telegraph key*, and the latter transmits conversation and music by means of a *microphone transmitter*. In other words, the same difference exists between them in this respect as between the Morse telegraph and the Bell telephone.

Parts of a Wireless System.—Every complete wireless station, whether telegraph or telephone, consists of three chief separate and distinct parts and these are: (*a*) the *aerial wire system*, or *antenna* as it is often called, (*b*) the *transmitter*, or *sender*, and (*c*) the *receiver*, or, more properly, the *receptor*. The aerial wire is precisely the same for either wireless telegraphy or wireless telephony. The transmitter of a wireless telegraph set generally uses a *spark gap* for setting up the electric oscillations, while usually for wireless telephony a *vacuum tube* is employed for this purpose. The receptor for wireless telegraphy and telephony is the same and may include either a *crystal detector* or a *vacuum tube detector,* as will be explained presently.

The Easiest Way to Start.—First of all you must obtain a government license to operate a sending set, but you do not need a license to put up and use a receiving set, though you are required by law to keep secret any messages which you may overhear. Since no license is needed for a receiving set the easiest way to break into the wireless game is to put up an aerial and hook up a receiving set to it; you can then listen-in and hear what is going on in the all-pervading ether around you, and you will soon find enough to make things highly entertaining.

Nearly all the big wireless companies have great stations fitted with powerful telephone transmitters and at given hours of the day and night they send out songs by popular singers, dance music by jazz orchestras, fashion talks by and for the ladies, agricultural reports, government weather forecasts and other interesting features. Then by simply shifting the slide on your tuning coil you can often tune-in someone who is sending *Morse,* that is, messages in the dot and dash code, or, perhaps a friend who has a wireless telephone transmitter and is talking. Of course, if you want to *talk back* you must have a wireless transmitter, either telegraphic or telephonic, and this is a much more expensive part of the apparatus than the receptor, both in its initial cost and in its operation. A wireless telegraph transmitter is less costly than a wireless telephone transmitter and it is a very good scheme for you to learn to send and receive telegraphic messages.

At the present time, however, there are fifteen amateur receiving stations in the United States to every sending station, so you can see that the majority of wireless folks care more for listening in to the broadcasting of news and music than to sending out messages on their own account. The easiest way to begin wireless, then, is to put up an aerial and hook up a receiving set to it.

About Aerial Wire Systems.—To the beginner who wants to install a wireless station the aerial wire system usually looms up as the biggest obstacle of all, and especially is this true if his house is without a flag pole, or other elevation from which the aerial wire can be conveniently suspended.

If you live in the congested part of a big city where there are no yards and, particularly, if you live in a flat building or an apartment house, you will have to string your aerial wire on the roof, and to do this you should get the owner's, or agent's, permission. This is usually an easy thing to do where you only intend to receive messages, for one or two thin wires supported at either end of the building are all that are needed. If for any reason you cannot put your aerial on the roof then run a wire along the building outside of your apartment, and, finally, if this is not feasible, connect your receiver to a wire strung up in your room, or even to an iron or a brass bed, and you can still get the near-by stations.

An important part of the aerial wire system is the *ground,* that is, your receiving set must not only be connected with the aerial wire, but with a wire that leads to and makes good contact with the moist earth of the ground. Where a house or a building is piped for water or steam, it is easy to make a ground connection, for all you have to do is to fasten the wire to one of the pipes with a clamp. Where the house is isolated, then a lot of wires or a sheet of copper or of zinc must be buried in the ground at a sufficient depth to insure their being kept moist.

About the Receiving Apparatus.—You can either buy the parts of the receiving apparatus separate and hook them up yourself, or you can buy the apparatus already assembled in a set which is, in the beginning, perhaps, the better way.

The simplest receiving set consists of (1) a *detector,* (2) a *tuning coil,* and (3) a *telephone receiver* and these three pieces of apparatus are, of course, connected together and are also connected to the aerial and ground as the diagram in *Fig. 1* clearly shows. There are two chief kinds of detectors used at the present time and these are: (*a*) the *crystal detector,* and (*b*) the *vacuum tube detector.* The crystal detector is the cheapest and simplest, but it is not as sensitive as the vacuum tube detector and it requires frequent adjustment. A crystal detector can be used with or without a battery while the vacuum tube detector requires two small batteries.

A tuning coil of the simplest kind consists of a single layer of copper wire wound on a cylinder with an adjustable, or sliding, contact, but for sharp tuning you need a *loose coupled tuning coil.* Where a single coil tuner is used a *fixed*

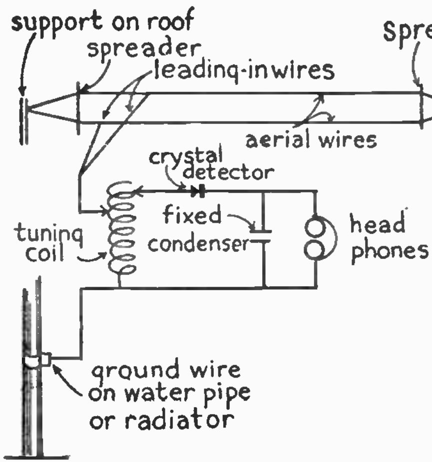


FIG. 1.—Simple Receiving Set.

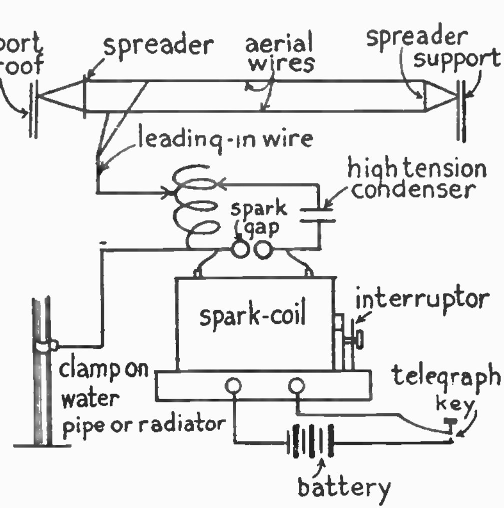


Fig. 2.—Simple Transmitting Set.

condenser should be connected around the telephone receivers. Where a loose coupled tuner is employed you should have a variable condenser connected across the *closed oscillation circuit* and a *fixed condenser* across the telephone receivers.

When listening-in to distant stations the energy of the received wireless waves is often so very feeble that in order to hear distinctly an *amplifier* must be used. To amplify the incoming sounds a vacuum tube made like a detector is used and sometimes as many as half-a-dozen of these tubes are connected in the receiving circuit, or in *cascade,* as it is called, when the sounds are *amplified,* that is magnified, many hundreds of times.

The telephone receiver of a receiving set is equally as important as the detector. A single receiver can be used but a pair of receivers connected with a head-band gives far better results. Then again the higher the resistance of the receivers the more sensitive they often are and those wound to as high a resistance as 3,200 ohms are made for use with the best sets. To make the incoming signals, conversation or music, audible to a room full of people instead of to just yourself you must use what is called a *loud speaker.* In its simplest form this consists of a metal cone like a megaphone to which is fitted a telephone receiver.

About Transmitting Stations—Getting Your License.—If you are going to install a wireless sending apparatus, either telegraphic or telephonic, you will have to secure a government license for which no fee or charge of any kind is made. There are three classes of licenses issued to amateurs who want to operate transmitting stations and these are: (1) the *restricted amateur license,* (2) the *general amateur license,* and (3) the *amateur extra first grade license.*

If you are going to set up a transmitter within five nautical miles of any naval wireless station then you will have to get a *restricted amateur license* which limits the current you use to half a *kilowatt* [1] and the wave length you send out to 200 *meters.* Should you live outside of the five-mile range of a navy station then you can get a *general amateur license* and this permits you to use a current of 1 kilowatt, but you are likewise limited to a wave length of 200 meters. But if you can show that you are doing some special kind of wireless work and not using your sending station for the mere pleasure you are getting out of it you may be able to get an *amateur extra*

[1] A *Kilowatt* is 1,000 *watts.* There are 746 watts in a horsepower.

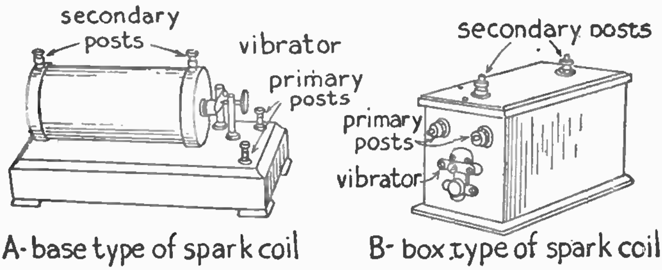
first grade license which gives you the right to send out on wave lengths of from 150 to 220 meters providing you use what is known as a pure continuous wave.

When you are ready to apply for your license write to the *Radio Inspector* of whichever one of the following districts you live in:

First	District	..............Boston, Mass.
Second	"	..............New York City
Third	"	..............Baltimore, Md.
Fourth	"	..............Norfolk, Va.
Fifth	"	..............New Orleans, La.
Sixth	"	..............San Francisco, Cal.
Seventh	"	..............Seattle, Wash.
Eighth	"	..............Detroit, Mich.
Ninth	"	..............Chicago, Ill.

Kinds of Transmitters.—There are two general types of transmitters used for sending out wireless messages and these are: (1) *wireless telegraph* transmitters, and (2) *wireless telephone* transmitters. Telegraph transmitters may use either: (*a*) a *jump-spark,* (*b*) an *electric arc,* or (*c*) a *vacuum tube* apparatus for sending out dot and dash messages, while telephone transmitters may use either, (*a*) an *electric arc,* or (*b*) a *vacuum tube* for sending out vocal and musical sounds. The *jump spark* type of telegraph transmitter has given way to the *vacuum tube* which is more efficient in operation and economical as to upkeep. The amateur of to-day uses the vacuum tube for the transmission of both telegraph and telephone.

The Spark Gap Wireless Telegraph Transmitter.—The simplest kind of a wireless tele-



(*A*) and (*B*) Fig. 3.—Types of Spark Coils.

graph transmitter consists of: (1) a *source of direct or alternating current,* (2) a *telegraph key,* (3) a *spark-coil* or a *transformer,* (4) a *spark gap,* (5) an *adjustable condenser* and (6) an *auto-transformer.* Where *dry cells* or a *storage battery* must be used to supply the current for energizing the transmitter a spark-coil can be employed and these may be had in various sizes from a little fellow which gives a ¼-inch spark up to a larger one which gives a 6-inch

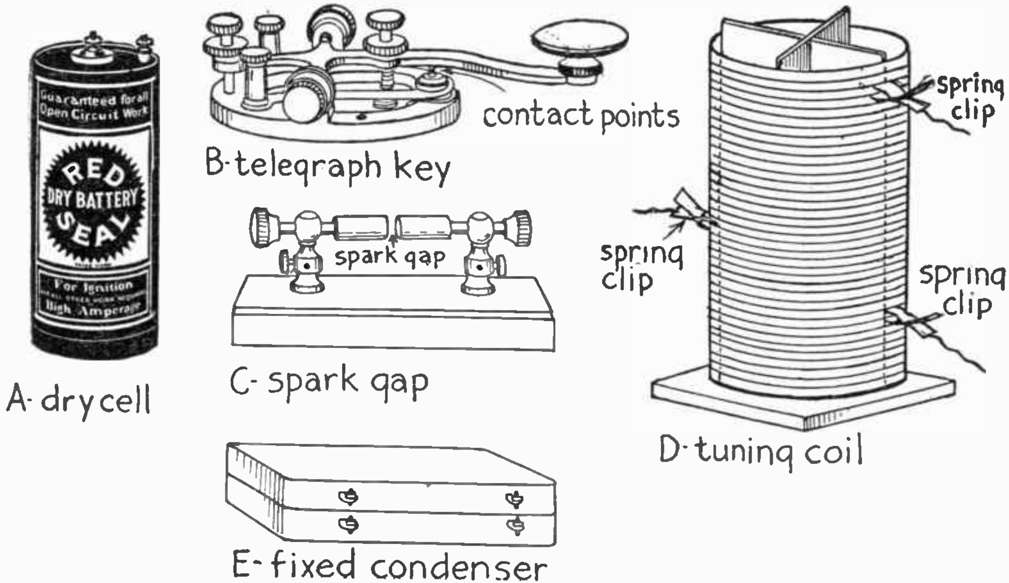


FIG. 4.—Parts for Transmitting Set.

spark. Where more energy is needed it is better practice to use a transformer and this can be worked on an alternating current of 110 volts, or if only a 110 volt direct current is available then an *electrolytic interrupter* must be used to make and break the current. A simple transmitting set with an induction coil is shown in *Fig. 2.*

A wireless key is made like an ordinary telegraph key except that where large currents are to be used it is somewhat heavier and is provided with large silver contact points. Spark gaps for amateur work are usually of: (1) the *plain* or *stationary type,* (2) the *rotating type,* and (3) the *quenched gap* type. The plain spark-gap is more suitable for small spark-coil sets, and it is not so apt to break down the transformer and condenser of the larger sets as the rotary gap. The rotary gap on the other hand tends to prevent *arcing* and so the break is quicker and there is less dragging of the spark. The quenched gap is more efficient than either the plain or rotary gap and moreover it is noiseless.

Condensers for spark telegraph transmitters can be ordinary Leyden jars or glass plates coated with tin or copper foil and set into a frame, or they can be built up of mica and sheet metal embedded in an insulating composition. The glass plate condensers are the cheapest and will serve your purpose well, especially if they are immersed in oil. Tuning coils, sometimes called *transmitting inductances* and *oscillation transformers,* are of various types. The simplest kind is an *auto-transformer* which consists of 25 or 30 turns of copper wire wound on an insulating tube or frame. An *oscillation transformer* is a loose coupled tuning coil and it consists of a primary coil formed of a number of turns of copper wire wound on a fixed insulating support, and a secondary coil of about twice the number of turns of copper wire which is likewise fixed in an insulating support, but the coils are relatively movable.

It is far better practice to use an *oscillation transformer* instead of an *auto-transformer.* The Government regulations regarding "the use of a sharp wave" render it difficult to keep within the legal *decrement* of waves when using an auto-transformer.[1] An oscillation transformer enables you to adjust your set so that it will send out a very sharp wave. This will not only prevent its interfering with other amateur stations, but also—what is of greater importance—with the big broadcasting stations.

[1] See Radio Laws, 1912, Section IV, Regulation 4.

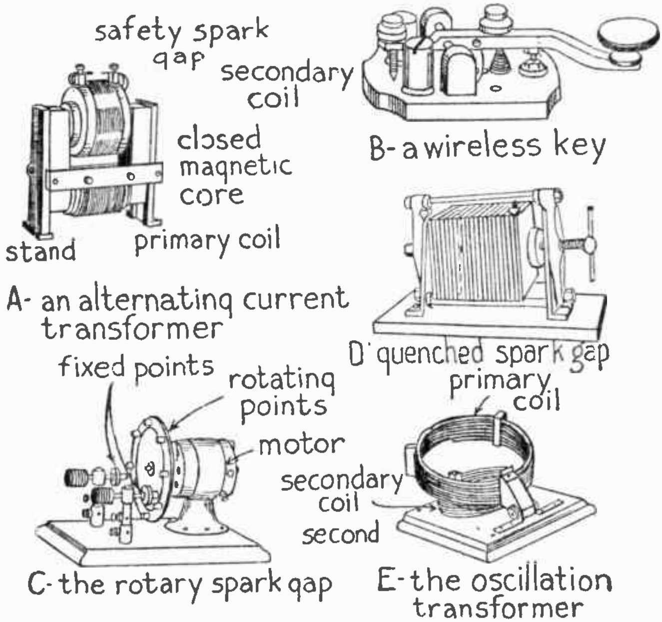


FIG. 5.—Parts for a Transformer Sending Set.

The Vacuum Tube Telegraph Transmitter.—This consists of: (1) a *source of direct or alternating current*, (2) a *telegraph key*, (3) a *vacuum tube oscillator*, (4) a *tuning coil*, and (5) a *condenser*. This kind of a transmitter sets up *sustained* oscillations instead of *periodic* oscillations which are produced by a spark gap set. The advantages of this kind of a system will be found explained in *Chapter XV*.

The Wireless Telephone Transmitter.—Because a jump-spark sets up *periodic oscillations,* that is, the oscillations are discontinuous, it cannot be used for wireless telephony. An electric arc or a vacuum tube sets up *sustained* oscillations, that is, oscillations which are continuous. As it is far easier to keep the oscillations going with a vacuum tube than it is with an arc the former means has all but supplanted the latter for wireless telephone transmitters. The apparatus required and the connections used for wireless telephone sets will be described in later chapters.

CHAPTER II

PUTTING UP YOUR AERIAL

As inferred in the first chapter, an aerial for receiving does not have to be nearly as well made or put up as one for sending. But this does not mean that you can slipshod the construction and installation of it, for however simple it is, the job must be done right and in this case it is as easy to do it right as wrong.

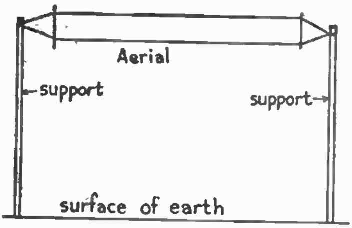
To send wireless telegraph and telephone messages to the greatest distances and to receive them as distinctly as possible from the greatest distances you must use for your aerial (1) copper or aluminum wire, (2) two or more wires, (3) have them the proper length, (4) have them as high in the air as you can, (5) have them well apart from each other, and (6) have them well insulated from their supports. If you live in a flat building or an apartment house you can string your aerial wires from one edge of the roof to the other and support them by wooden stays as high above it as may be convenient.

Should you live in a detached house in the city you can usually get your next-door neighbor to let you fasten one end of the aerial to his house and this will give you a good stretch and a fairly high aerial. In the country you can stretch your wires between the house and barn or the windmill. From this you will see that no matter where you live you can nearly always find ways and means of putting up an aerial that will serve your needs without going to the expense of erecting a mast.

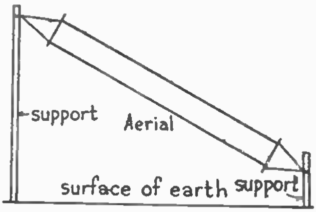
Kinds of Aerial Wire Systems.—An amateur wireless aerial can be anywhere from 25 feet to 100 feet long and if you can get a stretch of the latter length and a height of from 30 to 75 feet you will have one with which you can receive a thousand miles or more and send out as much energy as the government will allow you to send.

The kind of an aerial that gives the best results is one whose wire, or wires, are *horizontal,* that is, parallel with the earth under it as shown at *A* in *Fig. 6.* If only one end can be fixed to some elevated support then you can secure the other end to a post in the ground, but the slope of the aerial should not be more than 30 or 35 degrees from the horizontal at most as shown at *B.*

The *leading-in wire,* that is, the wire that leads from and joins the aerial wire with your sending and receiving set, can be connected to the aerial anywhere it is most convenient to do so, but the

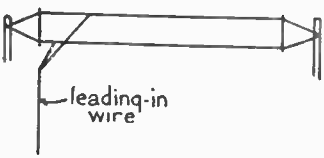


(*A*) Fig. 6.—Flat top, or Horizontal Aerial.

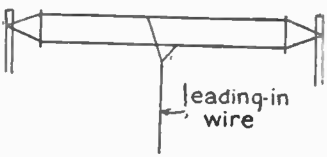


(*B*) Fig. 6.—Inclined Aerial.

best results are had when it is connected to one end as shown at *A* in *Fig. 7*, in which case it is called an *inverted L aerial*, or when it is connected to it at the middle as shown at *B*, when



(*A*) Fig. 7.—Inverted L Aerial.



(*B*) Fig. 7.—T Aerial.

it is called a *T aerial.* The leading-in wire must be carefully insulated from the outside of the building and also where it passes through it to the inside. This is done by means of an insulating tube known as a *leading-in insulator,* or *bulk-head insulator* as it is sometimes called.

As a protection against lightning burning out your instruments you can use either: (1) an *air-gap lightning arrester,* (2) a *vacuum tube protector,* or (3) a *lightning switch,* which is better. Whichever of these devices is used it is connected in between the aerial and a ground wire so that a direct circuit to the earth will be provided at all times except when you are sending or receiving. So your aerial instead of being a menace really acts during an electrical storm like a lightning rod and it is therefore a real protection. The air-gap and vacuum tube lightning arresters are little devices that can be used only where you are going to receive, while the lightning switch must be used where you are going to send; indeed, in some localities the *Fire Underwriters* require a lightning switch to be used for receiving sets as well as sending sets.

How to Put Up a Cheap Receiving Aerial.—The kind of an aerial wire system you put up will depend, chiefly, on two things, and these are: (1) your pocketbook, and (2) the place where you live.

A Single Wire Aerial.—This is the simplest and cheapest kind of a receiving aerial that can be put up. The first thing to do is to find out the length of wire you need by measuring the span between the two points of support; then add a sufficient length for the leading-in wire and enough more to connect your receiving set with the radiator or water pipe.

You can use any size of copper or aluminum wire that is not smaller than *No. 16 Brown and Sharpe gauge*. When you buy the wire get also the following material: (1) two *porcelain insulators* as shown at *A* in *Fig. 8;* (2) three or four *porcelain knob insulators,* see *B;* (3) either (*a*) an *air gap lightning arrester,* see *C,* or (*b*) a *lightning switch* see *D;* (4) a *leading-in porcelain tube insulator,* see *E,* and (5) a *ground clamp,* see *F.*

To make the aerial, slip each end of the wire through a hole in each insulator and twist it fast; next cut off and slip two more pieces of wire through the other holes in the insulators and twist them fast and then secure these to the supports at the ends of the building. Take the piece you are going to use for the leading-in wire, twist it around the aerial wire and solder it there when it will look like *A* in *Fig. 9.* Now if you intend to use the *air gap lightning arrester* fasten it to the wall of the building outside of your window,

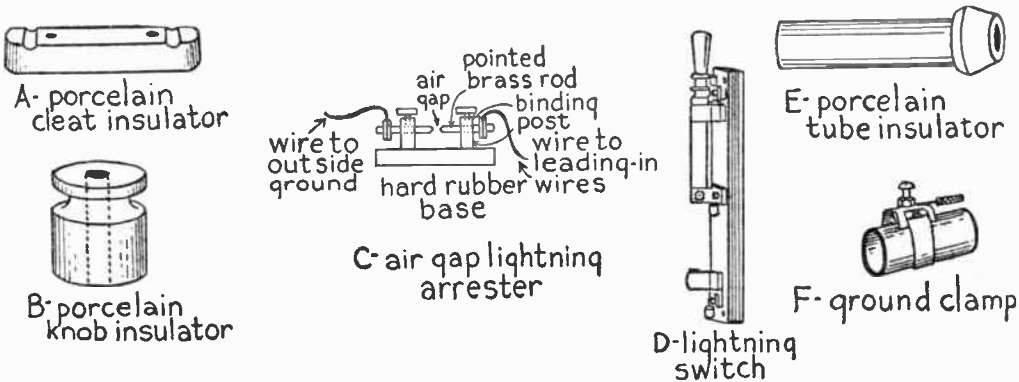
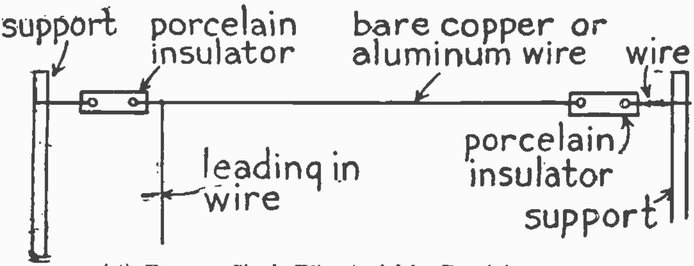


FIG. 8.—Material for a Simple Aerial Wire System.

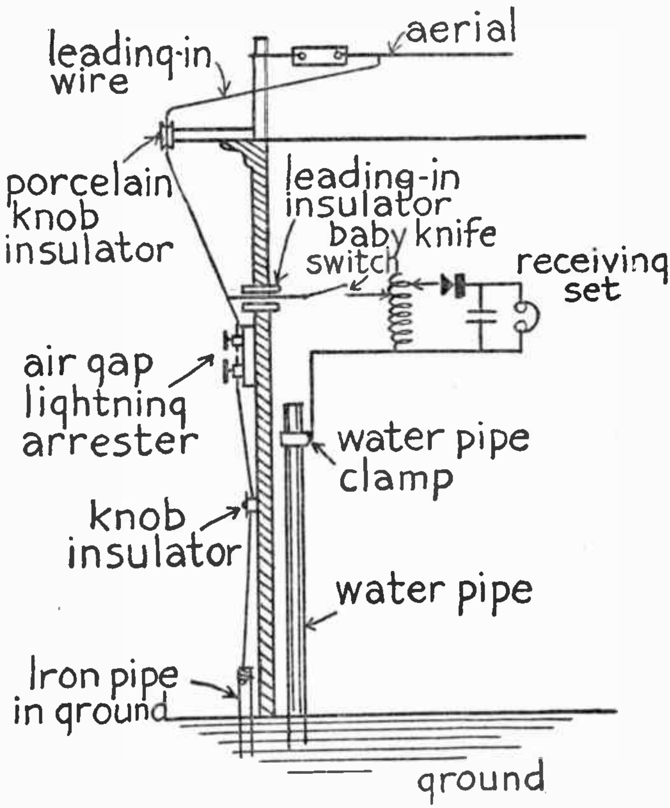
and bring the leading-in wire from the aerial to the top binding post of your arrester and keep it clear of everything as shown at *B*. If your aerial is on the roof and you have to bring the leading-in wire over the cornice or around a corner fix a porcelain knob insulator to the one or the other and fasten the wire to it.

Next bore a hole through the frame of the window at a point nearest your receiving set and push a porcelain tube 5/8 inch in diameter and 5 or 6 inches long, through it. Connect a length of wire to the top post of the arrester or just above it to the wire, run this through the leading-in insulator and connect it to the slider of your tuning coil. Screw the end of a piece of heavy copper wire to the lower post of the arrester and run it to the ground, on porcelain knobs if necessary, and solder it to an iron rod or pipe which



(*A*) Fig. 9.—Single Wire Aerial for Receiving.

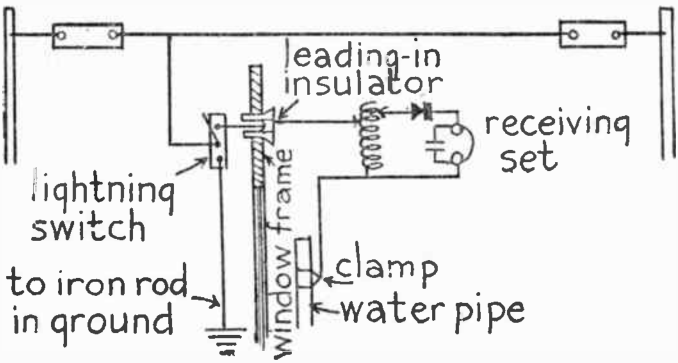
you have driven into the earth. Finally connect the fixed terminal of your tuning coil with the



(*B*) Fig. 9.—Receiving Aerial with Air Gap Lightning Arrester.

water pipe or radiator inside of the house by means of the ground clamp as shown in the diagrammatic sketch at *B* in *Fig. 9* and you are ready to tune in.

If you want to use a lightning switch instead of the air-gap arrester then fasten it to the outside wall instead of the latter and screw the free end of the leading-in wire from the aerial to the middle post of it as shown at *C* in *Fig. 9*. Run a



(*C*) Fig. 9.—Aerial with Lightning Switch.

wire from the top post through the leading-in insulator and connect it with the slider of your tuning coil. Next screw one end of a length of heavy copper wire to the lower post of the aerial switch and run it to an iron pipe in the ground as described above in connection with the spark-gap lightning arrester; then connect the fixed terminal of your tuning coil with the radiator or water pipe and your aerial wire system will be complete as shown at *C* in *Fig. 9*.

A Two-wire Aerial.—An aerial with two wires will give better results than a single wire and three wires are better than two, but you must keep them well apart. To put up a two-wire aerial get (1) enough *No. 16,* or preferably *No. 14,* solid or stranded copper or aluminum wire, (2) four porcelain insulators, see *B* in *Fig. 8,* and (3) two sticks about 1 inch thick, 3 inches wide and 3 or 4 feet long, for the *spreaders,* and bore one 1/8-inch hole through both ends of each one. Now twist the ends of the wires to the insulators and then cut off four pieces of wire about 6 feet long and run them through the holes in the wood spreaders. Finally twist the ends of each pair of short wires to the free ends of the insulators and then twist the free ends of the wires together.

For the leading-in wire that goes to the lightning switch take two lengths of wire and twist one end of each one around the aerial wires and solder them there. Twist the short wire around the long wire and solder this joint also when the aerial will look like *Fig. 10.* Bring the free end of the leading-in wire down to the middle post of the lightning switch and fasten it there and connect up the receiver to it and the ground as described under the caption of *A Single Wire Aerial.*

Connecting in the Ground.—If there is a water system or a steam-heating plant in your house you can make your ground connection by clamping a ground clamp to the nearest pipe as has been previously described. Connect a length

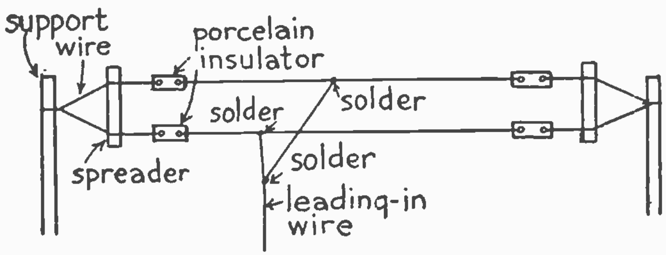


FIG. 10.—Two Wire Aerial.

of bare or insulated copper wire with it and bring this up to the table on which you have your receiving set. If there are no grounded pipes available then you will have to make a good ground which we shall describe presently and lead the ground wire from your receiving set out of the window and down to it.

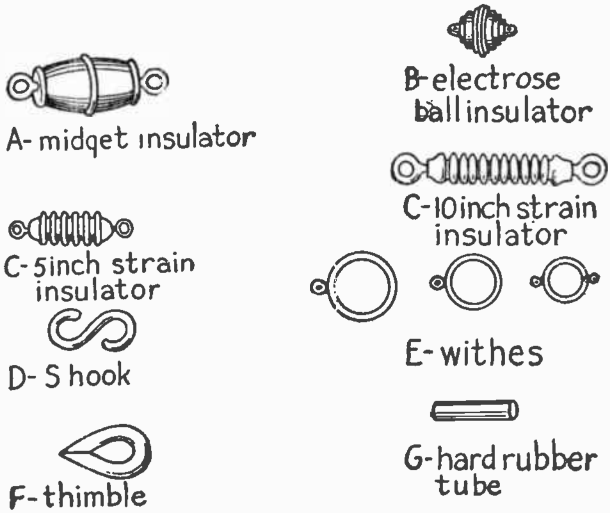
How to Put Up a Good Aerial.—While you can use the cheap aerial already described for a small spark-coil sending set you should have a better insulated one for a ½ or a 1 *kilowatt* transformer set.

An Inexpensive Good Aerial.—A far better aerial, because it is more highly insulated, can be made by using *midget insulators* instead of the porcelain insulators described under the caption of *A Single Wire Aerial* and using a small *electrose leading-in insulator* instead of the porcelain bushing. This makes a good sending aerial for small sets as well as a good receiving aerial.

It is very important to have a well insulated aerial for a vacuum tube C.W. set irrespective of the power used.

The Best Aerial that Can be Made.—To make this aerial get the following material together: (1) enough *stranded or braided wire* for three or four lengths of parallel wires, according to the number you want to use (2) six or eight *electrose ball insulators,* see *B, Fig. 11;* (3) two 5-inch or 10-inch *electrose strain insulators,* see *C;* (4) six or eight *S-hooks,* see *D;* one large *withe* with one eye for middle of end spreader, see *E;* (6) two smaller *withes* with one eye each for the end spreader, see *E;* (7) two still smaller *withes,* with two eyes each for the ends of the end spreaders, see *E;* (2) two *thimbles,* see *F,* for ¼-inch wire cable; (9) six or eight *hard rubber tubes* or *bushings* as shown at *G;* and (10) two *end spreaders,* see *H;* one *middle spreader, see I;* and one *leading-in spreader,* see *J.*

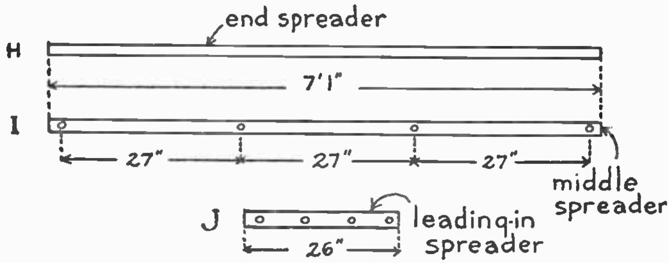
For this aerial any one of a number of kinds of wire can be used and among these are (*a*)



(*A*) FIG. 11.—Parts of a Good Aerial.

stranded copper wire; (*b*) *braided copper wire;* (*c*) *stranded silicon bronze wire,* and (*d*) *stranded phosphor bronze wire.* Stranded and braided copper wire is very flexible as it is formed of seven strands of fine wire twisted or braided together and it is very good for short and light aerials. Silicon bronze wire is stronger than copper wire and should be used where aerials are more than 100 feet long, while phosphor bronze wire is the strongest aerial wire made and is used for high grade aerials by the commercial companies and the Government for their high-power stations.

The spreaders should be made of spruce, and should be 4 feet 10 inches long for a three-wire



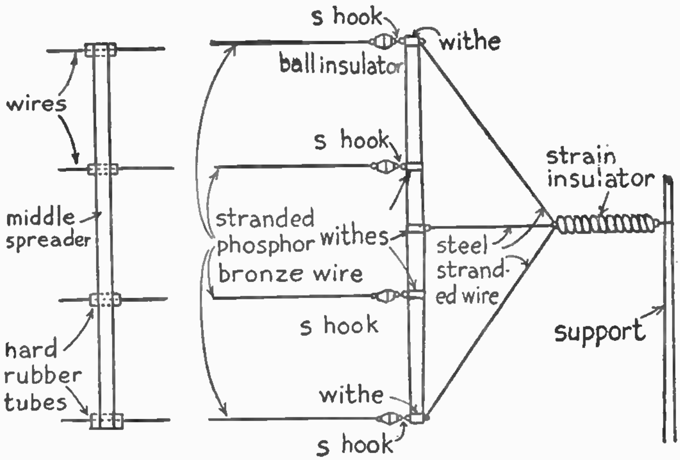
(*B*) Fig. 11.—The Spreaders.

aerial and 7 feet 1 inch long for a four-wire aerial as the distance between the wires should be about 27 inches. The end spreaders can be turned cylindrically but it makes a better looking job if they taper from the middle to the ends. They should be 2¼ inches in diameter at the middle and 1¾ inches at the ends. The middle spreader can be cylindrical and 2 inches in diameter. It must have holes bored through it at equidistant points for the hard rubber tubes; each of these should be 5/8 inch in diameter and have a hole 5/32 inch in diameter through it for the aerial wire. The leading-in spreader is also made of spruce and is 1½ inches square and 26 inches long. Bore three or four 5/8-inch holes at equidistant points through this spreader and insert hard rubber tubes in them as with the middle spreader.

Assembling the Aerial.—Begin by measuring off the length of each wire to be used and see to it that all of them are of exactly the same length. Now push the hard rubber insulators through the holes in the middle spreader and thread the wires through the holes in the insulators as shown at *A* in *Fig. 12.*

Next twist the ends of each wire to the rings of the ball insulators and then put the large withes on the middle of each of the end spreaders; fix the other withes on the spreaders so that they will be 27 inches apart and fasten the ball insulators to the eyes in the withes with the S-hooks. Now slip a thimble through the eye of one of the long strain insulators, thread a length of stranded steel wire ¼ inch in diameter through it and fasten the ends of it to the eyes in the withes on the ends of the spreaders.

Finally fasten a 40-inch length of steel stranded wire to each of the eyes of the withes on the middle of each of the spreaders, loop the other end over the thimble and then wrap the end around the wires that are fixed to the ends of the spreaders. One end of the aerial is shown complete at *B* in *Fig. 12,* and from this you can see

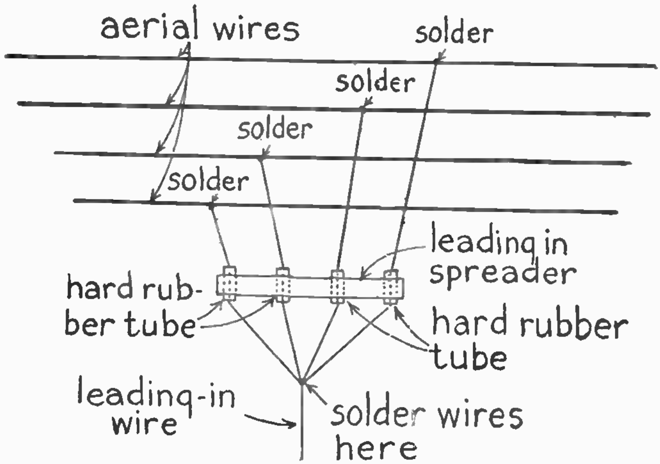


(*A*) Fig. 12.—Middle Spreader.

(*B*) Fig. 12.—One End of Aerial Complete.

exactly how it is assembled. Now cut off three or four pieces of wire 15 or 20 feet long and twist and solder each one to one of the aerial wires; then slip them through the hard rubber tubes in the leading-in spreader, bring their free ends together as at *C* and twist and solder them to a length of wire long enough to reach to your lightning switch or instruments.

Making a Good Ground.—Where you have to make a *ground* you can do so either by (1) burying sheets of zinc or copper in the moist earth; (2) burying a number of wires in the moist earth,



(*C*) Fig. 12.—Leading in Spreader.

or (3) using a *counterpoise*. To make a ground of the first kind take half a dozen large sheets of copper or zinc, cut them into strips a foot wide, solder them all together with other strips and bury them deeply in the ground.

It is easier to make a wire ground, say of as many or more wires as you have in your aerial and connect them together with cross wires. To put such a ground in the earth you will have to use a plow to make the furrows deep enough to insure them always being moist. In the counterpoise ground you make up a system of wires exactly like your aerial, that is, you insulate them just as carefully; then you support them so that they will be approximately twelve feet above the ground. This and the other two grounds just described should be placed directly under the aerial wire if the best results are to be had. In using a counterpoise you must bring the wire from it up to and through another leading-in insulator to your instruments.

You can, if you wish, spread out a number of wires under your aerial and let them run in all directions beyond it, which makes it more efficient.

CHAPTER III

SIMPLE TELEGRAPH AND TELEPHONE RECEIVING SETS

With a crystal detector receiving set you can receive either telegraphic dots and dashes or telephonic speech and music. You can buy a receiving set already assembled or you can buy the different parts and assemble them yourself. An assembled set is less bother in the beginning but if you like to experiment you can *hook up,* that is, connect the separate parts together yourself and it is perhaps a little cheaper to do it this way. Then again, by so doing you get a lot of valuable experience in wireless work and an understanding of the workings of wireless that you cannot get in any other way.

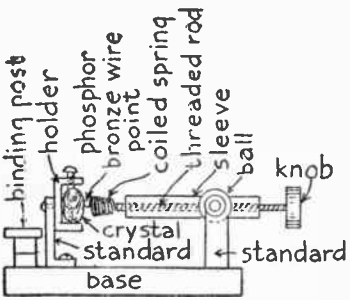
Assembled Wireless Receiving Sets.—The cheapest assembled receiving set advertised is one in which the detector and tuning coil is mounted in a box. It costs $15.00, and can be bought of dealers in electric supplies generally.

This price also includes a crystal detector, an adjustable tuning coil, a single telephone receiver with head-band and the wire, porcelain insulators, lightning switch and ground clamp for the aerial wire system. It will receive wireless telegraph and telephone messages over a range of from 10 to 25 miles from either broadcasting or commercial stations.

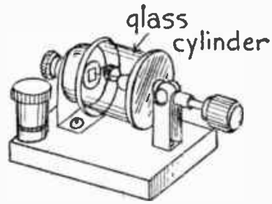
Another cheap unit receptor, that is, a complete wireless receiving set already mounted which can be used with a single aerial is sold for $25.00. This set includes a crystal detector, a variable tuning coil, a fixed condenser and a pair of head telephone receivers. It can also be used to receive either telegraph or telephone messags from distances up to 25 miles. The aerial equipment is not included in this price, but it can be obtained at a slight additional cost.

Assembling Your Own Receiving Set.—In this chapter we shall go only into the apparatus used for two simple receiving sets, both of which have a *crystal detector.* The first set includes a *double-slide tuning coil* and the second set employs a *loose-coupled tuning coil,* or *loose coupler,* as it is called for short. For either set you can use a pair of 2,000- or 3,000-ohm head phones.

The Crystal Detector.—A crystal detector consists of: (1) *the frame,* (2) *the crystal,* and (3) *the wire point.* There are any number of different designs for frames, the idea being to provide a device that will (*a*) hold the sensitive crystal firmly in place, and yet permit of its removal, (*b*) to permit the *wire point,* or *elec-*



(*A*) Fig. 13.—Cross Section of Crystal Detector.



(*B*) Fig. 13.—The Crystal Detector Complete.

trode, to be moved in any direction so that the free point of it can make contact with the most sensitive spot on the crystal and (*c*) to vary the pressure of the wire on the crystal.

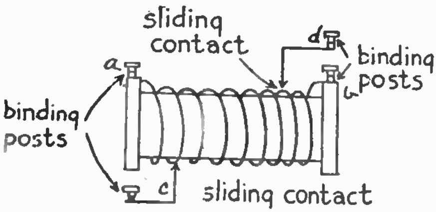
A simple detector frame is shown in the cross-section at *A* in *Fig. 13;* the crystal, which may be *galena, silicon* or *iron pyrites,* is held securely in a holder while the *phosphor-bronze wire point* which makes contact with it, is fixed to one end of a threaded rod on the other end of which is a knob. This rod screws into and through a sleeve fixed to a ball that sets between two brass standards and this permits an up and down or a side to side adjustment of the metal point while the pressure of it on the crystal is regulated by the screw.

A crystal of this kind is often enclosed in a glass cylinder and this makes it retain its sensitiveness for a much longer time than if it were exposed to dust and moisture. A horizontal type of this detector is shown at *B* of *Fig. 13.* Galena is the crystal that is generally used, for, while it is not quite as sensitive as silicon and iron pyrites, it is easier to obtain a sensitive piece.

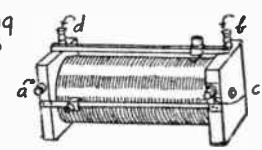
The Tuning Coil.—It is with the tuning coil that you *tune in* and *tune out* different stations and this you do by sliding the contacts to and fro over the turns of wire; in this way you vary the *inductance* which is a *constant* of the receiving circuits and so make them receive *electric waves,* that is, wireless waves, of different lengths.

The Double Slide Tuning Coil.—With this tuning coil you can receive waves from any station up to 1,000 meters in length. One of the ends of the coil of wire connects with the binding post marked *a* in *Fig. 14* and the other end connects with the other binding post marked *b,* while one of the sliding contacts is connected to the binding post *c,* and the *other sliding contact* is connected with the binding post *d.*

When connecting in the tuning coil, only the post *a* or the post *b* is used as may be most con-



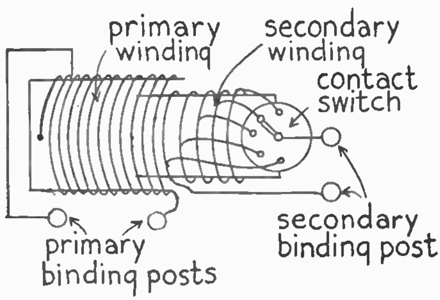
(*A*) FIG. 14.—Schematic Diagram of Double Slide Tuning Coil.



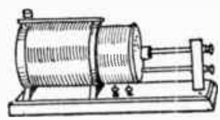
(*B*) FIG. 14.—Double Slide Tuning Coil Complete.

venient, but the other end of the wire which is connected to a post is left free; just bear this point in mind when you come to connect the tuning coil up with the other parts of your receiving set. The tuning coil is shown complete at *B*. A *triple slide* tuning coil constructed like the double slide tuner just described, only with more turns of wire on it, makes it possible to receive wave lengths up to 1,500 meters.

The Loose Coupled Tuning Coil.—With a *loose coupler,* as this kind of a tuning coil is called for short, very *selective tuning* is possible, which means that you can tune in a station very sharply, and it will receive any wave lengths according to size of coils. The primary coil is wound on a fixed cylinder and its inductance is varied by means of a sliding contact like the double slide tuning coil described above. The secondary coil



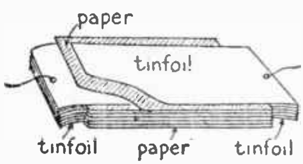
(*A*) Fig. 15.—Schematic Diagram of Loose Coupler.



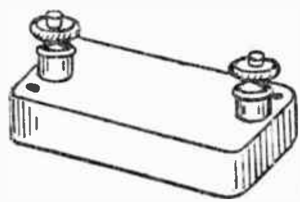
(*B*) Fig. 15.—Loose Coupler Complete.

is wound on a cylinder that slides in and out of the primary coil. The inductance of this coil is varied by means of a switch that makes contact with the fixed points, each of which is connected with every twentieth turn of wire as shown in the diagram *A* in *Fig. 15.* The loose coupler is shown complete at *B*.

Fixed and Variable Condensers.—You do not require a condenser for a simple receiving set, but if you will connect a *fixed condenser* across your head phones you will get better results, while a *variable condenser* connected in the *closed circuit of a direct coupled receiving set,* that is, one where a double slide tuning coil is used, makes it easy to tune very much more sharply; a variable condenser is absolutely necessary where the circuits are *inductively coupled,* that is, where a loose coupled tuner is used.



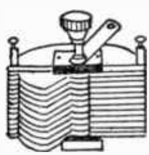
(*A*) FIG. 16.—How a Fixed Receiving Condenser is Built up.



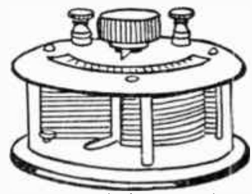
(*B*) FIG. 16.—The Fixed Condenser Complete.

A fixed condenser consists of a number of sheets of paper or mica with leaves of tin-foil in between them and so built up that one end of every other leaf of tin-foil projects from the opposite end of the paper as shown at *A* in *Fig. 16.* The paper and tin-foil are then pressed together and impregnated with an insulating compound. A fixed condenser of the exact capacitance required for connecting across the head phones is mounted in a base fitted with binding posts, as shown at *B*.

A variable condenser, see *C*, of the rotating type is formed of a set of fixed semi-circular metal plates which are slightly separated from each other and between these a similar set of movable semi-circular metal plates is made to interleave; the latter are secured to a shaft on the



C-fixed and movable plates of a rotary condenser



D-variable rotary condenser

(*C*) and (*D*) Fig. 16.—The Variable Rotary Condenser.

top end of which is a knob and by turning it the capacitance of the condenser, and, hence, of the circuit in which it is connected, is varied. This condenser, which is shown at *D*, is made in two sizes, the smaller one being large enough for all ordinary wave lengths while the larger one is for proportionately longer wave lengths.*

About Telephone Receivers.—There are a number of makes of head telephone receivers on

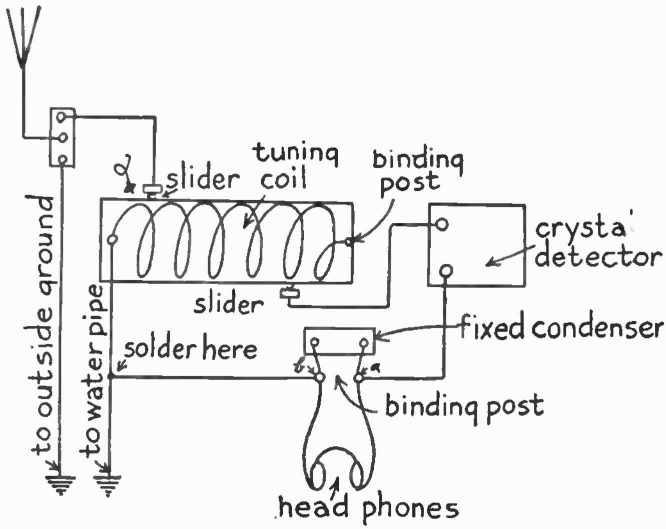
* See Radio Frequency Amplification in Appendix, page 393.

the market that are designed especially for wireless work. These phones are wound to *resistances* of from 75 *ohms* to 8,000 *ohms*. You can get a receiver wound to any resistance in between the above values but for either of the simple receiving sets such as described in this chapter you

Fig. 17.—Pair of Wireless Head Phones.

ought to have a pair wound to at least 2,000 ohms. A pair of head phones of this type is shown in *Fig. 17*.

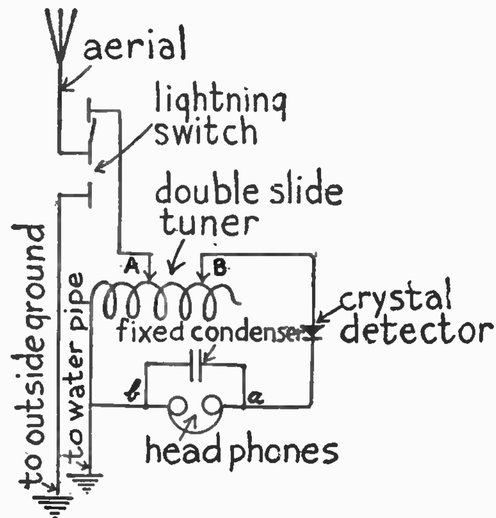
Connecting Up the Parts for the Receiving Set.—For this set get (1) a *crystal detector,* (2) a *two-slide tuning coil,* (3) a *fixed condenser,* and (4) a pair of 2,000 ohm head phones. Mount the detector on the right-hand side of a board and the tuning coil on the left-hand side. Screw in two binding posts for the cord ends of the telephone receivers at *a* and *b* as shown at *A* in *Fig. 18.* This done connect one of the end binding posts of the tuning coil with the ground



(A) Fig. 18.—Top View of Apparatus Layout for Receiving Set.

wire and a post of one of the contact slides with the lightning arrester or switch which leads to the aerial wire.

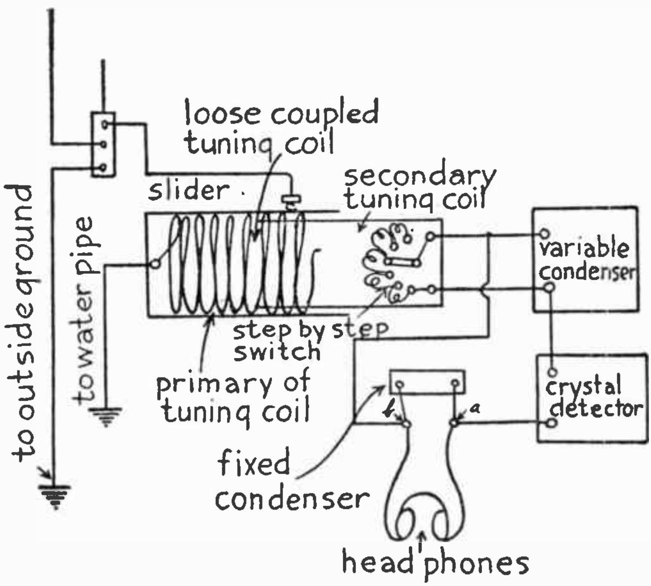
Now connect the post of the other contact slide to one of the posts of the detector and the other post of the latter with the binding post *a*, then connect the binding post *b* to the ground wire and solder the joint. Next connect the ends of the telephone receiver cord to the posts *a* and *b* and connect a fixed condenser also with these posts, all of which are shown in the wiring dia-



(*B*) Fig. 18.—Wiring Diagram for Receiving Set.

gram at *B*, and you are ready to adjust the set for receiving.

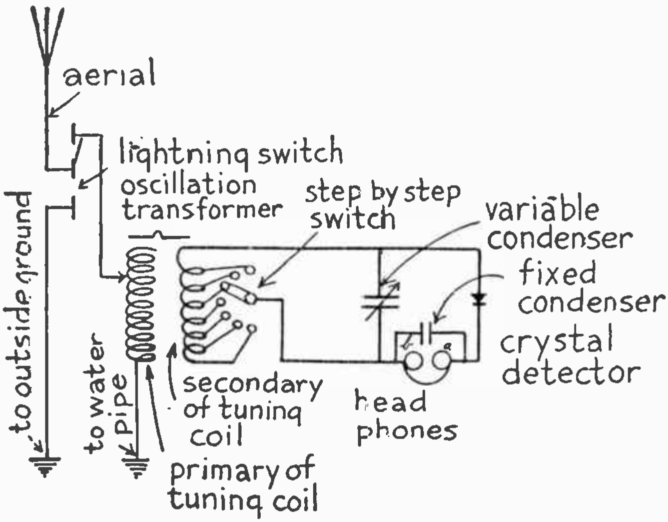
A Loose Coupler Receiving Set.—Use the same kind of a detector and a pair of head phones as before, but get (1) a *loose coupled tuning coil*, and (2) a *variable rotary condenser*. Mount the loose coupler at the back of a board on the left-hand side and the variable condenser on the right-hand side. Then mount the detector in front of the variable condenser and screw two



(*A*) Fig. 19.—Top View of Apparatus Layout for Loose Coupler Receiving Set.

binding posts, *a* and *b,* in front of the tuning coil as shown at *A* in *Fig. 19.*

Now connect the post of the sliding contact of the loose coupler with the wire that runs to the lightning switch and thence to the aerial; connect the post of the primary coil, which is the outside coil, with the ground wire; then connect the binding post leading to the switch of the secondary coil, which is the inside coil, with one of the posts of the variable condenser, and finally,



(*B*) FIG. 19.—Wiring Diagram for Loose Coupler Receiving Set.

connect the post that is joined to one end of the secondary coil with the other post of the variable condenser.

This done, connect one of the posts of the condenser with one of the posts of the detector, the other post of the detector with the binding post *a*, and the post *b* to the other post of the variable condenser. Next connect a fixed condenser to the binding posts *a* and *b* and then connect the telephone receivers to these same posts, all of which is shown in the wiring diagram at *B*. You are now ready to adjust the instruments. In making the connections use No. 16 or 18 insulated copper wire and scrape the ends clean where they go into the binding posts. See, also, that all of the connections are tight and where you have to cross the wires keep them apart by an inch or so and always cross them at right angles.

Adjusting the First Set—The Detector.—The first thing to do is to test the detector in order to find out if the point of the contact wire is on a sensitive spot of the crystal. To do this you need a *buzzer, a switch* and a *dry cell*. An electric bell from which the gong has been removed will do for the buzzer, but you can get one that is made specially for the purpose, which gives out a clear, high-pitched note that sounds like a high-power station.

Connect one of the binding posts of the buzzer with one post of the switch, the other post of the latter with the zinc post of the dry cell and the carbon post of this to the other post of the buzzer. Then connect the post of the buzzer that is joined to the vibrator, to the ground wire as shown in the wiring diagram, *Fig. 20.* Now close the switch of the buzzer circuit, put on your head

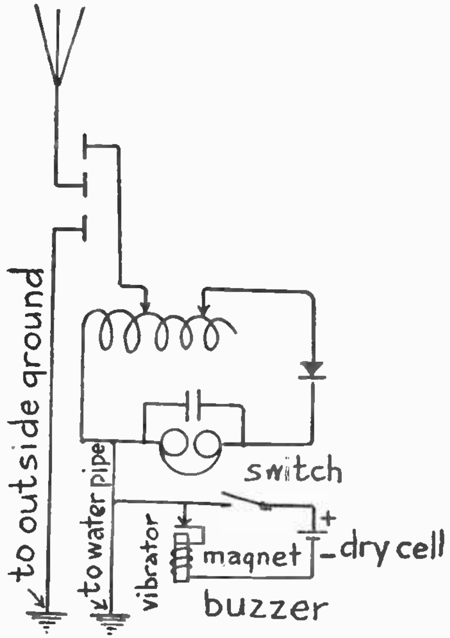


FIG. 20.—Adjusting the Receiving Set.

phones, and move the wire point of the detector to various spots on the crystal until you hear the sparks made by the buzzer in your phones.

Then vary the pressure of the point on the crystal until you hear the sparks as loud as possible. After you have made the adjustment, open the switch and disconnect the buzzer wire from the ground wire of your set. This done, be very careful not to jar the detector or you will throw it out of adjustment and then you will have to do it all over again. You are now ready to tune the set with the tuning coil and listen in.

The Tuning Coil.—To tune this set move the slide *A* of the double-slide tuner, see *B* in *Fig. 15,* over to the end of the coil that is connected with the ground wire and the slide *B* near the opposite end of the coil, that is, the one that has the free end. Now move the slide *A* toward the *B* slide and when you hear the dots and dashes, or speech or music, that is coming in as loud as you can move the *B* slide toward the *A* slide until you hear still more plainly. A very few trials on your part and you will be able to tune in or tune out any station you can hear, if not too close or powerful.

Adjusting the Loose Coupler Set.—First adjust the crystal detector with the buzzer set as described above with the other set, then turn the knob of your variable condenser so that the movable plates are just half-way in, pull the secondary coil of your loose-coupled tuner half-way out; turn the switch lever on it until it makes a contact with the middle contact point and set the slider of the primary coil half-way between the ends.

Now listen in for telegraphic signals or telephonic speech or music; when you hear one or the other, slide the secondary coil in and out of the primary coil until the sounds are loudest; now move the contact switch over the points forth and back until the sounds are still louder, then move the slider to and fro until the sounds are yet louder and, finally, turn the knob of the condenser until the sounds are clear and crisp. When you have done all of these things you have, in the parlance of the wireless operator, *tuned in* and you are ready to receive whatever is being sent.

CHAPTER IV

ELECTRICITY SIMPLY EXPLAINED

It is easy to understand how electricity behaves and what it does if you get the right idea of it at the start. In the first place, if you will think of electricity as being a fluid like water its fundamental actions will be greatly simplified. Both water and electricity may be at rest or in motion. When at rest, under certain conditions, either one will develop pressure, and this pressure when released will cause them to flow through their respective conductors and thus produce a current.

Electricity at Rest and in Motion.—Any wire or a conductor of any kind can be charged with electricity, but a Leyden jar, or other condenser, is generally used to hold an electric charge because it has a much larger *capacitance,* as its capacity is called, than a wire. As a simple analogue of a condenser, suppose you have a tank of water raised above a second tank and that these are connected together by means of a pipe with a valve in it, as shown at *A* in *Fig. 21.*

Now if you fill the upper tank with water and the valve is turned off, no water can flow into the lower tank but there is a difference of pressure between them, and the moment you turn the valve on a current of water will flow through the pipe. In very much the same way when you have a condenser charged with electricity the latter will be under *pressure,* that is, a *difference of potential* will be set up, for one of the sheets of metal will be charged positively and the other one, which is insulated from it, will be charged negatively, as shown at *B*. On closing the switch the opposite charges rush together and form a current which flows to and fro between the metal plates.[1]

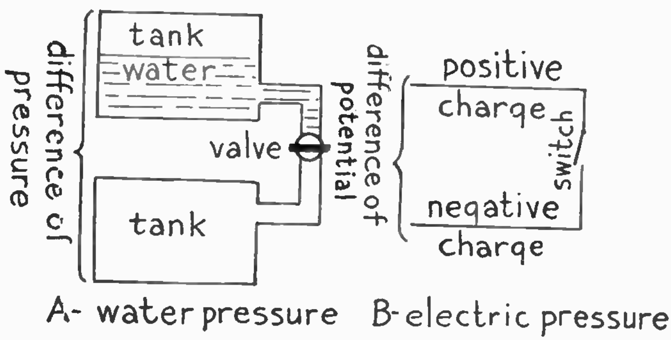


FIG. 21.—Water Analogue for Electric Pressure.

[1] Strictly speaking it is the difference of potential that sets up the electromotive force.

The Electric Current and Its Circuit.—Just as water flowing through a pipe has *quantity* and *pressure* back of it and the pipe offers friction to it which tends to hold back the water, so, likewise, does electricity flowing in a circuit have: (1) *quantity,* or *current strength,* or just *current,* as it is called for short, or *amperage,* and (2) *pressure,* or *potential difference,* or *electromotive force,* or *voltage,* as it is variously called, and the wire, or circuit, in which the current is flowing has (3) *resistance* which tends to hold back the current.

A definite relation exists between the current and its electromotive force and also between the current, electromotive force and the resistance of the circuit; and if you will get this relationship clearly in your mind you will have a very good insight into how direct and alternating currents act. To keep a quantity of water flowing in a loop of pipe, which we will call the circuit, pressure must be applied to it and this may be done by a rotary pump as shown at *A in Fig. 22;* in the same way, to keep a quantity of electricity flowing in a loop of wire, or circuit, a battery, or other means for generating electric pressure must be used, as shown at *B*.

If you have a closed pipe connected with a

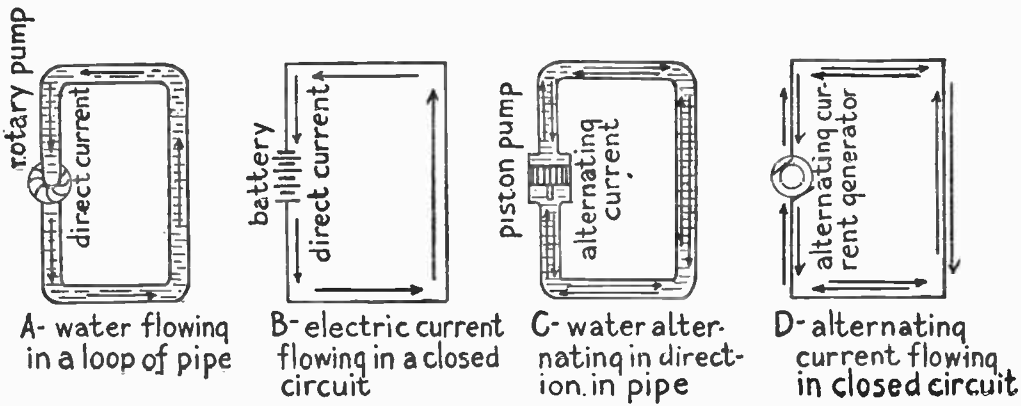


FIG. 22.—Water Analogues for Direct and Alternating Currents.

piston pump, as at *C,* as the piston moves to and fro the water in the pipe will move first one way and then the other. So also when an alternating current generator is connected to a wire circuit, as at *D,* the current will flow first in one direction and then in the other, and this is what is called an *alternating current.*

Current and the Ampere.—The amount of water flowing in a closed pipe is the same at all parts of it and this is also true of an electric current, in that there is exactly the same quantity of electricity at one point of the circuit as there is at any other.

The amount of electricity, or current, flowing in a circuit in a second is measured by a unit called the *ampere,*[1] and it is expressed by the symbol *I.*[2] Just to give you an idea of the quantity of current in an *ampere,* we will say that a dry cell when fresh gives a current of about 20 amperes. To measure the current in amperes an instrument called an *ammeter* is used, as shown at *A* in *Fig. 23,* and this is always connected in *series* with the line, as shown at *B.*

Electromotive Force and the Volt.—When you have a pipe filled with water or a circuit

[1] For definition of *ampere* see *Appendix.*

[2] This is because the letter *C* is used for the symbol of *capacitance.*

charged with electricity and you want to make them flow you must use a pump in the first case and a battery or a dynamo in the second case. It is the battery or dynamo that sets up the electric

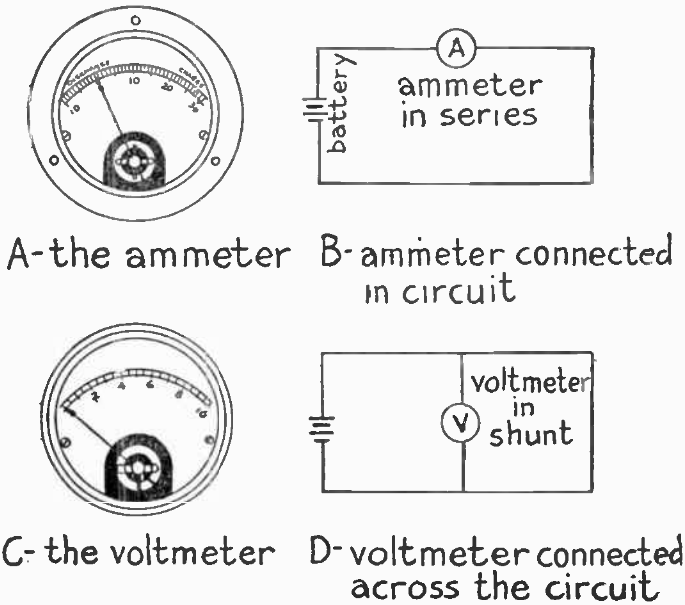


FIG. 23.—How the Ammeter and Voltmeter are Used.

pressure as the circuit itself is always charged with electricity.

The more cells you connect together in *series* the greater will be the electric pressure developed and the more current it will move along just as the amount of water flowing in a pipe can be increased by increasing the pressure of the pump. The unit of electromotive force is the *volt,* and this is the electric pressure which will force a current of *1 ampere* through a resistance of *1 ohm;* it is expressed by the symbol *E.* A fresh dry cell will give a reading of about 1.5 volts. To measure the pressure of a current in volts an instrument called a *voltmeter* is used, as shown at *C* in *Fig. 23,* and this is always connected across the circuit, as shown at *D.*

Resistance and the Ohm.—Just as a water pipe offers a certain amount of resistance to the flow of water through it, so a circuit opposes the flow of electricity in it and this is called *resistance.* Further, in the same way that a small pipe will not allow a large amount of water to flow through it, so, too, a thin wire limits the flow of the current in it.

If you connect a *resistance coil* in a circuit it acts in the same way as partly closing the valve in a pipe, as shown at *A* and *B* in *Fig. 24.* The resistance of a circuit is measured by a unit called the *ohm,* and it is expressed by the symbol *R.* A No. 10, Brown and Sharpe gauge soft copper wire, 1,000 feet long, has a resistance of about 1 ohm. To measure the resistance of a circuit an apparatus called a *resistance bridge is used.* The resistance of a circuit can, however, be easily calculated, as the following shows.

What Ohm's Law Is.—If, now, (1) you know what the current flowing in a circuit is in *amperes,* and the electromotive force, or pressure,

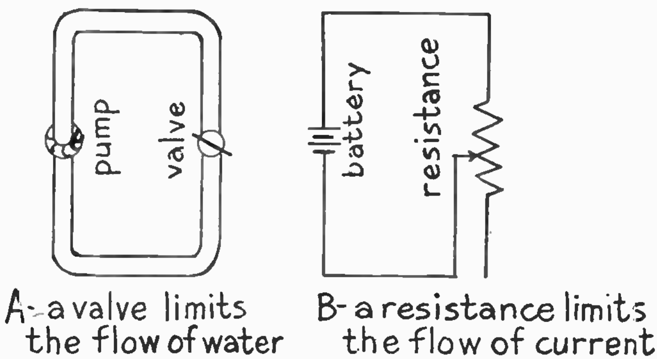


FIG. 24.—Water Valve Analogue of Electric Resistance.

is in *volts,* you can then easily find what the resistance is in *ohms* of the circuit in which the current is flowing by this formula:

$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms, or } \frac{E}{I} = R$$

That is, if you divide the electromotive force in volts by the current in amperes the quotient will give you the resistance in ohms.

Or (2) if you know what the electromotive force of the current is in *volts* and the resistance of the circuit is in *ohms* then you can find what the current flowing in the circuit is in *amperes,* thus:

$$\frac{\text{Volts}}{\text{Ohms}} = \text{Amperes, or } \frac{E}{R} = I$$

That is, by dividing the electromotive force in volts by the resistance of the current in ohms you will get the amperes flowing in the circuit.

Finally (3) if you know what the resistance of the circuit is in *ohms* and the current is in *amperes* then you can find what the electromotive force is in *volts* since:

$$\text{Ohms} \times \text{Amperes} = \text{Volts, or } R \times I = E,$$

That is, if you multiply the resistance of the circuit in ohms by the current in amperes the result will give you the electromotive force in volts.

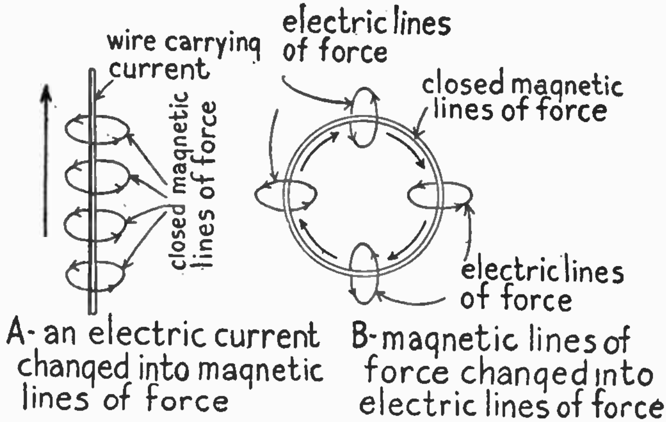
From this you will see that if you know the value of any two of the constants you can find the value of the unknown constant by a simple arithmetical process. This relation between these three constants is known as *Ohm's Law* and as they are very important you should memorize them.

What the Watt and Kilowatt Are.—Just as *horsepower* or *H.P.*, is the unit of work that steam has done or can do, so the *watt* is the unit of work that an electric current has done or can do. To find the *watts* a current develops you need only to multiply the *amperes* by the *volts.* There are *746 watts* to *1 horsepower, and 1,000 watts are equal to 1 kilowatt.*

Electromagnetic Induction.—To show that a current of electricity sets up a magnetic field around it you have only to hold a compass over a wire whose ends are connected with a battery when the needle will swing at right angles to the length of the wire. By winding an insulated wire into a coil and connecting the ends of the latter with a battery you will find, if you test it with a compass, that the coil is magnetic.

This is due to the fact that the energy of an electric current flowing in the wire is partly changed into magnetic lines of force which rotate at right angles about it as shown at *A* in *Fig. 25.* The magnetic field produced by the current flowing in the coil is precisely the same as that set up by a permanent steel magnet. Conversely, when a magnetic line of force is set up a part of its energy goes to make up electric currents which whirl about in a like manner, as shown at *B*.

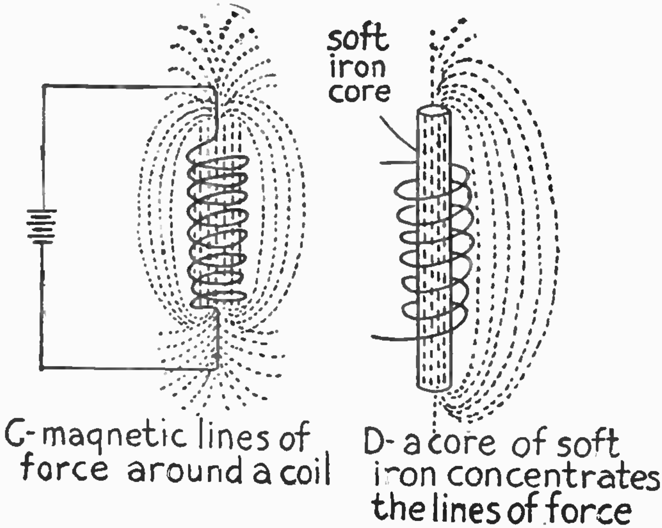
Self-induction or Inductance.—When a current is made to flow in a coil of wire the magnetic lines of force produced are concentrated, as at *C*, so that each turn of wire sets up action in the one next to it, and this action is called *self-induction, self-inductance* or just *inductance*. The



(*A*) and (*B*) Fig. 25.—How an Electric Current is Changed into Magnetic Lines of Force and These into an Electric Current.

self-induction, or inductance, forms a concentrated *magnetic field,* see *C,* as it is called, and if a bar of soft iron is slipped into the coil it will be magnetized, as at *D,* and it will remain a magnet until the current is cut off.

Mutual Induction.—When two loops of wire, or better, two coils of wire, are placed close together the electromagnetic induction between them is reactive, that is, when a current is made to flow through one of the coils closed magnetic lines of force are set up and when these cut the other loop or turns of wire of the other coil, they in turn produce electric currents in it.



(*C*) and (*D*) FIG. 25.—How an Electric Current Sets up a Magnetic Field.

It is the mutual induction that takes place between two coils of wire which makes it possible to transform *low voltage currents* from a battery or a 110 volt source of current into high pressure currents, or *high potential currents,* as they are called, by means of a spark coil or a transformer, as well as to *step up* and *step down* the potential of the high frequency currents that are set up in sending and receiving oscillation transformers. Soft iron cores are not often used in oscillation inductance coils and oscillation transformers as the frequency of the current is so high the iron unless very soft and laminated, would not have time to magnetize and demagnetize and so would not help along the mutual induction to any appreciable extent.

High-Frequency Currents.—High frequency currents, or electric oscillations as they are called, are currents of electricity that surge to and fro in a circuit a million times, more or less, per second. Currents of such high frequencies will *oscillate,* that is, surge to and fro, in an *open circuit,* such as an aerial wire system, as well as in a *closed circuit.*

Now there is only one method by which currents of high frequency, or *radio-frequency,* as they are termed, can be set up by spark transmitters, and this is by discharging a charged condenser through a circuit having inductance and a small resistance. To charge a condenser a spark coil or a transformer is used and the ends of the secondary coil, which delivers the high potential alternating current, are connected with the condenser. To discharge the condenser automatically a *spark*, or an *arc*, or the *flow of electrons* in a vacuum tube, is employed.

Constants of an Oscillation Circuit.—An oscillation circuit, as pointed out before, is one in which high frequency currents surge or oscillate. Now the number of times a high frequency current will surge forth and back in a circuit depends upon two factors of the latter and these are called the constants of the circuit, namely: (1) its *capacitance*, and (2) its *inductance*.

What Capacitance Is.—The word *capacitance* means the *electrostatic capacity* of a condenser or a circuit. The capacitance of a condenser or a circuit is the quantity of electricity which will raise its pressure, or potential, to a given amount. The capacitance of a condenser or a circuit depends on its size and form and the voltage of the current that is charging it.

The capacitance of a condenser or a circuit is directly proportional to the quantity of electricity that will keep the charge at a given potential. The *farad*, whose symbol is *M*, is the unit of capacitance and a condenser or a circuit to have a capacitance of one farad must be of such size that one *coulomb*, which is the unit of electrical quantity, will raise its charge to a potential of one volt. Since the farad is far too large for practical purposes a millionth of a farad, or *microfarad*, whose symbol is *mfd.*, is used.

What Inductance Is.—Under the sub-caption of *Self-Induction* and *Inductance* in the beginning of this chapter it was shown that it was the inductance of a coil that makes a current flowing through it produce a strong magnetic field, and here, as one of the constants of an oscillation circuit, it makes a high-frequency current act as though it possessed *inertia.*

Inertia is that property of a material body that requires time and energy to set in motion, or stop. Inductance is that property of an oscillation circuit that makes an electric current take time to start and time to stop. Because of the inductance, when a current flows through a circuit it causes the electric energy to be absorbed and changes a large part of it into magnetic lines of force. Where high frequency currents surge in a circuit the inductance of it becomes a powerful factor. The practical unit of inductance is the *henry* and it is represented by the symbol *L*.

What Resistance Is.—The resistance of a circuit to high-frequency currents is different from that for low voltage direct or alternating currents, as the former do not sink into the conductor to nearly so great an extent; in fact, they stick

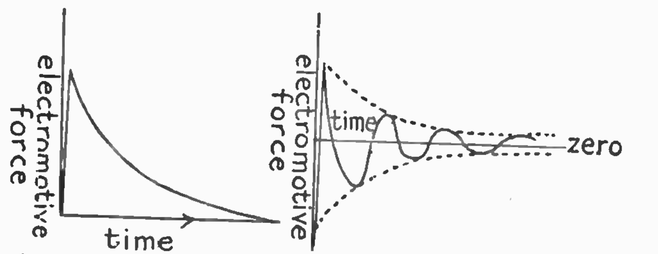


FIG. 26.—The Effect of Resistance on the Discharge of an Electric Current.

practically to the surface of it, and hence their flow is opposed to a very much greater extent. The resistance of a circuit to high frequency currents is generally found in the spark gap, arc gap, or the space between the electrodes of a vacuum tube. The unit of resistance is, as stated, the *ohm*, and its symbol is *R*.

The Effect of Capacitance, Inductance and Resistance on Electric Oscillations.—If an oscillation circuit in which high frequency currents surge has a large resistance, it will so oppose the flow of the currents that they will be damped out and reach zero gradually, as shown at *A* in *Fig. 26*. But if the resistance of the circuit is small, and in wireless circuits it is usually so small as to be negligible, the currents will oscillate, until their energy is damped out by radiation and other losses, as shown at *B*.

As the capacitance and the inductance of the circuit, which may be made of any value, that is amount you wish, determines the *time period,* that is, the length of time for a current to make one complete oscillation, it must be clear that by varying the values of the condenser and the inductance coil you can make the high frequency current oscillate as fast or as slow as you wish within certain limits. Where the electric oscillations that are set up are very fast, the waves sent out by the aerial will be short, and, conversely, where the oscillations are slow the waves emitted will be long.

CHAPTER V

HOW THE TRANSMITTING AND RECEIVING SETS WORK

THE easiest way to get a clear conception of how a wireless transmitter sends out electric waves and how a wireless receptor receives them is to take each one separately and follow: (1) in the case of the transmitter, the transformation of the low voltage direct, or alternating current into high potential alternating currents; then find out how these charge the condenser, how this is discharged by the spark gap and sets up high-frequency currents in the oscillation circuits; then (2) in the case of the receptor, to follow the high frequency currents that are set up in the aerial wire and learn how they are transformed into oscillations of lower potential when they have a larger current strength, how these are converted into intermittent direct currents by the detector and which then flow into and operate the telephone receiver.

How a Battery and Spark Coil Transmitting Set Works.—When you press down on the knob of the key the silver points of it make contact and this closes the circuit; the low voltage direct current from the battery now flows through the primary coil of the spark coil and this magnetizes the soft iron core. The instant it becomes mag-

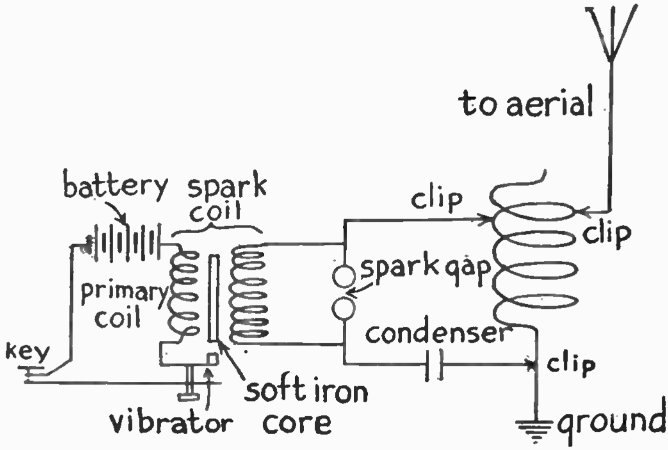


FIG. 27.—Wiring of Diagram for Spark Coil Sending Set.

netic it pulls the spring of the vibrator over to it and this breaks the circuit; when this takes place the current stops flowing through the primary coil; this causes the core to lose its magnetism when the vibrator spring flies back and again makes contact with the adjusting screw; then the cycle of operations is repeated.

A condenser is connected across the contact points of the vibrator since this gives a much higher voltage at the ends of the secondary coil than where the coil is used without it; this is because: (1) the self-induction of the primary coil makes the pressure of the current rise and when the contact points close the circuit again it discharges through the primary coil, and (2) when the break takes place the current flows into the condenser instead of arcing across the contact points.

Changing the Primary Spark Coil Current Into Secondary Currents.—Now every time the vibrator contact points close the primary circuit the electric current in the primary coil is changed into closed magnetic lines of force and as these cut through the secondary coil they set up in it a *momentary current* in one direction. Then the instant the vibrator points break apart the primary circuit is opened and the closed magnetic lines of force contract, and as they do so they cut the turns of wire in the secondary coil in the opposite direction, and this sets up another momentary current in the secondary coil in the other direction. The result is that the low voltage direct current of the battery is changed into alternating currents whose frequency is precisely that of the spring vibrator, but while the frequency of the currents is low, their potential, or voltage, is enormously increased.

What Ratio of Transformation Means.—To make a spark coil step up the low voltage direct current into high potential alternating current the primary coil is wound with a couple of layers of thick insulated copper wire, and the secondary is wound with a thousand, more or less, number of turns of very fine insulated copper wire. If the primary and secondary coils were wound with the same number of turns of wire then the pressure, or voltage, of the secondary coil at its terminals would be the same as that of the current which flowed through the primary coil. Under these conditions the *ratio of transformation,* as it is called, would be unity.

The ratio of transformation is directly proportional to the number of turns of wire on the primary and secondary coils, and since this is the case, if you wind 10 turns of wire on the primary coil and 1,000 turns of wire on the secondary coil then you will get 100 times as high a pressure, or voltage, at the terminals of the secondary as that which you caused to flow through the primary coil, but, naturally, the current strength, or amperage, will be proportionately decreased.

The Secondary Spark Coil Circuit.—This includes the secondary coil and the spark gap which are connected together. When the alternating, but high potential currents which are developed by the secondary coil, reach the balls, or *electrodes* of the spark gap, the latter are alternately charged positively and negatively.

Now take a given instant when one electrode is charged positively and the other one is charged negatively, then when they are charged to a high enough potential the electric strain breaks down the air gap between them and the two charges rush together as described in the chapter before this one in connection with the discharge of a condenser. When the charges rush together they form a current which burns out the air in the gap and this gives rise to the spark, and as the heated gap between the two electrodes is a very good conductor the electric current surges forth and back with high frequency, perhaps a dozen times, before the air replaces that which has burned out. It is the inrushing air to fill the vacuum of the gap that makes the crackling noise which accompanies the discharge of the electric spark.

In this way then, electric oscillations of the order of a million, more or less, are produced and if an aerial and a ground wire are connected to the spark balls, or electrodes, the oscillations will surge up and down it and the energy of these in turn, are changed into electric waves which travel out into space. An open circuit transmitter of this kind will send out waves that are four times as long as the aerial itself, but as the waves it sends out are strongly damped the Government will not permit it to be used.

The Closed Oscillation Circuit.—By using a closed oscillation circuit the transmitter can be tuned to send out waves of a given length and while the waves are not so strongly damped more current can be sent into the aerial wire system. The closed oscillation circuit consists of: (1) a *spark gap,* (2) a *condenser* and (3) an *oscillation transformer.* The high potential alternating current delivered by the secondary coil not only charges the spark gap electrodes which necessarily have a very small capacitance, but it charges the condenser which has a large capacitance and the value of which can be changed at will.

Now when the condenser is fully charged it discharges through the spark gap and then the electric oscillations set up surge to and fro through the closed circuit. As a closed circuit is a very poor radiator of energy, that is, the electric oscillations are not freely converted into electric waves by it, they surge up to, and through the aerial wire; now as the aerial wire is a good radiator nearly all of the energy of the electric oscillations which surge through it is converted into electric waves.

How a Transmitting Set Works with Alternating Current.—The operation of a transmitting set that uses an alternating current transformer, or *power transformer,* as it is sometimes called, is even more simple than one using a spark coil. The transformer needs no vibrator when used with alternating current. The current from a generator flows through the primary coil of the transformer and the alternations of the usual lighting current is 60 cycles per second. This current sets up an alternating magnetic field in the core of the transformer and as these magnetic lines of force expand and contract they set up alternating currents of the same frequency but of much higher voltage at the terminals of the secondary coil according to the ratio of the primary and secondary turns of wire as explained under the sub-caption of *Ratio of Transformation.*

With Direct Current.—When a 110 volt direct current is used to energize the power transformer an *electrolytic* interrupter is needed to make and break the primary circuit, just as a vibrator is needed for the same purpose with a spark coil. When the electrodes are connected in series with the primary coil of a transformer and a source of

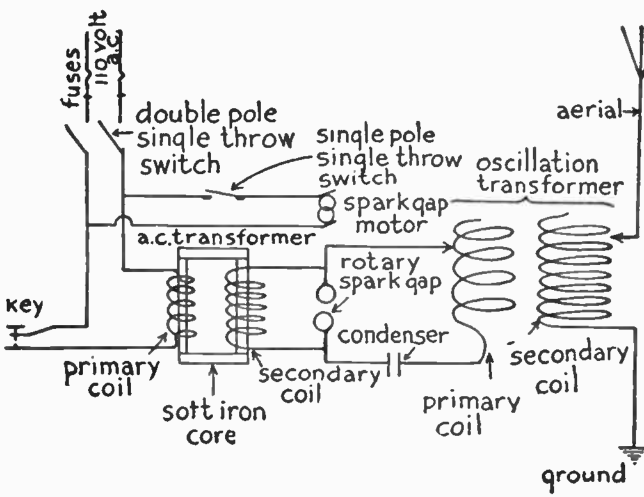


FIG. 28.—Wiring Diagram for Transformer Sending Set.

direct current having a potential of 40 to 110 volts, bubbles of gas are formed on the end of the platinum, or alloy anode, which prevent the current from flowing until the bubbles break and then the current flows again. In this way the current is rapidly made and broken and the break is very sharp.

Where this type of interrupter is employed the condenser that is usually shunted around the break is not necessary as the interrupter itself has a certain inherent capacitance, due to electrolytic action, and which is called its *electrolytic capacitance,* and this is large enough to balance the self-induction of the circuit since the greater the number of breaks per minute the smaller the capacitance required.

The Rotary Spark Gap.—In this type of spark gap the two fixed electrodes are connected with the terminals of the secondary coil of the power transformer and also with the condenser and primary of the oscillation transformer. Now whenever any pair of electrodes on the rotating disk are in a line with the pair of fixed electrodes a spark will take place, hence the pitch of the note depends on the speed of the motor driving the disk. This kind of a rotary spark-gap is called *non-synchronous* and it is generally used where a 60 cycle alternating current is available but it will work with other higher frequencies.

The Quenched Spark Gap.—If you strike a piano string a single quick blow it will continue to vibrate according to its natural period. This is very much the way in which a quenched spark

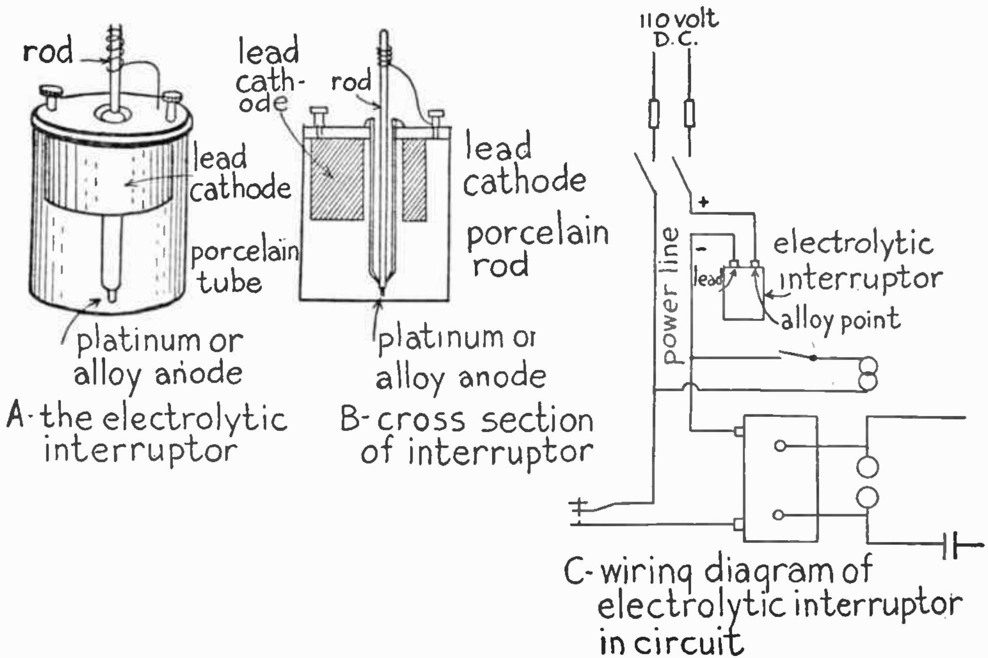


FIG. 29.—Using 110-Volt Direct Current with an Alternating Current Transformer.

gap sets up oscillations in a coupled, closed, and open circuit. The oscillations set up in the primary circuit by a quenched spark make only three or four sharp swings and in so doing transfer all of their energy over to the secondary circuit, where it will oscillate some fifty times or more before it is damped out, because the high frequency currents are not forced, but simply oscillate to the natural frequency of the circuit. For this reason the radiated waves approach somewhat the condition of continuous waves, and so sharper tuning is possible.

The Oscillation Transformer.—In this set the condenser in the closed circuit is charged and discharged and sets up oscillations that surge through the closed circuit. Here, however, an oscillation transformer is used and as the primary coil of it is included in the closed circuit the oscillations set up in it produce strong oscillating magnetic lines of force. The magnetic field thus produced sets up in turn electric oscillations in the secondary coil of the oscillation transformer and these surge through the aerial wire system where their energy is radiated in the form of electric waves.

The great advantage of using an oscillation transformer instead of a simple inductance coil is that the capacitance of the closed circuit can be very much larger than that of the aerial wire system. This permits more energy to be stored up by the condenser and this is impressed on the aerial when it is radiated as electric waves.

How the Tuning Coil Receiving Set Works.—When electric waves from a sending station impinge on the wire of a receiving aerial their energy is changed into electric oscillations that are of exactly the same frequency (assuming the receptor is tuned to the transmitter) but whose current strength (amperage) and potential (voltage) are very small. These electric waves surge through the closed circuit but when they reach the crystal detector the contact of the metal point on the crystal permits more current to flow through it in one direction than it will allow to pass in the other direction. For this reason a crystal detector is sometimes called a *rectifier,* which it really is.

Thus the high frequency currents which the steel magnet cores of the telephone receiver would choke off are changed by the detector into intermittent direct currents which can flow through the magnet coils of the telephone receiver. Since the telephone receiver chokes off the oscillations, a small condenser can be shunted around it so that a complete closed oscillation circuit is formed and this gives better results.

When the intermittent rectified current flows through the coils of the telephone receiver it energizes the magnet as long as it lasts, when it is de-energized; this causes the soft iron disk, or *diaphragm* as it is called, which sets close to the ends of the poles of the magnet, to vibrate; and this in turn gives forth sounds such as dots and dashes, speech or music, according to the nature of the electric waves that sent them out at the distant station.

How the Loose Coupler Receiving Set Works.—When the electric oscillations that are set up by the incoming electric waves on the aerial wire surge through the primary coil of the oscillation transformer they produce a magnetic field and as the lines of force of the latter cut the secondary coil, oscillations of the same frequency are set up in it. Since the secondary coil of the tuner and the condenser forms an oscillation circuit, the oscillations set up in it impress their voltage on the detector.

The oscillations then flow through the closed circuit where they are rectified by the crystal detector and transformed into sound waves by the telephone receiver as described in connection with

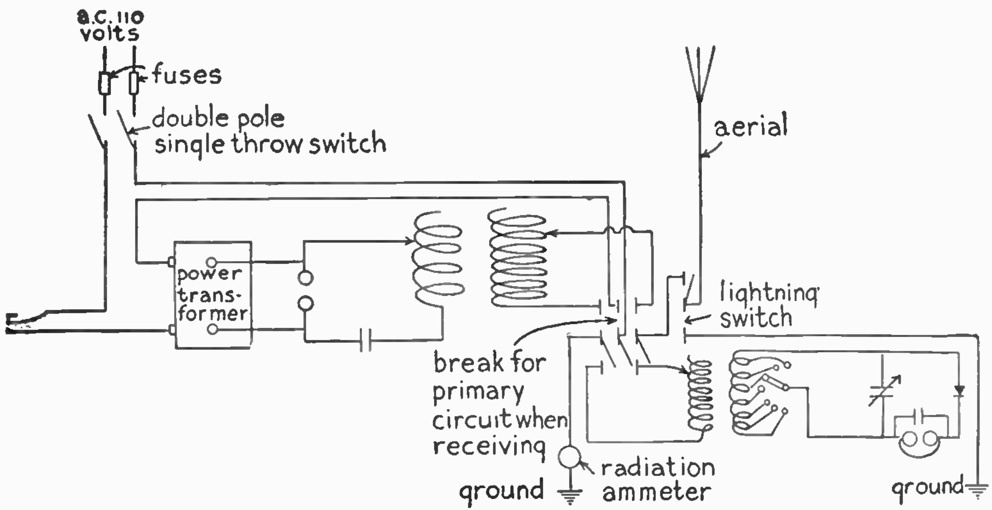


FIG. 30.—Wiring Diagram of Complete Sending and Receiving Set.

the other set. The variable condenser shunted across the closed circuit permits finer secondary tuning to be done than is possible without it. Where you are receiving continuous waves from a wireless telephone transmitter (speech or music) you have to tune sharper than is possible with the tuning coil alone and to do this a variable condenser connected in parallel with the secondary coil is necessary.

CHAPTER VI

MECHANICAL AND ELECTRICAL TUNING

THERE is a strikingly close resemblance between *sound waves* and the way they are set up in *the air* by a mechanically vibrating body, such as a steel spring or a tuning fork, and *electric waves* and the way they are set up in *the ether* by a current oscillating in a circuit. As it is easy to grasp the way that sound waves are produced and behave, something will be told about them in this chapter and also an explanation of how electric waves are produced and behave, and thus you will be able to get a clear understanding of them and of tuning in general.

Damped and Sustained Mechanical Vibrations.—If you will place one end of a flat steel spring in a vice and screw it up tight as shown at *A* in *Fig. 31*, and then pull the free end over and let it go, it will vibrate to and fro with decreasing amplitude until it comes to rest as shown at *B*. When you pull the spring over you store up energy in it and when you let it go, the stored up energy is changed into energy of motion and the spring moves forth and back, or *vibrates* as we call it, until all of its stored up energy is spent.

If it were not for the air surrounding it and

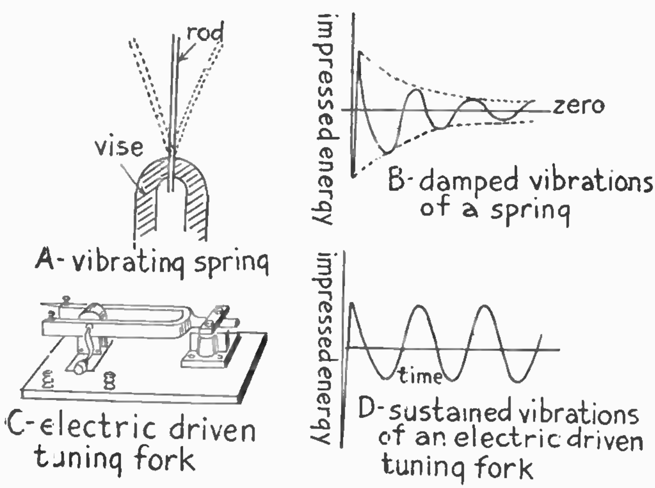


Fig. 31.—Damped and Sustained Mechanical Vibrations.

other frictional losses, the spring would vibrate for a very long time as the stored up energy and the energy of motion would practically offset each other and so the energy would not be used up. But as the spring beats the air, the latter is sent out in impulses and the conversion of the vibrations of the spring into waves in the air soon uses up the energy you have imparted to it and it comes to rest.

In order to send out *continuous waves* in the air instead of *damped waves* as with a flat steel spring, you can use an *electric driven tuning fork,* see *C,* in which an electromagnet is fixed on the inside of the prongs and when this is energized by a battery current the vibrations of the prongs of the fork are kept going, or are *sustained,* as shown in the diagram at *D.*

Damped and Sustained Electric Oscillations.—The vibrating steel spring described above is a very good analogue of the way that damped electric oscillations which surge in a circuit set up and send out periodic electric waves in the ether, while the electric driven tuning fork, just described, is likewise a good analogue of how sustained oscillations surge in a circuit, and set up and send out continuous electric waves in the ether, as the following shows.

Now the inductance and resistance of a circuit such as is shown at *A* in *Fig. 32,* slows down, and finally damps out entirely, the electric oscillations of the high frequency currents, see *B,* where these are set up by the periodic discharge of a condenser, precisely as the vibrations of the spring

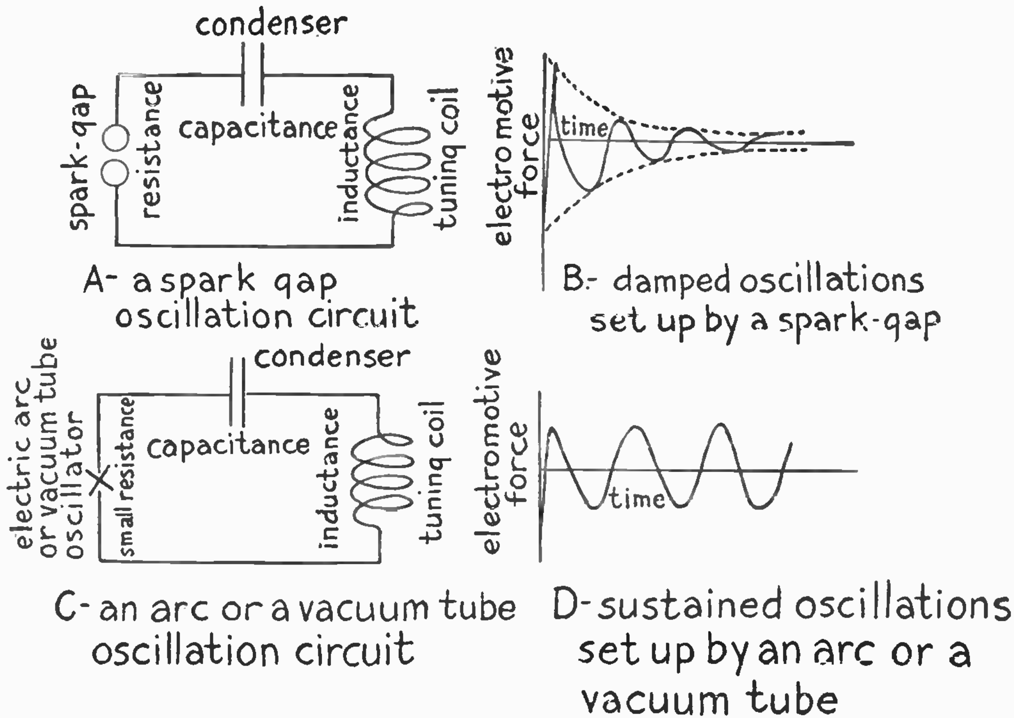


FIG. 32.—Damped and Sustained Electric Oscillations.

are damped out by the friction of the air and other resistances that act upon it. As the electric oscillations surge to and fro in the circuit it is opposed by the action of the ether which surrounds it and electric waves are set up in and sent out through it and this transformation soon uses up the energy of the current that flows in the circuit.

To send out *continuous waves* in the ether such as are needed for wireless telephony instead of *damped waves* an *electric oscillation arc* or a *vacuum tube oscillator* must be used, see *C*, instead of a spark gap. Where a spark gap is used, the condenser in the circuit is charged periodically and with considerable lapses of time between each of the charging processes, when, of course, the condenser discharges periodically and with the same time element between them. Where an oscillation arc or a vacuum tube is used the condenser is charged as rapidly as it is discharged and the result is the oscillations are sustained as shown at *D*.

About Mechanical Tuning.—A tuning fork is better than a spring or a straight steel bar for setting up mechanical vibrations. As a matter of fact a tuning fork is simply a steel bar bent in the middle so that the two ends are parallel. A handle is attached to middle point of the fork so that it can be held easily and which also allows it to vibrate freely, when the ends of the prongs alternately approach and recede from one another. When the prongs vibrate the handle vibrates up and down in unison with it, and imparts its motion to the *sounding box,* or *resonance case* as it is sometimes called, where one is used.

If, now, you will mount the fork on a sounding box which is tuned so that it will be in resonance with the vibrations of the fork there will be a direct reinforcement of the vibrations when the note emitted by it will be augmented in strength and quality. This is called *simple resonance.* Further, if you mount a pair of forks, each on a separate sounding box, and have the forks of the same size, tone and pitch, and the boxes *synchronized,* that is, tuned to the same frequency of vibration, then set the two boxes a foot or so apart, as shown at A in *Fig. 33,* when you strike one of the forks with a rubber hammer it will vibrate with a definite frequency and, hence, send out sound waves of a given length. When the latter strike the second fork the impact of the molecules of air of which the sound waves are formed will set its prongs to vibrating and it will, in turn, emit sound waves of the same length and this is called *sympathetic resonance,* or as we would say in wireless the forks are *in tune.*

Tuning forks are made with adjustable weights on their prongs and by fixing these to different parts of them the frequency with which the forks vibrate can be changed since the frequency varies inversely with the square of the length and directly with the thickness[1] of the prongs. Now by adjusting one of the forks so that it vibrates at a frequency of, say, 16 per second and adjusting the other fork so that it vibrates at a frequency of, say, 18 or 20 per second, then the forks will not be in tune with each other and, hence, if you strike one of them the other will not respond. But if you make the forks vibrate at the same frequency, say 16, 20 or 24 per second, when you strike one of them the other will vibrate in unison with it.

About Electric Tuning.—Electric resonance and electric tuning are very like those of acoustic resonance and acoustic tuning which I have just described. Just as acoustic resonance may be

[1] This law is for forks having a rectangular cross-section. Those having a round cross-section vary as the radius.

simple or sympathetic so electric resonance may be simple or sympathetic. *Simple acoustic resonance* is the direct reinforcement of a simple vibration and this condition is had when a tuning fork is mounted on a sounding box. In simple electric resonance an oscillating current of a given frequency flowing in a circuit having the proper

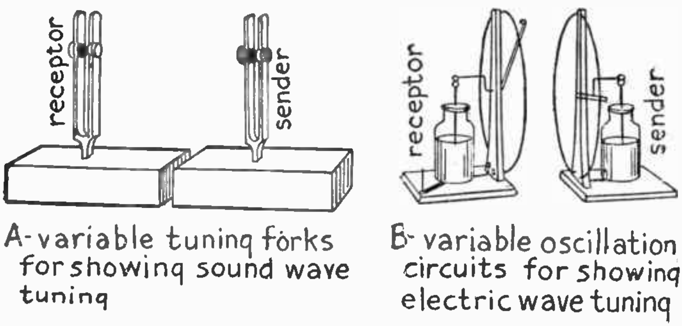


FIG. 33.—Sound Wave and Electric Wave Tuned Senders and Receptors.

inductance and capacitance may increase the voltage until it is several times greater than its normal value. Tuning the receptor circuits to the transmitter circuits are examples of sympathetic electric resonance. As a demonstration if you have two Leyden jars (capacitance) connected in circuit with two loops of wire (inductance) whose inductance can be varied as shown at *B* in *Fig. 33,* when you make a spark pass between the knobs of one of them by means of a spark coil then a spark will pass in the gap of the other one provided the inductance of the two loops of wire is the same. But if you vary the inductance of the one loop so that it is larger or smaller than that of the other loop no spark will take place in the second circuit.

When a tuning fork is made to vibrate it sends out waves in the air, or sound waves, in all directions and just so when high frequency currents surge in an oscillation circuit they send out waves in the ether, or electric waves, that travel in all directions. For this reason electric waves from a transmitting station cannot be sent to one particular station, though they do go further in one direction than in another, according to the way your aerial wire points.

Since the electric waves travel out in all directions, any receiving set properly tuned to the wave length of the sending station will receive the waves and the only limit on your ability to receive from high-power stations throughout the world depends entirely on the wave length and sensitivity of your receiving set. As for tuning, just as changing the length and the thickness of the prongs of a tuning fork varies the frequency with which it vibrates and, hence, the length of the waves it sends out, so, too, by varying the capacitance of the condenser and the inductance of the tuning coil of the transmitter the frequency of the electric oscillations set up in the circuit may be changed and, consequently, the length of the electric waves they send out. Likewise, by varying the capacitance and the inductance of the receptor the circuits can be tuned to receive incoming electric waves of whatever length within the limitation of the apparatus.

CHAPTER VII

A SIMPLE VACUUM TUBE DETECTOR RECEIVING SET

WHILE you can receive dots and dashes from spark wireless telegraph stations and hear spoken words and music from wireless telephone stations with a crystal detector receiving set such as described in *Chapter III*, you can get stations that are much farther away and hear them better with a *vacuum tube detector* receiving set.

Though the vacuum tube detector requires two batteries to operate it and the receiving circuits are somewhat more complicated than where a crystal detector is used still the former does not have to be constantly adjusted as does the latter and this is another very great advantage. Taken all in all, the vacuum tube detector is the most sensitive and the most satisfactory of the detectors that are in use at the present time.

Not only is the vacuum tube a detector of electric wave signals and speech and music but it can also be used to *amplify* them, that is, to make them stronger and, hence, louder in the telephone receiver, and further, its powers of amplification are so great that it will reproduce them by means of a *loud speaker*, just as a horn amplifies the sounds of a phonograph reproducer, until they can be heard by a room or an auditorium full of people. There are two general types of loud speakers, though both use the principle of the telephone receiver. The construction of these loud speakers will be fully described in a later chapter.

Assembled Vacuum Tube Receiving Sets.—You can buy a receiving set with a vacuum tube detector from the very simplest type, which is described in this chapter, to those that are provided with *regenerative circuits* and *amplifying* tubes or both, which we shall describe in later chapters, from dealers in electrical apparatus generally. While one of these sets costs more than you can assemble a set for yourself, still, especially in the beginning, it is a good plan to buy an assembled one for it is fitted with a *panel* on which the adjusting knobs of the rheostat, tuning coil and condenser are mounted and this makes it possible to operate it as soon as you get it home and without the slightest trouble on your part.

You can, however, buy all the various parts separately and mount them yourself. If you want the receptor simply for receiving, then it is a good scheme to have all of the parts mounted in a box or enclosed case, but if you want it for experimental purposes, then the parts should be mounted on a base or a panel so that all of the connections are in sight and accessible.

A Simple Vacuum Tube Receiving Set.—For this set you should use: (1) a *loose coupled tuning coil,* (2) a *variable condenser,* (3) a *vacuum tube detector,* (4) an *A or filament heating battery,* (5) a *B* or *dry cell* battery giving 22½ volts, (6) a *rheostat* for varying the *A* battery current, and (7) a pair of 2,000-ohm *head telephone receivers.* The loose coupled tuning coil, the variable condenser and the telephone receivers are the same as those described in *Chapter III.*

The Vacuum Tube Detector. With Two Electrodes.—A vacuum tube in its simplest form consists of a glass bulb like an incandescent lamp in which a *wire filament* and a *metal plate* are sealed as shown in *Fig. 34.* The air is then pumped out of the tube and a vacuum left or after it is exhausted it is filled with nitrogen, which cannot burn.

When the vacuum tube is used as a detector, the wire filament is heated red-hot and the metal plate is charged with positive electricity though it remains cold. The wire filament is formed into a loop like that of an incandescent lamp and

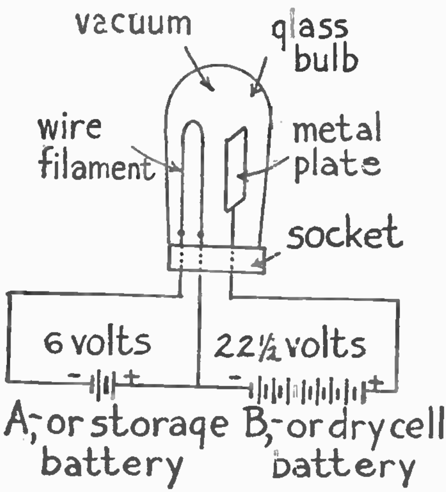


FIG. 34.—Two Electrode Vacuum Tube Detector.

its outside ends are connected with a filament heating battery, which is called the *A* battery; then the + or *positive* terminal of a 22½ volt dry cell battery, called the *B* battery, is connected to the metal plate while the — or *negative* terminal of the battery is connected to one of the terminals of the wire filament. The diagram, *Fig. 34,* simply shows how the two electrode vacuum tube, the *A* battery, and the *B* battery are connected up.

Three Electrode Vacuum Tube Detector.—The three electrode vacuum tube detector shown

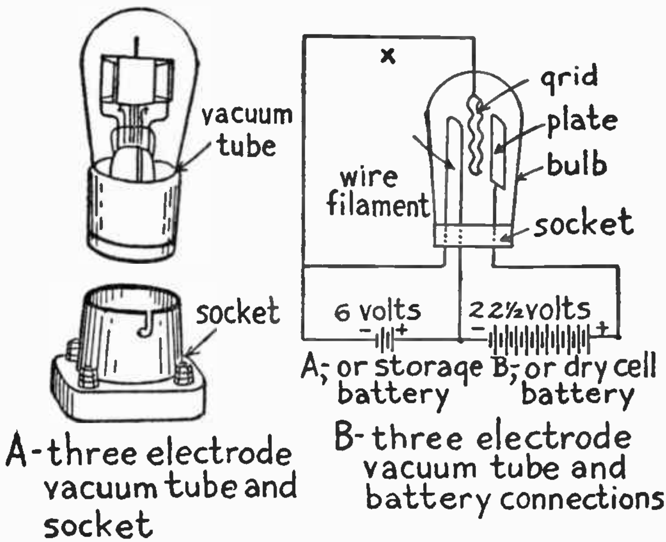


FIG. 35.—Three Electrode Vacuum Tube Detector and Battery Connections.

at *A* in *Fig. 35*, is much more sensitive than the two electrode tube and has, in consequence, supplanted it. In this more recent type of vacum tube the third electrode, or *grid,* as it is called, is placed between the wire filament and the metal plate and this allows the current to be increased or decreased at will to a very considerable extent.

At the present time there are numerous types of three electrode vacuum tubes on the market and it is for the reader to decide what ones he wishes to use. Some are designed for use as detectors, some as amplifiers and others are adapted to both uses.

Their sub-division is what is of most importance as you may be so situated that the use of a storage battery would be out of the question. In such a case it would be necessary to use dry cells to light the filament of the vacuum tube. Now the large 6 volt tubes draw a large amount of current and dry cells would last no time. The small 1½ volt or 4 volt tubes however draw very little current and therefore dry cells are satisfactory. One dry cell is enough to light the filament of a WD-11 or WD-12 vacuum tube while three dry cells connected in series will light from one to three UV-199 vacuum tubes for a long period of time before becoming exhausted.

The various types of vacuum tubes you can use are illustrated in *Fig. 36* and the vacuum tube chart in the back of the book will tell you what kind of *A* or filament heating battery must be used with each.

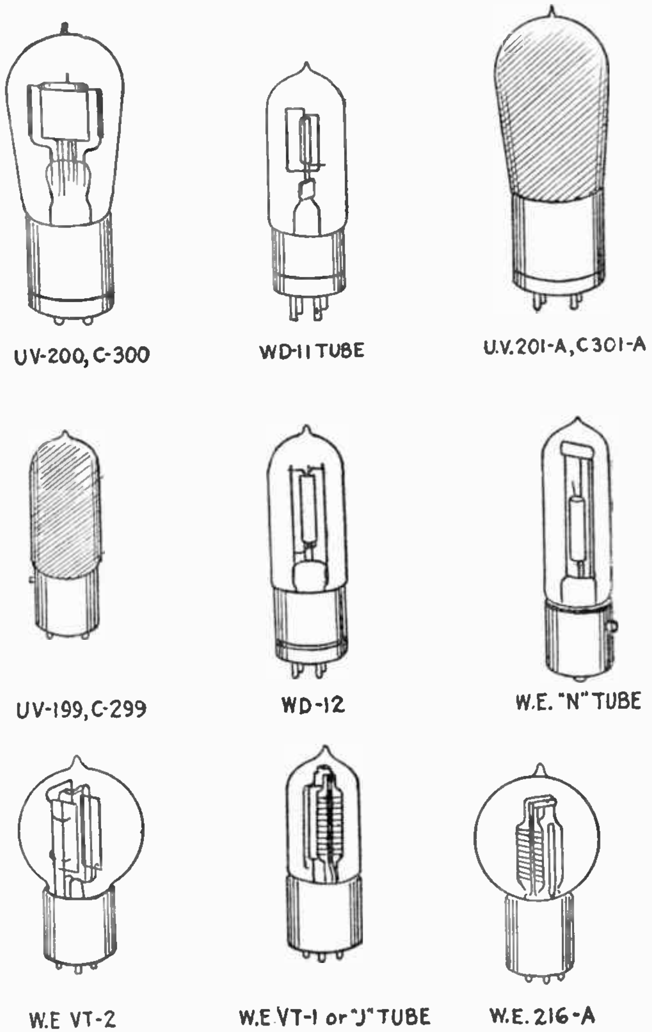


FIG. 36.—The Various Types of Vacuum Tubes.

The way the three electrode vacuum tube detector is connected with the batteries is shown at *B*. The plate, the *B* or dry cell battery and one terminal of the filament are connected in *series*—that is, one after the other, and the ends of the filament are connected to the *A* or filament heating battery. In assembling a receiving set

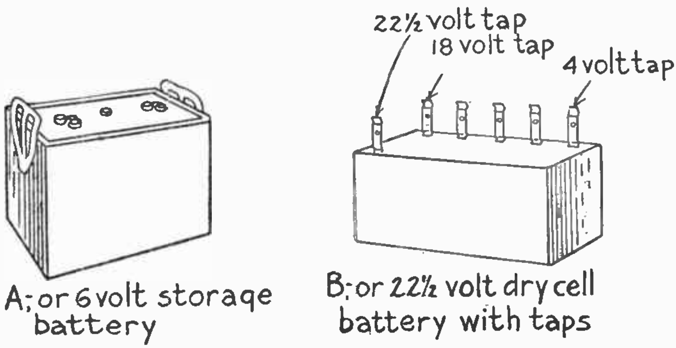


FIG. 37.—*A* and *B* Batteries for Vacuum Tube Detectors.

you must, of course, have a socket for the vacuum tube.

The Filament Heating and Plate Batteries.—The filament heating or *A* battery, as mentioned previously, can be one of two types; a storage battery as shown in *A* of *Fig. 37* or one or more 1½ volt dry cells of the kind shown in *A* of *Fig. 4*. The *B* or dry cell battery for the vacuum tube plate circuit that gives 22½ volts can be bought already assembled in sealed boxes. The small size is fitted with a pair of terminals while the larger size is provided with *taps* so that the voltage required by the plate can be adjusted as the proper operation of the tube requires careful reg-

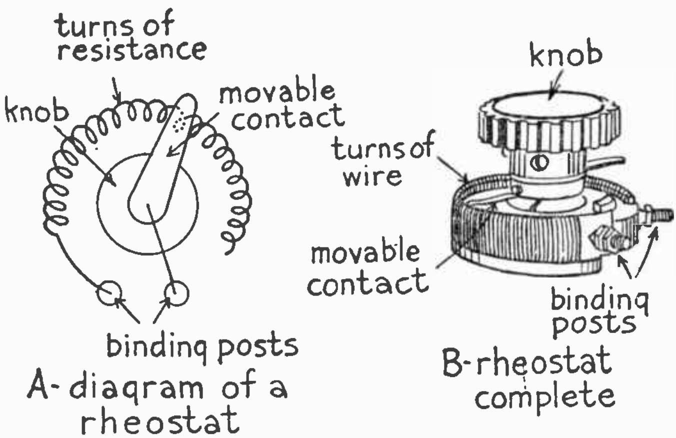
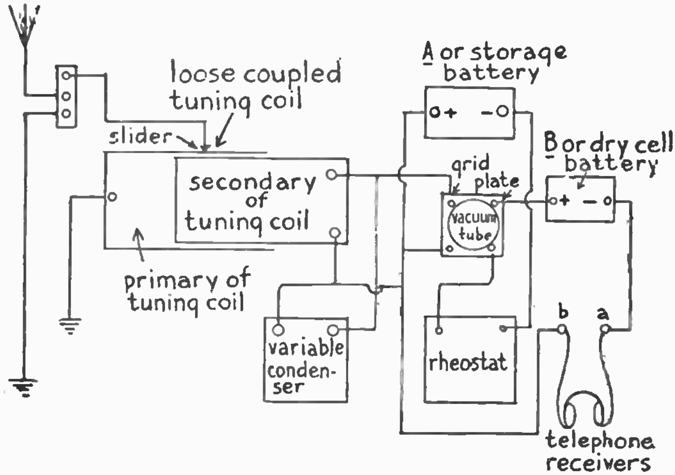


FIG. 38.—Rheostat for the *A* Battery Current.

ulation of the plate voltage. A dry cell battery for a plate circuit is shown at *B*.

The Filament Rheostat.—An adjustable resistance, called a *rheostat,* must be used in the filament and *A* battery circuit so that the current flowing through the filament can be controlled to a nicety. The rheostat consists of an insulating and a heat resisting form on which is wound a number of turns of resistance wire. A movable contact arm that slides over and presses on the turns of wire is fixed to the knob on top of the rheostat. The resistance of the rheostat depends upon what vacuum tube it is designed to



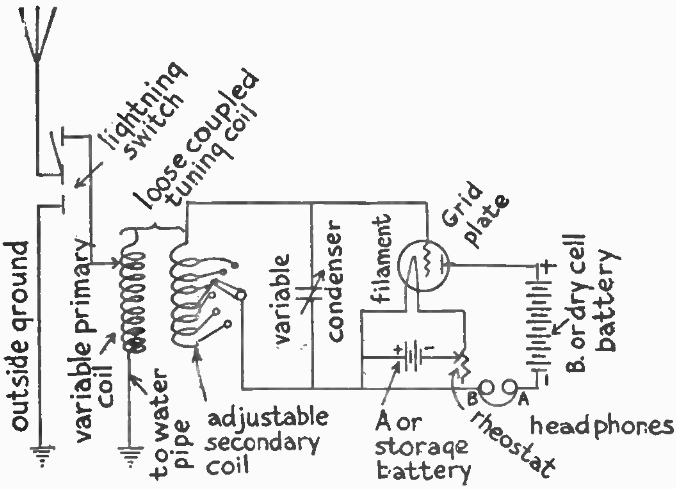
(A) Fig. 39.—Top View of Apparatus Layout for a Vacuum Tube Detector Receiving Set.

be used with. This can be determined from the vacuum tube chart in the back of the book. A popular type of rheostat is shown at *A* and *B* of *Fig. 38.*

Assembling the Parts.—Begin by placing all of the separate parts of the receiving set on a board or a base of other material and set the tuning coil on the left-hand side with the adjustable switch end toward the right hand side so that you can reach it easily. Then set the variable condenser in front of it, set the vacuum tube detector at the right-hand end of the tuning coil and the rheostat in front of the detector. Place the two sets of batteries back of the instruments and screw a couple of binding posts *a* and *b* to the right-hand lower edge of the base for connecting in the head phones, all of which is shown at *A* in *Fig. 39*.

Connecting Up the Parts.—To wire up the different parts begin by connecting the sliding contact of the primary coil of the loose coupled tuning coil (this you will remember is the outside one that is wound with heavy wire) to the upper post of the lightning switch and connect one terminal of this coil with the water pipe. Now connect the free end of the secondary coil of the tuning coil (this is the inside coil that is wound with fine wire) to one of the binding posts of the variable condenser and connect the movable contact arm of the adjustable switch of the secondary of the tuning coil with the other post of the variable condenser.

Next connect the grid of the vacuum tube to one of the posts of the condenser and then connect the plate of the tube to the *carbon terminal* of the *B* or dry cell battery which is the + or *positive pole* and connect the *zinc terminal* or the — or *negative* pole to the binding post *a*, connect the post *b* to the other side of the variable



(*B*) Fig. 39.—Wiring Diagram of a Simple Vacuum Tube Receiving Set.

condenser and then connect the terminals of the head phones to the binding posts *a* and *b*. Whatever you do be careful not to get the plate connections of the battery reversed.

Now connect one of the posts of the rheostat to one terminal of the filament and the other terminal of the filament to the + or *positive* terminal of the *A* battery and the — or *negative* terminal of the *A* battery to the other post of the rheostat. Finally connect the + or positive terminal of the *A* battery with the wire that runs from the head phones to the variable condenser, all of which is shown in the wiring diagram at *B* in *Fig. 39.*

Adjusting the Vacuum Tube Detector Receiving Set.—A vacuum tube detector is tuned exactly in the same way as the *Loose Coupler Crystal Detector Set* described in *Chapter III,* in-so-far as the tuning coil and variable condenser are concerned. The sensitivity of the vacuum tube detector receiving set and, hence, the distance over which signals and other sounds can be heard, depends very largely on the sensitivity of the vacuum tube itself and this in turn depends on: (1) the right amount of heat developed by the filament, or *filament brilliancy* as it is called, (2) the right amount of voltage applied to the plate, and (3) the extent to which the tube is exhausted where this kind of a tube is used.

To vary the current flowing from the *A* battery through the filament so that it will be heated to the right degree you adjust the rheostat while you are listening in to the signals or other sounds. By carefully adjusting the rheostat you can easily find the point at which it makes the tube the most sensitive. A rheostat is also useful in that it keeps the filament from burning out when the current from the battery first flows through it.

When the sensitiveness of the vacuum tube starts to decrease, the storage battery should be recharged or the dry cells renewed as the case may be. Furthermore, when crackling noises are heard in the head phones it is time to purchase new dry cell *B* batteries.

The degree to which a vacuum tube has been exhausted has a very pronounced effect on its sensitivity. The longer a gas tube is used the lower its vacuum gets and generally the less sensitive it becomes. When this takes place (and you can only guess at it) you can very often make it more sensitive by warming it over the flame of a candle. Vacuum tubes having a gas content (in which case they are, of course, no longer vacuum tubes in the strict sense) make better detectors than tubes from which the air has been exhausted and which are sealed off in this evacuated condition because their sensitiveness is not dependent on the degree of vacuum as in the latter tubes.

CHAPTER VIII

VACUUM TUBE AMPLIFIER RECEIVING SETS

THE reason a vacuum tube detector is more sensitive than a crystal detector is because while the latter merely *rectifies* the oscillating current that surges in the receiving circuits, the former acts as an *amplifier* at the same time. The vacuum tube can be used as a separate amplifier in connection with either: (1) a *crystal detector* or (2) a *vacuum tube detector,* and (*a*) it will amplify either the *radio frequency currents,* that is the high frequency oscillating currents which are set up in the oscillation circuits or (*b*) it will amplify the *audio frequency currents,* that is, the *low frequency* currents that flow through the head phone circuit.

To use the amplified radio frequency oscillating currents or amplified audio frequency currents that are set up by an amplifier tube, either a high resistance, such as a *grid leak,* or an *amplifying transformer,* with or without an iron core, must be connected with the plate circuit of the first amplifier tube and the grid circuit of the next amplifier tube or detector tube, or with the wire point of a crystal detector. Where two or more amplifier tubes are coupled together in this way the scheme is known as *cascade amplification.*

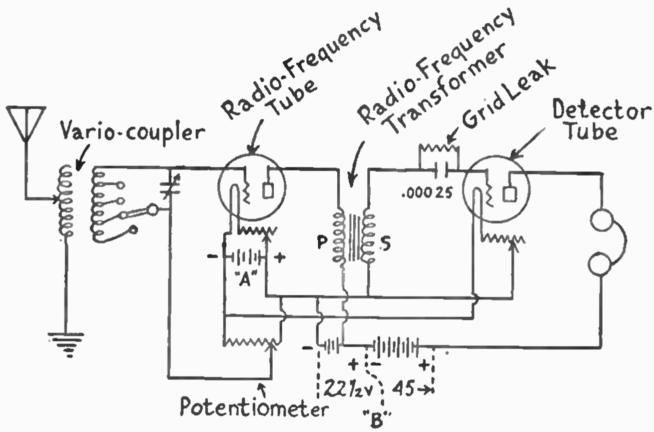
The Vacuum Tube Amplifier.—This consists of a three electrode vacuum tube exactly like the vacuum tube detector described in *Chapter VII,* except that instead of being filled with a non-combustible gas it is evacuated, that is, the air has been completely pumped out of it. The gas filled tube, however, can be used as an amplifier and either kind of tube can be used for either radio frequency or audio frequency amplification, though with the exhausted tube it is easier to obtain the right plate and filament voltages for good working.

The vacuum tube chart in the back of the book will tell you what tubes are best adapted to this purpose.

A Radio Frequency Amplifier Receiving Set.—The *resistance coupled* type of radio frequency amplifier will not be taken up as it is out of date, having given way to the *transformer coupled* type.*

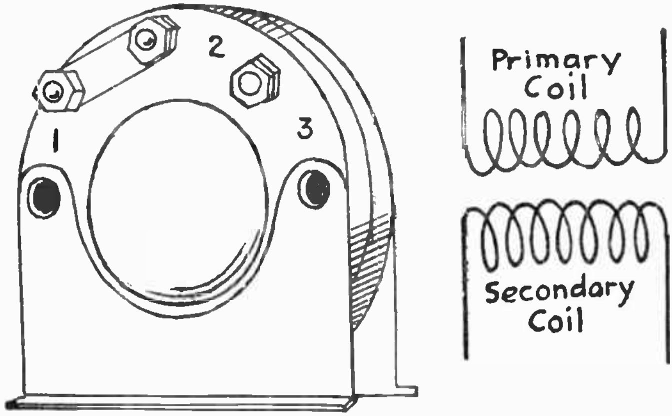
* See Radio Frequency Amplification and Tuned Radio Frequency Receiver in Appendix, pages 393–397.

A *radio frequency transformer* is made like a loose coupled tuning coil but usually has an iron core as shown in the wiring diagram *A* of *Fig. 40.* In this set the amplifier tube is placed in the *first* oscillation circuit and the detector tube in the *second* circuit.



(*A*) Fig. 40.—Vacuum Tube Detector Receiving Set with One Step Radio Frequency Amplifier.

The high frequency, or *radio frequency* oscillation currents, as they are called, surge through the amplifier and are not changed into low frequency, or *audio frequency* pulsating currents, until they flow through the detector. Since the diagram shows only one amplifier and one radio frequency transformer, it is consequently a *one* *step* amplifier; however, more tubes can be connected up by means of an equal number of radio frequency transformers but it is best in general practice to use no more than two steps as a greater number prove very difficult to handle. In fact even with this one step amplifier it is



(*B*) Fig. 40.—Radio Frequency Transformer.

necessary to use a *potentiometer* (see *Fig. 40*) in order to control or *stabilize* the circuit, that is to keep it from *oscillating*. A typical radio frequency amplifying transformer is shown in *B* of *Fig. 40*.

The Parts and How to Connect Them Up.—You will need the following parts for the one step radio frequency amplifier: (1) a variocoupler; (2) a 23 plate variable condenser; (3) a radio frequency amplifying transformer that will cover the broadcast wave lengths; (4) a 200 ohm potentiometer; (5) a .00025 mfd. grid condenser; (6) a grid leak; (7) an *A* battery; (8) two 22½ volt *B* batteries; (9) two rheostats; (10) an amplifier vacuum tube; (11) a detector vacuum tube; (12) two vacuum tube sockets; (13) a pair of head phones.

The wiring diagram *A* of *Fig. 40* is easy to follow and you should have no difficulty in getting the set hooked up properly. Be sure that you get the *primary* and *secondary* windings of the radio frequency transformer connected in the right circuits. The *right-hand* winding in the diagram is the *secondary*.

A Neutrodyne Receiver.—The *Neutrodyne* circuit was invented by Professor Hazeltine of Stevens Institute of Technology. It is a very sensitive form of radio frequency amplifier and is a decided improvement over the usual type. As explained, it is necessary to use a *potentiometer* with a radio frequency amplifier to stabilize the circuit, that is to prevent it from oscillating. The very means by which it is prevented represents a considerable loss of energy that cannot be made up for. In other words it is essential that an amount of amplification be sacrificed in order that we may receive broadcast programs that are free from distortion.

The Neutrodyne kills two birds with one stone. First, small condensers called *neutralizing condensers* are employed to neutralize the *inter-element* capacity of the vacuum tubes which is the cause for the circuit oscillating. This eliminates the potentiometer and its accompanying losses. Second, since the circuit cannot oscillate after once being neutralized, advantage is taken of *tuned plate radio frequency amplification* which is a much more sensitive system than the transformer type but too critical to use effectively in a circuit where a potentiometer is the only means for controlling oscillation. This type of transformer is called a *Neutroformer* and is tuned by means of a variable condenser connected across its secondary winding. Unlike the usual type of radio frequency transformer, the *Neutroformer* has no iron core. In this three-tube Neutrodyne set there are three variable condensers and they are the only controls. The first two tubes serve as radio frequency amplifiers and the third as a detector. The *regenerative* feature, which will be described fully in a later chapter, may be added by placing a variometer in the plate circuit of the detector

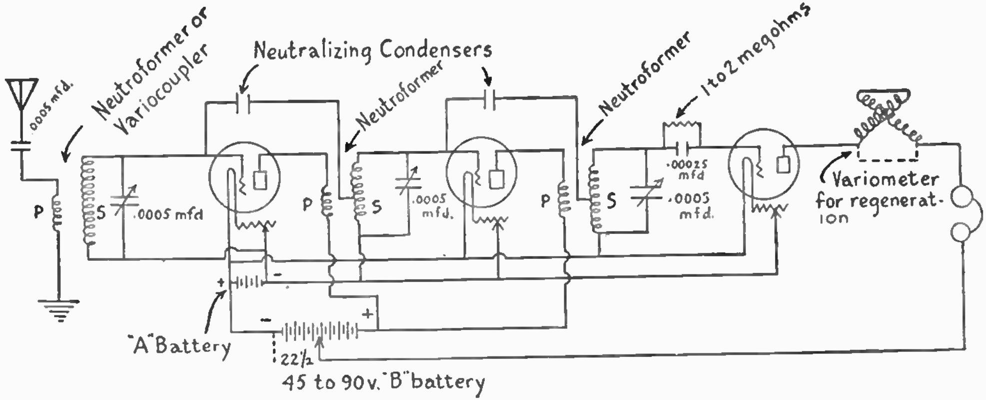


FIG. 41.—The Circuit Diagram of a Three Tube Neutrodyne Receiving Set.

vacuum tube as shown in the diagram of *Fig. 41*.

Although it is possible to construct the Neutroformers and the neutralizing condensers it is advised that they be purchased, as little mistakes are apt to cause no end of trouble. Radio dealers carry complete parts for these sets which makes their construction easy.

The Parts and How to Connect Them Up.—You will need (1) three Neutroformers; (2) three 23 plate variable condensers (these are usually parts of the neutroformers); (3) one .0005 mfd. fixed condenser; (4) one .00025 mfd. fixed grid condenser; (5) a grid leak; (6) two neutralizing condensers; (7) two amplifier vacuum tubes; (8) one detector vacuum tube; (9) three tube sockets; (10) three 22½ volt *B* batteries; (11) an *A* battery; (12) three rheostats; (13) a variometer if you wish *regeneration;* (14) a pair of head phones or loud speaker.

The circuit of *Fig. 41* shows how the instruments are connected up. If you do not wish regeneration the variometer is eliminated and the circuit continued as shown by the dotted line.

A Super-Heterodyne Receiver.—This is the most sensitive type of short wave radio receiver in existence to-day and is another of Major Armstrong's contributions to the radio field. Although at least six vacuum tubes are required, the control of this receiver is quite simple. Two variable condensers are provided for this purpose.

The first vacuum tube in this set functions as an *oscillator* and together with its own circuit is known as the *external heterodyne.* The second tube is the *first* detector or *frequency changer,* the third, fourth and fifth tubes are the radio frequency amplifiers, and the sixth vacuum tube is the *second* detector.

The radio frequency transformers for this set are designed to amplify signals at a wave length of from *5,000* to *25,000* meters instead of at the true wave length of the signal which in our case is from 220 to 550 meters, the broadcast waves. Just how this is done is described in *Chapter XIV* which you should read before attempting the construction of one of these sets. The radio frequency transformers just mentioned are very similar in their appearance to the one shown in *B* of *Fig. 40.*

The *oscillator coil unit* which is a part of the *external heterodyne* is constructed as follows: On a cardboard tube 3 inches in diameter, starting at the left end, wind 8 turns of No. 20 D.C.C. copper wire. This forms coil *A* as shown in the diagram. Starting 2 inches from the end of coil *A* wind 20 turns of the same size wire. This is coil *B*. About ¾ inch from the end of coil *B* wind 35 turns of the same size wire. This forms coil *C* and completes the unit.

The two 750 turn honeycomb coils really make up another radio frequency transformer but they are used so as to provide coupling and so make the circuit more selective. The correct coupling is had when the received signals are the loudest. When the coupling is once found the coils need not be touched again.

The Parts and How to Connect Them Up.—You will need the following parts for building the Super-Heterodyne receiver: (1) a variocoupler; (2) a 23 plate (.0005 mfd.) variable condenser; (3) a 43 plate (.001 mfd.) variable condenser; (4) a .001 mfd. fixed condenser; (5) four .00025 mfd. fixed condensers; (6) two 750 turn honeycomb coils; (7) three long wave radio frequency amplifying transformers; (8) ½ pound of copper wire and a cardboard tube for constructing the oscillator coil unit; (9) two 2 megohm grid leaks; (10) five 30 ohm rheostats; (11) a 400 ohm potentiometer; (12) an *A* bat-

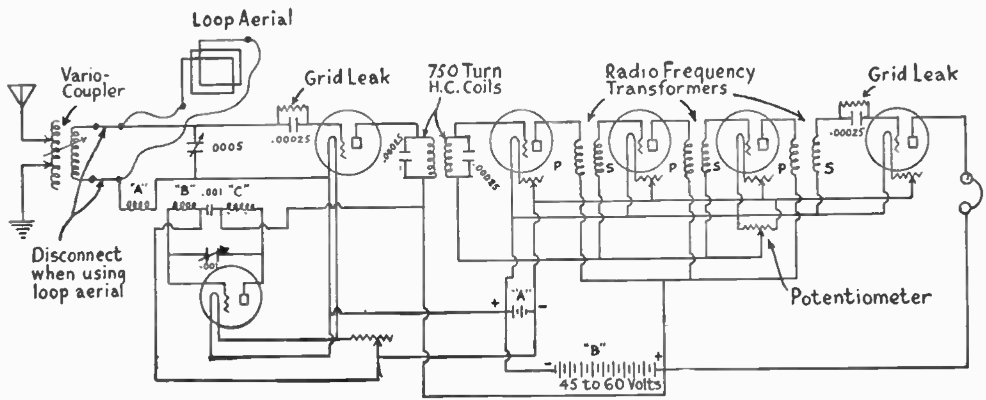


FIG. 42.—The Circuit Diagram of a Super-Heterodyne Receiving Set with Six Vacuum Tubes.

tery; (13) three $22\frac{1}{2}$ volt *B* batteries; (14) six UV 199 or UV 201-A vacuum tubes; (15) six vacuum tube sockets; (16) a pair of head-phones or a loud speaker.

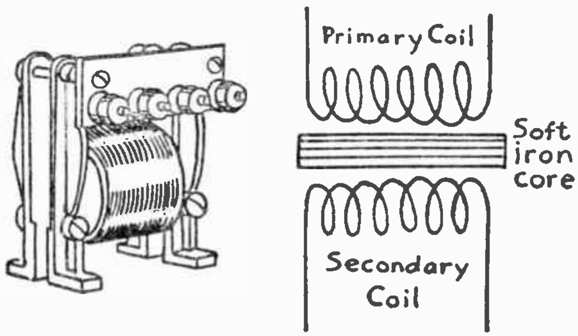
The circuit diagram of *Fig. 42* shows how the different instruments are connected up. Included in this diagram are connections showing how a loop aerial can be employed in place of the aerial and ground if desirable. If you wish more volume than this receiver gives, the two-step audio frequency amplifier described in this Chapter and shown in *Fig. 43* can be added by taking out the head-phones in the Super-Heterodyne circuit and connecting the two *primary* terminals of the first audio frequency transformer to where the head-phones were attached. A loud-speaker is then connected to the *output* terminals of the amplifier.

An Audio Frequency Transformer Amplifying Receiving Set.—Where audio frequency transformers are used for stepping up the voltage of the current of the detector and amplifier tubes, the radio frequency current does not get into the plate circuit of the detector at all, for the reason that the iron core of the transformer chokes them off, hence, the succeeding amplifiers operate at audio frequencies.* An audio fre-

* See Audio Frequency Amplification in Appendix, page 397.

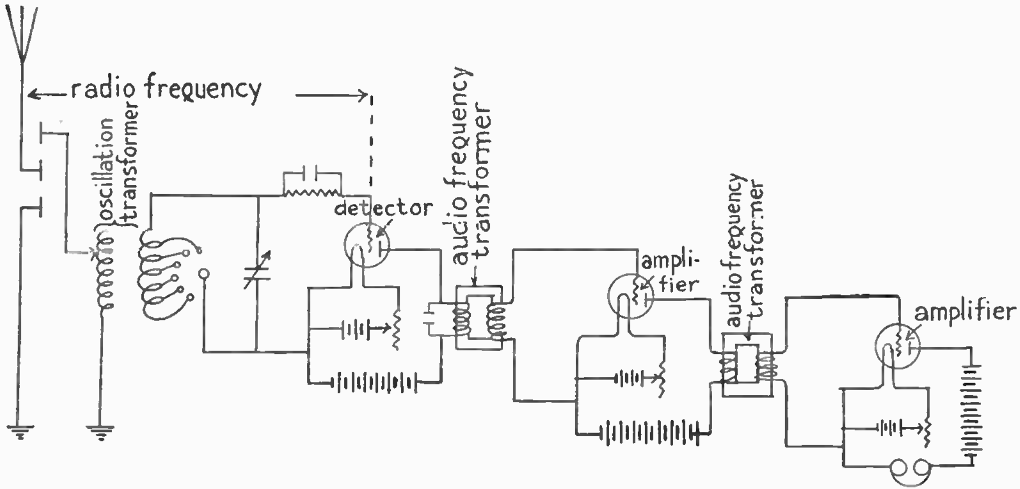
quency transformer is shown at *A* in *Fig. 43* and a wiring diagram showing how the tubes are connected in *cascade* with the transformers is shown at *B;* it is therefore a two-step audio frequency amplifying receiving set.

A Push-Pull Amplifier.—If you want the best in the way of *audio frequency amplifiers,* one that



(*A*) Fig. 43.—Audio Frequency Transformer.

will give you immense volume and undistorted speech and music, the *push-pull amplifier* is the one to build. In this amplifier the circuit is so arranged that the energy from a single stage amplifier is fed into a second stage containing *two* amplifying tubes and special transformers which are connected so that the energy is evenly distributed between the two tubes. The increased capacity afforded by the two tubes working in



(*B*) FIG. 43.—Wiring Diagram for an Audio Frequency Transformer Amplifying Receiving Set. (With Vacuum Tube Detector and Two Step Amplifier Tubes.)

parallel allows for immense amplification free of distortion.

The Parts and How They Are Connected.—You will require the following parts: (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) a

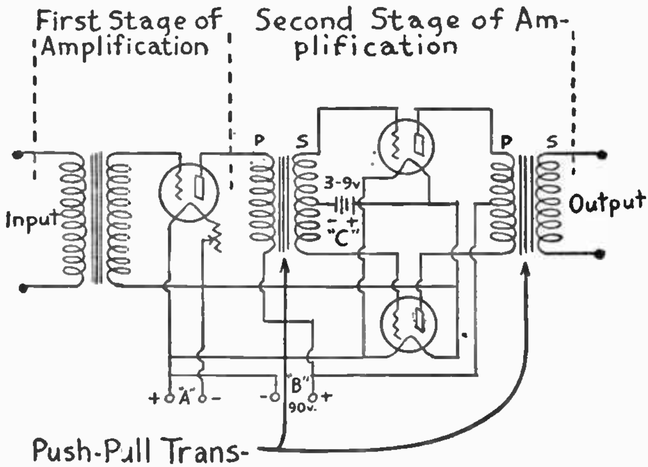


FIG. 44.—Wiring for a Push-Pull Audio Frequency Amplifier.

standard audio frequency amplifying transformer; (4) 2 *push-pull amplifying transformers;* (5) a 9 volt *C* battery; (6) five 22½ volt *B* batteries; (7) an *A* battery; (8) a rheostat for the *A* battery; (9) a loud speaker.

The circuit of the *push-pull amplifier* is shown in *Fig. 44*. It should be noted that the push-pull transformers have *center taps* and that it is taken off the *secondary winding* of the *first* transformer and off the *primary winding* of the *second* transformer. Be sure that you get the two transformers situated correctly before starting to wire up the instruments.

A One-Tube Reflex Receiver.—Before describing this combination radio and audio frequency amplifier receiver it might be well to explain what is meant by *reflex.* It has until recently been a general practice to use one vacuum tube for but one purpose. Marius Latour, a well-known French inventor, found that a single vacuum tube could be so connected in a circuit as to perform two duties at practically the same time; thus, it would amplify an incoming signal before it was detected (radio frequency) and again after it had been detected (audio frequency). Either a crystal or another vacuum tube would be used for the purpose of rectification, but preferably a crystal. The manner in which this is accomplished is quite simple. The incoming signal first passes through the usual tuning circuit composed of a vario-coupler and a variable condenser; thence through the vacuum tube and radio frequency amplifying transformer where it is amplified at *radio frequency.*

through the detector where it is *rectified*, through an audio frequency transformer and back through the same tube where it is again amplified, but this time at *audio frequency*. It then passes through the head-phones or loud-speaker. Thus the signal energy is fed back or *reflexed* through the same vacuum tube.

Now it is necessary that fixed condensers be placed in the circuit to allow the radio frequency currents, before they are rectified, to by-pass the windings of the audio frequency transformer and head phones or loud speaker which would otherwise impede the flow of the currents because of their resistance. The capacity values of these is a very important consideration in the operation of a reflex receiver. This is particularly so when employing more than one tube and it is a very difficult proposition for the novice to find for himself the exact capacities necessary. If they are not correct the set will not operate properly. For this reason it is believed best to describe only a one-tube reflex receiver which is not difficult to construct if specifications are strictly adhered to.

The Parts You Will Need and How to Connect Them Up.—You will need the following parts for building the one-tube reflex receiver: (1) a vario coupler; (2) a 43 plate variable condenser; (3) a 23 plate variable condenser; (4) three .001 mfd. fixed condensers; (5) a 200 or 400 ohm potentiometer; (6) a crystal detector; (7) an audio frequency amplifying transformer; (8) a radio frequency amplifying transformer of the iron core type capable of covering the broadcast wave-lengths which are from 220 to

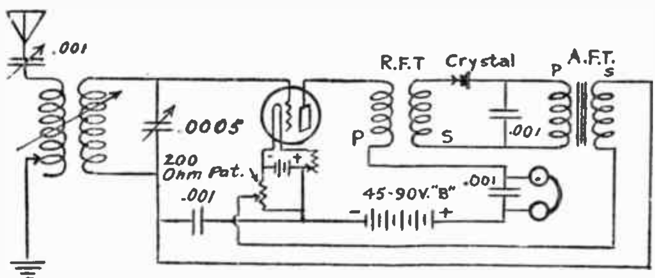


Fig. 45.—Connections for the One-tube Reflex Receiver.

550 meters; (9) three 22½ volt *B* batteries; (10) an *A* battery; (11) a rheostat; (12) an amplifier vacuum tube; (13) a vacuum tube socket; (14) a pair of head-phones or a loud-speaker.

The connections for the instruments composing this reflex set are shown in *Fig. 45.* It should be noted that the resistance wire of the potentiometer is connected directly across the terminals of the *A* battery exactly as explained before. The center connection or contact arm leads directly to one of the *secondary* terminals of the audio frequency transformer.

If after completing the wiring of the circuit, the receiver fails to operate properly, the two wires connecting to the primary terminals of the audio frequency transformer should be reversed. Remember that the potentiometer plays an important part in the function of the receiver. Only by its adjustment can howling and distortion be eliminated.

How to Prevent Howling.—Where radio frequency or audio frequency amplifiers are used to couple your amplifier tubes in cascade you may have to shield them from one another in order to prevent the *feed back* of the currents through them, which makes the head phones or loud speaker *howl*. To shield them from each other the tubes should be enclosed in metal boxes and placed at least 6 inches apart while the transformers should be set so that their cores are at right angles to each other and these also should be not less than 6 inches apart.

CHAPTER IX

REGENERATIVE AMPLIFICATION RECEIVING SETS

WHILE a vacuum tube detector has an amplifying action of its own, and this accounts for its great sensitiveness, its amplifying action can be further increased to an enormous extent by making the radio frequency currents that are set up in the oscillation circuits react on the detector.

Such currents are called *feed-back* or *regenerative* currents and when circuits are so arranged as to cause the currents to flow back through the detector tube the amplification keeps on increasing until the capacity of the tube itself is reached. It is like using steam over and over again in a steam turbine until there is no more energy left in it. A system of circuits which will cause this regenerative action to take place is known as the *Armstrong circuits* and is so called after the young man who discovered it.

Since the regenerative action of the radio frequency currents is produced by the detector tube itself and which sets up an amplifying effect without the addition of an amplifying tube, this type of receiving set has found great favor with amateurs, while in combination with amplifying tubes it multiplies their power proportionately and it is in consequence used in one form or another in all the better sets.

There are many different kinds of circuits which can be used to produce the regenerative amplification effect while the various kinds of tuning coils will serve for coupling them; for instance a two or three slide single tuning coil will answer the purpose but as it does not give good results it is not advisable to spend either time or money on it. A better scheme is to use a loose coupler formed of two or three honeycomb or other compact coils, while a *vario-coupler* or a *variometer* or two will produce the maximum regenerative action.

The Simplest Type of Regenerative Receiving Set. With Loose Coupled Tuning Coil.—While this regenerative set is the simplest that will give anything like fair results it is here described not on account of its desirability, but because it will serve to give you the fundamental idea of how the *feed-back* circuit is formed.

For this set you need: (1) a *loose-coupled tun-*

ing coil such as described in *Chapter III*, (2) a *variable condenser* of *.001 mfd.* (microfarad) capacitance; (3) one *fixed condenser* of *.001 mfd.;* (4) one *fixed condenser* for the grid leak circuit of *.00025 mfd.;* (5) a *grid leak* of ½ to 2 megohms resistance; (6) a *vacuum tube detector;* (7) an *A battery;* (8) a *rheostat;* (9) a *B 22½ volt battery;* and (10) a pair of *2,000 ohm head phones.*

Connecting Up the Parts.—Begin by connecting the leading-in wire of the aerial with the binding post end of the primary coil of the loose coupler as shown in the wiring diagram *Fig. 46* and then connect the sliding contact with the water pipe or other ground. Connect the binding post end of the primary coil with one post of the variable condenser, and also with one of the posts of the *.00025 mfd.* condenser and the other end of this with the grid of the detector tube; then around this condenser shunt the grid leak resistance.

Next connect the sliding contact of the primary coil with the other post of the variable condenser and from this lead a wire on over to one of the terminals of the filament of the vacuum tube; to the other terminal of the filament connect one of the posts of the rheostat and connect the other post to the — or negative electrode of the *A* battery and then connect the + or positive electrode of it to the other terminal of the filament.

Connect the + or positive electrode of the *A*

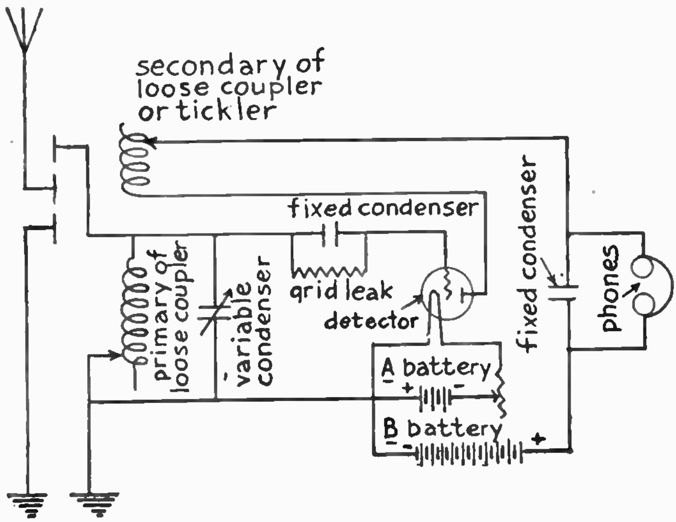
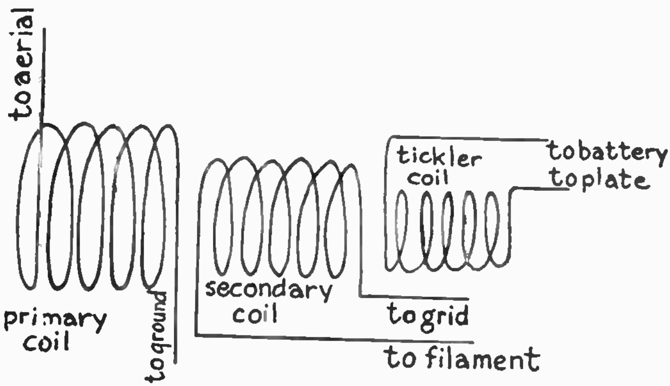


Fig. 46.—Simple Regenerative Receiving Set. (With Loose Coupler Tuner.)

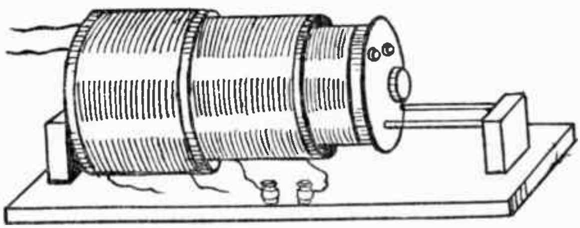
battery with the — or negative electrode of the *B* battery and connect the + or positive electrode of the *B* with one post of the fixed .001 condenser and connect the other post of this to one of the ends of the secondary coil of the tuning coil and which is now known as the *tickler coil;* then connect the other end of the secondary, or tickler coil to the plate of the vacuum tube. In the wiring diagram the secondary, or tickler coil is shown above and in a line with the primary coil but this is only for the sake of making the connections clear; in reality the secondary, or



(*A*) Fig. 47.—Diagram of a Three Coil Coupler.

tickler coil slides to and fro in the primary coil as shown and described in *Chapter III.* Finally connect the head phones across the fixed condenser when your regenerative set is complete.

An Efficient Regenerative Receiving Set. With Three Coil Loose Coupler.—To construct a really good regenerative set you must use a loose coupled tuner that has three coils, namely a *primary,* a *secondary* and a *tickler coil.* A tuner of this kind is made like an ordinary loose coupled tuning coil but it has a *third* coil as shown at *A* and *B* in *Fig. 47.* The middle coil, which is the *secondary,* is fixed to the base, and the large outside coil, which is the *primary,* is movable, that is it slides to and fro over the middle coil, while



(*B*) Fig. 47.—Three Coil Loose Coupler Tuner.

the small inside coil, which is the *tickler,* is also movable and can slide in or out of the middle coil. None of these coils is variable; all are wound to receive waves up to 360 meters in length when used with a variable condenser of *.001 mfd.* capacitance. In other words you slide the coils in and out to get the right amount of coupling and you tune by adjusting the variable condenser to get the exact wave length you want.

With Compact Coils.—Compact coil tuners are formed of three fixed inductances wound in flat coils, and these are pivoted in a mounting so that the distance between them and, therefore, the coupling, can be varied, as shown at *A* in *Fig. 48*. These coils are wound up by the makers for various wave lengths ranging from a small one that will receive waves of any length up to 360 meters to a large one that has a maximum of 24,000 meters. For an amateur set, get three of

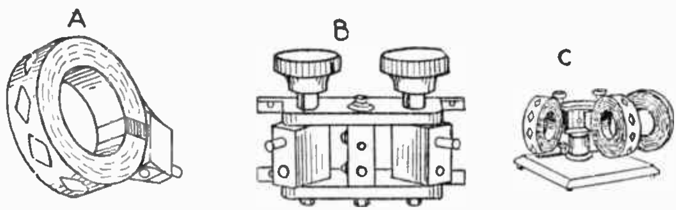


Fig. 48.—Honeycomb Inductance Coils. *A*. **Multilayer Inductance Coil.** *B*. **Mounting for Three Multilayer Inductance Coils.** *C*. **Multilayer Coils Mounted.**

the second smallest coils, when you can not only hear amateur stations that send on a 200 meter wave but broadcasting stations that send on wave lengths up to 550 meters.

These three coils are mounted with panel plugs which latter fit into a stand, or mounting, so that the middle coil is fixed, that is, stationary, while the two outside coils can be swung to and fro like a door; this scheme permits small variations of coupling to be had between the coils and this can be done either by handles or by means of knobs on a panel board. While I have suggested the use of the smallest size coils, you can get and use those wound for any wave length you want to receive and when those are connected with variometers or variable condensers, and with a proper aerial, you will have a highly efficient receptor that will work over all ranges of wave lengths.

You can determine what coils you should use for the different wave lengths by referring to the coil table in *Chapter XI.*

The A Battery Potentiometer.—This device is simply a resistance like the rheostat described in connection with the preceding vacuum tube receiving sets but it is wound to 200 or 300 ohms resistance as against 6 to 30 ohms of the rheostat. It is, however, used as well as the rheostat. With a vacuum tube detector, and especially with one having a gas-content, a potentiometer is very necessary as it is only by means of it that the potential of the plate of the detector can be accurately regulated. The result of proper regulation is that when the critical potential value is reached there is a marked increase in the loudness of the sounds that are emitted by the head phones.

As you will see from *A* in *Fig. 49* it has three taps. The two taps which are connected with the ends of the resistance coil are shunted around the *A* battery and the third tap, which is attached to the movable contact arm, is connected with the *B* battery tap, see *B*, at which this battery gives 18 volts. Since the *A* battery gives 6 volts in this case you can vary the potential of the plate from 18 to 24 volts. The potentiometer must never be shunted around the *B* battery or the latter will soon run down.

The Parts and How to Connect Them Up.—For this regenerative set you will need: (1) a *honeycomb* or other compact *three-coil tuner,* (2) two *variable* (*.001* and *.0005 mfd.*) *condensers;* (3) a *.00025 mfd. fixed condenser;* (4) a *½ to 2 megohm grid leak;* (5) a *tube detector;* (6) *A battery;* (7) a *rheostat;* (8) a *potentiometer;* (9) a *tapped B battery;* (10) a *fixed condenser* of *.001 mfd. fixed condenser;* and (11) a *pair of 2,000 ohm head phones.*

To wire up the parts connect the leading-in wire of the aerial with the primary coil, which is the left-hand one of the tuner, and connect the other terminal with the ground. Connect the ends of the secondary coil, which is the middle one, with the posts of the variable condenser and connect one of the posts of the latter with one post of the fixed .00025 mfd. condenser and the other post of this with the grid; then shunt the grid leak around it. Next connect the other post of the variable condenser to the — or *negative* electrode of the *A battery;*

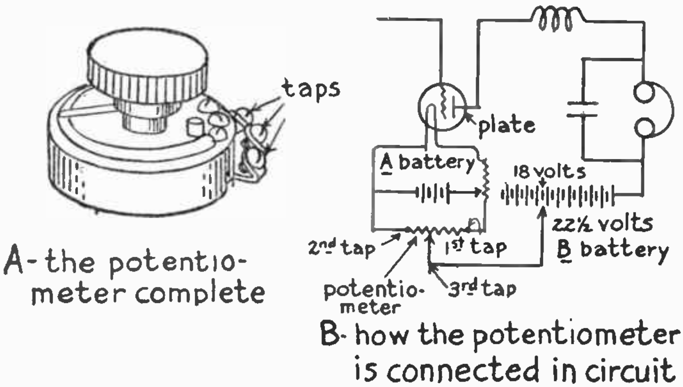


FIG. 49.—The Use of the Potentiometer.

the + or *positive* electrode of this to one terminal of the detector filament and the other end of the latter to the electrode of the *A* battery.

Now connect one end of the tickler coil with the detector plate and the other post to the fixed .001 mfd. condenser, then the other end of this to the positive or carbon pole of the *B* battery. This done shunt the potentiometer around the *A* battery and run a wire from the movable contact of it (the potentiometer) over to the 18 volt tap, (see *B, Fig. 49*), of the *B* battery. Finally, shunt the head phones across the .001 mfd. fixed condenser and you are ready to try out conclusions.

A Regenerative Audio Frequency Amplifier Receiving Set.—The use of regenerative cascade audio frequency receiving sets is getting to be quite common. To get the greatest amplification possible with amplifying tubes you have to keep a negative potential on the grids. You can, however, get very good results without any special charging arrangement by simply connecting one post of the rheostat with the negative terminal of the filament and connecting the *low potential* end of the secondary of the tuning coil with the — or negative electrode of the *A* battery. This scheme will give the grids a negative bias of about 1 volt. You do not need to bother about these added factors that make for high efficiency until after you have got your receiving set in working order and understand all about it.

The Parts and How to Connect Them Up.—Exactly the same parts are needed for this set as the one described above, but in addition you will want: (1) *two* more *rheostats;* (2) one 45 volt *B* battery with a mid tap; (3) *two amplifier tubes,* and (4) *two audio frequency transformers* as described in *Chapter VIII* and pictured at *A* in *Fig. 43.*

To wire up the parts begin by connecting the leading-in wire to one end of the primary of the tuning coil and then connect the other end of the coil with the ground. A variable condenser of .001 mfd. capacitance can be connected in the ground wire, as shown in *Fig. 50,* to good advantage although it is not absolutely needed. Now connect one end of the secondary coil to one post of a *.001 mfd.* variable condenser and the other end of the secondary to the other post of the condenser.

Next bring a lead (wire) from the first post of the variable condenser over to the post of the first fixed condenser and connect the other post of the latter with the grid of the detector tube. Shunt a ½ to 2 megohm grid leak resistance around the fixed condenser and then connect the second post of the variable condenser to one terminal of the detector tube filament. Run this wire on over and connect it with the first post of the second rheostat, the second post of which is connected with one terminal of the filament of

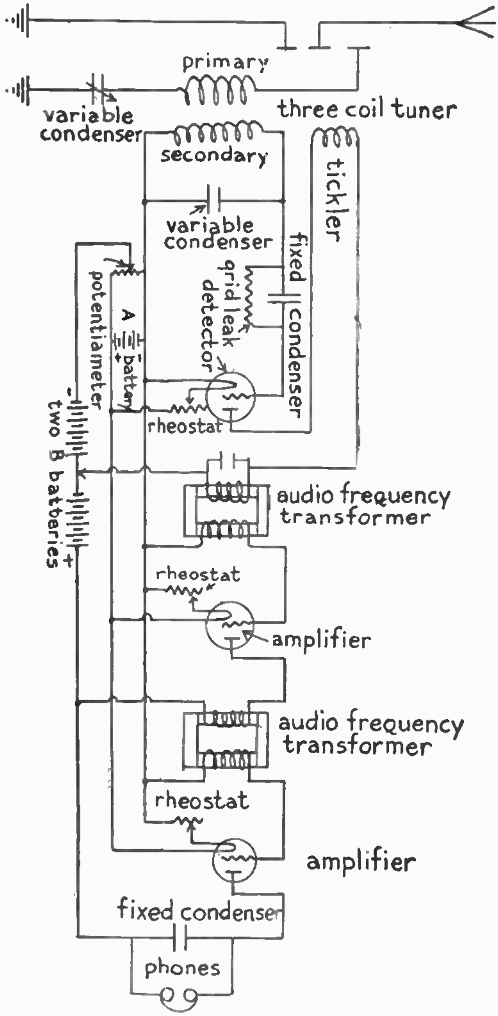


FIG. 50.—Regenerative Audio Frequency Amplifier Receiving Set.

the first amplifying tube; then connect the first post of the rheostat with one end of the secondary coil of the first audio frequency transformer, and the other end of this coil with the grid of the first amplifier tube.

Connect the lead that runs from the second post of variable condenser to the first post of the third rheostat, the second post of which is connected with one terminal of the second amplifying tube; then connect the first post of the rheostat with one end of the secondary coil of the second audio frequency transformer and the other end of this coil with the grid of the second amplifier tube.

This done connect the — or negative electrode of the *A* battery with the second post of the variable condenser and connect the + or positive electrode with the free post of the first rheostat, the other post of which connects with the free terminal of the filament of the detector. From this lead tap off a wire and connect it to the free terminal of the filament of the first amplifier tube, and finally connect the end of the lead with the free terminal of the filament of the second amplifier tube.

Next shunt a potentiometer around the *A* battery and connect the third post, which connects with the sliding contact, to the negative or zinc pole of a *B* battery, then connect the positive or carbon pole of it to the negative or zinc pole of a second *B* battery and the positive or carbon pole of the latter with one end of the primary coil of the second audio frequency transformer and the other end of it to the plate of the first amplifying tube. Run the lead on over and connect it to one of the terminals of the second fixed condenser and the other terminal of this with the plate of the second amplifying tube. Then shunt the headphones around the condenser.

Connect one end of the tickler coil of the tuner with the plate of the detector tube and connect the other end of the tickler to one end of the primary coil of the first audio frequency transformer and the other end of it to the wire that connects the two *B* batteries together. Finally, shunt a .001 mfd. fixed condenser around the primary coil of the first audio frequency transformer.

CHAPTER X

SHORT WAVE REGENERATIVE RECEIVING SETS

A *short wave receiving set* is one that will receive a range of wave lengths of from 150 to 600 meters while the distance over which the waves can be received as well as the intensity of the sounds reproduced by the headphones depends on: (1) whether it is a regenerative set and (2) whether it is provided with amplifying tubes.

High-grade regenerative sets designed especially for receiving amateur sending stations that must use a short wave length are built on the regenerative principle just like those described in the last chapter and further amplification can be had by the use of amplifier tubes as explained in *Chapter VIII,* but the new feature of these sets is the use of the *variocoupler* and one or more *variometers.* These tuning devices can be connected up in different ways and are very popular with amateurs at the present time.

Differing from the ordinary loose coupler the variometer has no movable contacts while the variocoupler is provided with taps so that you can connect it up for the wave length you want to receive. All you have to do to tune the oscillation circuits to each other is to turn the *rotor,* which is the secondary coil, around in the *stator,* as the primary coil is called in order to get a very fine variation of the wave length. It is this construction that makes *sharp tuning* with these sets possible, by which is meant that all wave lengths are tuned out except the one which the receiving set is tuned for.

A Short Wave Regenerative Receiver—With One Variometer and Three Variable Condensers. —This set also includes a variocoupler and a *grid coil.* The way that the parts are connected together makes it a simple and at the same time a very efficient regenerative receiver for short waves. While this set can be used without shielding the parts from each other the best results are had when shields are used.

The parts you need for this set include: (1) one *variocoupler;* (2) one *.001 microfarad variable condenser;* (3) one *.0005 microfarad variable condenser;* (4) one *.0007 microfarad variable condenser;* (5) *one 2 megohm grid leak;* (6) one *vacuum tube detector;* (7) one

A battery; (8) one *rheostat;* (9) one *200 ohm potentiometer;* (10) one *22½ volt B battery;* (11) one *.001 microfarad fixed condenser,* (12) one pair of *2,000 ohm head phones,* (13) *a variometer,* and (14) one *grid coil.*

The Variocoupler.—A variocoupler consists

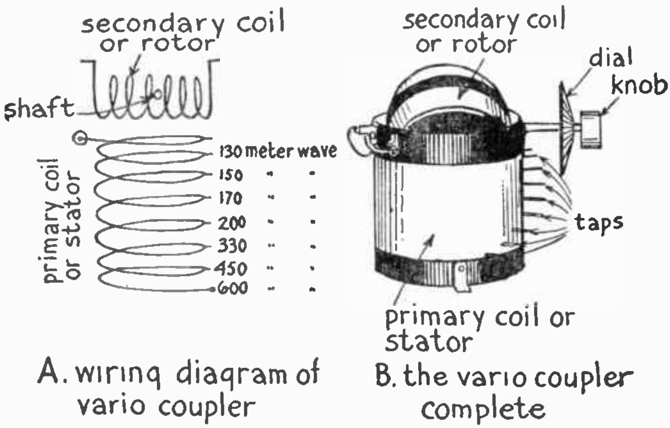


Fig. 51.—How the Variocoupler is Made and Works.

of a primary coil wound on the outside of a tube of insulating material and to certain turns of this, taps are connected, so that you can fix the wave length which your aerial system is to receive from the shortest wave; *i.e.,* 150 meters on up by steps to the longest wave, *i.e.,* 600 meters, which is the range of most amateur variocouplers that are sold in the open market. This is the part of the variocoupler that is called the *stator.*

The secondary coil is wound on the section of a ball mounted on a shaft and this is swung in bearings on the stator so that it can turn in it. This part of the variocoupler is called the *rotor* and is arranged so that it can be mounted on a panel and adjusted by means of a knob or a dial. A diagram of a variocoupler is shown at *A* in *Fig. 51,* and the coupler itself at *B.* There are various makes and modifications of variocouplers on the market but all of them are about the same in general design.

The Variometer.—This device is quite like the variocoupler, but with these differences: (1) the rotor turns in the stator, which is also the section of a ball, and (2) one end of the primary is connected with one end of the secondary coil. To be really efficient a variometer must have a small resistance and a large inductance as well as a small dielectric loss. To secure the first two of these factors the wire should be formed of a number of fine, pure copper wires each of which is insulated and the whole strand then covered with silk. This kind of wire is the best that has yet been devised for the purpose and is sold under the trade name of *litzendraht.*

A new type of variometer has what is known as a *basket weave,* or *wavy wound* stator and rotor. There is no wood, insulating compound or other dielectric materials in large enough quantities to absorb the weak currents that flow between them, hence weaker sounds can be heard when this kind of a variometer is used. With it you can tune sharply to waves under 200 meters in length and up to and including wave lengths of 360 meters. When amateur stations of small power are sending on these short waves this style of variometer keeps the electric oscillations at their greatest strength and, hence, the reproduced sounds will be of maximum intensity. A wiring diagram of a variometer is shown at *A* in *Fig. 52* and a *basketball* variometer is shown complete at *B*.

The Grid Coil.—This is simply a small inductance coil that is used in the secondary oscillation circuit where only one variometer is employed. Generally the secondary of the coupler is used for the grid coil.

Connecting Up the Parts.—To hook-up the set connect the leading-in wire to one end of the primary coil, or stator, of the variocoupler and solder a wire to one of the taps that gives the longest wave length you want to receive. Connect the arm of the switch which makes contact with the taps of this coil with one post of a .001 microfarad variable condenser and connect the other post with the ground as shown in *Fig. 53*. Now connect one end of the secondary coil,

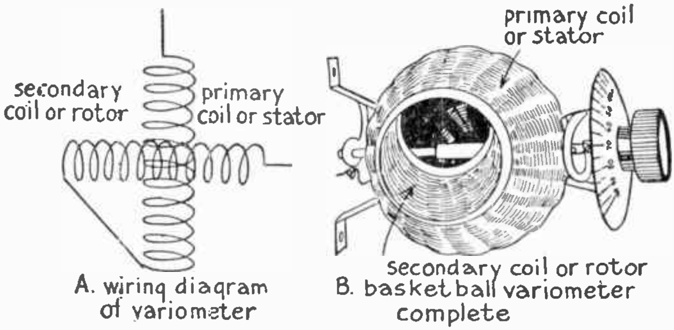


Fig. 52.—How the Variometer is Made and Works.

or rotor, to one post of a .0007 mfd. variable condenser, the other post of this to one end of the grid coil and the other end of this with the remaining end of the rotor of the variocoupler.

Next connect one post of the .0007 mfd. condenser with one of the terminals of the detector filament; then connect the other post of this condenser with one post of the .0005 mfd.

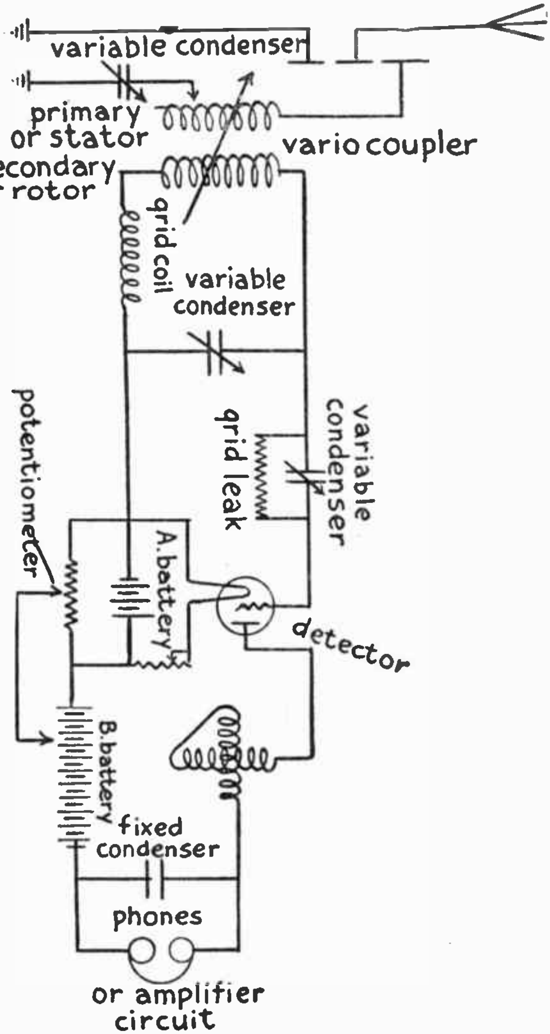


FIG. 53.—Short Wave Regenerative Receiving Set (one Variometer and three Variable Condensers.)

variable condenser and the other post of this with the grid of the detector, then shunt the grid leak around the latter condenser. This done connect the other terminal of the filament to one post of the rheostat, the other post of this to the — or negative electrode of the *A* battery and the + or positive electrode of the latter to the other terminal of the filament.

Shunt the potentiometer around the *A* battery and connect the sliding contact with the — or zinc pole of the *B* battery and the + or carbon pole with one terminal of the headphone; connect the other terminal to one of the posts of the variometer and the other post of the variometer to the plate of the detector. Finally shunt a .001 mfd. fixed condenser around the headphones. If you want to amplify the current with a vacuum tube amplifier connect in the terminals of the amplifier circuit shown in *Fig. 43* at the point where they are connected with the detector tube in that diagram with the binding posts of *Fig. 53* where the phones are usually connected in.

Short Wave Regenerative Receiver. With Two Variometers and Two Variable Condensers.—This type of regenerative receptor is very popular with amateurs who are using high-grade short-wave sets. When you connect up this receptor you must keep the various parts well separated. Screw the variocoupler to the middle of the base board or panel, and secure the variometers on either side of it so that the distance between them will be 9 or 10 inches. By so placing them the coupling will be the same on both sides and besides you can shield them from each other easier.

For the shield use a sheet of copper on the back of the panel and place a sheet of copper between the parts, or better, enclose the variometers and detector and amplifying tubes if you use the latter in sheet copper boxes. When you set up the variometers place them so that their stators are at right angles to each other for otherwise the magnetic lines of force set up by the coils of each one will be mutually inductive and this will make the headphones or loud speaker *howl.* Whatever tendency the receptor has to howl with this arrangement can be overcome by putting in a grid leak of the right resistance and adjusting the condenser.

The Parts and How to Connect Them Up.— For this set you require: (1) one *variocoupler;* (2) two *variometers;* (3) one *.001 microfarad variable condenser;* (4) one *.0005 microfarad* *variable condenser;* (5) one *grid leak resistance;* (6) one *vacuum tube detector;* (7) one *A battery;* (8) one *200 ohm potentiometer;* (9) one 22½ *volt B battery;* (10) one *.001 microfarad fixed condenser, and* (11) one pair of *2,000 ohm headphones.*

To wire up the set begin by connecting the leading-in wire to the fixed end of the primary coil, or *stator,* of the variocoupler, as shown in *Fig. 54,* and connect one post of the .001 mfd. variable condenser to the stator by soldering a short length of wire to the arm of the switch that makes contact with the taps. Now connect one end of the secondary coil, or *rotor,* of the variocoupler with one post of the .0005 mfd. variable condenser and the other part to the grid of the detector tube. Connect the other end of the rotor of the variocoupler to one of the posts of the first variometer and the other post of this to one of the terminals of the detector filament shunt grid leak around grid coil.

Connect this filament terminal with the − or negative electrode of the *A* battery and the + or positive electrode of this with one post of the rheostat and lead a wire from the other post to the free terminal of the filament. This done shunt the potentiometer around the *A* battery and

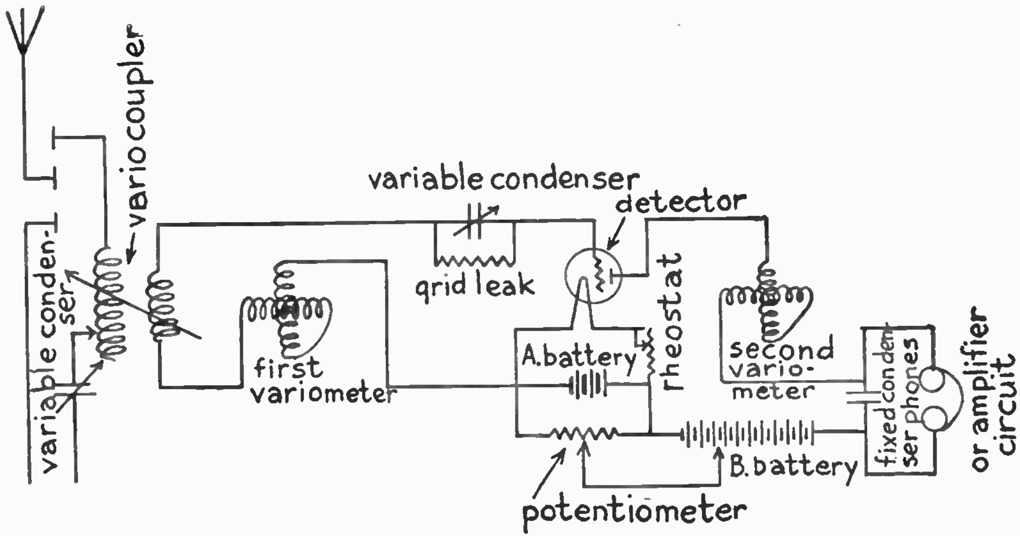


Fig. 54.—Short Wave Regenerative Receiving Set (two Variometers and two Variable Condensers).

connect the sliding contact to the — or zinc pole of the *B* battery and the + or carbon pole of this to one terminal of the headphones, while the other terminal of this leads to one of the posts of the second variometer, the other post of which is connected to the plate of the detector tube. If you want to add an amplifier tube then connect it to the posts instead of the headphones as described in the foregoing set.

A Short Wave, Super-regenerative Receiving Set.—This is the very latest invention in wireless and is an entirely new kind of regenerative receiving system. Like those described in the previous and following chapters, it is the invention of Major E. H. Armstrong. It is, however, based on an entirely different principle and it is as great an advance over the original regenerative system, as the latter was over the simple vacuum tube detector scheme.

The super-regenerative system is of especial interest to the amateur for it does what the ordinary regenerative circuit cannot do, it amplifies the energy of short waves inversely as their wave length. This means that the shorter the wave length the greater it will be amplified. Thus the energy of a wave that is 100 meters long is ampli-

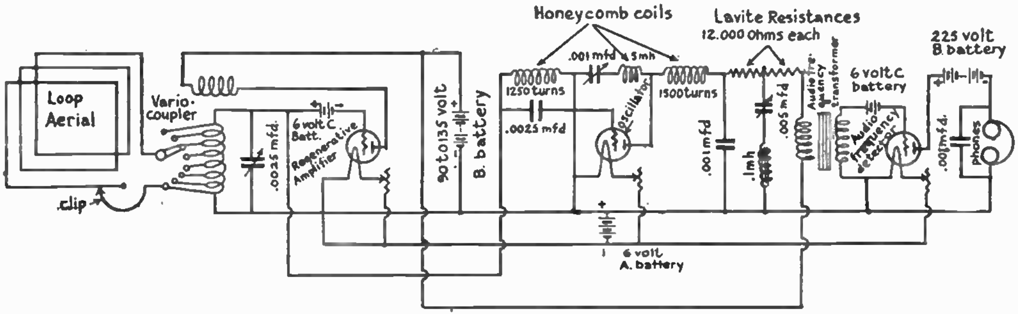


FIG. 55.—Wiring Diagram for New Armstrong Super-regenerative Receiving Set.

fied four times as much as when the wave is 200 meters long.

This scheme of regeneration, therefore, opens up an entirely new field for the amateur who is confined to short wave lengths. Super-regeneration can be accomplished by using one, two or three vacuum tubes, but as the three-tube receiving set is the simplest to adjust, it is the one we shall describe here.

The Parts and How to Connect Them Up.—For this set you will have to get the following parts: (1) one *vario-coupler;* (2) one *.0025 variable condenser;* (3) two *6-volt C batteries;* (4) one *amplifier tube;* (5) three *filament rheostats;* (6) one *90- to 130-volt B battery;* (7) two *honeycomb* or *duo-lateral coils,* of *1250* and *1500 turns* respectively; (8) one *.0025 fixed condenser;* (9) one *.001-mfd. variable condenser;* (10) one *5-milli-henry air core choke coil;* (11) one *oscillator tube;* (12) one *6-volt storage battery;* (13) two *.001-mfd. fixed condensers;* (14) two *12,000-ohm resistances;* (15) one *.005 variable condenser;* (16) one *100-millihenry iron core choke coil;* (17) one *audio-frequency amplifier transformer;* (18) one *detector tube;* (19) one *225-volt B battery,* and (20) one set of *head phones* or a *loud-speaker.*

When a loop aerial is used, it may be provided with an adjustable clip so that the number of turns of wire, and, hence, its inductance, can be varied. All three vacuum tubes used for this receiving set can be either *amplifier tubes,* as described on *page 109,* or they can be *5-watt oscillator tubes* of the *hard type,* that is they must be exhausted to a high degree; these latter tubes are described on *page 234.* Low voltage tubes such as the WD-11 cannot be used.

The *A battery* for heating the filaments of the tubes where the latter are of the usual amplifier type is a 6-volt one. The battery connected in the grid circuit to give the grid a negative voltage is known as the *C battery,* and this is formed of four dry cells. For the *B* battery, which is the plate battery, enough 22½-volt *B* batteries can be connected in series to give the high voltage necessary.

The honeycomb, or duo-lateral coils (see *page 165*) are not connected together inductively as they are when used for tuning coils, but instead they are set in a line, or at right angles, to each other and at some little distance apart. The 5-milli-henry coil can also be a honeycomb, or duo-lateral coil which has this value of inductance. The 100-milli-henry coil is wound on an iron core and so acts as a choke coil. Finally the *lavite resistances* are formed of high-resistance wire wound on a heat-resisting material called *lavite*.

The way in which the parts are connected together is clearly shown in the diagram, *Fig. 55*. Before you build this super-regenerative set, or try to adjust one that is already built, be sure to read the explanation of the way it works in *Chapter XIV*, or you will more than likely make a failure of it.

A Reinartz Regenerative Receiving Set.—The Reinartz circuit has gained considerable popularity because of its ability to receive over long distances, the ease with which it can be handled and its comparatively low cost of construction. This circuit incorporates the advantages of the three circuit receiver for selectivity and of the single circuit receiver for sensitivity to weak signals. Furthermore, both *capacitive* and *inductive* feed-back or regeneration are combined so as to take advantage of the good qualities of both. The antenna circuit is *semi-aperiodic*, that is, it is capable of transferring energy to the secondary, which in this case is *conductively coupled* to it, over a wide band of wave lengths without any appreciable loss and without the usual fine adjustments necessary in the case of a *periodic* or *tuned primary* circuit. Having the secondary coil connected *directly* to the primary coil allows a direct flow of energy into it and at the same time provides for a step up in voltage which is very desirable in a vacuum tube circuit.

As has been pointed out, the Reinartz receiver is easy to operate and the three switches provided are used only when large changes in wave length are required. This boils down the important controls to the two variable condensers, one for *tuning* and the other for *regeneration*. From the diagram of this circuit it is seen that there are two coils, one being the *tickler*. They are both wound on the same form, however, and the coupling between them is *fixed*.

The Parts and How to Connect Them Up.—The parts you will need for building this set are: (1) a *Reinartz Spider-web coil* (this can be purchased from your radio dealer); (2) two 23 plate variable condensers; (3) an *A* battery; (4) a 22½ volt *B* battery; (5) a rheostat; (6) a grid leak; (7) a .00025 mfd. grid condenser; (8) 15 switch points and 6 switch stops; (9) 3 switch arms; (1) a vacuum tube detector; (11) a tube socket; (12) a pair of head phones.

The wiring of the various parts can be easily followed from the diagram of the circuit in *Fig. 56*. It should be noted that the inside wire or *starting end* is the *tickler coil* and the next four tap wires are a part of it. The 5th, 6th, 7th, 8th and 9th tap wires from the center compose the

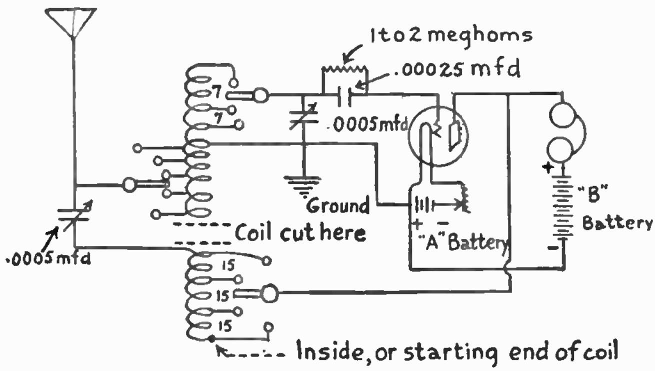


FIG. 56.—Wiring Diagram of the Original Reinartz Regenerative Receiving Set.

primary coil and the last three are the *secondary connections.*

Before purchasing any of the parts, the vacuum tube chart in the back of the book should be consulted and the type of vacuum tube you wish to use decided upon. Then *make sure* that you get the right kind of rheostat, *A* battery, etc., for this tube.

A Cockaday Four Circuit Regenerative Receiver.—This circuit has a number of advantages over similar types of regenerative receivers. Its merits can be understood from the following explanation: One of the most sensitive of regenerative circuits is the original *deForest Ultra Audion* receiver. It has one drawback, however, in that it is very difficult to keep the circuit from *oscillating*. Naturally this is detrimental to good reception.

It took Mr. Cockaday to devise a means to stabilize the action of the Ultra Audion circuit and this he did by the use of what is known as an *absorption* or *sensitizing* circuit. This circuit is in no way connected to any other portion of the circuit but is merely in *inductive relation* or, in other words, coupled to the coil in the grid circuit. Its function there is to *absorb* just enough energy from the grid circuit to keep it from oscillating and this it does very well. It should be remembered that it is the *feed-back* action that creates both *regeneration* and *oscillation*. Since the feed-back in the Ultra Audion circuit is difficult to control it is easy to understand that if too much energy is transferred from the plate to the grid circuit, the *absorption* or *fourth circuit* in this receiver will control it. The primary or antenna circuit of this receiver is, like the Reinartz, *semi-aperiodic* but *inductive* rather than conductive coupling is employed. As seen from the diagram of the circuit in *Fig. 57* the coupling coil consists of but *one turn of wire.*

The Parts and How to Connect Them Up.—For this set you will need: (1) a *Cockaday coil*

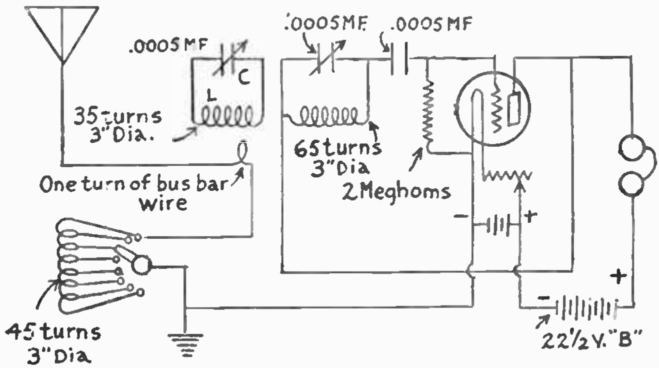


FIG. 57.—Connections for the Cockaday Four Circuit Receiver.

unit (you can purchase this at any radio store); (2) two 23 plate variable condensers; (3) an *A* battery; (4) a 22½ volt *B* battery; (5) a rheostat; (6) a grid leak; (7) a .0005 mfd. grid condenser; (8) 8 switch points and 2 switch stops; (9) a switch arm; (10) a vacuum tube detector; (11) a tube socket; (12) a pair of head-phones.

The circuit diagram is shown in *Fig. 57* and is easy to follow. It differs slightly from the average hook-up in that the *grid leak* instead of being connected directly across the grid condenser, is run from between it and the grid of the tube to the negative terminal of the filament of the vacuum tube. This connection is *important* and should be strictly followed.

CHAPTER XI

INTERMEDIATE AND LONG WAVE REGENERATIVE RECEIVING SETS

ALL receiving sets that receive over a range of wave lengths of from 150 meters to 3,000 meters are called *intermediate wave sets* and all sets that receive wave lengths over a range of anything more than 3,000 meters are called *long wave sets.* The range of intermediate wave receptors is such that they will receive amateur, broadcasting, ship and shore Navy, commercial, Arlington's time and all other stations using *spark telegraph damped waves* or *arc* or *vacuum tube telephone continuous waves and continuous wave telegraph signals.* Just how these receptors can receive *continuous wave* telegraph signals is described in *Chapter XII.*

Intermediate Wave Receiving Sets.—There are two chief schemes employed to increase the range of wave lengths that a set can receive and these are by using: (1) *loading coils* and *shunt condensers*, and (2) *bank-wound coils* and *variable condensers*. If you have a short-wave set and plan to receive intermediate waves with it then loading coils and fixed condensers shunted around them affords you the way to do it, but if you prefer to buy a new receptor then the better way is to get one with bank-wound coils and variable condensers; this latter way preserves the electrical balance of the oscillation circuits better, the electrical losses are less and the tuning easier and sharper.

Intermediate Wave Set With Loading Coils.—For this intermediate wave set you can use either of the short-wave sets described in the foregoing chapter. For the loading coils use *honeycomb coils*, or other good compact inductance coils, as shown in *Chapter IX* and having a range of whatever wave length you wish to receive. The following table shows the range of wave length of the various sized coils when used with a variable condenser having a .001 microfarad *capacitance*, the approximate *inductance* of each coil in *millihenries* and prices at the present writing:

TABLE OF CHARACTERISTICS OF HONEYCOMB COILS

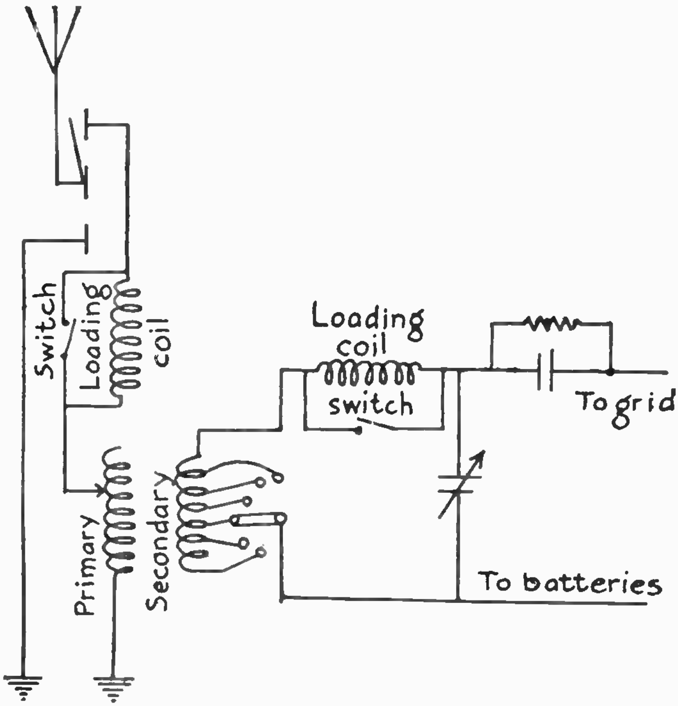
Millihenries Inductance Appx.	Approximate Wave Length in Meters in .001 mfd. Variable Air Condenser.	Mounted on Plug
.040	130— 375	$1.40
.075	180— 515	1.40
.15	240— 730	1.50
.3	330— 1030	1.50
.6	450— 1460	1.55
1.3	660— 2200	1.60
2.3	930— 2850	1.65
4.5	1300— 4000	1.70
6.5	1550— 4800	1.75
11.	2050— 6300	1.80
20.	3000— 8500	2.00
40.	4000—12000	2.15
65.	5000—15000	2.35
100.	6200—19000	2.60
125.	7000—21000	3.00
175.	8200—24000	3.50

These and other kinds of compact coils can be bought at electrical supply houses that sell wireless goods. If your aerial is not very high or long you can use loading coils, but to get anything like efficient results with them you must have an aerial of large capacitance and the only way to get this is to put up a high and long one with two or more parallel wires spaced a goodly distance apart.

The Parts and How to Connect Them Up.—Get (1) *two honeycomb or other coils* of the greatest wave length you want to receive, for in order to properly balance the aerial, or primary oscillation circuit, and the closed, or secondary oscillation circuit, you have to tune them to the same wave length; (2) two *.001 mfd. variable condensers,* though fixed condensers will do, and (3) two small *single-throw double-pole knife switches* mounted on porcelain bases.

To use the loading coils all you have to do is to connect one of them in the aerial above the primary coil of the loose coupler, or variocoupler as shown in the wiring diagram in *A* of *Fig. 58,* and then connect one of the switches around this; this switch enables you to cut in or out the loading coil at will. Likewise connect the other loading coil in one side of the closed, or secondary circuit between the variable .0007 mfd. condenser and the secondary coil of the loose coupler or variocoupler.

An Intermediate Wave Set With Variocoupler Inductance Coils.—By using the coil wound on the rotor of the variocoupler as the tickler the coupling between the detector tube circuits and the aerial wire system increases as the set is tuned for greater wave lengths. This scheme makes the control of the regenerative circuit far more



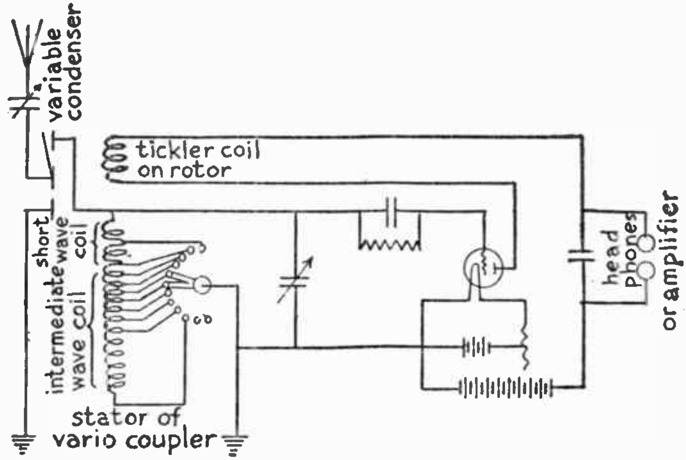
(*A*) Fig. 58.—Wiring Diagram Showing Fixed Loading Coils for Intermediate Wave Set.

stable than it is where an ordinary loose coupled tuning coil is used.

When the variocoupler is adjusted for receiving very long waves the rotor sets at right angles to the stator and, since when it is in this position there is no mutual induction between them, the tickler coil serves as a loading coil for the detector plate oscillation circuit. Inductance coils for short wave lengths are usually wound in single layers but *bank-wound coils,* as they are called are necessary to get compactness where long wave lengths are to be received. By winding inductance coils with two or more layers the highest inductance values can be obtained with the least resistance. A wiring diagram of a multipoint inductance coil is shown in *B* of *Fig. 58.* You can buy this intermediate wave set assembled and ready to use or get the parts and connect them up yourself.

The Parts and How to Connect Them Up.—For this regenerative intermediate wave set get: (1) one *12 section triple bank-wound inductance coil,* (2) one *variocoupler,* and (3) all the other parts shown in the diagram *B* of *Fig. 58* except the variocoupler. First connect the free end of the condenser in the aerial to one of the terminals of the stator of the variocoupler; then connect the other terminal of the stator with one of the ends of the bank-wound inductance coil and connect the movable contact of this with the ground.

Next connect a wire to the aerial between the variable condenser and the stator and connect this to one post of a .0005 microfarad fixed con-



(*E*) FIG. 58.—Wiring Diagram for Intermediate Wave Receptor with one Variocoupler and 12-section Bank-wound Inductance Coil.

denser, then connect the other post of this with the grid of the detector and shunt a grid leak around it. Connect a wire to the ground wire between the bank-wound inductance coil and the ground proper, *i.e.*, the radiator or water pipe, connect the other end of this to the + electrode of the *A* battery and connect this end also to one of the terminals of the filament. This done connect the other terminal of the filament to one post of the rheostat and the other post of this to the − or negative side of the *A* battery.

To the + electrode of the *A* battery connect the − or zinc pole of the *B* battery and connect the + or carbon pole of the latter with one post of the fixed .001 microfarad condenser. This done connect one terminal of the tickler coil which is on the rotor of the variocoupler to the plate of the detector and the other terminal of the tickler to the other post of the .001 condenser and around this shunt your headphones. Or if you want to use one or more amplifying tubes connect the circuit of the first one, see *Fig. 43,* to the posts on either side of the fixed condenser instead of the headphones.

A Long Wave Receiving Set.—The vivid imagination of Jules Verne never conceived anything so fascinating as the reception of messages without wires sent out by stations half way round the world; and in these days of high power cableless stations on the five continents you can listen-in to the messages and hear what is being sent out by the Lyons, Paris and other French stations, by Great Britain, Italy, Germany and even far off Russia and Japan.

A long wave set for receiving these stations must be able to tune to wave lengths up to 20,000 meters. Differing from the way in which the regenerative action of the short wave sets described in the preceding chapter is secured and which depends on a tickler coil and the coupling action of the detector in this long wave set, this action is obtained by the use of a tickler coil in the plate circuit which is inductively coupled to the grid circuit and this feeds back the necessary amount of current. This is a very good way to connect up the circuits for the reason that: (1) the wiring is simplified, and (2) it gives a single variable adjustment for the entire range of wave lengths the receptor is intended to cover.

The Parts and How to Connect Them Up.—The two chief features as far as the parts are concerned of this long wave length receiving set are (1) the *variable condensers,* and (2) the *tuning inductance coils.* The variable condenser used in series with the aerial wire system has 26 plates and is equal to a capacitance of *.0008 mfd.*

which is the normal aerial capacitance. The condenser used in the secondary coil circuit has 14 plates and this is equal to a capacitance of *.0004 mfd.*

There are a number of inductance coils and these are arranged so that they can be connected in or cut out and combinations are thus formed which give a high efficiency and yet allow them to be compactly mounted. The inductance coils of the aerial wire system and those of the secondary coil circuit are practically alike. For wave lengths up to 2,200 meters *bank litz-wound coils* are used and these are wound up in 2, 4 and 6 banks in order to give the proper degree of coupling and inductance values.

Where wave lengths of more than 2,200 meters are to be received *coto-coils* are used as these are the "last word" in inductance coil design, and are especially adapted for medium as well as long wave lengths. These various coils are cut in and out by means of two five-point switches which are provided with auxiliary levers and contactors for *dead-ending* the right amount of the coils. In cutting in coils for increased wave lengths,

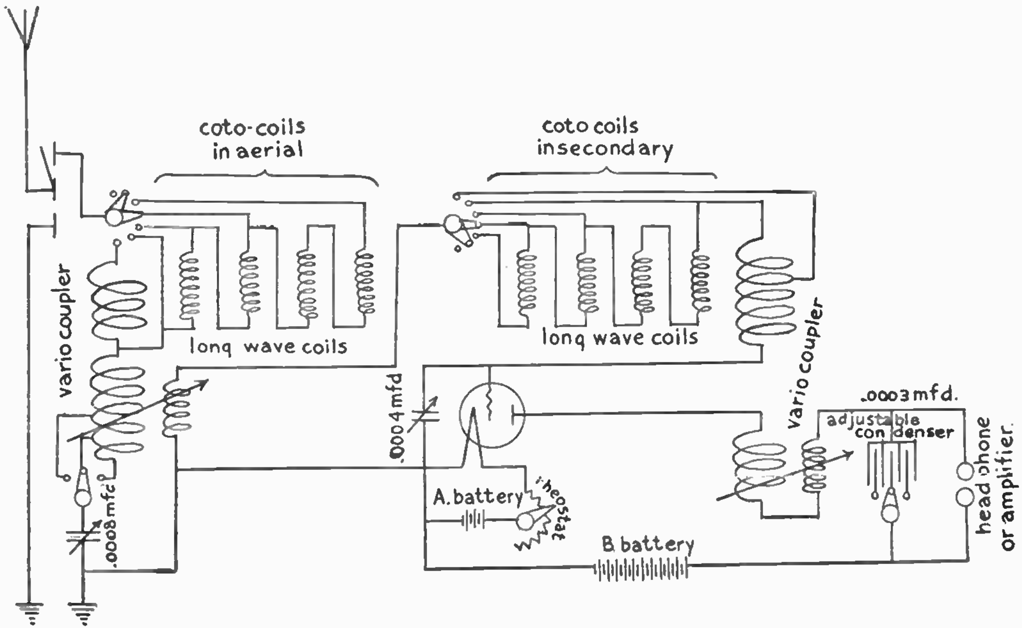


Fig. 59.—Wiring Diagram Showing Long Wave Receptor with Variocouplers and 8 Bank-wound Inductance Coils.

that is from 10,000 to 20,000 meters, all of the coils of the aerial are connected in series as well as all of the coils of the secondary circuit. The connections for a long wave receptor are shown in the wiring diagram in ***Fig. 59***.

CHAPTER XII

HETERODYNE OR BEAT LONG WAVE TELEGRAPH RECEIVING SET

ANY of the receiving sets described in the foregoing chapters will respond to either: (1) a wireless telegraph transmitter that uses a spark gap and which sends out periodic waves, or to (2) a wireless telegraph or telephone transmitter that uses an arc or a vacuum tube oscillator and which sends out interrupted or modulated continuous waves. To receive wireless telegraph signals, however, from a transmitter that uses an arc or a vacuum tube oscillator and which sends out continuous waves, an *oscillating* regenerative receiving set or a similar arrangement must be used so that the continuous waves will be broken up into groups of audio frequency.

There are four different ways employed at the present time to break up the continuous waves of a wireless telegraph transmitter into groups and these are: (*a*) the *heterodyne,* or *beat,* method, in which waves of different lengths are impressed on the received waves and so produces beats; (*b*) the *tikker,* or *chopper* method, in which the high frequency currents are rapidly broken up; (*c*) the *variable condenser* method, in which the movable plates are made to rapidly rotate; (*d*) the *tone wheel,* or *frequency transformer,* as it is often called, and which is really a modified form of and an improvement on the tikker. The heterodyne method will be described in this chapter.

What the Heterodyne or Beat Method Is.—The word *heterodyne* was coined from the Greek words *heteros* which means *other,* or *different,* and *dyne* which means *power;* in other words it means when used in connection with a wireless receptor that another and different high frequency current is used besides the one that is received from the sending station. In music a *beat* means a regularly recurrent swelling caused by the reinforcement of a sound and this is set up by the interference of sound waves which have slightly different periods of vibration as, for instance, when two tones take place that are not quite in tune with each other. This, then, is the principle of the heterodyne, or beat, receptor.

In the heterodyne, or beat method, separate sustained oscillations, that are just about as strong as those of the incoming waves, are set up in the receiving circuits and their frequency is just a little higher or a little lower than those that are set up by the waves received from the distant transmitter. The result is that these oscillations of different frequencies interfere and reinforce each other when *beats* are produced, the period of which is slow enough to be heard in the headphones, hence the incoming signals can be heard only when waves from the sending station are being received. A fuller explanation of how this is done will be found in *Chapter XIV.*

The Autodyne or Self-Heterodyne Long-Wave Receiving Set.—This is the simplest type of heterodyne receptor and it will receive periodic waves from spark telegraph transmitters or continuous waves from an arc or vacuum tube telegraph transmitter. In this type of receptor the detector tube itself is made to set up the *heterodyne oscillations* which interfere with those that are produced by the incoming waves that are a little out of tune with it.

With a long wave *autodyne,* or *self-heterodyne* receptor, as this type is called, and a two-step audio-frequency amplifier you can clearly hear many of the cableless stations of Europe and others that send out long waves. For receiving long wave stations, however, you must have a long aerial—a single wire 200 or more feet in length will do—and the higher it is the louder will be the signals. Where it is not possible to put the aerial up a hundred feet or more above the ground, you can use a lower one and still get mesages in *International Morse* fairly strong.

The Parts and Connections of an Autodyne, or Self-Heterodyne, Receiving Set.—For this long wave receiving set you will need: (1) one *variocoupler* with the primary coil wound on the stator and the secondary coil and tickler coil wound on the rotor, or you can use three honeycomb or other good compact coils of the longest wave you want to receive, a table of which is given in *Chapter XI;* (2) two *.001 mfd. variable condensers;* (3) one *.0005 mfd. variable condenser;* (4) one *.5 to 2 megohm grid leak resistance;* (5) one *vacuum tube detector;* (6) one *A battery;* (7) one *rheostat;* (8) one *B battery;* (9) one *potentiometer;* (10) one *.001 mfd. fixed condenser* and (11) one pair of *headphones.* For the two-step amplifier you must, of course, have besides the above parts the amplifier tubes, variable condensers, batteries, rheostats, potentiometers and fixed condensers as explained in *Chap-*

ter VIII. The connections for the autodyne, or self-heterodyne, receiving set are shown in *Fig. 60.*

The Separate Heterodyne Long Wave Receiving Set.—This is a better long wave receptor than the self heterodyne set described above for

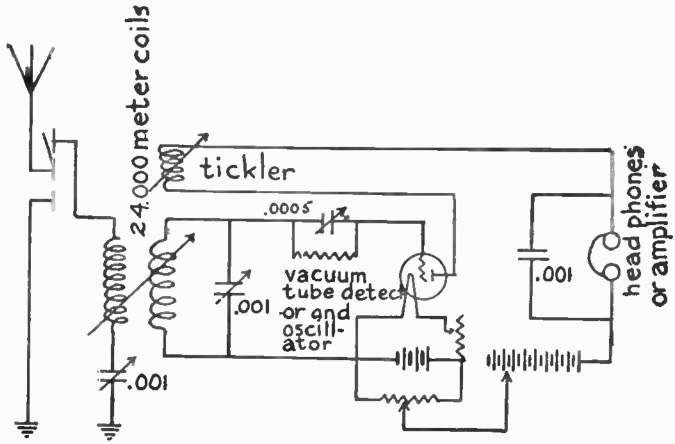


FIG. 60.—Wiring Diagram of Long Wave Antodyne, or Self-Heterodyne Receptor.

receiving wireless telegraph signals sent out by a continuous long wave transmitter. The great advantage of using a separate vacuum tube to generate the heterodyne oscillations is that you do not have to detune the detector oscillation circuit to obtain the beat note. At high frequencies this effect is not noticeable but at low frequencies it may cause a marked decrease in the strength of the signals.

The Parts and Connections of a Separate Heterodyne Long Wave Receiving Set.—The

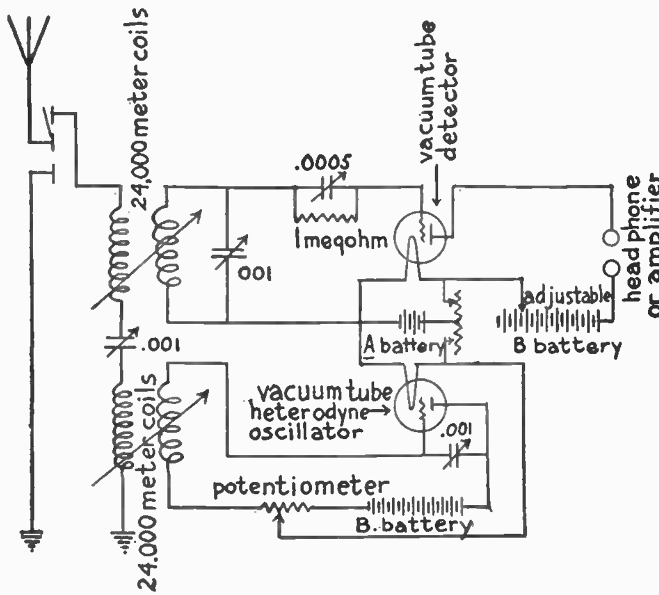


FIG. 61.—Wiring Diagram of Long Wave Separate Heterodyne Receiving Set.

parts required for this long wave receiving set are: (1) four honeycomb or other good *compact inductance* coils of the longest wave length that you want to receive; (2) three *.001 mfd. variable* *condensers;* (3) one *.0005 mfd. variable condenser;* (4) one *1 megohm grid leak resistance;* (5) one *vacuum tube detector;* (6) one *A battery;* (7) two *rheostats;* (8) two *B batteries,* one of which is supplied with taps; (9) one *potentiometer;* (10) one *vacuum tube amplifier,*[1] for setting up the heterodyne oscillations; (11) a pair of *headphones* and (12) all of the parts for a *two-step amplifier* as detailed in *Chapter VIII,* that is if you are going to use amplifiers. The connections are shown in *Fig. 61.*

In using either of these heterodyne receivers with gas content tubes be sure to carefully adjust the *B* battery by means of the potentiometer as the sensitiveness of the detector depends largely on the voltage impressed on the plate and especially must you do so when you exchange a new for an old detector tube.

[1] The amplifier tube in this case is used as a generator of oscillations.

CHAPTER XIII

HEADPHONES AND LOUD SPEAKERS

Wireless Headphones.—A telephone receiver for a wireless receiving set is made exactly on the same principle as an ordinary Bell telephone receiver. The only difference between them is that the former is made flat and compact so that a pair of them can be fastened together with a band and worn on the head (when it is called a *headset*), while the latter is long and cylindrical so that it can be held to the ear. A further difference between them is that the wireless headphone is made as sensitive as possible so that it will respond to very feeble currents, while the ordinary telephone receiver is far from being sensitive and will respond only to comparatively large currents.

How a Bell Telephone Receiver Is Made.—An ordinary telephone receiver consists of three chief parts and these are: (1) a hard-rubber, or composition, shell and cap, (2) a permanent steel bar magnet on one end of which is wound

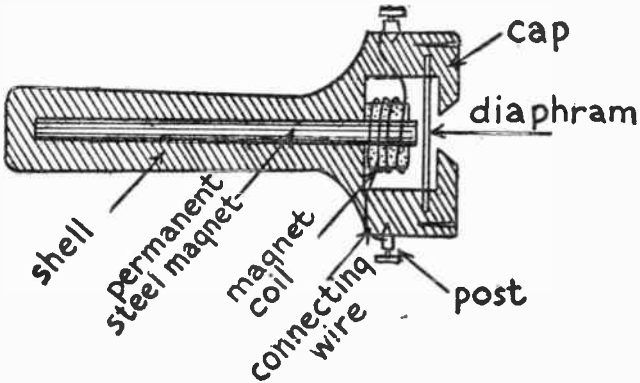


FIG. 62.—Cross-section of Bell Telephone Receiver.

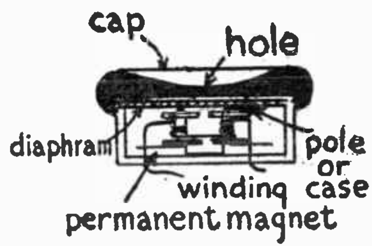


FIG. 63.—Wireless Headphone.

a coil of fine insulated copper wire, and (3) a soft iron disk, or *diaphragm,* all of which are shown in the cross-section in *Fig. 62.* The bar magnet is securely fixed inside of the handle so that the outside end comes to within about 1/32 of an inch of the diaphragm when this is laid on top of the shell and the cap is screwed on.

The ends of the coil of wire are connected with two binding posts which are in the end of the shell, but are shown in the picture at the sides for the sake of clearness. This coil usually has a resistance of about 75 ohms and the meaning of the *ohmic resistance* of a receiver and its bearing on the sensitiveness of it will be explained a little farther along. After the disk, or diaphragm, which is generally made of thin, soft sheet iron that has been tinned or japanned,[1] is placed over the end of the magnet, the cap, which has a small opening in it, is screwed on and the receiver is ready to use.

How a Wireless Headphone Is Made.—For wireless work a receiver of the watch-case type is used and nearly always two such receivers are connected with a headband. It consists of a permanent bar magnet bent so that it will fit into the shell of the receiver as shown at *A* in *Fig. 63.*

[1] A disk of photographic tin-type plate is generally used.

The ends of this magnet, which are called *poles,* are bent up, and hence this type is called a *bipolar* receiver. The magnets are wound with fine insulated wire as before and the diaphragm is held securely in place over them by screwing on the cap.

About Resistance, Turns of Wire and Sensitivity of Headphones.—If you are a beginner in wireless you will hear those who are experienced speak of a telephone receiver as having a resistance of 75 ohms, 1,000 ohms, 2,000 or 3,000 ohms, as the case may be; from this you will gather that the higher the resistance of the wire on the magnets the more sensitive the receiver is. In a sense this is true, but it is not the

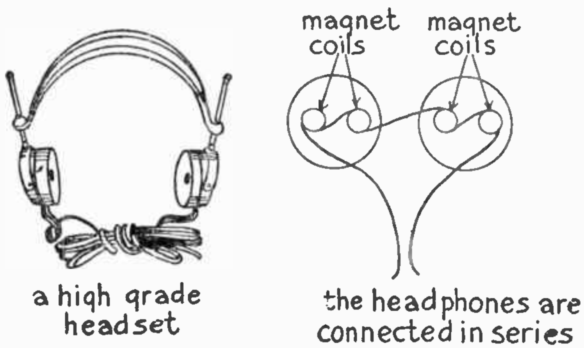


FIG. 64.—Wireless Headphones.

resistance of the magnet coils that makes it sensitive, in fact, it cuts down the current, but it is the *number of turns* of wire on them that determines its sensitiveness; it is easy to see that this is so, for the larger the number of turns the more often will the same current flow round the cores of the magnet and so magnetize them to a greater extent.

But to wind a large number of turns of wire close enough to the cores to be effective the wire must be very small and so, of course, the higher the resistance will be. Now the wire used for winding good receivers is usually No. 40, and this has a diameter of .0031 inch; consequently, when you know the ohmic resistance you get an idea of the number of turns of wire and from this you gather in a general way what the sensitivity of the receiver is.

A receiver that is sensitive enough for wireless work should be wound to not less than 1,000 ohms (this means each ear phone), while those of a better grade are wound to as high as 3,000 ohms for each one. A high-grade headset is shown in *Fig. 64*. Each phone of a headset should be wound to the same resistance, and these are connected in series as shown. Where two or more headsets are used with one wireless receiving set they must all be of the same resistance and connected in series, that is, the coils of one head set are connected with the coils of the next head set and so on to form a continuous circuit.

The Impedance of Headphones.—When a current is flowing through a circuit, the material of which the wire is made not only opposes its passage—this is called its *ohmic resistance*—but a *counter-electromotive force* to the current is set up due to the inductive effects of the current on itself and this is called *impedance.* Where a wire is wound in a coil the impedance of the circuit is increased, and where an alternating current is used the impedance grows greater as the frequency gets higher. The impedance of the magnet coils of a receiver is so great for high frequency oscillations that the latter cannot pass through them; in other words, they are choked off.

How the Headphones Work.—As you will see from the cross-sections in *Figs. 62* and *63* there is no connection, electrical or mechanical, between the diaphragm and the other parts of the receiver. Now when either feeble oscillations, which have been rectified by a detector, or small currents from a *B* battery, flow through the magnet coils the permanent steel magnet is energized to a greater extent than when no current is flowing through it. This added magnetic energy makes the magnet attract the diaphragm more than it would do by its own force. If, on the other hand, the current is cut off the pull of the magnet is lessened and as its attraction for the diaphragm is decreased the latter springs back to its original position. When varying currents flow through the coils the diaphragm vibrates accordingly and sends out sound waves.

About Loud Speakers.—The simplest acoustic instrument ever invented is the *megaphone,* which latter is a Greek word meaning *great sound.* It is a very primitive device and our Indians made it out of birch-bark before Columbus discovered America. In its simplest form it consists of a cone-shaped horn and as the speaker talks into the small end the concentrated sound waves pass out of the large end in whatever direction it is held.*

Now a loud speaker of whatever kind consists of two chief parts and these are: (1) a *telephone receiver,* and (2) a *megaphone,* or *horn* as it is called. A loud speaker when connected with a wireless receiving set makes it possible for a room, or an auditorium, full of people, or an outdoor crowd, to hear what is being sent out by a

* See Loud Speakers in Appendix, page 400.

distant station instead of being limited to a few persons listening-in with headphones. To use a loud speaker you should have a vacuum tube detector receiving set and this must be provided with a one-step amplifier at least.

To get really good results you need a two-step amplifier and then energize the plate of the second vacuum tube amplifier with a 100 volt *B* battery; or if you have a three-step amplifier then use the high voltage on the plate of the third amplifier tube. Amplifying tubes are made to stand a plate potential of 100 volts and this is the kind you must use. Now it may seem curious, but when the current flows through the coils of the telephone receiver in one direction it gives better results than when it flows through in the other direction; to find out the way the current gives the best results try it out both ways and this you can do by simply reversing the connections.

The Simplest Type of Loud Speaker.—This loud speaker, which is called the *Arkay,* will work on a one- or two-step amplifier. It consists of a brass horn with a curve in it and in the bottom there is an *adapter,* or frame, with a set screw in it so that you can fit in one of your headphones and this is all there is to it. The construction is rigid enough to prevent overtones, or distortion of speech or music. It is shown in *Fig. 65.*

Another Simple Kind of Loud Speaker.—Another loud speaker, see *Fig. 66,* is known as the *Amplitone* and it likewise makes use of the headphones as the sound producer. This device

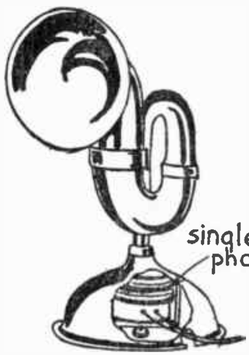


FIG. 65.—Arkay Loud Speaker.

FIG. 66.—Amplitone Loud Speaker.

has a cast metal horn which improves the quality of the sound, and all you have to do is to slip the headphones on the inlet tubes of the horn and it is ready for use. The two headphones not only give a greater volume of sound than where a single one is used but there is a certain blended quality which results from one phone smoothing out the imperfections of the other.

A Third Kind of Simple Loud Speaker.—The operation of the *Amplitron,* as this loud speaker is called, is slightly different from others used for the same purpose. The sounds set up by the headphone are conveyed to the apex of an inverted copper cone which is 7 inches long and 10 inches in diameter. Here it is reflected by a parabolic mirror which greatly amplifies the sounds. The amplification takes place without distortion, the sounds remaining as clear and crisp as when projected by the transmitting station. By removing the cap from the receiver the shell is screwed into a receptable on the end of the loud speaker and the instrument is ready for use. It is pictured in *Fig. 67.*

A Super Loud Speaker.—This loud speaker, which is known as the *Magnavox Telemegafone,* was the instrument used by Lt. Herbert E. Metcalf, 3,000 feet in the air, and which startled the City of Washington on April 2, 1919, by repeating President Wilson's *Victory Loan Message* from an airplane in flight so that it was distinctly heard by 20,000 people below.

This wonderful achievement was acomplished through the installation of the *Magnavox* and amplifiers in front of the Treasury Building. Every word Lt. Metcalf spoke into his wireless telephone transmitter was caught and swelled in volume by the *Telemegafones* below and persons

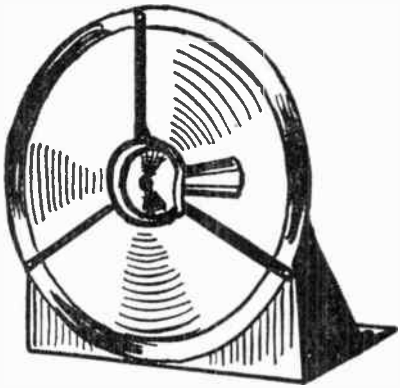


FIG. 67.—Amplitron Loud Speaker.

blocks away could hear the message plainly. Two kinds of these loud speakers are made and these are: (1) a small loud speaker for the use of operators so that headphones need not be worn, and (2) a large loud speaker for auditorium and out-door audiences.

Either kind may be used with a one- or two-step amplifier or with a cascade of half a dozen amplifiers, according to the degree of loudness desired. The *Telemegafone* itself is not an amplifier in the true sense inasmuch as it contains no elements which will locally increase the incoming current. It does, however, transform the variable electric currents of the wireless receiving set into sound vibrations in a most wonderful manner.

A *telemegafone* of either kind is formed of: (1) a telephone receiver of large proportions, (2) a step-down induction coil, and (3) a 6 volt storage battery that energizes a powerful electromagnet which works the diaphragm. An electromagnet is used instead of a permanent magnet and this is energized by a 6-volt storage battery as shown in the wiring diagram at *A* in *Fig. 68.* One end of the core of this magnet is fixed to the iron case of the speaker and together these form the equivalent of a horseshoe magnet. A movable coil of wire is supported from the center of the diaphragm the edge of which is rigidly held between the case and the small end of the horn. This coil is placed over the upper end of the magnet and its terminals are connected to the secondary of the induction coil. Now when the coil is energized by the current from the amplifiers, it and the core act like a solenoid in that the coil tends to suck the core into it; but since the core is fixed and the coil is movable the core draws the coil down instead. The result is that with every variation of the current that flows

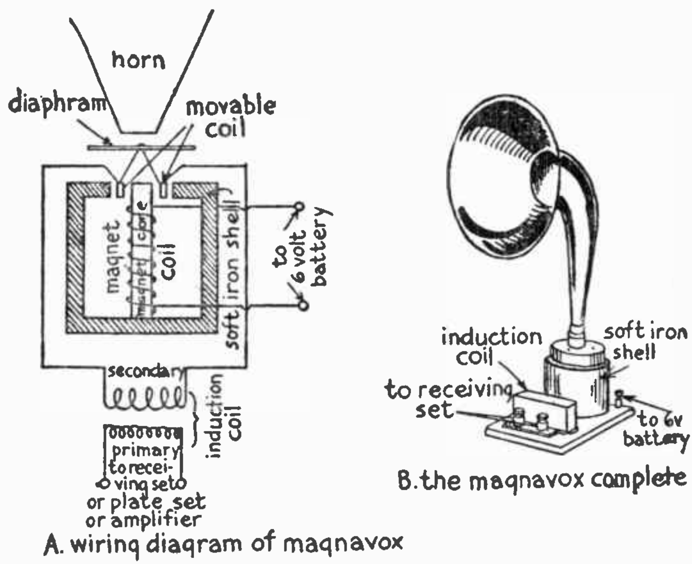


FIG. 68.—Magnavox Loud Speaker.

through the coil it moves up and down and pulls and pushes the diaphragm down and up with it. The large amplitude of the vibrations of the latter set up powerful sound waves which can be heard several blocks away from the horn. In this way then are the faint incoming signals, speech and music which are received by the amplifying receiving set reproduced and magnified enormously. The *Telemegafone* is shown complete at *B*.

CHAPTER XIV

OPERATION OF VACUUM TUBE RECEPTORS

From the foregoing chapters you have seen that the vacuum tube can be used either as a *detector* or an *amplifier* or as a *generator* of electric oscillations, as in the case of the heterodyne receiving set. To understand how a vacuum tube acts as a detector and as an amplifier you must first know what *electrons* are. The way in which the vacuum tube sets up sustained oscillations will be explained in *Chapter XVII* in connection with the *Operation of Vacuum Tube Transmitters.**

What Electrons Are.—Science teaches us that masses of matter are made up of *molecules,* that each of these is made up of *atoms,* and each of these, in turn, is made up of a central core of positive particles of electricity surrounded by negative particles of electricity as shown in the schematic diagram, *Fig. 69.* The little black circles inside the large circle represent *positive*

* See "A" and "B" Battery Eliminators in Appendix, page 403.

particles of electricity and the little white circles outside of the large circle represent *negative particles of electricity,* or *electrons* as they are called.

It is the number of positive particles of electricity an atom has that determines the kind of

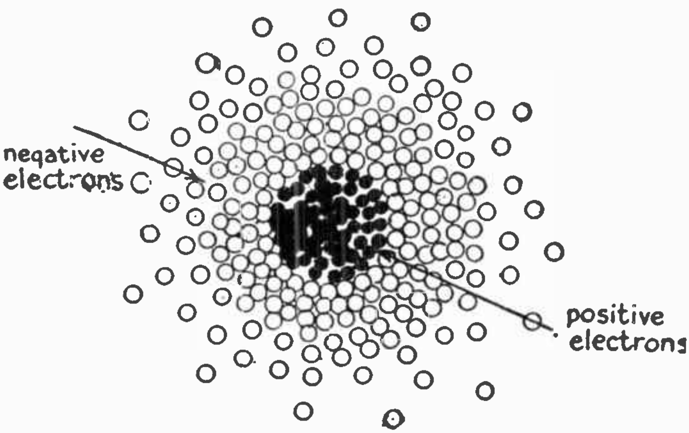


FIG. 69.—Schematic Diagram of an Atom.

an element that is formed when enough atoms of the same kind are joined together to build it up. Thus hydrogen, which is the lightest known element, has one positive particle for its nucleus, while uranium, the heaviest element now known, has 92 positive particles. Now before leaving the atom please note that it is as much smaller than the diagram as the latter is smaller than our solar system.

What Is Meant by Ionization.—A hydrogen atom is not only lighter but it is smaller than the atom of any other element while an electron is more than a thousand times smaller than the atom of which it is a part. Now as long as all of the electrons remain attached to the surface of an atom its positive and negative charges are equalized and it will, therefore, be neither positive nor negative, that is, it will be perfectly neutral. When, however, one or more of its electrons are separated from it, and there are several ways by which this can be done, the atom will show a positive charge and it is then called a *positive ion.*

In other words a *positive ion* is an atom that has lost some of its negative electrons while a *negative ion* is one that has acquired some additional negative *electrons.* When a number of electrons are being constantly given by the atoms of an element, which let us suppose is a metal, and are being attracted to atoms of another element, which we will say is also a metal, a flow of electrons takes place between the two oppositely charged elements and form a current of negative electricity as represented by the arrows at *A* in *Fig. 70.*

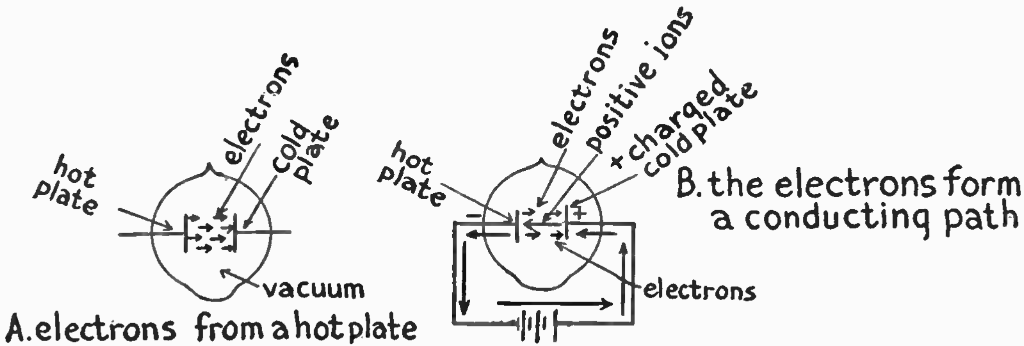


FIG. 70.—Action of Two-electrode Vacuum Tube.

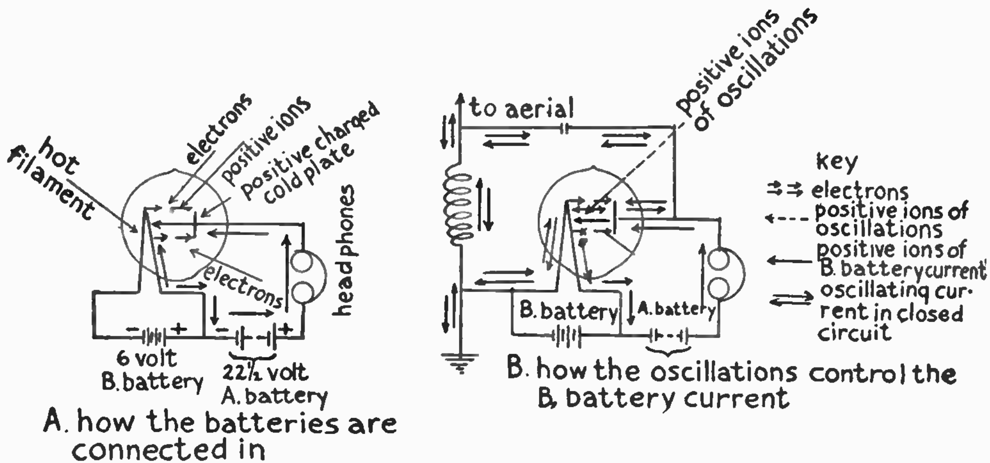
When a stream of electrons is flowing between two metal elements, as a filament and a plate in a vacuum tube detector, or an amplifier, they act as *carriers* for more negative electrons and these are supplied by a battery as we shall presently explain. It has always been customary for us to think of a current of electricity as flowing from the positive pole of a battery to the negative pole of it and hence we have called this the *direction of the current.* Since the electronic theory has been evolved it has been shown that the electrons, or negative charges of electricity, flow from the negative to the positive pole and that the ionized atoms, which are more positive than negative, flow in the opposite direction as shown at *B.*

How Electrons are Separated from Atoms.—The next question that arises is how to make a metal throw off some of the electrons of the atoms of which it is formed. There are several ways that this can be done but in any event each atom must be given a good, hard blow. A simple way to do this is to heat a metal to incandescence when the atoms will bombard each other with terrific force and many of the electrons will be knocked off and thrown out into the surrounding space.

But all, or nearly all, of them will return to the atoms from whence they came unless a means of some kind is employed to attract them to the atoms of some other element. This can be done by giving the latter piece of metal a positive charge. If now these two pieces of metal are placed in a bulb from which the air has been exhausted and the first piece of metal is heated to brilliancy while the second piece of metal is kept positively electrified then a stream of electrons will flow between them.

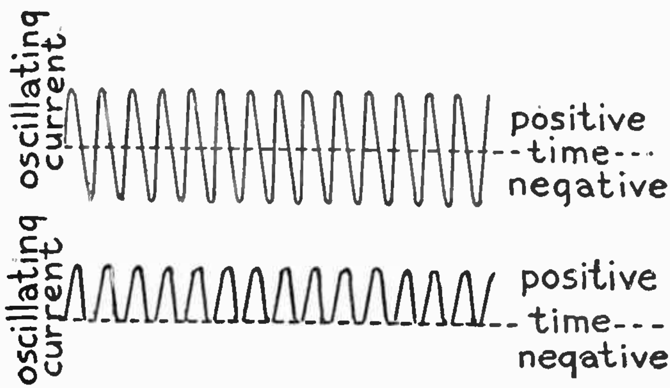
Action of the Two Electrode Vacuum Tube.—Now in a vacuum tube detector a wire filament, like that of an incandescent lamp, is connected with a battery and this forms the hot element from which the electrons are thrown off, and a metal plate with a terminal wire secured to it is connected to the positive or carbon tap of a dry battery; now connect the negative or zinc tap of this with one end of a telephone receiver and the other end of this with the terminals of the filament as shown at *A* in *Fig. 71.* If now you heat the filament and hold the phone to your ear you can hear the current from the *B* battery flowing through the circuit.

Since the electrons are negative charges of electricity they are not only thrown off by the



(*A*) and (*B*) Fig. 71.—How a Two Electrode Tube Acts as a Relay or a Detector.

hot wire but they are attracted by the positive charged metal plate and when enough electrons pass, or flow, from the hot wire to the plate they form a conducting path and so complete the circuit which includes the filament, the plate and the *B* or plate battery, when the current can then



(*C*) FIG. 71.—Only the Positive Part of Oscillations Goes through the Tube.

flow through it. As the number of electrons that are thrown off by the filament is not great and the voltage of the plate is not high the current that flows between the filament and the plate is always quite small.

How the Two Electrode Tube Acts as a Detector.—As the action of a two electrode tube as a detector[1] is simpler than that of the three electrode vacuum tube we shall describe it first. The two electrode vacuum tube was first made by Mr. Edison when he was working on the incandescent lamp but that it would serve as a detector of electric waves was discovered by Prof. Fleming, of University College, London. As a matter of fact, it is not really a detector of electric waves, but it acts as: (1) a *rectifier* of the oscillations that are set up in the receiving circuits, that is, it changes them into pulsating direct currents so that they will flow through and affect a telephone receiver, and (2) it acts as a *relay* and the feeble received oscillating current controls the larger direct current from the *B* battery in very much the same way that a telegraph relay does. This latter relay action will be explained when we come to its operation as an amplifier.

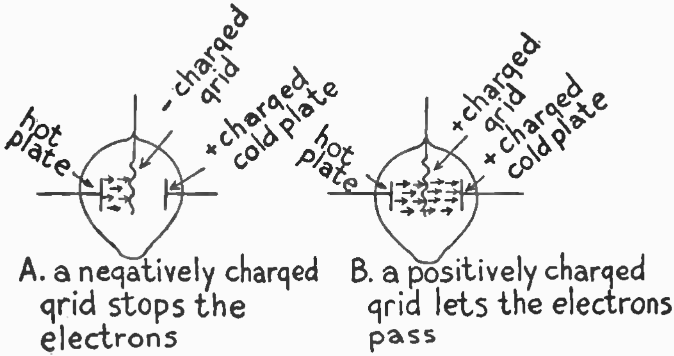
We have just learned that when the stream of electrons flow from the hot wire to the cold positive plate in the tube they form a conducting path through which the battery current can flow. Now when the electric oscillations surge through the closed oscillation circuit, which includes the secondary of the tuning coil, the variable con-

[1] The three electrode vacumn tube has entirely taken the place of the two electrode type.

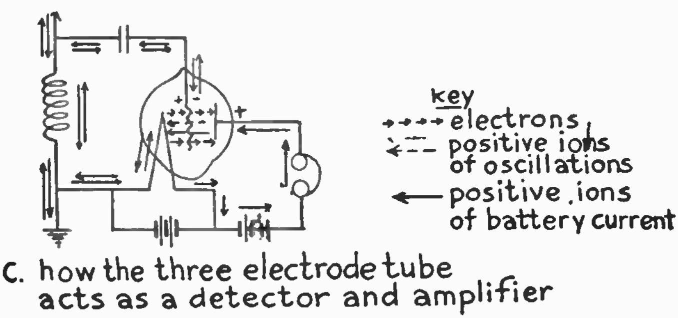
denser, the filament and the plate as shown at *B* in *Fig. 71* the positive part of them passes through the tube easily while the negative part cannot get through, that is, the top, or positive, part of the wave-form remains intact while the lower, or negative, part is cut off as shown in the diagram at *C*. As the received oscillations are either broken up into wave trains of audio frequency by the telegraph transmitter or are modulated by a telephone transmitter they carry the larger impulses of the direct current from the *B* battery along with them and these flow through the headphones. This is the reason the vacuum tube amplifies as well as detects.

How the Three Electrode Tube Acts as a Detector.—The vacuum tube as a detector has been made very much more sensitive by the use of a third electrode shown in *Fig. 72*. In this type of vacuum tube the third electrode, or *grid,* is placed between the filament and the plate and this controls the number of electrons flowing from the filament to the plate; in passing between these two electrodes they have to go through the holes formed by the grid wires.

If now the grid is charged to a higher *negative* voltage than the filament the electrons will be stopped by the latter, see *A,* though some of them will go through to the plate because they travel at a high rate of speed. The higher the negative



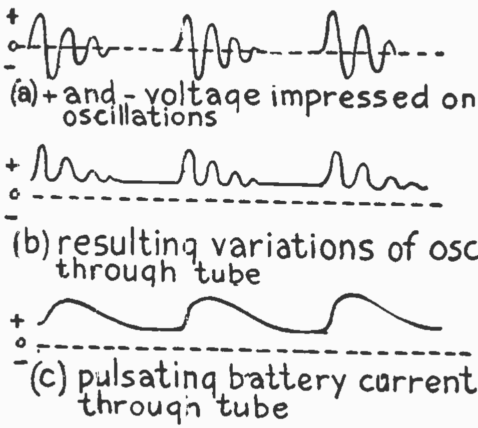
(*A*) and (*B*) Fig. 72.—How the Positive and Negative Voltages of Oscillations Act on the Electrons.



(*C*) Fig. 72.—How the Three Electrode Tube Acts as a Detector and Amplifier.

charge on the grid the smaller will be the number of electrons that will reach the plate and, of course, the smaller will be the amount of current that will flow through the tube and the headphones from the *B* battery.

On the other hand if the grid is charged *positively,* see *B,* then more electrons will strike the plate than when the grid is not used or when it is



(*D*) Fig. 72.—How the Oscillations Control the Flow of the Battery Current through the Tube.

negatively charged. But when the three electrode tube is used as a detector the oscillations set up in the circuits change the grid alternately from negative to positive as shown at *C* and hence the voltage of the *B* battery current that is allowed to flow through the detector from the plate to the filament rises and falls in unison with the voltage of the oscillating currents. The way the positive and negative voltages of the oscillations which are set up by the incoming waves, energize the grid; how the oscillator tube clips off the negative parts of them, and, finally, how these carry the battery current through the tube are shown graphically by the curves at *D*.

How the Vacuum Tube Acts as an Amplifier.—If you connect up the filament and the plate of a three electrode tube with the batteries and do not connect in the grid, you will find that the electrons which are thrown off by the filament will not get farther than the grid regardless of how high the voltage is that you apply to the plate. This is due to the fact that a large number of electrons which are thrown off by the filament strike the grid and give it a negative charge, and consequently, they cannot get any farther. Since the electrons do not reach the plate the current from the *B* battery cannot flow between it and the filament.

Now with a properly designed amplifier tube a very small negative voltage on the grid will keep a very large positive voltage on the plate from sending a current through the tube, and oppositely, a very small positive voltage on the grid will let a very large plate current flow through the tube; this being true it follows that any small variation of the voltage from positive to negative on the grid and the other way about will vary a large current flowing from the plate to the filament.

In the Morse telegraph the relay permits the small current that is received from the distant sending station to energize a pair of magnets, and these draw an armature toward them and close a second circuit when a large current from a local battery is available for working the sounder. The amplifier tube is a variable relay in that the feeble currents set up by the incoming waves constantly and proportionately vary a large current that flows through the headphones. This then is the principle on which the amplifying tube works.

The Operation of a Simple Vacuum Tube Receiving Set.—The way a simple vacuum tube detector receiving set works is like this: when the filament is heated to brilliancy it gives off electrons as previously described. Now when the electric waves impinge on the aerial wire they set up oscillations in it and these surge through the primary coil of the loose coupled tuning coil, a diagram of which is shown at *B* in *Fig. 39*.

The energy of these oscillations sets up oscillations of the same frequency in the secondary coil and these high frequency currents whose voltage is first positive and then negative, surge in the closed circuit which includes the secondary coil and the variable condenser. At the same time the alternating positive and negative voltage of the oscillating currents is impressed on the grid; at each change from + to − and back again it allows the electrons to strike the plate and then shuts them off; as the electrons form the conducting path between the filament and the plate the larger direct current from the *B* battery is permitted to flow through the detector tube and the headphones.

Operation of a Regenerative Vacuum Tube Receiving Set.—By feeding back the pulsating direct current from the *B* battery through the tickler coil it sets up other and stronger oscillations in the secondary of the tuning coil when these act on the detector tube and increase its sensitiveness to a remarkable extent. The regenerative, or *feed back,* action of the receiving circuits used will be better understood by referring back to *Fig. 60.*

When the waves set up oscillations in the primary of the tuning coil the energy of them produces like oscillations in the closed circuit which includes the secondary coil and the condenser; the alternating positive and negative voltages of these are impressed on the grid and these, as we have seen before, cause similar variations of the direct current from the *B* battery which acts on the plate and which flows between the latter and the filament.

This varying direct current, however, is made to flow back through the third, or tickler coil of the tuning coil and sets up in the secondary coil and circuits other and larger oscillating currents and these augment the action of the oscillations produced by the incoming waves. These extra and larger currents which are the result of the feed-back then act on the grid and cause still larger variations of the current in the plate voltage and hence of the current of the *B* battery that flows through the detector and the headphones. At the same time the tube keeps on responding to the feeble electric oscillations set up in the circuits by the incoming waves. This regenerative action of the battery current augments the original oscillations many times and hence produce sounds in the headphones that are many times greater than where the vacuum tube detector alone is used.

Operation of the Short Wave, Super-regenerative Receiving Set.—When an ordinary regenerative receiving set, as described above, reaches a certain point of amplification, the detector tube begins to set up oscillations and this puts an end to further useful regeneration. Up to this critical point, and especially just before it is reached, the effects of regeneration are enormously increased but they cannot go beyond it.

The reason for this is that the oscillation circuit has so small an effective resistance that after the initial energy of the feed back sets up the amplifying oscillations in the tube these oscillations continue to surge and with such persistency that the oscillations which follow from the feed back have very little effect upon them. The energy of the oscillations set up by the incoming waves is, naturally, less and, it follows, the signal, speech or music is weaker when this condition is reached, than when the effective resistance of the circuit is small enough to allow the current rectified by the detector tube to get back to the same valve after each variation of the oscillations set up by the incoming waves.

Now the purpose of the super-regenerative system is to circumvent this limitation of the original regenerative circuit so that amplification can go on beyond it, and this is the way it is done: in this new system the factors of the circuits are so arranged that the amplifying oscillations set up by the tube do not depend so much on the feed back oscillations as on those which the oscillator tube itself sets up. This is done by alternating the values of positive and negative resistance from moment to moment; that is, an alternating positive and a negative resistance are set up by the oscillations of the oscillator tube.

The result is that while the initial, or first, oscillations set up by the incoming waves are amplified, as long as the negative resistance is larger than the positive resistance, the oscillations are instantly cut off by reversing these resistances, when the next incoming wave sets up fresh oscillations. In other words, the tube is kept from setting up oscillations when the critical point is reached, by changing the negative resistance to the positive and then changing them about the other way.

While an oscillation tube that generates oscillations cf a frequency of about 15,000 cycles per second is used to change the resistances, it is possible to use several different kinds of circuits. The frequency of the oscillations set up by the tube for this purpose must be just high enough so that you cannot hear them surging in your head-phones, and a frequency of 15,000 cycles is high enough to be beyond the limits of audibility.

If, now, you will turn back to page 154 and look at the wiring diagram shown in *Fig. 55,* you will see that the first tube is the regenerative amplifying tube, and that the positive and negative resistances of its plate circuit are constantly changed about by the second tube, which is the oscillation tube. After the low-frequency oscillating currents have been transformed by the audio-frequency transformer, they pass through a third tube, called the detector, which simply rectifies the currents, that is, it changes them into a pulsating direct current which will operate the head-phones.

Operation of Autodyne and Heterodyne Receiving Sets.—At *A* in *Fig. 33* is shown a picture of two tuning forks mounted on sounding boxes to illustrate the principle of electrical tuning. When a pair of these forks are made to vibrate exactly the same number of times per second there will be a condensation of the air between them and the sound waves that are sent out will be augmented. But if you adjust one of the forks so that it will vibrate 256 times a second and the other fork so that it will vibrate 260 times a second then there will be a phase difference between the two sets of waves and the latter will augment

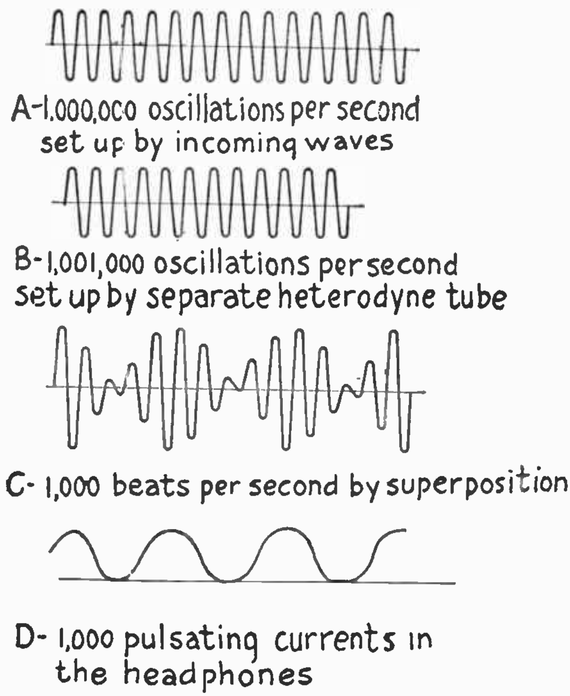


FIG. 73.—How the Heterodyne Receptor Works.

each other 4 times every second and you will hear these rising and falling sounds as *beats.*

Now electric oscillations set up in two circuits that are coupled together act in exactly the same way as sound waves produced by two tuning forks that are close to each other. Since this is true if you tune one of the closed circuits so that the oscillations in it will have a frequency

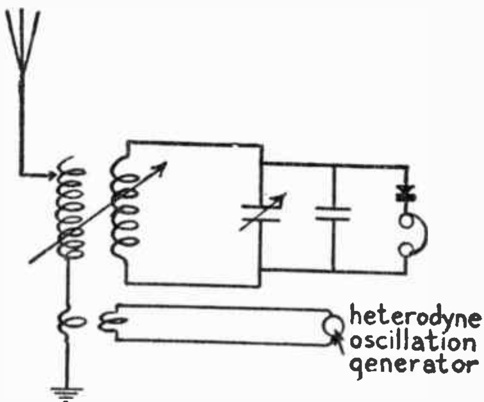


FIG. 74.—Separate Heterodyne Oscillator.

of a 1,000,000 and tune the other circuit so that the oscillations in it have a frequency of 1,001,000 a second then the oscillations will augment each other 1,000 times every second.

As these rising and falling currents act on the pulsating currents from the *B* battery which flow through the detector tube and the headphones you will hear them as *beats*. A graphic representation of the oscillating currents set up by the incoming waves, those produced by the heterodyne oscillator and the beats they form is shown in *Fig. 73.* To produce these beats a receptor can use: (1) a single vacuum tube for setting up oscillations of both frequencies when it is called an *autodyne,* or *self-heterodyne* receptor, or (2) a separate vacuum tube for setting up the oscillations for the second circuit when it is called a *heterodyne* receptor.

The Autodyne, or Self-Heterodyne Receiving Set.—Where only one vacuum tube is used for producing both frequencies you need only a regenerative, or feed-back receptor; then you can tune the aerial wire system to the incoming waves and tune the closed circuit of the secondary coil so that it will be out of step with the former by 1,000 oscillations per second, more or less, the exact number does not matter in the least. From this you will see that any regenerative set can be used for autodyne, or self-heterodyne, reception.

The Separate Heterodyne Receiving Set.—The better way, however, is to use a separate vacuum tube for setting up the heterodyne oscillations. The latter then act on the oscillations that are produced by the incoming waves and which energize the grid of the detector tube. Note that the vacuum tube used for producing the heterodyne oscillations is a *generator* of electric oscillations; the latter are impressed on the director circuits through the variable coupling, the secondary of which is in series with the aerial wire as shown in *Fig. 74*. The way in which the tube acts as a generator of oscillations will be told in *Chapter XVII*.

Operation of the Super-Heterodyne Receiving Set.—Major Armstrong devised the Super-Heterodyne receiver in his attempt to eliminate the inefficiency of radio frequency amplification at short wave lengths and gain the immense amplification possible on the longer wave lengths. The only logical solution to the problem was to convert an incoming signal of a short wave to a longer wave length of say 5,000 meters and then run it through a long wave radio frequency amplifier. This is exactly what Major Armstrong succeeded in doing.

You have learned from preceding chapters that a definite wave length corresponds to a definite frequency and that the longer the wave the lower the frequency and vice versa. You have also learned that in order to receive continuous wave signals on a vacuum tube receiver it is necessary to employ the *autodyne* or *heterodyne* method wherein a second frequency or wave length is impressed on the receiving circuit so as to produce a *beat note* of the original signal that would be audible.

The separate heterodyne method is used in conjunction with the Super-Heterodyne receiver, only instead of adjusting it so as to produce an audible beat note, a *radio frequency* beat note is produced having a frequency not of approximately 1,000 cycles, but of the exact frequency that corresponds with the wave length upon which the radio frequency amplifying transformers are designed to work. In this way the incoming signal is actually converted to a longer wave length, passed through the first detector (frequency changer) where the original radio frequency wave is eliminated, then through the radio frequency amplifiers and finally through the second detector where the signal is rectified and made into an audio frequency.

CHAPTER XV

CONTINUOUS WAVE TELEGRAPH TRANSMITTING SETS WITH DIRECT CURRENT

In the first part of this book we learned about spark-gap telegraph sets and how the oscillations they set up are *damped* and the waves they send out are *periodic*. In this and the next chapter we shall find out how vacuum tube telegraph transmitters are made and how they set up oscillations that are *sustained* and radiate waves that are *continuous*.

Sending wireless telegraph messages by continuous waves has many features to recommend it as against sending them by periodic waves and among the most important of these are that the transmitter can be: (1) more sharply tuned, (2) it will send signals farther with the same amount of power, and (3) it is noiseless in operation. The disadvantageous features are that: (1) a battery current is not satisfactory, (2) its circuits are somewhat more complicated, and (3) the oscillator tubes burn out occasionally. There is, however, a growing tendency among amateurs to use continuous wave transmitters and they are certainly more up-to-date and interesting than spark gap sets.

Now there are three practical ways by which continuous waves can be set up for sending either telegraphic signals or telephonic speech and music and these are: (a) with an *oscillation arc lamp,* (b) a *vacuum tube oscillator,* and (c) a *high frequency alternator.* The oscillation arc was the earliest known way of setting up sustained oscillations, and it is now largely used for commercial high power, long distance work. But since the vacuum tube has been developed to a high degree of efficiency and is the scheme that is now in vogue for amateur stations we shall confine our efforts here to explaining the apparatus necessary and how to wire the various parts together to produce several sizes of vacuum tube telegraph transmitters. The high frequency alternator is used only for high power stations.

Sources of Current for Telegraph Transmitting Sets.—Differing from a spark-gap transmitter you cannot get any practical results with a low voltage battery current to start with. For a purely experimental vacuum tube telegraph transmitter you can use enough *B* batteries to operate it but the current strength of these drops so fast when they are in use, that they are not at all satisfactory for the work.

You can, however, use 110 volt direct current from a lighting circuit as your initial source of power to energize the plate of the vacuum tube oscillator of your experimental transmitter. Where you have a 110 volt *direct current* lighting service in your home and you want a higher voltage for your plate, you will then have to use a motor-generator set and this costs money. If you have 110 volt *alternating current* lighting service at hand your troubles are over so far as cost is concerned for you can step it up to any voltage you want with a power transformer. In this chapter will be shown how to use a direct current for your source of initial power and in the next chapter how to use an alternating current for the initial power.

An Experimental Continuous Wave Telegraph Transmitter.—You will remember that in *Chapter XIV* we learned how the heterodyne receiver works and that in the separate heterodyne receiving set the second vacuum tube is used solely to set up oscillations. Now while this extra tube is used as a generator of oscillations these are, of course, very weak and hence a detector tube cannot be used to generate oscillations that are useful for other purposes than heterodyne receptors and measurements.

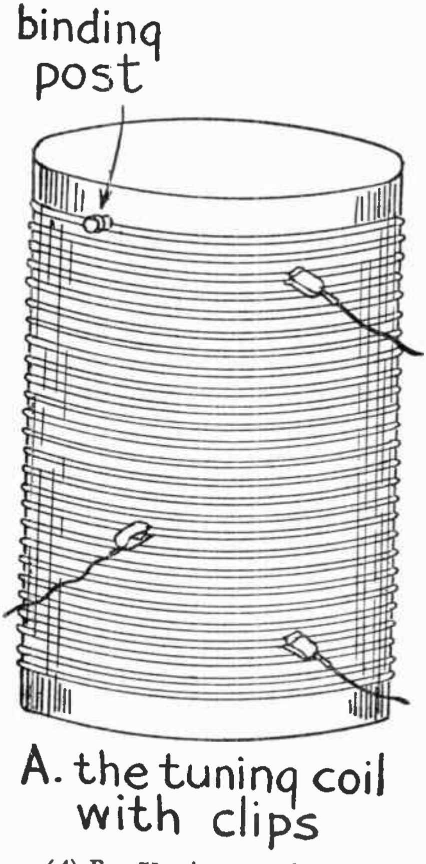
There is a vacuum tube amplifier made, that will stand a plate potential of 100 volts, and this can be used as a generator of oscillations by energizing it with a 110 volt direct current from your lighting service. Or in a pinch you can use five standard *B* batteries to develop the plate voltage, but these will soon run down. But whatever you do, never use a current from a lighting circuit on a tube of any kind that has a rated plate potential of less than 100 volts.

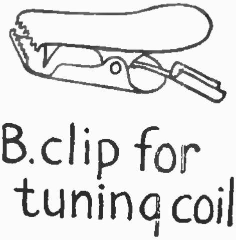
By consulting the vacuum tube chart in the back of the book you can tell at a glance what vacuum tubes you can and cannot safely use.

The Apparatus You Need.—For this experimental continuous wave telegraph transmitter get the following pieces of apparatus: (1) one *single coil tuner with three clips;* (2) one *.002 mfd. fixed condenser;* (3) three *.001 mfd. condensers;* (4) one *adjustable grid leak;* (5) one *hot-wire ammeter;* (6) one *buzzer;* (7) one *dry cell;* (8) one *telegraph key;* (9) one *vacuum tube amplifier;* (10) one *6 volt storage battery;* (11) one *rheostat;* (12) one *oscillation choke coil;* (13) one *panel cut-out* with a *single-throw, double-pole switch,* and a pair of *fuse sockets* on it.

The Tuning Coil.—You can either make this tuning coil or buy one. To make it get two disks of wood ¾-inch thick and 5 inches in diameter and four strips of hard wood, or better, hard rubber or composition strips, such as *bakelite,* ½-inch thick, 1 inch wide and 5¾ inches long, and screw them to the disks as shown at *A* in *Fig. 75.* Now wrap on this form about 25 turns of No. 8 or 10, Brown and Sharpe gauge, bare copper wire with a space of ⅛-inch between each turn. Get three of the smallest size terminal clips, see *B,* and clip them on to the different turns, when your tuning coil is ready for use.

The Condensers.—For the aerial series condenser get one that has a capacitance of .002 mfd. and that will stand a potential of 3,000 volts. It is shown at *C.* The other three condensers, see *D,* are also of the fixed type and may have a capacitance of .001 mfd.; the blocking condenser should preferably have a capacitance

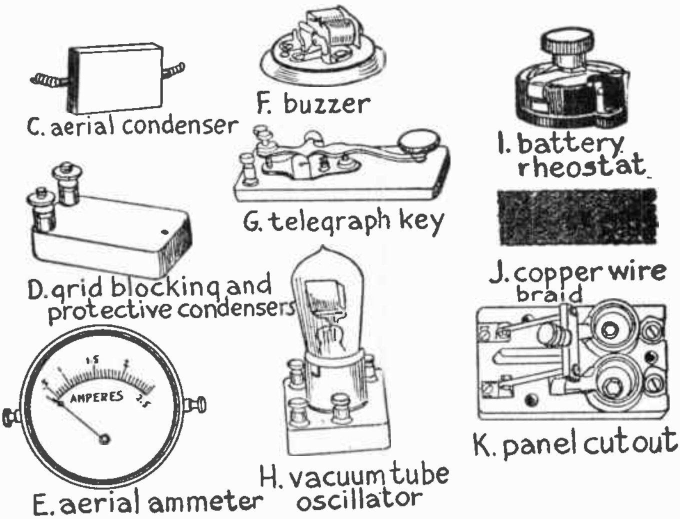




(*A*) Fig. 75.—Apparatus for Experimental C. W. Telegraph Transmitter.

of ½ a mfd. In these condensers the leaves of the sheet metal are embedded in composition.

The Aerial Ammeter.—This instrument is also called a *hot-wire* ammeter because the oscillating



(*B*) Fig. 75.—Apparatus for Experimental C. W. Telegraph Transmitter.

currents flowing through a piece of wire heat it according to their current strength and as the wire contracts and expands it moves a needle over a scale. The ammeter is connected in the aerial wire system, either in the aerial side or the ground side—the latter place is usually the most convenient. When you tune the transmitter so that the ammeter shows the largest amount of current surging in the aerial wire system you can consider that the oscillation circuits are in tune. A hot-wire ammeter reading to 1.5 amperes will serve your needs; it is shown at *E* in *Fig. 75*.

The Buzzer and Dry Cell.—While a heterodyne, or beat, receptor can receive continuous wave telegraph signals an ordinary crystal or vacuum tube detector receiving set cannot receive them unless they are broken up into trains either at the sending station or at the receiving station, and it is considered the better practice to do this at the former rather than at the latter station. For this small transmitter you can use an ordinary buzzer as shown at *F*. A dry cell or two must be used to energize the buzzer.

The Telegraph Key.—Any kind of a telegraph key will serve to break up the trains of sustained oscillations into dots and dashes. The key shown at *G* is mounted on a composition base and is the cheapest key made.

The Vacuum Tube Oscillator.—As explained before, you can use any amplifying tube that is made for a plate potential of 100 volts or over. The current required for heating the filament is about 1 ampere at 6 volts. A porcelain socket should be used for this tube as it is the best insulating material for the purpose. An amplifier tube of this type is shown at *H*.

The Storage Battery.—A storage battery is used to heat the filament of the tube, just as it is with a detector tube, and it can be of any make or capacity as long as it will develop 6 volts. The cheapest 6 volt storage battery on the market has a 20 to 40 ampere-hour capacity.

The Battery Rheostat.—As with the receptors a rheostat is needed to regulate the current that heats the filament. A rheostat of this kind is shown at *I*.

The Oscillation Choke Coil.—This coil is connected in between the oscillation circuits and the source of current which feeds the oscillator tube to keep the oscillations set up by the latter from surging back into the service wires where they would break down the insulation. You can make an oscillation choke coil by winding say 100 turns of No. 28 Brown and Sharpe gauge double cotton covered magnet wire on a cardboard cylinder 2 inches in diameter and 2½ inches long.

Transmitter Connectors.—For connecting up the different pieces of apparatus of the transmitter it is a good scheme to use *copper braid;*

this is made of braided copper wire in three sizes. A piece of it is pictured at *J*.

The Panel Cut-Out.—This is used to connect the cord of the 110-volt lamp socket with the transmitter. It consists of a pair of *plug cut-outs and a single-throw, double-pole* switch mounted on a porcelain base as shown at *K*. In some localities it is necessary to place these in an iron box to conform to the requirements of the fire underwriters.

Connecting Up the Transmitting Apparatus.—The way the various pieces of apparatus are connected together is shown in the wiring diagram, *Fig. 76*. Begin by connecting one post of the ammeter with the wire that leads to the aerial and the other post of it to one end of the tuning coil; connect clip *1* to one terminal of the .002 mfd. 3,000 volt aerial condenser and the other post of this with the ground.

Now connect the end of the tuning coil that leads to the ammeter with one end of the .001 mfd. grid condenser and the other end of this with the grid of the vacuum tube. Connect the telegraph key, the buzzer and the dry cell in series and then shunt them around the grid condenser. Next connect the plate of the tube with one end of the .001 mfd. blocking condenser and the other end of this with the clip *2* on the tuning coil.

Connect one end of the filament with the + or positive electrode of the storage battery, the

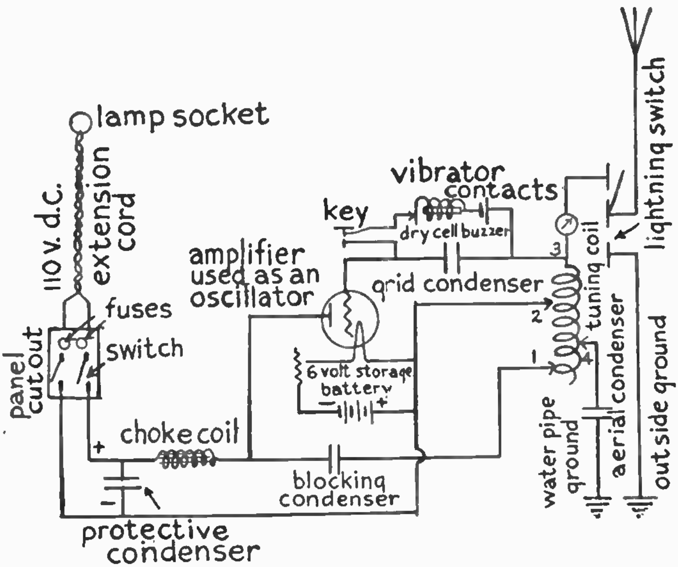


FIG. 76.—Experimental C. W. Telegraph Transmitter.

— or negative electrode of this with one post of the rheostat and the other post of the latter with the other end of the filament; then connect clip *3* with the + or positive side of the storage battery. This done connect one end of the choke coil to the conductor that leads to the plate and connect the other end of the choke coil to one of the taps of the switch on the panel cut-out. Connect the + or positive electrode of the storage battery to the other switch tap and between the switch and the choke coil connect the protective condenser across the 110 volt feed wires. Finally connect the lamp cord from the socket to the plug fuse taps when your experimental continuous wave telegraph transmitter is ready to use.

A 25 Mile C. W. Telegraph Transmitter.—Here is a continuous wave telegraph transmitter that will cover distances up to 25 miles that you can rely on. It is built on exactly the same lines as the experimental transmitter just described, but instead of using a 100 volt plate amplifier as a makeshift generator of oscillations it employs a 5 watt vacuum tube made especially for setting up oscillations and instead of having a low plate voltage it is energized with 350 volts.

The Apparatus You Need.—For this transmitter you require: (1) one *oscillation transformer;* (2) one *hot-wire ammeter;* (3) one *aerial series condenser;* (4) one *grid leak resistance;* (5) one *chopper;* (6) one *key circuit choke coil;* (7) one *5 watt vacuum tube oscillator;* (8) one *6 volt storage battery;* (9) one *battery rheostat;* (10) one *battery voltmeter;* (11) one *blocking condenser;* (12) one *power circuit choke coil,* and (13) one *motor-generator.*

The Oscillation Transformer.—The tuning coil, or *oscillation transformer* as this one is called, is a conductively coupled tuner—that is, the primary and secondary coils form one continuous coil instead of two separate coils. This tuner is made up of 25 turns of thin copper strip, 3/8 inch wide and with its edges rounded, and this is secured to a wood base as shown at *A* in *Fig. 77*. It is fitted with one fixed tap and three clips to each of which a length of copper braid is attached. It has a diameter of 6¼ inches, a height of 7⅞ inches and a length of 9⅜ inches.

The Aerial Condenser.—This condenser is made up of three fixed condensers of different capacitances, namely .0003, .0004 and .0005 mfd., and these are made to stand a potential of 7500 volts. The condenser is therefore adjustable and, as you will see from the picture *B*, it has one terminal wire at one end and three terminal wires at the other end so that one, two or three condensers can be used in series with the aerial.

The Aerial Ammeter.—This is the same kind of a hot-wire ammeter already described in connection with the experimental set.

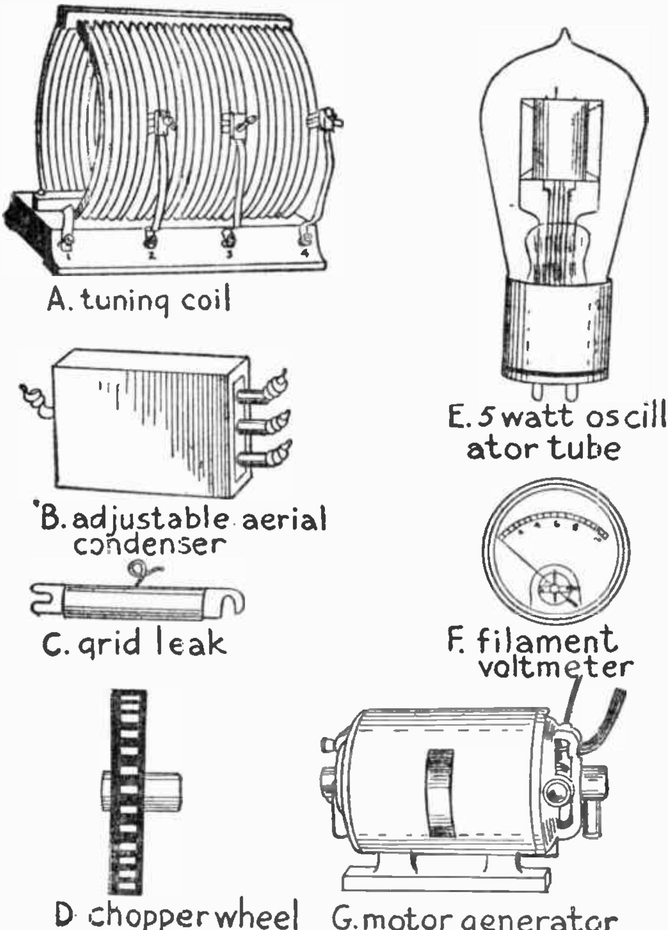


FIG. 77.—Apparatus of 100 Mile C. W. Telegraph Transmitter.

The Grid and Blocking Condensers.—Each of these is a fixed condenser of .002 mfd. capacitance and is rated to stand 3,000 volts. It is made like the aerial condenser but has only two terminals.

The Key Circuit Apparatus.—This consists of: (1) the *grid leak;* (2) the *chopper;* (3) the *choke coil,* and (4) the *key.* The grid leak is connected in the lead from the grid to the aerial to keep the voltage on the grid at the right potential. It has a resistance of 5,000 ohms with a mid-tap at 2,500 ohms as shown at *C*.

The chopper is simply a rotary interrupter driven by a small motor. It comprises a wheel of insulating material in which 30 or more metal segments are set in an insulating disk as shown at *D*. A metal contact called a brush is fixed on either side of the wheel. The choke coil is wound up of about 250 turns of No. 30 Brown and Sharpe gauge cotton covered magnet wire on a spool which has a diameter of 2 inches and a length of 3¼ inches.

The 5 Watt Oscillator Vacuum Tube.—This tube is made like the amplifier tube described for use with the preceding experimental transmitter, but it is larger, has a more perfect vacuum, and will stand a plate potential of 350 volts while the plate current is .045 ampere. The filament takes a current of a little more than 2 amperes at 7.5 volts. A standard 4-tap base is used with it. The tube is shown at *E*.

The Storage Battery and Rheostat.—This must be a 5-cell battery so that it will develop 10 volts. A storage battery of any capacity can be used but the lowest priced one costs about $22.00. The rheostat for regulating the battery current is the same as that used in the preceding experimental transmitter.

The Filament Voltmeter.—To get the best results it is necessary that the voltage of the current which heats the filament be kept at the same value all of the time. For this transmitter a direct current voltmeter reading from 0 to 15 volts is used. It is shown at *F*.

The Oscillation Choke Coil.—This is made exactly like the one described in connection with the experimental transmitter.

The Motor-Generator Set.—Where you have only a 110 or a 220 volt direct current available as a source of power you need a *motor-generator* to change it to 350 volts, and this is an expensive piece of apparatus. It consists of a single armature core with a motor winding and a generator winding on it and each of these has its own commutator. Where the low voltage current flows into one of the windings it drives it as a motor and this in turn generates the higher voltage current in the other winding. Get a 100 watt 350 volt motor-generator; it is shown at *F*.

The Panel Cut-Out.—This switch and fuse block is the same as that used in the experimental set.

The Protective Condenser.—This is a fixed condenser having a capacitance of 1 mfd. and will stand 750 volts.

Connecting Up the Transmitting Apparatus.—From all that has gone before you have seen that each piece of apparatus is fitted with terminal, wires, taps or binding posts. To connect up the parts of this transmitter it is only necessary to make the connections as shown in the wiring diagram *Fig. 78.*

A 50 Mile C. W. Telegraph Transmitter.—To make a continuous wave telegraph transmitter that will cover distances up to 50 miles all you have to do is to use two 5 watt vacuum tubes in *parallel,* all of the rest of the apparatus being exactly the same. Connecting the oscillator tubes up in parallel means that the two filaments are connected across the leads of the storage battery, the two grids on the same lead that goes to the aerial and the two plates on the same lead that goes to the positive pole of the generator. Where two or more oscillator tubes are used only one storage battery is needed, but each filament must have its own rheostat. The wiring diagram

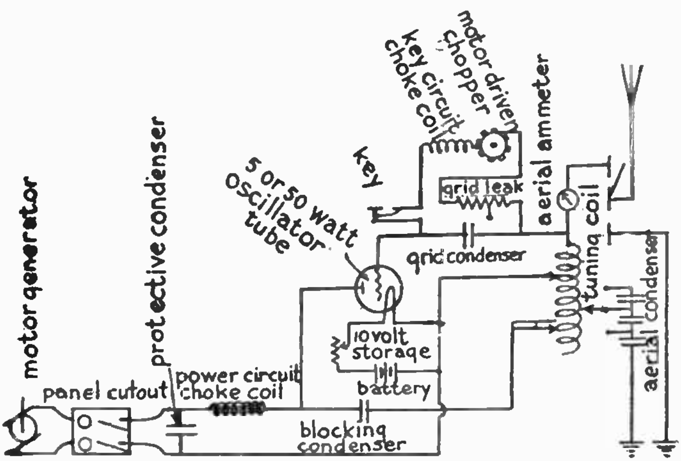


FIG. 78.—5 to 50 Watt C. W. Telegraph Transmitter. (With Single Oscillator Tube.)

Fig. 79 shows how the two tubes are connected up in parallel.

A 100 Mile C. W. Telegraph Transmitter.—For sending to distances of over 50 miles and up to 100 miles you can use either: (1) three or four 5 watt oscillator tubes in parallel as described above, or (2) one 50 watt oscillator tube. Much of the apparatus for a 50 watt tube set is exactly the same as that used for the 5 watt sets. Some of the parts, however, must be proportionately larger though the design all the way through remains the same.

The Apparatus and Connections.—The aerial series condenser, the blocking condenser, the grid condenser, the telegraph key, the chopper, the choke coil in the key circuit, the filament voltmeter and the protective condenser in the power circuit are identical with those described for the 5 watt transmitting set.

The 50 Watt Vacuum Tube Oscillator.—This is the size of tube generally used by amateurs for long distance continuous wave telegraphy. A single tube will develop 2 to 3 amperes in your aerial. The filament takes a 10 volt current and a plate potential of 1,000 volts is needed. One of these tubes is shown in *Fig. 80.*

The Aerial Ammeter.—This should read to 5 amperes and should preferably be of the *thermo-coupled* type.

The Grid Leak Resistance.—It has the same resistance, namely 5,000 ohms, as the one used with the 5 watt tube transmitter, but it is a little larger.

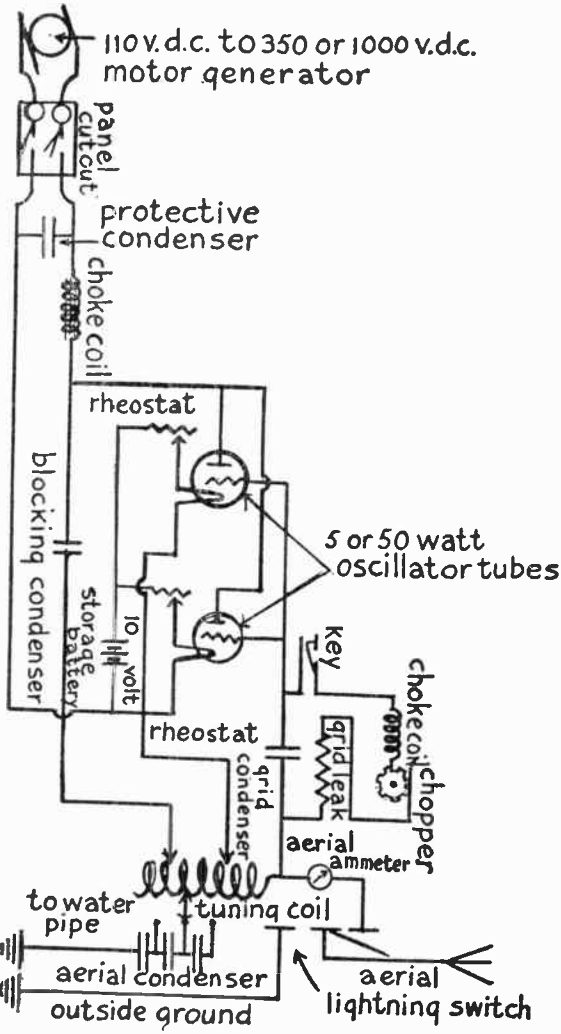


FIG. 79.—50 to 100 Mile C. W. Telegraph Transmitter. (With Two Tubes in Parallel.)

The Oscillation Choke Coil.—The choke coil in the power circuit is made of about 260 turns of No. 30 B. & S. cotton covered magnet wire wound on a spool 2¼ inches in diameter and 3¼ inches long.

The Filament Rheostat.—This is made to take care of a large current and is wound with heavy wire.

The Filament Storage Battery.—This must develop 12 volts and should have an output of 40 ampere-hours.

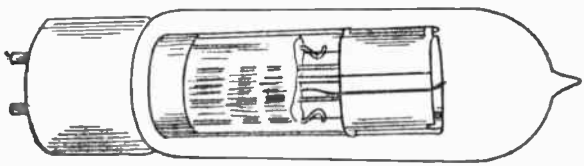


Fig. 80.—50 Watt Oscillator Vacuum Tube.

The Protective Condenser.—This condenser has a capacitance of 1 mfd.

The Motor-Generator.—Where you use one 50 watt oscillator tube you will need a motor-generator that develops a plate potential of 1000 volts and has an output of 200 watts.

The different pieces of apparatus for this set are connected up exactly the same as shown in the wiring diagram in *Fig. 78.*

A 200 Mile C. W. Telegraph Transmitter.—All of the parts of this transmitting set are the same as for the 100 mile transmitter just described except the motor generator and while this develops the same plate potential, *i.e.*, 1,000 volts, it must have an output of 100 watts. For this long distance transmitter you use two 50 watt oscillator tubes in parallel and all of the parts are connected together exactly the same as for the 100 mile transmitter shown in the wiring diagram in *Fig. 79*.

CHAPTER XVI

CONTINUOUS WAVE TELEGRAPH TRANSMITTING SETS WITH ALTERNATING CURRENT

WITHIN the last few years alternating current has largely taken the place of direct current for light, heat and power purposes in and around towns and cities and if you have alternating current service in your home you can install a long distance continuous wave telegraph transmitter with very little trouble and at a comparatively small expense.

A 25 Mile C. W. Telegraph Transmitting Set.—The principal pieces of apparatus for this transmitter are the same as those used for the *25 Mile Continuous Wave Telegraph Transmitting Set* described and pictured in the preceding chapter which used direct current, except that an *alternating current power transformer* is employed instead of the more costly *motor-generator*.

The Apparatus Required. — The various pieces of apparatus you will need for this transmitting set are: (1) one *hot-wire ammeter* for the aerial as shown at *E* in *Fig. 75,* (2) one *tuning coil* as shown at *A* in *Fig. 77;* (3) one *aerial condenser* as shown at *B* in *Fig. 77;* (4) one *grid leak* as shown at *C* in *Fig. 77;* (5) one *telegraph key* as shown at *G* in *Fig. 75;* (6) one *grid condenser,* made like the aerial condenser but having only two terminals; (7) one *5 watt oscillator tube* as shown at *E* in *Fig. 77;* (8) one *.002 mfd. 3,000 volt by-pass condenser,* made like the aerial and grid condensers; (9) one pair of *choke coils* for the high voltage secondary circuit; (10) one *milli-ammeter;* (11) one *A. C. power transformer;* (12) one *rheostat* as shown at *I* in *Fig. 75*, and (13) one *panel cut-out* as shown at *K* in *Fig. 75.*

The Choke Coils.—Each of these is made by winding about 100 turns of No. 28, Brown and Sharpe gauge, cotton covered magnet wire on a spool 2 inches in diameter and 2½ inches long, when it will have an inductance of about 0.5 *millihenry* [1] at 1,000 cycles.

[1] A millihenry is $\frac{1}{1000}$th part of a henry.

The Milli-ammeter.—This is an alternating current ammeter and reads from 0 to 250 *milli-amperes;*[1] and is used for measuring the secondary current that energizes the plate of the oscillator tube. It is similar in appearance to the aerial ammeter.

The A. C. Power Transformer.—Differing from the motor generator set, the power transformer has no moving parts. It is made to work on a 50 to 60 cycle current at 102.5 to 115 volts, which is the range of voltage of the ordinary alternating lighting current. This adjustment for voltage is made by means of taps brought out from the primary coil to a rotary switch.

The high voltage secondary coil which energizes the plate has an output of 175 watts and develops a potential of from 350 to 1,100 volts. The low voltage secondary coil which heats the filament has an output of 175 watts and develops 7.5 volts. This transformer, which is shown in *Fig. 81*, is large enough to take care of from one to four 5 watt oscillator tubes. It weighs about 15 pounds.

Connecting Up the Apparatus.—The wiring diagram *Fig. 82* shows clearly how all of the connections are made. It will be observed that a

[1] A *milliampere is the* $\frac{1}{1000}$th part of an ampere.

storage battery is not needed as the secondary coil of the transformer supplies the current to heat

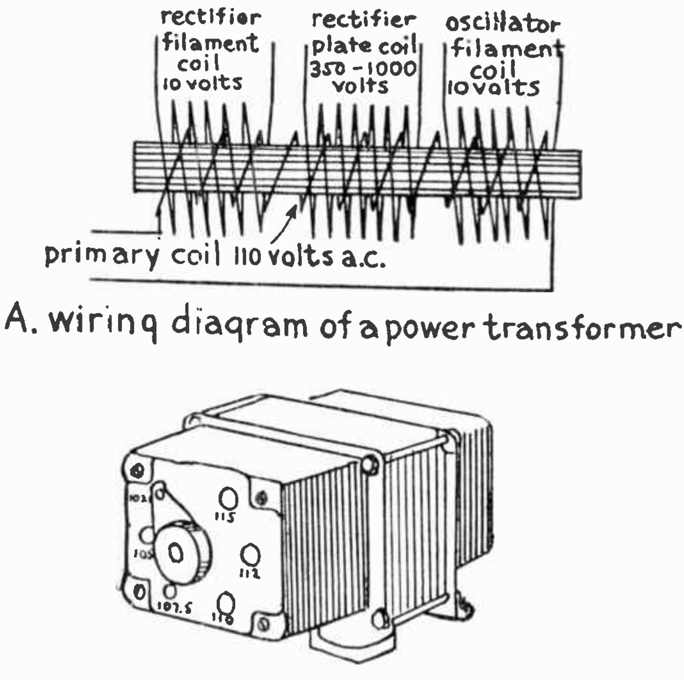


FIG. 81 —Alternating Current Power Transformer. (For C. W. Telegraphy and Wireless Telephony.)

the filament of the oscillator. The filament voltmeter is connected across the filament secondary coil terminals, while the plate milli-ammeter is

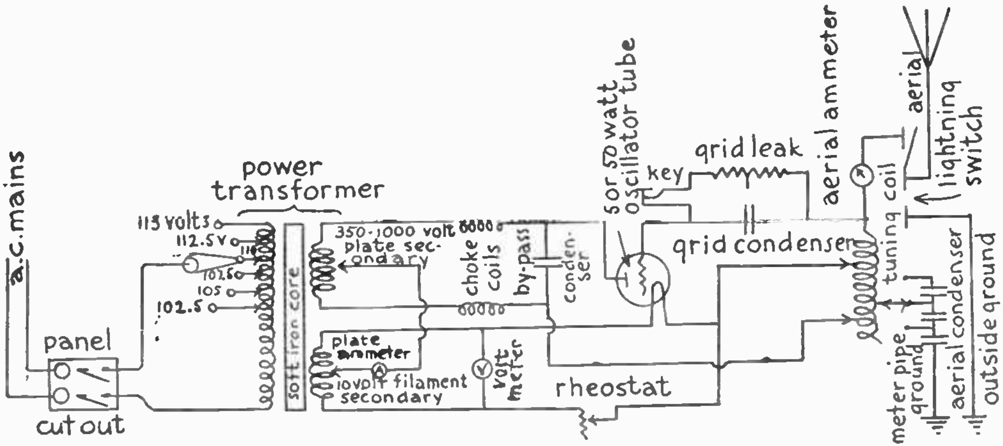


Fig. 82.—Wiring Diagram for 50 to 100 Mile C. W. Telegraph Transmitting Set. (With Alternating Current.)

connected to the mid-taps of the plate secondary coil and the filament secondary coil.

A 50 to 100 Mile C. W. Telegraph Transmitting Set.—Distances of from 50 to 100 miles can be successfully covered with a telegraph transmitter using two, three or four 5 watt oscillator tubes in parallel. The other apparatus needed is identical with that used for the transmitter just described. The tubes are connected in parallel as shown in the wiring diagram in *Fig. 83.*

A 100 to 200 Mile C. W. Telegraph Transmitting Set.—With the apparatus described for the above set and a single 50 watt oscillator tube a distance of upwards of 100 miles can be covered, while with two 50 watt oscillator tubes in parallel you can cover a distance of 200 miles without difficulty, and over 1,000 miles have been covered with this set.

The Apparatus Required.—All of the apparatus for this C. W. telegraph transmitting set is the same as that described for the 25 and 50 mile sets but you will need: (1) one or two *50 watt oscillator tubes* with *sockets;* (2) one *key condenser* that has a capacitance of 1 mfd., and a rated potential of 1,750 volts; (3) one *0* to *500 milli-ammeter;* (4) one *aerial ammeter* reading

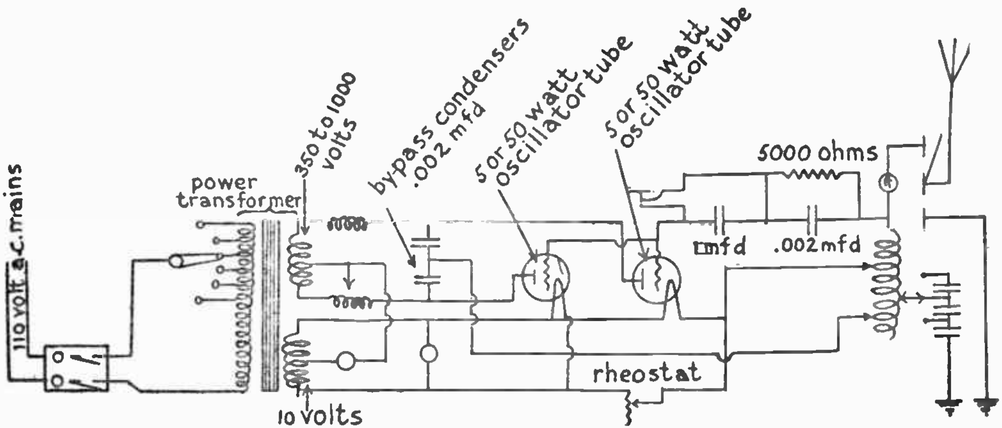


FIG. 83.—Wiring Diagram for 100 to 200 Mile C. W. Telegraph Transmitter.

to 5 amperes, and (5) an *A. C. power transformer* for one or two 50 watt tubes.

The Alternating Current Power Transformer.—This power transformer is made exactly like the one described in connection with the preceding 25 mile transmitter and pictured in *Fig. 81,* but it is considerably larger. Like the smaller one, however, it is made to work with a 50 to 60 cycle current at 102.5 to 115 volts and, hence, can be used with any A. C. lighting current.

The high voltage secondary coil which energizes the plate has an output of 450 watts and develops 1,500 to 3,000 volts. The low voltage secondary coil which heats the filament develops 10.5 volts. This transformer will supply current for one or two 50-watt oscillator tubes.

Connecting Up the Apparatus.—Where a single oscillator tube is used the parts are connected as shown in *Fig. 82,* and where two tubes are connected in parallel the various pieces of apparatus are wired together as shown in *Fig. 83.* The only difference between the 5 watt tube transmitter and the 50 watt tube transmitter is in the size of the apparatus with one exception; where one or two 50 watt tubes are used a second condenser of large capacitance (1 mfd.) is placed in the grid circuit and the telegraph key is shunted around it as shown in the diagram *Fig. 83.*

CHAPTER XVII

WIRELESS TELEPHONE TRANSMITTING SETS WITH DIRECT AND ALTERNATING CURRENTS

In time past the most difficult of all electrical apparatus for the amateur to make, install and work was the wireless telephone. This was because it required a *direct current* of not less than 500 volts to set up the sustained oscillations and all ordinary direct current for lighting purposes is usually generated at a potential of 110 volts.

Now as you know it is easy to *step-up* a 110 volt alternating current to any voltage you wish with a power transformer but until within comparatively recent years an alternating current could not be used for the production of sustained oscillations for the very good reason that the state of the art had not advanced that far. In the new order of things these difficulties have all but vanished and while a wireless telephone transmitter still requires a high voltage direct current to operate it this is easily obtained from 110 volt source of alternating current by means of *vacuum tube rectifiers.*

The pulsating direct currents are then passed through a filtering reactance coil, called a *reactor,* and one or more condensers, and these smooth them out until they approximate a continuous direct current. The latter is then made to flow through a vacuum tube oscillator when it is converted into high frequency oscillations and these are *varied,* or *modulated,* as it is called, by a *microphone transmitter* such as is used for ordinary wire telephony. The energy of these sustained modulated oscillations is then radiated into space from the aerial in the form of electric waves.

The distance that can be covered with a wireless telephone transmitter is about one-fourth as great as that of a wireless telegraph transmitter having the same input of initial current, but it is long enough to satisfy the most enthusiastic amateur. For instance with a wireless telephone transmitter where an amplifier tube is used to set up the oscillations and which is made for a plate potential of 100 volts, distances of 5 or 10 miles can be covered.

With a single 5 watt oscillator tube energized by a direct current of 350 volts from either a motor-generator or from a power transformer (after it has been rectified and smoothed out) speech and music can be transmitted to upwards of 10 to 15 miles. Where two 5 watt tubes connected in parallel are used wireless telephone messages can be transmitted to distances of 15 to 25 miles. Further, a single 50 watt oscillator tube will send to distances of 25 to 50 miles while two of these tubes in parallel will send from 50 to 100 miles. Finally, where four or five oscillator tubes are connected in parallel, proportionately greater distances can be covered.

A Short Distance Wireless Telephone Transmitting Set—With 110 Volt Direct Lighting Current.—For this very simple, short distance wireless telephone transmitting set you need the same apparatus as that described and pictured in the beginning of *Chapter XV for a Short Distance C. W. Telegraph Transmitter,* except that you use a *microphone transmitter* instead of a *telegraph key.* If you have a 110 volt direct lighting current in your home you can put up this short distance set for very little money and it will be well worth your while to do so.

The Apparatus You Need.—For this set you require: (1) one *tuning coil* as shown at *A* and

B in *Fig. 75;* (2) one *aerial ammeter* as shown at *E* in *Fig. 75;* (3) one *aerial condenser* as shown at *C* in *Fig. 75;* (4) one *grid, blocking and protective condenser* as shown at *D* in *Fig. 75;* (5) one *grid leak* as shown at *C* in *Fig. 77;* (6) one *vacuum tube amplifier* which is used as an *oscillator;* (7) one *6 volt storage battery;* (8) one *rheostat* as shown at *I* in *Fig. 75;* (9) one *oscillation choke coil;* (10) one *panel cut-out* as shown at *K* in *Fig. 75* and an ordinary *microphone transmitter.*

The Microphone Transmitter.—The best kind of a microphone to use with this and other telephone transmitting sets is a *Western Electric No. 284-W*. This is known as a solid back transmitter and is the standard commercial type used on all long distance Bell telephone lines. It articulates sharply and distinctly and there are no current variations to distort the wave form of the voice and it will not buzz or sizzle. It is shown in *Fig. 84*. Any other good microphone transmitter can be used if desired.

Connecting Up the Apparatus.—Begin by connecting the leading-in wire with one of the terminals of the microphone transmitter, as shown in the wiring diagram *Fig. 85,* and the other terminal of this to one end of the tuning coil. Now connect *clip 1* of the tuning coil to one of the posts of the hot-wire ammeter, the other post of this to one end of aerial condenser and, finally, the other end of the latter with the water pipe or other ground. The microphone

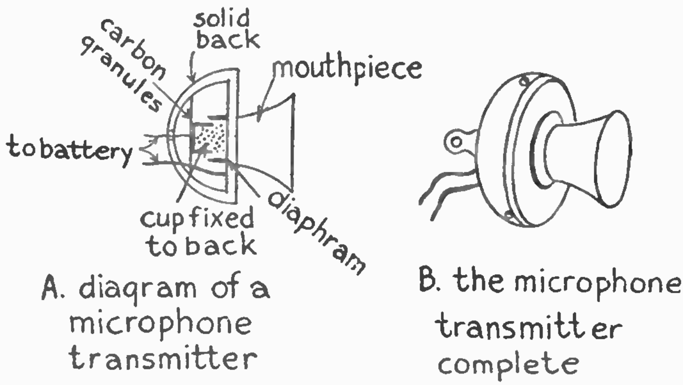


Fig. 84.—Standard Microphone Transmitter.

can be connected in the ground wire and the ammeter in the aerial wire and the results will be practically the same.

Next connect one end of the grid condenser to the post of the tuning coil that makes connection with the microphone and the other end to the grid of the tube, and then shunt the grid leak around the condenser. Connect the + or *positive* electrode of the storage battery with one terminal of the filament of the vacuum tube, the other terminal of the filament with one post of the rheostat and the other post of this with the — or *negative* electrode of the battery. This done,

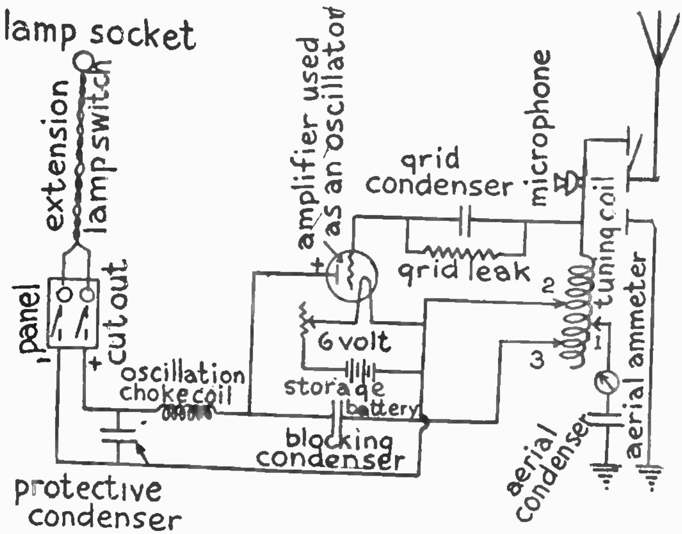


FIG. 85.—Wiring Diagram of Short Distance Wireless Telephone Set. (Microphone in Aerial Wire.)

connect *clip 2* of the tuning coil to the + or *positive* electrode of the battery and bring a lead from it to one of the switch taps of the panel cut-out.

Now connect *clip 3* of the tuning coil with one end of the blocking condenser, the other end of this with one terminal of the choke coil and the other terminal of the latter with the other switch tap of the cut-out. Connect the protective condenser across the direct current feed wires between the panel cut-out and the choke coil. Finally connect the ends of a lamp cord to the fuse socket taps of the cut-out, and connect the other ends to a lamp plug and screw it into the lamp socket of the feed wires. Screw in a pair of 5 ampere *fuse plugs,* close the switch and you are ready to tune the transmitter and talk to your friends.

A 10 to 25 Mile Wireless Telephone Transmitter—With Direct Current Motor Generator.—Where you have to start with 110 or 220 volt direct current and you want to transmit to a distance of more than 25 miles you will have to install a *motor-generator.* To make this transmitter you will need exactly the same apparatus as that described and pictured for the *25 Mile C. W. Telegraph Transmitting Set* in *Chapter XV,* except that you must substitute a *microphone transmitter* and a *telephone induction coil,* or a *microphone transformer,* or still better, a *magnetic modulator,* for the telegraph key and chopper.

The Apparatus You Need.—To reiterate; the pieces of apparatus you need are: (1) one *aerial ammeter* as shown at *E* in *Fig. 75;* (2) one *tuning coil* as shown at *A* in *Fig. 77;* (3) one *aerial condenser* as shown at *B* in *Fig. 77;* (4)

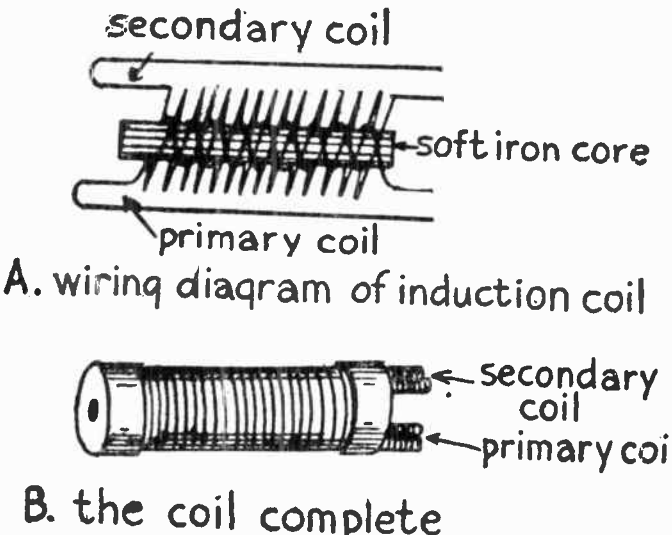


FIG. 86.—Telephone Induction Coil. (Used with Microphone Transmitter.)

one *grid leak* as shown at *C* in *Fig. 77;* (5) one *grid, blocking* and *protective condenser;* (6) one *5 watt oscillator tube* as shown at *E* in *Fig. 77;* (7) one *rheostat* as shown at *I* in *Fig. 75;* (8) one *10 volt* (*5 cell*) *storage battery;* (9) one *choke coil;* (10) one *panel cut-out* as shown at *K* in *Fig. 75,* and (11) a *motor-generator* having

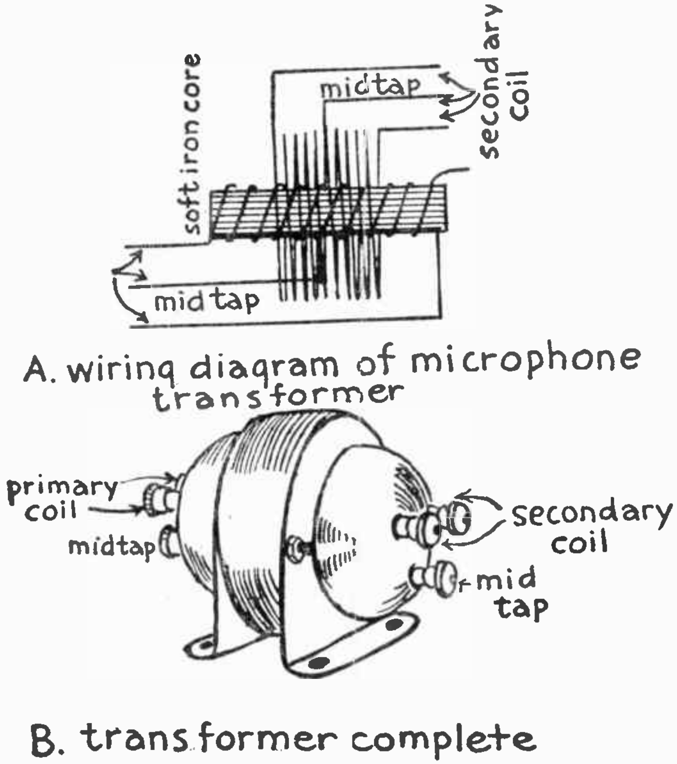


FIG. 87.—Microphone Transformer. (Used with Microphone Transmitter.)

an input of 110 or 220 volts and an output of 350 volts.

In addition to the above apparatus you will need: (12) a *microphone transmitter* as shown in *Fig. 84;* (13) a battery of four dry cells or a

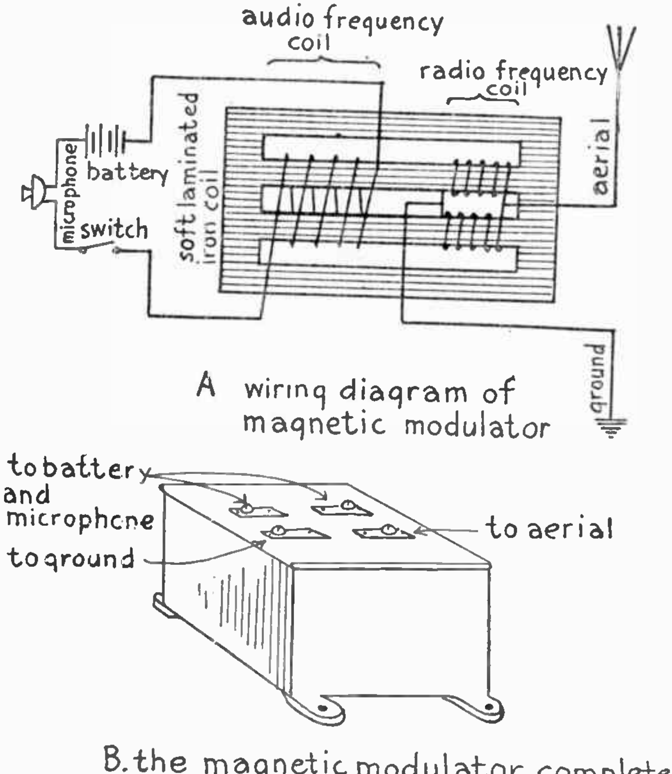


Fig. 88.—Magnetic Modulator. (Used with Microphone Transmitter.

6 volt storage battery, and either (14) a *telephone induction coil* as shown in *Fig. 86;* (15) a

microphone transformer as shown in *Fig. 87;* or a *magnetic modulator* as shown in *Fig. 88.* All of these parts have been described, as said above, in *Chapter XV,* except the microphone modulators.

The Telephone Induction Coil.—This is a little induction coil that transforms the 6-volt battery current after it has flowed through and been modulated by the microphone transmitter into alternating currents that have a potential of 1,000 volts or more. It consists of a primary coil of *No. 20 B. and S.* gauge cotton covered magnet wire wound on a core of soft iron wires while around the primary coil is wound a secondary coil of *No. 30 magnet wire.* Get a *standard telephone induction coil* that has a resistance of 500 or 750 ohms.

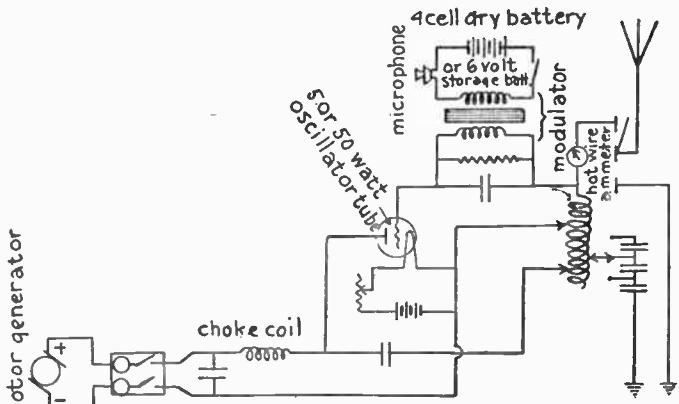
The Microphone Transformer.—This device is built on exactly the same principle as the telephone induction coil just described but it is more effective because it is designed especially for modulating the oscillations set up by vacuum tube transmitters. As with the telephone induction coil, the microphone transmitter is connected in series with the primary coil and a 6 volt dry or storage battery.

In the better makes of microphone transformer, there is a third winding, called a *side tone* coil, to which a headphone can be connected so that the operator who is speaking into the microphone can listen-in and so learn if his transmitter is working up to standard.

The Magnetic Modulator.—This is a small closed iron core transformer of peculiar design and having a primary and a secondary coil wound on it. This device is used to control the variations of the oscillating currents that are set up by the oscillator tube. It is made in three sizes and for the transmitter here described you want the smallest size, which has an output of ½ to 1½ amperes.

How the Apparatus Is Connected Up.—The different pieces of apparatus are connected together in exactly the same way as the *25 Mile C. W. Telegraph Set* in *Chapter XV* except that the microphone transmitter and microphone modulator (whichever kind you use) is substituted for the telegraph key and chopper.

Now there are several different ways that the microphone and its modulator can be connected in circuit. Two of these ways are shown at *A* and *B* in *Fig. 89*. In the first way the secondary terminals of the modulator are shunted around the grid leak in the grid circuit as at *A*, and in the second one of the secondary terminals of the microphone transformer is connected with one end of the rotor or movable coil of a vario-coupler while the other secondary terminal is connected to one of the taps of the filament. Where an induction coil or a microphone trans-

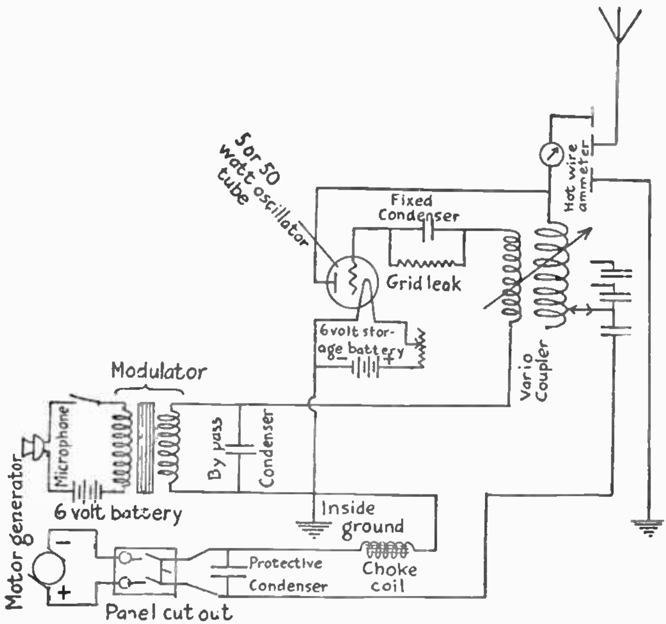


(*A*) FIG. 89.—Wiring Diagram of 10 to 25 Mile Wireless Telephone. (Microphone Modulator Shunted Around Grid-Leak Condenser.)

former is used they are shunted around a condenser, but this is not necessary with the magnetic modulator. Where a second tube is used as in *Fig. 90* then the microphone and its modulator are connected with the grid circuit and *clip 3* of the tuning coil.

A 25 to 50 Mile Wireless Telephone Trans-

mitter—With Direct Current Motor Generator.—As the initial source of current available is taken to be a 110 or 220 volt direct current a motor-generator having an output of



(*B*) Fig. 89.—Another Way to Connect in a Microphone Modulator.

350 volts must be used as before. The only difference between this transmitter and the preceding one is that: (1) two 5 watt tubes are used, the first serving as an *oscillator* and the second as a *modulator;* (2) an *oscillation choke coil* is used

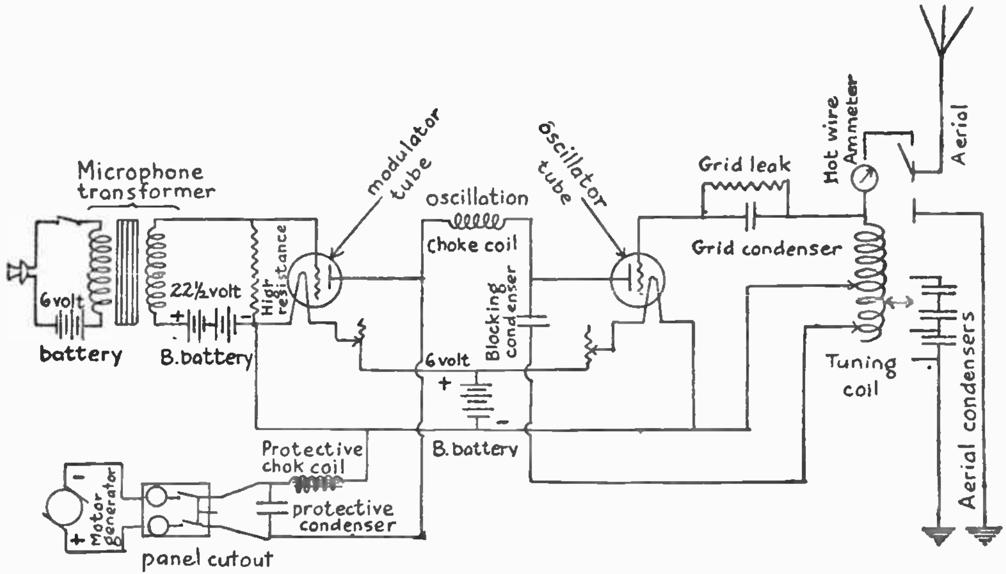


FIG. 90.—Wiring Diagram of 25 to 50 Mile Wireless Telephone Transmitting Set.

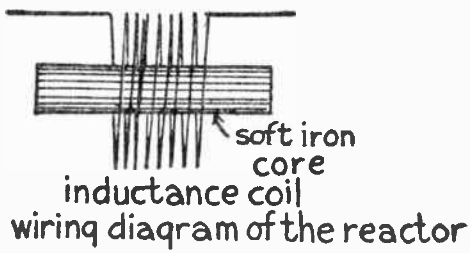
in the plate circuit; (3) a *reactance coil* or *reactor,* is used in the plate circuit; and (4) a *reactor* is used in the grid circuit.

The Oscillation Choke Coil.—You can make this choke coil by winding about 275 turns of *No. 28 B. and S. gauge* cotton covered magnet wire on a spool 2 inches in diameter and 4 inches long. Give it a good coat of shellac varnish and let it dry thoroughly.

The Plate and Grid Circuit Reactance Coils.—Where a single tube is used as an oscillator and a second tube is employed as a modulator, a *reactor*, which is a coil of wire wound on an iron core, is used in the plate circuit to keep the high voltage direct current of the motor-generator the same at all times. Likewise the grid circuit reactor is used to keep the voltage of the grid at a constant value. These reactors are made alike and a picture of one of them is shown in *Fig. 91.*

Connecting up the Apparatus.—All of the different pieces of apparatus are connected up as shown in *Fig. 89.* One of the ends of the secondary of the induction coil, or the microphone transformer, or the magnetic modulator is connected to the grid circuit and the other end to *clip 3* of the tuning coil.

A 100 to 200 Mile Wireless Telephone Transmitter—With Direct Current Motor Generator.—By using the same connections shown



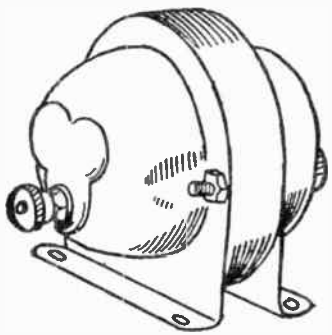


FIG. 91.—Plate and Grid Circuit Reactor.

in the wiring diagrams in *Fig. 89* and a single 50 watt oscillator tube your transmitter will then have a range of 100 miles or so, while if you connect up the apparatus as shown in *Fig. 90* and use two 50 watt tubes you can work up to 100 miles. Much of the apparatus for a 50 watt oscillator set where either one or two tubes are used is of the same size and design as that just described for the 5 watt oscillator sets, but, as in the C. W. telegraph sets, some of the parts must be proportionately larger. The required parts are (1) the *50 watt tube;* (2) the *grid leak resistance;* (3) the *filament rheostat;* (4) the *filament storage battery;* and (5) the *magnetic modulator.* All of these parts, except the latter, are described in detail under the heading of a *500 Mile C. W. Telegraph Transmitting Set* in *Chapter XV*, and are also pictured in that chapter.

It is not advisable to use an induction coil for the modulator for this set, but use, instead, either a telephone transformer, or better, a magnetic modulator of the second size which has an output of from 1½ to 3½ amperes. The magnetic modulator is described and pictured in this chapter.

A 25 to 50 Mile Wireless Telephone Transmitting Set—With 110 Volt Alternating Current.—If you have a 110 volt[1] alternating cur-

[1] Alternating current for lighting purposes ranges from 102.5 volts to 115 volts, so we take the medium and call it 110 volts.

rent available you can use it for the initial source of energy for your wireless telephone transmitter. The chief difference between a wireless telephone transmitting set that uses an alternating current and one that uses a direct current is that: (1) a *power transformer* is used for stepping up the voltage instead of a motor-generator, and (2) a *vacuum tube rectifier* must be used to convert the alternating current into direct current.

The Apparatus You Need.—For this telephone transmitting set you need: (1) *one aerial ammeter;* (2) one *tuning coil;* (3) one *telephone modulator;* (4) one *aerial series condenser;* (5) one *4 cell dry battery* or a 6 volt storage battery; (6) one *microphone transmitter;* (7) one *battery switch;* (8) one *grid condenser;* (9) one *grid leak;* (10) two *5 watt oscillator tubes with sockets;* (11) one *blocking condenser;* (12) one *oscillation choke coil;* (13) two *filter condensers;* (14) one *filter reactance coil;* (15) an *alternating current power transformer,* and (16) two *20 watt rectifier vacuum tubes.*

All of the above pieces of apparatus are the same as those described for the *25 Mile C. W. Telegraph Transmitter* in *Chapter XVI,* except: (a) the *microphone modulator;* (b) the *microphone transmitter* and (c) the *dry* or *storage battery,* all of which are described in this chapter; and the new parts which are: (d) the *rectifier vacuum tubes;* (e) the *filter condensers;* and (f) the *filter reactance coil;* further and finally, the power transformer has a *third* secondary coil on it and it is this that feeds the alternating current to the rectifier tubes, which in turn converts it into a pulsating direct current.

The Vacuum Tube Rectifier.—This rectifier has two electrodes, that is, it has a filament and a plate like the original vacuum tube detector, The smallest size rectifier tube requires a plate potential of 550 volts which is developed by one of the secondary coils of the power transformer. The filament terminal takes a current of 7.5 volts and this is supplied by another secondary coil of the transformer. This rectifier tube delivers a direct current of 20 watts at 350 volts. It looks exactly like the 5 watt oscillator tube which is pictured at *E* in *Fig. 77.*

The Filter Condensers.—These condensers are used in connection with the reactance coil to smooth out the pulsating direct current after it has passed through the rectifier tube. They have a capacitance of 1 mfd. and will stand 750 volts.

The Filter Reactance Coil.—This reactor which is shown in *Fig. 92,* has about the same

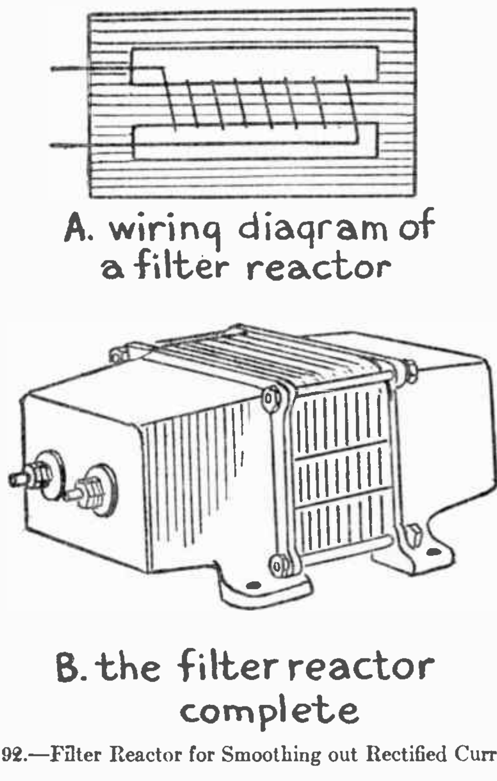


FIG. 92.—Filter Reactor for Smoothing out Rectified Currents.

appearance as the power transformer but it is somewhat smaller. It consists of a coil of wire wound on a soft iron core and has a large inductance, hence the capacitance of the filter condensers are proportionately smaller than where a small inductance is used which has been the general practice. The size you require for this set has an output of 160 milliamperes and it will supply current for one to four 5 watt oscillator tubes.

Connecting Up the Apparatus.—The wiring diagram in *Fig. 93* shows how the various pieces of apparatus for this telephone transmitter are connected up. You will observe: (1) that the terminals of the power transformer secondary coil which develops 10 volts are connected to the filaments of the oscillator tubes; (2) that the terminals of the other secondary coil which develops 10 volts are connected with the filaments of the rectifier tubes; (3) that the terminals of the third secondary coil which develops 550 volts are connected with the plates of the rectifier tubes; (4) that the pair of filter condensers are connected in parallel and these are connected to the mid-taps of the two filament secondary coils; (5) that the reactance coil and the third filter condenser are connected together in series and these are shunted across the filter condensers, which are in parallel; and, finally, (6) a lead connects the mid-tap of the 550-volt secondary coil of the power trans-

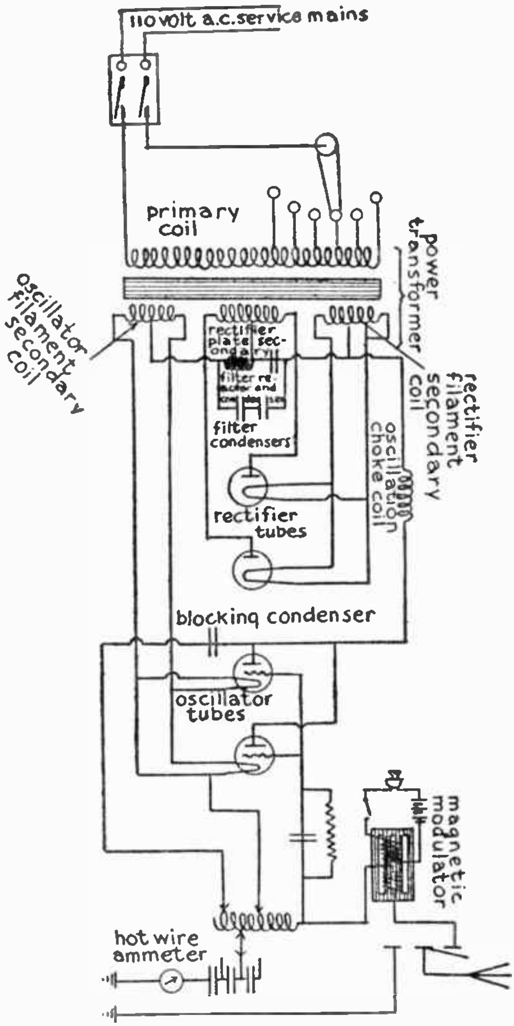


FIG. 98.—50 to 100 Mile Wireless Telephone Transmitter.

former with the connection between the reactor and the third filter condenser.

A 50 to 100 Mile Wireless Telephone Transmitting Set—With 110 Volt Alternating Current.—This telephone transmitter is built up of exactly the same pieces of apparatus and connected up in precisely the same way as the one just described and shown in *Fig. 93.*

Apparatus Required.—The only differences between this and the preceding transmitter are: (1) the *magnetic modulator,* if you use one, should have an output of 3½ to 5 amperes; (2) you will need two *50 watt oscillator tubes with sockets;* (3) two *150 watt rectifier tubes with sockets;* (4) an *aerial ammeter* that reads to *5 amperes;* (5) three *1 mfd. filter condensers* in parallel; (6) *two filter condensers of 1 mfd. capacitance* that will stand *1750 volts;* and (6) a *300 milliampere filter reactor.*

The apparatus is wired up as shown in *Fig. 93.*

CHAPTER XVIII

THE OPERATION OF VACUUM TUBE TRANSMITTERS

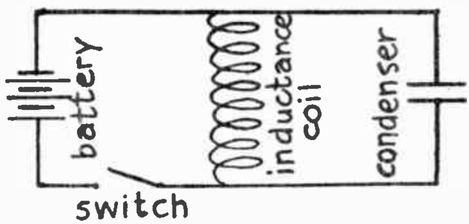
The three foregoing chapters explained in detail the design and construction of (1) two kinds of C. W. telegraph transmitters, and (2) two kinds of wireless telephone transmitters, the difference between them being whether they used (*A*) a direct current, or (*B*) an alternating current as the initial source of energy. Of course there are other differences between those of like types as, for instance, the apparatus and connections used (*a*) in the key circuits, and (*b*) in the microphone circuits. But in all of the transmitters described of whatever type or kind the same fundamental device is used for setting up sustained oscillations and this is the *vacuum tube.*

The Operation of the Vacuum Tube Oscillator.—The operation of the vacuum tube in producing sustained oscillations depends on (1) the action of the tube as a valve in setting up the oscillations in the first place and (2) the action of the grid in amplifying the oscillations thus set up, both of which we explained in *Chapter XIII.* In that chapter it was also pointed out that a very small change in the grid potential causes a corresponding and larger change in the amount of current flowing from the plate to the filament; and that if a vacuum tube is used for the production of oscillations the initial source of current must have a high voltage, in fact the higher the plate voltage the more powerful will be the oscillations.

To understand how oscillations are set up by a vacuum tube when a direct current is applied to it, take a look at the simple circuit shown at *A* in *Fig. 94.* Now when you close the switch the voltage from the battery charges the condenser and keeps it charged until you open it again; the instant you do this the condenser discharges through the circuit which includes it and the inductance coil, and the discharge of a condenser is always oscillatory.

Where an oscillator tube is included in the circuits shown at *B* and *C* in *Fig. 94,* the grid takes the place of the switch and any slight change in the voltage of either the grid or the plate is sufficient to start a train of oscillations going. As these oscillations surge through the tube the positive parts of them flow from the plate to the filament and these carry more of the direct current with them.

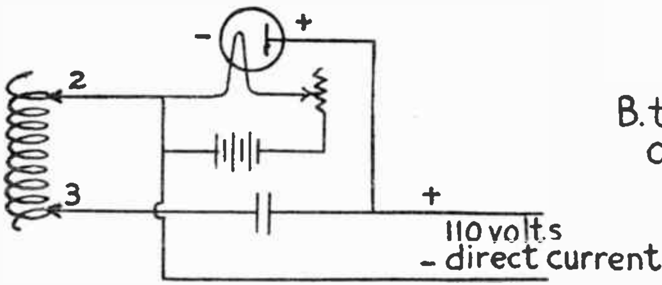
To make a tube set up powerful oscillations then, it is only necessary that an oscillation circuit shall be provided which will feed part of the oscillations set up by the tube back to the grid circuit and when this is done the oscillations will



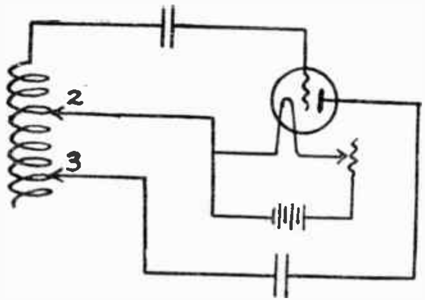
(*A*) Fig. 94.—How a Direct Current Sets up Oscillations.

keep on being amplified until the tube reaches the limit of its output.

The Operation of C. W. Telegraph Transmitters With Direct Current—Short Distance C. W. Transmitter.—In the transmitter shown in the wiring diagram in *Fig. 76* the positive part of the 110 volt direct current is carried down from the lamp socket through one side of the panel cut-out, thence through the choke coil and to the plate of the oscillator tube, when the latter



A- the high voltage direct current and plate oscillation circuits



B. the plate and grid oscillation circuits

(*B*) and (*C*) Fig. 94.—Operation of Vacuum Tube Oscillators.

is charged to the positive sign. The negative part of the 110 volt direct current then flows down the other wire to the filament so that there is a difference of potential between the plate and the filament of 110 volts. Now when the 6-volt battery current is switched on the filament is heated to brilliancy, and the electrons thrown off by it form a conducting path between it and the plate; the 110 volt current then flows from the latter to the former.

Now follow the wiring from the plate over to the blocking condenser, thence to *clip 1* of the tuning coil, through the turns of the latter to *clip 2* and over to the filament and, when the latter is heated, you have a *closed oscillation circuit*. The oscillations surging in the latter set up other and like oscillations in the tuning coil between the *end 3* which is connected with the grid, the aerial and the *clip 2,* and these surge through the circuit formed by this portion of the coil, the grid condenser and the filament; this is the amplifying circuit and it corresponds to the regenerative circuit of a receiving set.

When oscillations are set up in it the grid is alternately charged to the positive and negative signs. These reversals of voltage set up stronger and ever stronger oscillations in the plate circuit as before explained. Not only do the oscillations surge in the closed circuits but they run to and fro on the aerial wire when their energy is radiated in the form of electric waves. The oscillations are varied by means of the telegraph key which is placed in the grid circuit as shown in *Fig. 76.*

The Operation of the Key Circuit.—The effect in a C. W. transmitter when a telegraph key is connected in series with a buzzer and a battery and these are shunted around the condenser in the grid circuit, is to rapidly change the wave form of the sustained oscillations. While no sound can be heard in the headphones at the receiving station so long as the points of the key are not in contact, when they are in contact the oscillations are modulated and sounds are heard in the headphones that correspond to the frequency of the buzzer in the key circuit.

The Operation of C. W. Telegraph Transmitters with Direct Current.—The chief differences between the long distance sets which use a direct current, i.e., those described in *Chapter XV,* and the short distance transmitting sets are that the former use: (1) a motor-generator set for changing the low voltage direct current into high voltage direct current, and (2) a chopper in the key circuit. The way the motor-generator changes the low- into high-voltage current has been explained in *Chapter XV*.

The chopper interrupts the oscillations surging through the grid circuit at a frequency that the ear can hear, that is to say, about 800 to 1,000 times per second. When the key is open, of course, the sustained oscillations set up in the circuits will send out continuous waves but when the key is closed these oscillations are broken up and then they send out discontinuous waves. If a heterodyne receiving set, see *Chapter XIV*, is being used at the other end you can dispense with the chopper and the key circuit needed is very much simplified. The operation of key circuits of the latter kind will be described presently.

The Operation of C. W. Telegraph Transmitters with Alternating Current—With a Single Oscillator Tube.—Where an oscillator tube telegraph transmitter is operated by a 110 volt alternating current as the initial source of energy, a buzzer, chopper or other interruptor is not needed in the key circuit. This is because oscillations are set up only when the plate is energized with the positive part of the alternating current and this produces an intermittent musical tone in the headphones. Hence this kind of a sending set is called a *tone transmitter.*

Since oscillations are set up only by the positive part or voltage of an alternating current it is clear that, as a matter of fact, this kind of a transmitter does not send out continuous waves and therefore it is not a C. W. transmitter. This is graphically shown by the curve of the wave

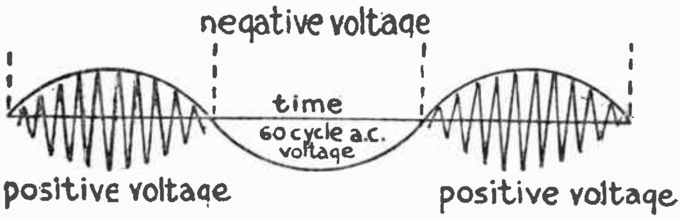


FIG. 95.—Positive Voltage only sets up Oscillations.

form of the alternating current and the oscillations that are set up by the positive part of it in *Fig. 95.* Whenever the positive half of the alternating current energizes the plate then oscillations are set up by the tube and, conversely, when the negative half of the current charges the plate no oscillations are produced.

You will also observe that the oscillations set up by the positive part of the current are not of constant amplitude but start at zero the instant the positive part begins to energize the plate and they keep on increasing in amplitude as the current rises in voltage until the latter reaches its maximum; then as it gradually drops again to zero the oscillations decrease proportionately in amplitude with it.

Heating the Filament with Alternating Current.—Where an alternating current power transformer is used to develop the necessary plate voltage a second secondary coil is generally provided for heating the filament of the oscillation tube. This is better than a direct current for it adds to the life of the filament. When you use an alternating current to heat the filament keep it at the same voltage rather than at the same amperage (current strength). To do this you need only to use a voltmeter across the filament terminals instead of an ammeter in series with it; then regulate the voltage of the filament with a rheostat.

The Operation of C. W. Telegraph Transmitters with Alternating Current—With Two Oscillator Tubes.—By using two oscillator tubes and connecting them up with the power transformer and oscillating circuits as shown in the wiring diagram in *Fig. 83* the plates are positively energized alternately with every reversal of the current and, consequently, there is no time period between the ending of the oscillations set up by one tube and the beginning of the oscillations set up by the other tube. In other words these oscillations are sustained but as in the case of those of a single tube, their amplitude rises and falls. This kind of a set is called a *full wave rectification* transmitter.

The waves radiated by this transmitter can be received by either a crystal detector or a plain vacuum-tube detector but the heterodyne receptor will give you better results than either of the foregoing types.

The Operation of Wireless Telephone Transmitters with Direct Current—Short Distance Transmitter.—The operation of this short distance wireless telephone transmitter, a wiring diagram of which is shown in *Fig. 85* is exactly the same as that of the *Direct Current Short Distance C. W. Telegraph Transmitter* already explained in this chapter. The only difference in the operation of these sets is the substitution of the *microphone transmitter* for the telegraph key.

The Microphone Transmitter.—The microphone transmitter that is used to vary, or modulate, the sustained oscillations set up by the oscillator tube and circuits is shown in *Fig. 84.* By referring to the diagram at *A* in this figure you will readily understand how it operates. When you speak into the mouthpiece the *sound waves,* which are waves in the air, impinge upon the diaphragm and these set it into vibration—that is, they make it move to and fro.

When the diaphragm moves toward the back of the transmitter it forces the carbon granules that are in the cup closer together; this lowers their resistance and allows more current from the battery to flow through them; when the pressure of the air waves is removed from the diaphragm it springs back toward the mouth-piece and the carbon granules loosen up when the resistance offered by them is increased and less current can flow through them. Where the oscillation current in the aerial wire is small the transmitter can be connected directly in series with the latter when the former will surge through it. As you speak into the microphone transmitter its resistance is varied and the current strength of the oscillations is varied accordingly.

The Operation of Wireless Telephone Transmitters with Direct Current—Long Distance Transmitters.—In the wireless telephone transmitters for long distance work which were shown and described in the preceding chapter a battery is used to energize the microphone transmitter, and these two elements are connected in series with a *microphone modulator.* This latter device may be either (1) a *telephone induction coil,* (2) a *microphone transformer,* or (3) a *magnetic modulator;* the first two of these devices step-up the voltage of the battery current and the amplified voltage thus developed is impressed on the oscillations that surge through the closed oscillation circuit or the aerial wire system according to the place where you connect it. The third device works on a different principle and this will be described a little farther along.

The Operation of Microphone Modulators—The Induction Coil.—This device is really a miniature transformer, see *A* in *Fig. 86,* and its purpose is to change the 6 volt direct current that flows through the microphone into 100 volts alternating current; in turn, this is impressed on the oscillations that are surging in either (1) the grid circuit as shown at *A* in *Fig. 89,* and in *Fig. 90,* (2) the aerial wire system, as shown at *B* in *Fig. 89* and *Fig. 93.* When the current from the battery flows through the primary coil it magnetizes the soft iron core and as the microphone varies the strength of the current the high voltage alternating currents set up in the secondary coil of the induction coil are likewise varied, when they are impressed upon and modulate the oscillating currents.

The Microphone Transformer.—This is an induction coil that is designed especially for wireless telephone modulation. The iron core of this transformer is also of the open magnetic circuit type, see *A* in *Fig. 87,* and the *ratio* of the turns[1] of the primary and the secondary coil is such that when the secondary current is impressed upon either the grid circuit or the aerial wire system it controls the oscillations flowing through it with the greatest efficiency.

The Magnetic Modulator.—This piece of apparatus is also called a *magnetic amplifier*. The iron core is formed of very thin plates, or *laminations* as they are called, and this permits high-frequency oscillations to surge in a coil wound on it. In this transformer, see *A* in *Fig. 88,* the current flowing through the microphone varies the magnetic permeability of the soft iron core by the magnetic saturation of the latter. Since the microphone current is absolutely distinct from the oscillating currents surging through the coil

[1] See Page 72.

of the transformer a very small direct current flowing through a coil on the latter will vary or modulate very large oscillating currents surging through the former. It is shown connected in the aerial wire system at *A* in *Fig. 88,* and in *Fig. 93.*

Operation of the Vacuum Tube as a Modulator.—Where a microphone modulator of the induction coil or microphone transformer type is connected in the grid circuit the modulation is not very effective, but by using a second tube as a *modulator,* as shown in *Fig. 90,* an efficient degree of modulation can be had. Now there are two methods by which a vacuum tube can be used as a modulator and these are: (1) by the *absorption* of the energy of the current set up by the oscillator tube, and (2) by *varying* the direct current that energizes the plate of the oscillator tube.

The first of these two methods is not used because it absorbs the energy of the oscillating current produced by the tube and it is therefore wasteful. The second method is an efficient one, as the direct current is varied before it passes into the oscillator tube. This is sufficient reason for describing only the second method. The voltage of the grid of the modulator tube is varied by the secondary coil of the induction coil or microphone transformer, above described. In this way the modulator tube acts like a variable resistance but it amplifies the variations impressed on the oscillations set up by the oscillator tube. As the magnetic modulator does the same thing, a vacuum tube used as a modulator is not needed where the former is employed. For this reason a magnetic modulator is the cheapest in the long run.

The Operation of Wireless Telephone Transmitters with Alternating Current.—Where an initial alternating current is used for wireless telephony, the current must be rectified first and then smoothed out before passing into the oscillator tube to be converted into oscillations. Further so that the oscillations will be sustained, two oscillator tubes must be used, and, finally, in order that the oscillations may not vary in amplitude the alternating current must be first changed into direct current by a pair of rectifier vacuum tubes, as shown in *Fig. 93.* When this is done the plates will be positively charged alternately with every reversal of the current in which case there will be no break in the continuity of the oscillations set up and therefore in the waves that are sent out.

The Operation of Rectifier Vacuum Tubes.—The vacuum tube rectifier is simply a two electrode vacuum tube. The way in which it changes a commercial alternating current into pulsating direct current is the same as that in which a two electrode vacuum tube detector changes an oscillating current into pulsating direct currents and this has been explained in detail under the heading of *The Operation of a Two Electrode Vacuum Tube Detector* in *Chapter XI.* In the *C. W. Telegraph Transmitting Sets* described in *Chapter XVI,* the oscillator tubes act as rectifiers as well as oscillators but for wireless telephony the alternating current must be rectified first so that a continuous direct current will result.

The Operation of Reactors and Condensers.—A reactor is a single coil of wire wound on an iron core, see *Fig. 90* and *A* in *Fig. 91,* and it should preferably have a large inductance. The reactor for the plate and grid circuit of a wireless telephone transmitter where one or more tubes are used as modulators as shown in the wiring diagram in *Fig. 90,* and the filter reactor shown in *Fig. 92,* operate in the same way.

When an alternating current flows through a coil of wire the reversals of the current set up a *counter electromotive force* in it which opposes, that is *reacts,* on the current, and the *higher* the frequency of the current the *greater* will be the *reactance.* When the positive half of an alternating current is made to flow through a large resistance the current is smoothed out but at the same time a large amount of its energy is used up in producing heat.

But when the positive half of an alternating current is made to flow through a large inductance it acts like a large resistance as before and likewise smooths out the current, but none of its energy is wasted in heat and so a coil having a large inductance, which is called an *inductive reactance,* or just *reactor* for short, is used to smooth out, or filter, the alternating current after it has been changed into a pulsating direct current by the rectifier tubes.

A condenser also has a reactance effect on an alternating current but different from an induction coil the *lower* the frequency the *greater* will be the reactance. For this reason both a filter reactor and *filter condensers* are used to smooth out the pulsating direct currents.

CHAPTER XIX

HOW TO MAKE A RECEIVING SET FOR $5.00 OR LESS

In the chapters on *Receptors* you have been told how to build up high-grade sets. But there are thousands of boys, and, probably, not a few men, who cannot afford to invest $25.00, more or less, in a receiving set and would like to experiment in a small way.

The following set is inexpensive, and with this cheap, little portable receptor you can get the Morse code from stations a hundred miles distant and messages and music from broadcasting stations if you do not live too far away from them. All you need for this set are: (1) a *crystal detector,* (2) a *tuning coil* and (3) an *earphone.* You can make a crystal detector out of a couple of binding posts, a bit of galena and a piece of brass wire, or, better, you can buy one all ready to use for 50 cents.

The Crystal Detector.—This is known as the *Rasco baby detector* and is shown in *Fig. 96.* The base is made of black composition and on it is mounted a standard in which a rod slides and on one end of this there is fixed a hard rubber adjusting knob while the other end carries a thin piece of *phosphor-bronze wire,* called a *cat-whisker.* To secure the galena crystal in the cup you simply unscrew the knurled cap, place it in the

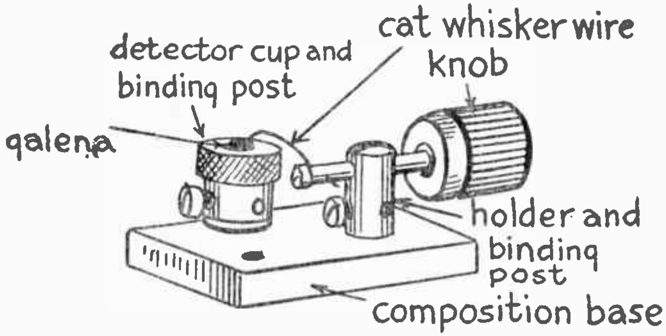


FIG. 96.—Rasco Baby Crystal Detector.

cavity of the post and screw the cap back on again. The free end of the cat-whisker wire is then adjusted so that it will rest lightly on the exposed part of the galena.

The Tuning Coil.—You will have to make this tuning coil, which you can do at a cost of less than $1.00, as the cheapest tuning coil you can buy costs at least $3.00, and we need the rest of our $5.00 to invest in the earphone. Get a cardboard tube, such as is used for mailing purposes, 2 inches in diameter and 3 inches long, see *A* in *Fig. 97*. Now wind on 250 turns of *No. 30 Brown and Sharpe gauge plain enameled magnet wire.* You can use *No. 30 double cotton covered magnet wire,* in which case you will have

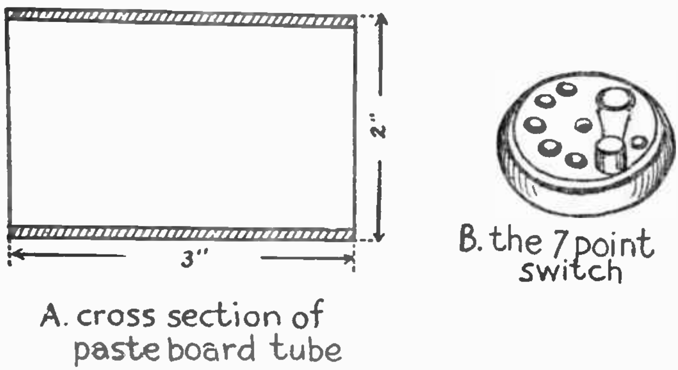


Fig. 97.—How the Tuning Coil is Made.

to shellac the tube and the wire after you get it on.

As you wind on the wire take off a tap at every 15th turn, that is, scrape the wire and solder on a piece about 7 inches long, as shown in *Fig. 99;* and do this until you have 6 taps taken off. Instead of leaving the wires outside of the tube bring them to the inside of it and then out through one of the open ends. Now buy a *round* *wood-base switch* with 7 contact points on it as shown at *B* in *Fig. 97.* This will cost you *25* or *50 cents.*

The Headphone.—An ordinary Bell telephone receiver is of small use for wireless work as it is wound to too low a resistance and the diaphragm is much too thick. If you happen to have

FIG. 98.—Mesco 1000 Ohm Head Set.

a Bell phone you can rewind it with *No. 40* single covered silk magnet wire, or enameled wire of the same size, when its sensitivity will be very greatly improved. Then you must get a thin diaphragm and this should *not* be enameled, as this tends to dampen the vibrations of it. You can get a diaphragm of the right kind for 5 cents.

The better way, though, is to buy an earphone made especially for wireless work. You can get one wound to 1000 ohms resistance for $1.75 and this price includes a cord. For $1.00 extra you

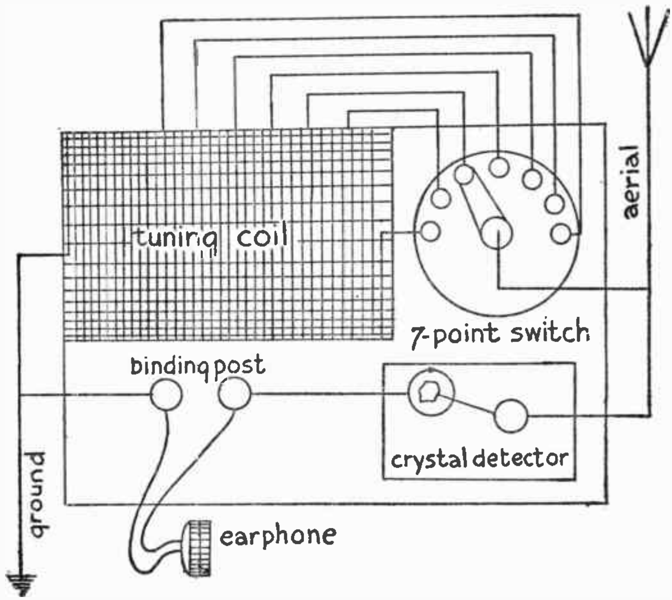


Fig. 99.—Schematic Layout of Receiving Set.

can get a head-band for it, and then your phone will look like the one pictured in *Fig. 98.*

How to Mount the Parts.—Now mount the coil on a wood base, ½ or 1 inch thick, 3½ inches wide and 5½ inches long, and then connect one end of the coil to one of the end points on the switch, and connect each succeeding tap to one of the switch points, as shown schematically in *Fig. 99* and diagrammatically in *Fig. 100*. This

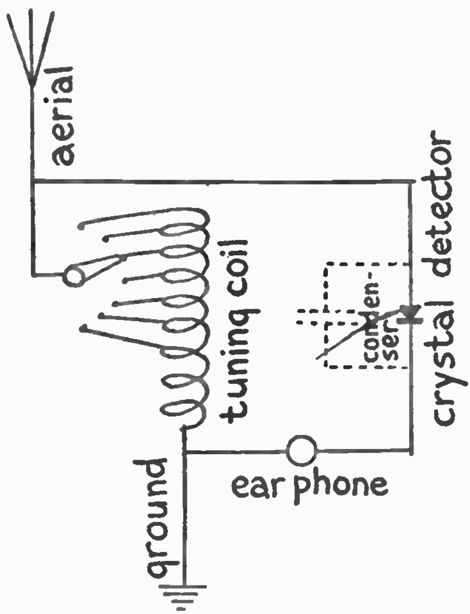


FIG. 100.—Wiring Diagram for Receiving Set.

done, screw the switch down to the base. Finally screw the detector to the base and screw two binding posts in front of the coil. These are for the earphone.

The Condenser.—You do not have to connect a condenser across the earphone but if you do you will improve the receiving qualities of the receptor.

How to Connect Up the Receptor.—Now connect up all the parts as shown in *Figs. 99* and *100,* then connect the leading-in wire of the aerial with the lever of the switch; and connect the free end of the tuning coil with the *ground.* If you have no aerial wire try hooking it up to a rain pipe that is *not grounded* or the steel frame of an umbrella. For a *ground* you can use a water pipe, an iron pipe driven into the ground, or a hydrant. Put on your headphone, adjust the detector and move the lever over the switch contacts until it is in adjustment and then, if all your connections are properly made, you should be able to pick up messages.

A 23 or 43 plate variable condenser connected from the switch arm of the coil to the ground connection will increase the wave length range of the set and at the same time assist in eliminating interference.

APPENDIX

USEFUL INFORMATION

ABBREVIATIONS OF UNITS

Unit	Abbreviation	Unit	Abbreviation
ampere	amp.	kilometers	km.
ampere-hours	amp.-hr.	kilowatts	kw.
centimeter	cm.	kilowatt-hours	kw.-hr.
centimeter-gram-second	c.g.s.	kilovolt-amperes	kv.-a.
cubic centimeters	$cm.^3$	meters	m.
cubic inches	cu. in.	microfarads	$\mu f.$
cycles per second	$\sim$	micromicrofarads	$\mu\mu f.$
degrees Centigrade	°C.	millihenries	mh.
degrees Fahrenheit	°F.	millimeters	mm.
feet	ft.	pounds	lb.
foot-pounds	ft.-lb.	seconds	sec.
grams	g.	square centimeters	$cm.^2$
henries	h.	square inches	sq. in.
inches	in.	volts	v.
kilograms	kg.	watts	w.

PREFIXES USED WITH METRIC SYSTEM UNITS

Prefix	Abbreviation	Meaning
micro	μ	1 millionth
milli	m.	1 thousandth
centi	c.	1 hundredth
deci	d.	1 tenth
deka	dk.	10
hekto	h.	1 hundred
kilo	k.	1 thousand
mega	m.	1 million

SYMBOLS USED FOR VARIOUS QUANTITIES

Quantity	Symbol	Quantity	Symbol
capacitance	C	magnetic field intensity	A
conductance	g	magnetic flux	ϕ
coupling co-efficient	k	magnetic induction	B
current, instantaneous value	i	period of a complete oscillation	T
current, effective value	I	potential difference	V
decrement	δ	quantity of electricity	Q
dielectric constant	α	ratio of the circumference of a circle to its diameter $=3.1416$	π
electric field intensity	ϵ	reactance	X
electromotive force, instantaneous value	E	resistance	R
electromotive force, effective value	F	time	t
energy	W	velocity	v
force	F	velocity of light	c
frequency	f	wave length	λ
frequency $\times 2\pi$	ω	wave length in meters	λm
impedance	Z	work	W
inductance, self	L	permeability	μ
inductance, mutual	M	square root	$\sqrt{}$

TABLE OF ENAMELED WIRE

No. of Wire, B. & S. Gauge	Turns per Linear Inch	Turns per Square Inch	Ohms per Cubic Inch of Winding	No. of Wire, B. & S. Gauge	Turns per Linear Inch	Turns per Square Inch	Ohms per Cubic Inch of Winding
20	30	885	.748	32	116	21,000	183.00
22	37	1400	1.88	34	145	13,430	456.00
24	46	2160	4.61	36	178	31,820	1098.00
26	58	3460	11.80	38	232	54,080	2968.00
28	73	5400	29.20	40	294	86,500	7547.00
30	91	8260	70.90				

TABLE OF FREQUENCY AND WAVE LENGTHS

W. L.—Wave Lengths in Meters. F.—Number of Kilocycles per Second. O. or $\sqrt{L.C.}$ is called Oscillation Constant. C.—Capacity in Microfarads. L.—Inductance in Centimeters. 1000 Centimeters = 1 Microhenry.

W. L.	F.	O. or $\sqrt{L.C.}$	L. C.	W. L.	F.	O. or $\sqrt{L.C}$	L. C.
1	300,000	0173	.0003	1,300	230	21.81	475.70
2	150,000	.0331	.0011	1,400	214	23.49	551.80
3	100,000	.0424	.0018	1,500	200	25.17	633.50
4	75,000	0671	.0045	1,600	187	26.84	720.40
5	60,000	0755	.0057	1,700	176	28.52	813.40
6	50,000	101	.0101	1,800	166	30.20	912.00
7	42,900	1174	.0138	1,900	157	31.88	1,016.40
8	37,500	134	.0180	2,000	150	33.55	1,125.60
9	33,330	.151	.0228	2,100	142	35.23	1,241.20
10	30,000	168	.0282	2,200	136	36.91	1,362.40
20	15,000	.336	.1129	2,300	130	38.59	1,489.30
30	10,000	.504	.2530	2,400	125	40.27	1,621.80
40	7,500	.671	.450	2,500	120	41.95	1,759.70
50	6,000	.839	.7039	2,600	115	43.62	1,902.60
100	3,000	1.68	2.82	2,700	111	45.30	2,052.00
150	2,000	2.52	6.35	2,800	107	46.89	2,207.00
200	1,500	3.36	11.29	2,900	103	48.66	2,366.30
250	1,200	4.19	17.55	3,000	100	50.33	2,533.20
300	1,000	5.05	25.30	4,000	75	67.11	4,504.00
350	857	5.87	34.46	5,000	60	83.89	7,038.00
400	750	6.71	45.03	6,000	50	100.7	10,130.00
450	666	7.55	57.00	7,000	41	117.3	13,630.00
500	600	8.39	70.39	8,000	37	134.1	18,000.00
550	545	9.23	85.19	9,000	33	151.0	22,820.00
600	500	10.07	101.41	10,000	30	167.9	28,150.00
700	428	11.74	137.83	11,000	27	184.8	34,150.00
800	375	13.42	180.10	12,000	25	201.5	40,600.00
900	333	15.10	228.01	13,000	23	218.3	47,600.00
1.000	300	16.78	281.57	14,000	21	235.0	55,200.00
1,100	272	18.45	340.40	15,000	20	252.0	63,500.00
1.200	250	20.13	405.20	16,000	18	269.0	72,300.00

TABLE OF SPARKING DISTANCES

In Air for Various Voltages between Needle Points

Volts	Distance		Volts	Distance	
	Inches	Centimeter		Inches	Centimeter
5,000	.225	.57	60,000	4.65	11.8
10,000	.470	1.19	70,000	5.85	14.9
15,000	.725	1.84	80,000	7.10	18.0
20,000	1.000	2.54	90,000	8.35	21.2
25,000	1.300	3.30	100,000	9.60	24.4
30,000	1.625	4.10	110,000	10.75	27.3
35,000	2.000	5.10	120,000	11.85	30.1
40,000	2.450	6.20	130,000	12.95	32.9
45,000	2.95	7.50	140,000	13.95	35.4
50,000	3.55	9.00	150,000	15.00	38.1

FEET PER POUND OF INSULATED MAGNET WIRE

No. of B. & S. Gauge	Single Cotton, 4-Mils	Double Cotton, 8-Mils	Single Silk, 1¾-Mils	Double Silk, 4-Mils	Enamel
20	311	298	319	312	320
21	389	370	403	389	404
22	488	461	503	493	509
23	612	584	636	631	642
24	762	745	800	779	810
25	957	903	1,005	966	1,019
26	1,192	1,118	1,265	1,202	1,286
27	1,488	1,422	1,590	1,543	1,620
28	1,852	1,759	1,972	1,917	2,042
29	2,375	2,207	2,570	2,485	2,570
30	2,860	2,534	3,145	2,909	3,240
31	3,800	2,768	3,943	3,683	4,082
32	4,375	3,737	4,950	4,654	5,132
33	5,390	4,697	6,180	5,689	6,445
34	6,500	6,168	7,740	7,111	8,093
35	8,050	6,737	9,600	8,534	10,197
36	9,820	7,877	12,000	10,039	12,813
37	11,860	9,309	15,000	10,666	16,110
38	14,300	10,636	18,660	14,222	20,274
39	17,130	11,907	23,150	16,516	25,519
40	21,590	14,222	28,700	21,333	32,107

CHART OF VACUUM TUBE

Type of Tube	"A" Battery Voltage	Filament Current	"B" Battery Voltage		"C" Battery Voltage	Value of Grid Leak Meg-ohms	Resistance of Rheostat Ohms	As Detector	As Audio-Frequency Amplifier	As Radio-Frequency Amplifier	As Power Amplifier	As Oscillator
			Detector	Amplifier								
UV 199 C 299	4.5 (dry cells)	0.06	22½–45	45–90	1–4.5	2–3	30.0	Good	Good	Very good	Fair	Poor
UV 201-A C 301-A	6.0	0.25	22½–45	45–100	3–6	2	30.0	Good	Very good	Good	Very good	Very good
UV 202 C 302	10.0	2.25	......	100–500	3–9	....	6.0	Fair	Good	Poor	Good	Good
W.E. "N" tube	1.5 (dry cell)	0.25	22½	45	1–2	½–2	6.0	Good	Fair	Very good	Poor	Good
UX-112	6	.5	22½–45	135	9	3–5	10	Good	Good	Poor	Good	Good
UX-120	3	.125	......	135	22½	....	30	Poor	Last stage only	Poor	Very Good	Good
UX-171	6	.5	......	135–180	40	....	10	Poor	Last stage only	Poor	Very good	Good
UX-210	7.5–6	1.25–1.1	......	90–425	4.5–35	....	None needed if 6 volts is used	....	Good	....	Good	Very good
UX-240	6	.25	45–180	135–180	1.5–3	2	6	Good	Very good	Fair	Poor	Fair

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to five dots.

A	· —
B	— · · ·
C	— · — ·
D	— · ·
E	·
F	· · — ·
G	— — ·
H	· · · ·
I	· ·
J	· — — —
K	— · —
L	· — · ·
M	— —
N	— ·
O	— — —
P	· — — ·
Q	— — · —
R	· — ·
S	· · ·
T	—
U	· · —
V	· · · —
W	· — —
X	— · · —
Y	— · — —
Z	— — · ·
Ä (German)	· — · —
Á or Å (Spanish-Scandinavian)	· — — · —
CH (German-Spanish)	— — — —
É (French)	· · — · ·
Ñ (Spanish)	— — · — —
Ö (German)	— — — ·
Ü (German)	· · — —
1	· — — — —
2	· · — — —
3	· · · — —
4	· · · · —
5	· · · · ·
6	— · · · ·
7	— — · · ·
8	— — — · ·
9	— — — — ·
0	— — — — —

Period	· · · · · ·
Semicolon	— · — · — ·
Comma	· — · — · —
Colon	— — — · · ·
Interrogation	· · — — · ·
Exclamation point	— — · · — —
Apostrophe	· — — — — ·
Hyphen	— · · · · —
Bar indicating fraction	— · · — ·
Parenthesis	— · — — · —
Inverted commas	· — · · — ·
Underline	· · — — · —
Double dash	— · · · —
Distress Call	· · · — — — · · ·
Attention call to precede every transmission	— · — · —
General inquiry call	— · — · — — · —
From (de)	— · · ·
Invitation to transmit (go ahead)	— · —
Warning—high power	— — · · — —
Question (please repeat after ... ..)—interrupting long messages	· · — — · ·
Wait	· — · · ·
Break (Bk.) (double dash)	— · · · —
Understand	· · · — ·
Error	· · · · · · · ·
Received (O. K.)	· — ·
Position report (to precede all position messages)	— · — ·
End of each message (cross)	· — · — ·
Transmission finished (end of work) (conclusion of correspondence)	· · · — · —

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

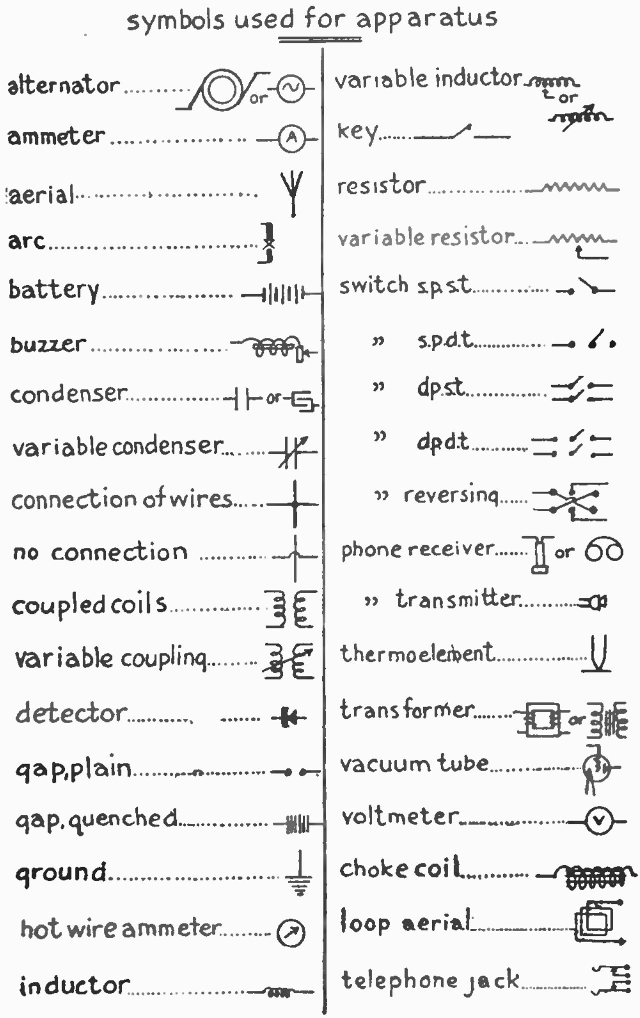
LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

ABBREVIATION	QUESTION	ANSWER OR NOTICE
PRB	Do you wish to communicate by means of the International Signal Code?	I wish to communicate by means of the International Signal Code.
QRA	What ship or coast station is that?	This is........
QRB	What is your distance?	My distance is........
QRC	What is your true bearing?	My true bearing is........degrees.
QRD	Where are you bound for?	I am bound for........
QRF	Where are you bound from?	I am bound from........
QRG	What line do you belong to?	I belong to the........Line.
QRH	What is your wave length in meters?	My wave length is........meters.
QRJ	How many words have you to send?	I have........words to send.
QRK	How do you receive me?	I am receiving well.
QRL	Are you receiving badly? Shall I send 20? • • • — • for adjustment?	I am receiving badly. Please send 20. • • • — • for adjustment.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are the atmospherics strong?	Atmospherics are very strong.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you anything for me?	I have nothing for you.
QRV	Are you ready?	I am ready. All right now.
QRW	Are you busy?	I am busy (or: I am busy with........). Please do not interfere.
QRX	Shall I stand by?	Stand by. I will call you when required.
QRY	When will be my turn?	Your turn will be No. ....
QRZ	Are my signals weak?	Your signals are weak.
QSA	Are my signals strong?	Your signals are strong.
QSB	Is my tone bad?	The tone is bad.
	Is my spark bad?	The spark is bad.
QSC	Is my spacing bad?	Your spacing is bad.
QSD	What is your time?	My time is........
QSF	Is transmission to be in alternate order or in series?	Transmission will be in alternate order.
QSG	....	Transmission will be in series of 5 messages.
QSH	....	Transmission will be in series of 10 messages.
QSJ	What rate shall I collect for........?	Collect ....
QSK	Is the last radiogram canceled?	The last radiogram is canceled.
QSL	Did you get my receipt?	Please acknowledge.
QSM	What is your true course?	My true course is........degrees.
QSN	Are you in communication with land?	I am not in communication with land.
QSO	Are you in communication with any ship or station (or: with........)?	I am in communication with........(through ....).
QSP	Shall I inform........that you are calling him?	Inform........that I am calling him.
QSQ	Is........calling me?	You are being called by........
QSR	Will you forward the radiogram?	I will forward the radiogram.
QST	Have you received the general call?	General call to all stations.
QSU	Please call me when you have finished (or: at ....o'clock)?	Will call when I have finished.
*QSV	Is public correspondence being handled?	Public correspondence is being handled. Please do not interfere.
QSW	Shall I increase my spark frequency?	Increase your spark frequency.
QSX	Shall I decrease my spark frequency?	Decrease your spark frequency.
QSY	Shall I send on a wave length of........meters?	Let us change to the wave length of........meters.
QSZ	....	Send each word twice. I have difficulty in receiving you.
QTA	....	Repeat the last radiogram.

*Public correspondence is any radio work, official or private, handled on commercial wave lengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

B—[illegible]


symbols used for apparatus
alternator .... or
ammeter ....
aerial ....
arc ....
battery ....
buzzer ....
condenser .... or
variable condenser........
connection of wires.....
no connection ....
coupled coils ....
variable coupling........
detector........... ....
gap, plain..............................
gap, quenched...............
ground...........................
hot wire ammeter.........
inductor.........................
variable inductor or
key.......
resistor ....
variable resistor...
switch s.p.s.t............
" s.p.d.t..............
" d.p.s.t..............
" d.p.d.t...........
" reversing......
phone receiver....... or
" transmitter...........
thermoelement..................
transformer........ or
vacuum tube..................
voltmeter.......................
choke coil..........
loop aerial.....................
telephone jack..............

DEFINITIONS OF ELECTRIC AND MAGNETIC UNITS

The *ohm* is the resistance of a thread of mercury at the temperature of melting ice, 14.4521 grams in mass, of uniform cross-section and a length of 106.300 centimeters.

The *ampere* is the current which when passed through a solution of nitrate of silver in water according to certain specifications, deposits silver at the rate of 0.00111800 of a gram per second.

The *volt* is the electromotive force which produces a current of 1 ampere when steadily applied to a conductor the resistance of which is 1 ohm.

The *coulomb* is the quantity of electricity transferred by a current of 1 ampere in 1 second.

The *ampere-hour* is the quantity of electricity transferred by a current of 1 ampere in 1 hour and is, therefore, equal to 3600 coulombs.

The *farad* is the capacitance of a condenser in which a potential difference of 1 volt causes it to have a charge of 1 coulomb of electricity.

The *henry* is the inductance in a circuit in which the electromotive force induced is 1 volt when the inducing current varies at the rate of 1 ampere per second.

The *watt* is the power spent by a current of 1 ampere in a resistance of 1 ohm.

The *joule* is the energy spent in 1 second by a flow of 1 ampere in 1 ohm.

The *horse-power* is used in rating steam machinery. It is equal to 746 watts.

The *kilowatt* is 1,000 watts.

The units of capacitance actually used in wireless work are the *microfarad,* which is the millionth part of a farad, because the farad is too large a unit; and the *C. G. S. electrostatic unit of capacitance,* which is often called the *centimeter of capacitance,* which is about equal to 1.11 microfarads.

The units of inductance commonly used in radio work are the *millihenry,* which is the thousandth part of a henry; and the *centimeter of inductance,* which is one one-thousandth part of a microhenry.

Note.—For further information about electric and magnetic units get the *Bureau of Standards Circular No. 60,* called *Electric Units and Standards,* the price of which is 15 cents; also get *Scientific Paper No. 292,* called *International System of Electric and Magnetic Units,* price 10 cents. These and other informative papers can be had from the *Superintendent of Documents, Government Printing Office,* Washington, D. C.

WIRELESS BOOKS

The Admiralty Manual of Wireless Telegraphy. 1920. Published by His Majesty's Stationery Office, London.

Ralph E. Batcher.—*Prepared Radio Measurements.* 1921. Wireless Press, Inc., New York City.

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Elmer E. Bucher.—*Vacuum Tubes in Wireless Communication.* 1919. Wireless Press, Inc., New York City.

Elmer E. Bucher.—*The Wireless Experimenter's Manual.* 1920. Wireless Press, Inc., New York City.

A. Frederick Collins.—*Wireless Telegraphy, Its History, Theory, and Practice.* 1905. McGraw Pub. Co., New York City.

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H. M. Dorsett.—*Wireless Telegraphy and Telephony.* 1920. Wireless Press, Ltd., London.

J. A. Fleming.—*Principles of Electric Wave Telegraphy.* 1919. Longmans, Green and Co., London.

Charles B. Hayward.—*How to Become a Wireless Operator.* 1918. *Modern Radio Practice,* Revised Edition. 1923. American Technical Society, Chicago, Ill.

G. D. Robinson.—*Manual of Radio Telegraphy and Telephony.* 1920. United States Naval Institute, Annapolis, Md.

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James L. Thomas.—*Fundamentals of Radio.* 1923. D. Van Nostrand Company, New York City.

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U. S. Standards Bureau.—*Radio Instruments and Measurements* (Circular 74) Wash. Supt, of Docs. 1918. 341 p. illus.

Zenneck, J.—*Wireless Telegraphy.* 1915. McGraw-Hill Book Company, New York City.

Send to the *Superintendent of Documents, Government Printing Office,* Washington, D. C., for a copy of *Price List No. 64* which lists the Government's books and pamphlets on wireless. It will be sent to you free of charge.

The Government publishes: (1) *A List af Commercial Government and Special Wireless Stations,* every year, price 15 cents; (2) *A List of Amateur Wireless Stations,* yearly, price 15 cents; (3) *A Wireless Service Bulletin* is published monthly, price 5 cents a copy, or 25 cents yearly; and (4) *Radio Communication Laws of the United States,* the *International Radio Telegraphic Convention and Regulations Governing Wireless Operators and the Use of Wireless on Ships and on Land,* price 15 cents a copy. Orders for the above publications should be addressed to the *Superintendent of Documents, Government Printing Office, Washington, D. C.*

MANUFACTURERS AND DEALERS IN APPARATUS AND SUPPLIES

Acme Apparatus Co., Cambridge, Mass.

American Hard Rubber Co., 11 Mercer Street, New York.

American Radio and Research Corporation, Medford Hillside, Mass.

Brach (L. S.) Mfg. Co., 127 Sussex Ave., Newark, N. J.

Brandes (C.) Inc., 237 Lafayette St., New York City.
Bunnell (J. H.) Company, Park Place, New York City.
Burgess Battery Company, Harris Trust Co. Bldg., Chicago, Ill.
Clapp-Eastman Co., 120 Main St., Cambridge, Mass.
Connecticut Telephone and Telegraph Co., Meriden, Conn.
Continental Fiber Co., Newark, Del.
Coto-Coil Co., Providence, R. I.
Crosley Mfg. Co., Cincinnati, Ohio.
Edison Storage Battery Co., Orange, N. J.
Electric Specialty Co., Stamford, Conn.
Electrose Mfg. Co., 60 Washington St., Brooklyn, N. Y.
General Electric Co., Schenectady, N. Y.
Grebe (A. H.) and Co., Inc., Richmond Hill, N. Y. C.
International Brass and Electric Co., 176 Beekman St., New York City.
International Insulating Co., 25 West 45th St., New York City.
King Amplitone Co., 82 Church St., New York City.
Kennedy (Colin B.) Co., Rialto Bldg., San Francisco, Cal.
Magnavox Co., Oakland, Cal.
Manhattan Electrical Supply Co., Park Place, N. Y.
Marshall-Gerken Co., Toledo, Ohio.
Michigan Paper Tube and Can Co., 2536 Grand River Ave., Detroit, Mich.
Murdock (Wm. J.) Co., Chelsea, Mass.
National Carbon Co., Inc., Long Island City, N. Y.
Pittsburgh Radio and Appliance Co., 112 Diamond St., Pittsburgh, Pa.
Plymouth Electric Co., 153 Court St., New Haven, Conn.
Radio Corporation of America, 233 Broadway, New York City.

Riley-Klotz Mfg. Co., 17-19 Mulberry St., Newark, N. J.
Radio Specialty Co., 96 Park Place, New York City.
Roller-Smith Co., 15 Barclay St., New York City.
Sleeper Radio Corporation, 88 Park Place, New York City.
Tuska (C. D.) Co., Hartford, Conn.
Western Electric Co., Chicago, Ill.
Westinghouse Electric Co., Pittsburgh, Pa.
Weston Electrical Instrument Co., 173 Weston Ave., Newark, N. J.
Westfield Machine Co., Westfield, Mass.

Allen-Bradley Co., 287 Greenfield Ave., Milwaukee, Wis.
Atwater-Kent Mfg. Co., 4713 Wissahickon Ave., Philadelphia, Pa.
Bruno Radio Corp., 223 Fulton St., New York City.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Dubilier Condenser & Radio Corp., 4377 Bronx Blvd., New York City.
Electric Storage Battery Co., Philadelphia, Pa.
Fansteel Products Co., Inc., North Chicago, Ill.
Fitch Radio Co., 105 West 40th St., New York City.
Hammarlund Mfg. Co., 424 West 33rd St., New York City.
Music Master Corp., 128 North 10th St., Philadelphia, Pa.
Schickerling Products Co., Newark, N. J.

ABBREVIATIONS OF COMMON TERMS

A. ....Aerial
A.C. ....Alternating Current
A.F. ....Audio Frequency
B. and S. ....Brown & Sharpe Wire Gauge
C. ....Capacity or Capacitance
C.G.S. ....Centimeter-Gram-Second
Cond. ....Condenser
Coup. ....Coupler
C.W. ....Continuous Waves
D.C. ....Direct Current
D.P.D.T. ....Double Point Double Throw
D.P.S.T. ....Double Point Single Throw
D.X. ....Distance
E. ....Short for Electromotive Force (Volt)
E.M.F. ....Electromotive Force
F. ....Filament or Frequency
G. ....Grid
Gnd. ....Ground
I. ....Current Strength (Ampere)
I.C.W. ....Interrupted Continuous Waves
KW. ....Kilowatt
L. ....Inductance
L.C. ....Loose Coupler
Litz. ....Litzendraht
Mfd. ....Microfarad
Neg. ....Negative
O.T. ....Oscillation Transformer
P. ....Plate
Prim. ....Primary
Pos. ....Positive
R. ....Resistance

R.F. .... Radio Frequency
Sec. .... Secondary
S.L.F. .... Straight Line Frequency
S.P.D.T. .... Single Point Double Throw
S.P.S.T. .... Single Point Single Throw
S.R. .... Self Rectifying
T. .... Telephone or Period (time) of Complete Oscillation
Tick. .... Tickler
V. .... Potential Difference
Var. .... Variometer
Var. Cond. .... Variable Condenser
V.T. .... Vacuum Tube
W.L. .... Wave Length
X. .... Reactance

GLOSSARY

A Battery.—See *Battery A*.

Abbreviations, Code.—Abbreviations of questions and answers used in wireless communication. The abbreviation *of a question* is usually in three letters of which the first is *Q*. Thus *Q R B* is the code abbreviation of *"what is your distance?"* and the answer *"My distance is . . ."* See *Page 305*.

Abbreviations, Units.—Abbreviations of various units used in wireless electricity. These abbreviations are usually lower case letters of the Roman alphabet, but occasionally Greek letters are used and other signs. Thus *amperes* is abbreviated *amp., micro,* which means *one millionth,* μ, etc. See *Page 299*.

Abbreviations of Words and Terms.—Letters used instead of words and terms for shortening them up where there is a constant repetition of them, as *A.C.* for *alternating current; C.W.* for *continuous waves; V.T.* for *vacuum tube,* etc. See *Page 313*.

Aerial.—Also called *antenna*. An aerial wire. One or more wires suspended in the air and insulated from its supports. It is the aerial that sends out the waves and receives them.

Aerial, Amateur.—An aerial suitable for sending out 200 meter wave lengths. Such an aerial wire system must not exceed 120 feet in length from the ground up to the aerial switch and from this through the leading-in wire to the end of the aerial.

Aerial Ammeter.—See *Ammeter, Hot Wire*.

Aerial, Bed-springs.—Where an outdoor aerial is not practicable *bed-springs* are often made to serve the purpose.

AERIAL CAPACITY.—See *Capacity, Aerial.*

AERIAL COUNTERPOISE.—Where it is not possible to get a good ground an *aerial counterpoise* or *earth capacity* can be used to advantage. The counterpoise is made like the aerial and is supported directly under it close to the ground but insulated from it.

AERIAL, DIRECTIONAL.—An inverted L or other aerial that will transmit and receive over greater distances to and from one direction than to and from another.

AERIAL, GROUND.—Signals can be received on a single long wire when it is placed on or buried in the earth or immersed in water. It is also called a *ground antenna* and an *underground aerial.*

AERIAL, LOOP.—Also called a *coil aerial, coil antenna, loop aerial, loop antenna* and when used for the purpose a *direction finder.* A coil of wire wound on a vertical frame.

AERIAL RESISTANCE.—See *Resistance, Aerial.*

AERIAL SWITCH.—See *Switch, Aerial.*

AERIAL WIRE.—(1) A wire or wires that form the aerial. (2) Wire that is used for aerials; this is usually copper or copper alloy.

AERIAL WIRE SYSTEM.—An aerial and ground wire and that part of the inductance coil which connects them. The open oscillation circuit of a sending or a receiving station.

AIR CORE TRANSFORMER.—See *Transformer, Air Core.*

AMATEUR AERIAL OR ANTENNA.—See *Aerial, Amateur.*

ALTERNATOR.—An electric machine that generates alternating current.

ALPHABET, INTERNATIONAL CODE.—A modified Morse alphabet of dots and dashes originally used in Continental Europe and, hence, called the *Continental Code.* It is now used for all general public service wireless communication all over the world and, hence, it is called the *International Code.* See *page 313.*

ALTERNATING CURRENT (*A.C*).—See *Current.*

ALTERNATING CURRENT TRANSFORMER.—See *Transformer.*

AMATEUR GROUND.—See *Ground, Amateur.*

AMMETER.—An instrument used for measuring the current strength, in terms of amperes, that flows in a circuit. Ammeters used for measuring direct and alternating currents make use of the *magnetic effects* of the currents. High frequency currents make use of the *heating effects* of the currents.

AMMETER, HOT-WIRE.—High frequency currents are usually measured by means of an instrument which depends on heating a wire or metal strip by the oscillations. Such an instrument is often called a *thermal ammeter, radio ammeter* and *aerial ammeter.*

AMMETER, AERIAL.—See *Ammeter, Hot Wire.*

AMMETER, RADIO.—See *Ammeter, Hot Wire.*

AMPERE.—The current which when passed through a solution of nitrate of silver in water according to certain specifications, deposits silver at the rate of 0.00111800 of a gram per second.

AMPERE-HOUR.—The quantity of electricity transferred by a current of 1 ampere in 1 hour and is, therefore, equal to 3600 coulombs.

AMPERE-TURNS.—When a coil is wound up with a number of turns of wire and a current is made to flow through it, it behaves like a magnet. The strength of the magnetic field inside of the coil depends on (1) the strength of the current and (2) the number of turns of wire on the coil. Thus a feeble current flowing through a large number of turns will produce as strong a magnetic field as a strong current flowing through a few turns of wire. This product of the current in amperes times the number of turns of wire on the coil is called the *ampere-turns.*

AMPLIFICATION, AUDIO FREQUENCY.—A current of audio frequency that is amplified by an amplifier tube or other means.

AMPLIFICATION, CASCADE.—See *Cascade Amplification.*

AMPLIFICATION, RADIO FREQUENCY.—A current of radio frequency that is amplified by an amplifier tube or other means before it reaches the detector.

AMPLIFICATION, REGENERATIVE.—A scheme that uses a third circuit to feed back part of the oscillations through a vacuum tube and which increases its sensitiveness when used as a detector and multiplies its action as an amplifier.

AMPLIFIER, AUDIO FREQUENCY.—A vacuum tube or other device that amplifies the signals after passing through the detector.

AMPLIFIER, MAGNETIC.—A device used for controlling radio frequency currents either by means of a telegraph key or a microphone transmitter. The controlling current flows through a separate circuit from that of the radio current and a fraction of an ampere will control several amperes in the aerial wire.

AMPLIFIERS, MULTI-STAGE.—A receiving set using two or more amplifiers. Also called *cascade amplification.*

AMPLIFIER, VACUUM TUBE.—A vacuum tube that is used either to amplify the radio frequency currents or the audio frequency currents.

AMPLITUDE OF WAVE.—The distance of the crest from the *O* line.

AMPLIFYING TRANSFORMER, AUDIO.—See *Transformer, Audio Amplifying.*

AMPLIFYING MODULATOR VACUUM TUBE.—See *Vacuum Tube, Amplifying Modulator.*

AMPLIFYING TRANSFORMER RADIO.—See *Transformer, Radio Amplifying.*

ANTENNA, AMATEUR.—See *Aerial, Amateur.*

ANTENNA SWITCH.—See *Switch, Aerial.*

APPARATUS SYMBOLS.—See *Symbols, Apparatus.*

ARMSTRONG CIRCUIT.—See *Circuit, Armstrong.*

ATMOSPHERICS.—Same as *Static,* which see.

ATTENUATION.—In sending wireless telegraph and telephone messages the energy of the electric waves decreases as the distance increases. This is called *attenuation* and it increases as the frequency is increased. This is the reason why short wave lengths will not carry as far as long wave lengths.

AUDIO FREQUENCY AMPLIFIER.—See *Amplifier, Audio Frequency.*

AUDIO FREQUENCY AMPLIFICATION.—See *Amplification, Audio Frequency.*

AUDIBILITY METER.—See *Meter, Audibility.*

AUDIO FREQUENCY.—See *Frequency, Audio.*

AUDIO FREQUENCY CURRENT.—See *Current, Audio Frequency.*

AUDION.—An early trade name given to the vacuum tube detector.

AUTODYNE RECEPTOR.—See *Receptor, Autodyne.*

AUTO TRANSFORMER.—See *Transformer, Auto.*

BAKELITE.—A manufactured insulating compound.

B BATTERY.—See *Battery B.*

BAND, WAVE LENGTH.—See *Wave Length Band.*

BASKET WOUND COILS.—See *Coils, Inductance.*

BATTERY, A.—The battery used to heat the filament of a vacuum tube, detector or amplifier.

BATTERY, B.—The battery used to energize the plate of a vacuum tube detector or amplifier.

BATTERY, BOOSTER.—This is the battery that is connected in series with the crystal detector.

BATTERY, C.—A small battery sometimes used to give the grid of a vacuum tube detector an extra negative, or bias, potential.

BATTERY, EDISON STORAGE.—A storage battery in which the elements are made of nickel and iron and immersed in an alkaline *electrolyte.*

BATTERY, LEAD STORAGE.—A storage battery in which the elements are made of lead and immersed in an acid electrolyte.

BATTERY POLES.—See *Poles, Battery.*

BATTERY, PRIMARY.—A battery that generates current by chemical action.

BATTERY, STORAGE.—A battery that develops a current after it has been charged.

BEAT RECEPTION.—See *Heterodyne Reception.*

BED SPRINGS AERIAL.—See *Aerial, Bed Springs.*

BLUB BLUB.—Over modulation in wireless telephony.

BROAD WAVE.—See *Wave, Broad.*

BRUSH DISCHARGE.—See *Discharge.*

BUZZER MODULATION.—See *Modulation, Buzzer.*

BLUE GLOW DISCHARGE.—See *Discharge.*

BOOSTER BATTERY.—See *Battery, Booster.*

BROADCASTING.—Sending out intelligence and music from a central station for the benefit of all who live within range of it and who have receiving sets.

CAPACITANCE.—Also called by the older name of *capacity.* The capacity of a condenser, inductance coil or other device capable of retaining a charge of electricity. Capacitance is measured in terms of the *microfarad.*

CAPACITIVE COUPLING.—See *Coupling, Capacitive.*

CAPACITY.—Any object that will retain a charge of electricity; hence an aerial wire, a condenser or a metal plate is sometimes called a *capacity.*

CAPACITY, AERIAL.—The amount to which an aerial wire system can be charged. The *capacitance* of a small amateur aerial is from 0.0002 to 0.0005 microfarad.

CAPACITY, DISTRIBUTED.—A coil of wire not only has inductance, but also a certain small capacitance. Coils wound with their turns parallel and having a number of layers have a *bunched capacitance* which produces untoward effects in oscillation circuits. In honeycomb and other stagger wound coils the capacitance is more evenly distributed.

CAPACITY REACTANCE.—See *Reactance, Capacity.*

CAPACITY UNIT.—See *Farad.*

CARBON RHEOSTATS.—See *Rheostat, Carbon.*

CARBORUNDUM DETECTOR.—See *Detector.*

CARRIER CURRENT TELEPHONY.—See *Wired-Wireless.*

CARRIER FREQUENCY.—See *Frequency, Carrier.*

CARRIER FREQUENCY TELEPHONY.—See *Wired-Wireless.*

CASCADE AMPLIFICATION.—Two or more amplifying tubes hooked up in a receiving set.

CAT WHISKER CONTACT.—A long, thin wire which makes contact with the crystal of a detector.

CENTIMETER OF CAPACITANCE.—Equal to 1.11 *microfarads.*

CENTIMETER OF INDUCTANCE.—Equal to one one-thousandth part of a *microhenry.*

CELLULAR COILS.—See *Coils, Inductance.*

C. G. S. ELECTROSTATIC UNIT OF CAPACITANCE.—See *Centimeter of Capacitance.*

CHARACTERISTICS.—The special behavior of a device, such as an aerial, a detector tube, etc.

CHARACTERISTICS, GRID.—See *Grid Characteristics.*

CHOKE COILS.—Coils that prevent the high voltage oscillations from surging back into the transformer and breaking down the insulation.

CHOPPER MODULATION.—See *Modulation, Chopper.*

CIRCUIT.—Any electrical conductor through which a current can flow. A low voltage current requires a loop of wire or other conductor both ends of which are connected to the source of current before it can flow. A high frequency current will surge in a wire which is open at both ends like the aerial.

Closed Circuit.—A circuit that is continuous.

Open Circuit.—A conductor that is not continuous.

Coupled Circuits.—Open and closed circuits connected together by inductance coils, condensers or resistances. See *coupling.*

Close Coupled Circuits.—Open and closed circuits connected directly together with a single inductance coil.

Loose Coupled Circuits.—Opened and closed currents connected together inductively by means of a transformer.

Stand-by Circuits.—Also called *pick-up* circuits. When listening-in for possible calls from a number of stations, a receiver is used which will respond to a wide band of wave lengths.

Armstrong Circuits.—The regenerative circuit invented by Major E. H. Armstrong.

CLOSE COUPLED CIRCUITS.—See *Currents, Close Coupled.*

CLOSED CIRCUIT.—See *Circuit, Closed.*

CLOSED CORE TRANSFORMER.—See *Transformer, Closed Core.*

CODE.—

Continental.—Same as *International.*

International.—On the continent of Europe land lines use the *Continental Morse* alphabetic code. This code has come to be used throughout the world for wireless telegraphy and hence it is now called the *International code.* It is given on Page *313.*

Morse.—The code devised by Samuel F. B. Morse and which is used on the land lines in the U. S.

National Electric.—A set of rules and requirements devised by the *National Board of Fire Underwriters* for the electrical installations in buildings on which insurance companies carry risks. This code also covers the requirements for wireless installations. A copy may be had from the *National Board of Fire Underwriters,* New York City, or from your insurance agent.

National Electric Safety.—The *Bureau of Standards,* Washington, D. C., have investigated the precautions which should be taken for the safe operation of all electric equipment. A copy of the *Bureau of Standards Handbook No. 3* can be had for 40 cents from the *Superintendent of Documents.*

COEFFICIENT OF COUPLING.—*See Coupling, Coefficient of.*

COIL AERIAL.—See *Aerial, Loop.*

Coil Antenna.—See *Aerial, Loop.*

Coil, Induction.—An apparatus for changing low voltage direct currents into high voltage, low frequency alternating currents. When fitted with a spark gap the high voltage, low frequency currents are converted into high voltage, high frequency currents. It is then also called a *spark coil* and a *Ruhmkorff coil.*

Coil, Loading.—A coil connected in the aerial or closed oscillation circuit so that longer wave lengths can be received.

Coil, Repeating.—See *Repeating Coil.*

Coil, Rotating.—One which rotates on a shaft instead of sliding as in a *loose coupler.* The *rotor* of a *variometer* or *variocoupler* is a *rotating coil.*

Coils, Inductance.—These are the tuning coils used for sending and receiving sets. For sending sets they are formed of one and two coils, a single sending coil is generally called a *tuning inductance coil,* while a two-coil tuner is called an *oscillation transformer.* Receiving tuning coils are made with a single layer, single coil, or a pair of coils, when it is called an *oscillation transformer.* A *loose-coupler* tuning coil is formed of two coils inductively connected; it is a receiving oscillation transformer. Some tuning inductance coils have more than one layer; they are then called *lattice wound, cellular, basket wound, honeycomb, duo-lateral, stagger wound, spider-web* and *slab* coils.

Commercial Frequency.—See *Frequency, Commercial.*

Condenser, Aerial Series.—A condenser placed in the aerial wire system to cut down the wave length.

Condenser, Vernier.—A small variable condenser used for receiving continuous waves where very sharp tuning is desired.

Condenser.—All conducting objects with their insulation form capacities, but a *condenser* is understood to mean two sheets or plates of metal placed closely together but separated by some insulating material.

Adjustable Condenser.—Where two or more condensers can be coupled together by means of plugs, switches or other devices.

Aerial Condenser.—A condenser connected in the aerial.

Air Condenser.—Where air only separates the sheets of metal.

By-Pass Condenser.—A condenser connected in the transmitting circuits so that the high frequency currents will have an alternative path to flow through.

Filter Condenser.—A condenser of large capacitance used in combination with a filter reactor for smoothing out the pulsating direct currents as they come from the rectifier.

Fixed Condenser.—Where the plates are fixed relatively to one another.

Grid Condenser.—A condenser connected in series with the grid lead.

Leyden Jar Condenser.—Where glass jars are used.

Mica Condenser.—Where mica is used.

Oil Condenser.—Where the plates are immersed in oil.

Paper Condenser.—Where paper is used as the insulating material.

Protective.—A condenser of large capacity connected across the low voltage supply circuit of a transmitter to form a by-path of kick-back oscillations.

Variable Condenser.—Where alternate plates can be moved and so made to interleave more or less with a set of fixed plates.

Vernier.—A small condenser with a vernier on it so that it can be accurately varied. It is connected in parallel with the variable condenser used in the primary circuit and is used for the reception of continuous waves where sharp tuning is essential.

CONDENSITE.—A manufactured insulating compound.

CONDUCTIVITY.—The conductance of a given length of wire of uniform cross section. The reciprocal of *resistivity.*

Conductively Coupled.—Two circuits that are connected together by means of a single tuning coil or helix.

Contact Detectors.—See *Detectors, Contact.*

Continental Code.—See *Code, Continental.*

Coulomb.—The quantity of electricity transferred by a current of 1 ampere in 1 second.

Convective Discharge.—See *Discharge.*

Conventional Signals.—See *Signals, Conventional.*

Counter Electromotive Force.—See *Electromotive Force, Counter.*

Counterpoise.—A duplicate of the aerial wire that is raised a few feet above the earth and insulated from it. Usually no connection is made with the earth itself.

Coupled Circuits.—See *Circuit, Coupled.*

Coupling.—When two oscillation circuits are connected together either by the magnetic field of an inductance coil, or by the electrostatic field of a condenser.

Coupling, Capacitive.—Oscillation circuits when connected together by condensers instead of inductance coils.

Coupling, Coefficient of.—The measure of the closeness of the coupling between two coils.

Coupling, Inductive.—Oscillation circuits when connected together by inductance coils.

Coupling, Resistance.—Oscillation circuits connected together by a resistance.

Crystal Rectifier.—A crystal detector.

Current, Alternating (*A.C.*).—A low frequency current that surges to and fro in a circuit.

Current, Audio Frequency.—A current whose frequency is low enough to be heard in a telephone receiver. Such a current usually has a frequency of between 200 and 2,000 cycles per second.

Current, Plate.—The current which flows between the filament and the plate of a vacuum tube.

Current, Pulsating.—A direct current whose voltage varies from moment to moment.

CURRENT, RADIO FREQUENCY.—A current whose frequency is so high it cannot be heard in a telephone receiver. Such a current may have a frequency of from 20,000 to 10,000,000 per second.

CURRENTS, HIGH FREQUENCY.—(1) Currents that oscillate from 10,000 to 300,000,000 times per second. (2) Electric oscillations.

CURRENTS, HIGH POTENTIAL.—(1) Currents that have a potential of more than 10,000 volts. (2) High voltage currents.

CYCLE.—(1) A series of changes which when completed are again at the starting point. (2) A period of time at the end of which an alternating or oscillating current repeats its original direction of flow.

DAMPING.—The degree to which the energy of an electric oscillation is reduced. In an open circuit the energy of an oscillation set up by a spark gap is damped out in a few swings, while in a closed circuit it is greatly prolonged, the current oscillating 20 times or more before the energy is dissipated by the sum of the resistances of the circuit.

DECREMENT.—The act or process of gradually becoming less. The quantity lost by diminution.

DETECTOR.—Any device that will (1) change the oscillations set up by the incoming waves into direct current, that is which will rectify them, or (2) that will act as a relay.

Carborundum.—One that uses a *carborundum* crystal for the sensitive element. Carborundum is a crystalline silicon carbide formed in the electric furnace.

Cat Whisker Contact.—See *Cat Whisker Contact.*

Chalcopyrite.—Copper pyrites. A brass colored mineral used as a crystal for detectors. See *Zincite.*

Contact.—A crystal detector. Any kind of a detector in which two dissimilar but suitable solids make contact.

Ferron.—A detector in which iron pyrites are used as the sensitive element.

Galena.—A detector that uses a galena crystal for the rectifying element.

Iron Pyrites.—A detector that uses a crystal of iron pyrites for its sensitive element.

Molybdenite.—A detector that uses a crystal of *sulphide of molybdenum* for the sensitive element.

Perikon.—A detector in which a *bornite* crystal makes contact with a *zincite* crystal.

Silicon.—A detector that uses a crystal of silicon for its sensitive element.

Vacuum Tube.—A vacuum tube (which see) used as a detector.

Zincite.—A detector in which a crystal of *zincite* is used as the sensitive element.

De-tuning.—A method of signaling by sustained oscillations in which the key when pressed down cuts out either some of the inductance or some of the capacity and hence greatly changes the wave length.

Dielectric.—An insulating material between two electrically charged plates in which there is set up an *electric strain,* or displacement.

Dielectric Strain.—The electric displacement in a dielectric.

Directional Aerial.—See *Aerial, Directional.*

Direction Finder.—See *Aerial, Loop.*

Discharge.—(1) A faintly luminous discharge that takes place from the positive pointed terminal of an induction coil, or other high potential apparatus; is termed a *brush discharge.* (2) A continuous discharge between the terminals of a high potential apparatus is termed a *convective discharge.* (3) The sudden breaking-down of the air between the balls forming the spark gap is termed a *disruptive discharge;* also called an *electric spark,* or just *spark* for short. (4) When a tube has a poor vacuum, or too large a battery voltage, it glows with a blue light and this is called a *blue glow discharge.*

DISRUPTIVE DISCHARGE.—See *Discharge.*

DISTRESS CALL. . . . — — — . . . (S O S).

DISTRIBUTED CAPACITY.—See *Capacity, Distributed.*

DOUBLE HUMP RESONANCE CURVE.—A resonance curve that has two peaks or humps which show that the oscillating currents which are set up when the primary and secondary of a tuning coil are closely coupled have two frequencies.

DUO-LATERAL COILS.—See *Coils, Inductance.*

DUPLEX COMMUNICATION.—A wireless telephone system with which it is possible to talk between both stations in either direction without the use of switches. This is known as the *duplex system.*

EARTH CAPACITY.—An aerial counterpoise.

EARTH CONNECTION.—Metal plates or wires buried in the ground or immersed in water. Any kind of means by which the sending and receiving apparatus can be connected with the earth.

EDISON STORAGE BATTERY.—See *Storage Battery, Edison.*

ELECTRIC ENERGY.—The power of an electric current.

ELECTRIC OSCILLATIONS.—See *Oscillations, Electric.*

ELECTRIC SPARK.—See *Discharge, Spark.*

ELECTRICITY, NEGATIVE.—The opposite of *positive electricity.* Negative electricity is formed of negative electrons which make up the outside particles of an atom.

ELECTRICITY, POSITIVE.—The opposite of *negative electricity.* Positive electricity is formed of positive electrons which make up the inside particles of an atom.

ELECTRODES.—Usually the parts of an apparatus which dip into a liquid and carry a current. The electrodes of a dry battery are the zinc and carbon elements. The electrodes of an Edison storage battery are the iron and nickel elements, and the electrodes of a lead storage battery are the lead elements.

Electrolytes.—The acid or alkaline solutions used in batteries.

Electromagnetic Waves.—See *Waves, Electric.*

Electromotive Force.—Abbreviated *emf.* The force that drives an electric current along a conductor. Also loosely called *voltage.*

Electromotive Force, Counter.—The emf. that is set up in a direction opposite to that in which the current is flowing in a conductor.

Electron.—(1) A negative particle of electricity that is detached from an atom. (2) A negative particle of electricity thrown off from the incandescent filament of a vacuum tube.

Electron Flow.—The passage of electrons between the incandescent filament and the cold positively charged plate of a vacuum tube.

Electron Relay.—See *Relay, Electron.*

Electron Tube.—A vacuum tube or a gas-content tube used for any purpose in wireless work. See *Vacuum Tube.*

Electrose Insulators.—Insulators made of a composition material the trade name of which is *Electrose.*

Energy, Electric.—See *Electric Energy.*

Energy Unit.—The *joule,* which see, *Page 316.*

Fading.—The sudden variation in strength of signals received from a transmitting station when all the adjustments of both sending and receiving apparatus remain the same. Also called *swinging.*

Farad.—The capacitance of a condenser in which a potential difference of 1 volt causes it to have a charge of 1 coulomb of electricity.

Feed-back Action.—Feeding back the oscillating currents in a vacuum tube to amplify its power. Also called *regenerative action.*

Ferromagnetic Control.—See *Magnetic Amplifier.*

FILAMENT.—The wire in a vacuum tube that is heated to incandescence and which throws off electrons.

FILAMENT RHEOSTAT.—See *Rheostat, Filament.*

FILTER.—Inductance coils or condensers or both which (1) prevent troublesome voltages from acting on the different circuits, and (2) smooth out alternating currents after they have been rectified.

FILTER REACTOR.—See *Reactor, Filter.*

FIRE UNDERWRITERS.—See *Code, National Electric.*

FIXED GAP.—See *Gap.*

FLEMING VALVE.—A two-electrode vacuum tube.

FORCED OSCILLATIONS.—See *Oscillations, Forced.*

FREE OSCILLATIONS.—See *Oscillations, Free.*

FREQUENCY, AUDIO.—(1) An alternating current whose frequency is low enough to operate a telephone receiver and, hence, which can be heard by the ear. (2) Audio frequencies are usually around 500 or 1,000 cycles per second, but may be as low as 14 and as high as 14,000 cycles per second.

Carrier.—A radio frequency wave modulated by an audio frequency wave which results in setting of *three* radio frequency waves. The principal radio frequency is called the *carrier frequency,* since it *carries* or transmits the audio frequency wave.

Commercial.—(1) Alternating current that is used for commercial purposes, namely, *light, heat* and *power.* (2) Commercial frequencies now in general use are from 25 to 50 cycles per second.

Natural.—The pendulum and vibrating spring have a *natural frequency* which depends on the size, material of which it is made, and the friction which it has to overcome. Likewise an oscillation circuit has a *natural frequency* which depends upon its *inductance, capacitance* and *resistance.*

Radio.—(1) An oscillating current whose frequency is too high to affect a telephone receiver and, hence, cannot be heard by the ear. (2) Radio frequencies are usually between 20,000 and 2,000,000 cycles per second but may be as low as 10,000 and as high as 800,000,000 cycles per second.

Spark.—The number of sparks per second produced by the discharge of a condenser.

GAP, FIXED.—One with fixed electrodes.

GAP, NON-SYNCHRONOUS.—A rotary spark gap run by a separate motor which may be widely different from that of the speed of the alternator.

GAP, QUENCHED.—(1) A spark gap for the impulse production of oscillating currents. (2) This method can be likened to one where a spring is struck a single sharp blow and then continues to set up vibrations.

GAP, ROTARY.—One having fixed and rotating electrodes.

GAP, SYNCHRONOUS.—A rotary spark gap run at the same speed as the alternator which supplies the power transformer. Such a gap usually has as many teeth as there are poles on the generator. Hence one spark occurs per half cycle.

GAS-CONTENT TUBE.—See *Vacuum Tube.*

GENERATOR TUBE.—A vacuum tube used to set up oscillations. As a matter of fact it does not *generate* oscillations, but changes the initial low voltage current that flows through it into oscillations. Also called an *oscillator tube* and a *power tube.*

GRID.—(1) The metal gauze element placed between the filament and the plate of a vacuum tube. It controls the current flowing from the plate to the filament. (2) One of the perforated lead plate elements of a storage battery.

GRID BATTERY.—See *Battery C.*

GRID CIRCUIT.—The circuit in which the grid of a vacuum tube is connected.

GRID CHARACTERISTICS.—The various relations that could exist between the voltages and currents of the grid of a vacuum tube, and the values which do exist between them when the tube is in operation. These characteristics are generally shown by curves.

Grid Coil.—An inductance coil connected in series with the grid circuit.

Grid Condenser.—See *Condenser, Grid.*

Grid Lead.—The wire or conductor that leads to and which is connected with the grid.

Grid Leak.—A high resistance unit connected in the grid lead of both sending and receiving sets. In a sending set it keeps the voltage of the grid at a constant value and so controls the output of the aerial. In a receiving set it controls the current flowing between the plate and filament.

Grid Modulation.—See *Modulation, Grid.*

Grid Potential.—The negative or positive voltage of the grid of a vacuum tube.

Grid Voltage.—See *Grid Potential.*

Grinders.—The most common form of *Static,* which see. They make a grinding noise in the headphones.

Ground.—See *Earth Connection.*

Ground, Amateur.—A water-pipe ground.

Ground, Waterpipe.—A common method of grounding by amateurs is to use the waterpipe, gaspipe or radiator.

Guided Wave Telephony.—See *Wired Wireless.*

Hard Tube.—A vacuum tube in which the vacuum is *high,* that is, exhausted to a high degree.

Helix.—(1) Any coil of wire. (2) Specifically a transmitter tuning inductance coil.

Henry.—The inductance in a circuit in which the electromotive force induced is 1 volt when the inducing current varies at the rate of 1 ampere per second.

Heterodyne Reception.—(1) Receiving by the *beat* method. (2) Receiving by means of superposing oscillations generated at the receiving station on the oscillations set up in the aerial by the incoming waves.

Heterodyne Receptor.—See *Receptor, Heterodyne.*

High Frequency Currents.—See *Currents, High Frequency.*

High Frequency Resistance.—See *Resistance, High Frequency.*

High Potential Currents.—See *Currents, High Potential.*

High Voltage Currents.—See *Currents, High Potential.*

Honeycomb Coils.—See *Coils, Inductance.*

Horse-Power.—Used in rating steam machinery. It is equal to 746 watts.

Hot Wire Ammeter.—See *Ammeter, Hot Wire.*

Howling.—Where more than three stages of radio amplification, or more than two stages of audio amplification, are used howling noises are apt to occur in the telephone receivers.

Impedance.—An oscillation circuit has *reactance* and also *resistance,* and when these are combined the total opposition to the current is called *impedance.*

Induction Coil.—See *Coil, Induction.*

Induction, Mutual.—Induction produced between two

Inductance Coils.—See *Coils, Inductance.*

Inductance Coil, Loading.—See *Coil, Loading Inductance.*

Inductive Coupling.—See *Coupling, Inductive.*

Inductively Coupled.—Circuits that are coupled together by means of a primary and secondary coil. Transformers are inductively coupled.

Inductive Reactance.—See *Reactance, Inductive.*

circuits or coils close to each other by the mutual interaction of their magnetic fields.

Insulation.—Materials used on and around wires and other conductors to keep the current from leaking away.

Inspector, Radio.—A U. S. inspector whose business it is to issue both station and operators' licenses in the district of which he is in charge.

INTERFERENCE.—The crossing or superposing of two sets of electric waves of the same or slightly different lengths which tend to oppose each other. It is the untoward interference between electric waves from different stations that makes selective signaling so difficult a problem.

INTERMEDIATE WAVES.—See *Waves.*

IONIC TUBES.—See *Vacuum Tubes.*

INTERNATIONAL CODE.—See Code, International.

JAMMING.—Waves that are of such length and strength that when they interfere with incoming waves they drown them out.

JOULE.—The energy spent in 1 second by a flow of 1 ampere in 1 ohm.

JOULE'S LAW.—The relation between the heat produced in seconds to the resistance of the circuit, to the current flowing in it.

KENOTRON.—The trade name of a vacuum tube rectifier made by the *Radio Corporation of America.*

KICK-BACK.—Oscillating currents that rise in voltage and tend to flow back through a low voltage circuit.

KILOCYCLES.—A thousand cycles. See *Cycle.*

KICK-BACK PREVENTION.—See *Prevention, Kick-Back.*

KILOWATT.—1,000 watts.

LATTICE WOUND COILS.—See *Coils, Inductance.*

LEAD.—A wire or other conductor that leads to and is connected with a piece of apparatus.

LIGHTNING SWITCH.—See *Switch, Lightning.*

LINE RADIO COMMUNICATION.—See *Wired Wireless.*

LINE RADIO TELEPHONY.—See *Telephony, Line Radio.*

LITZENDRAHT.—A conductor formed of a number of fine copper wires either twisted or braided together. It is used to reduce the *skin effect.* See *Resistance, High Frequency.*

LOAD FLICKER.—The flickering of electric lights on lines that supply wireless transmitting sets due to variations of the voltage on opening and closing the key.

LOADING COIL.—See *Coil, Loading.*

LONG WAVES.—See *Waves.*

LOOP AERIAL.—See *Aerial, Loop.*

LOOSE COUPLED CIRCUITS.—See *Circuits, Loose Coupled.*

LOOSE COUPLER.—See *Coils, Conductance.*

LOUD SPEAKER.—A telephone receiver connected to a horn, or a specially made one, that reproduces the incoming signals, words or music loud enough to be heard by a room or an auditorium full of people, or by large crowds out-doors.

MAGNETIC POLES.—See *Poles, Magnetic.*

MEGOHM.—One million ohms.

METER, AUDIBILITY.—An instrument for measuring the loudness of a signal by comparison with another signal. It consists of a pair of headphones and a variable resistance which have been calibrated.

MHO.—The unit of conductance. As conductance is the reciprocal of resistance it is measured by the *reciprocal ohm* or *mho.*

MICA.—A transparent mineral having a high insulating value and which can be split into very thin sheets. It is largely used in making condensers both for transmitting and receiving sets.

MICROFARAD.—The millionth part of a *farad.*

MICROHENRY.—The millionth part of a *farad.*

MICROMICROFARAD.—The millionth part of a *microfarad.*

MICROHM.—The millionth part of an *ohm.*

MICROPHONE TRANSFORMER.—See *Transformer, Microphone.*

MICROPHONE TRANSMITTER.—See *Transmitter, Microphone.*

MILLI-AMMETER.—An ammeter that measures a current by the one-thousandth of an ampere.

MILLIAMPERE.—The one-thousandth of an ampere.

MODULATION.—(1) Inflection or varying the voice. (2) Varying the amplitude of oscillations by means of the voice.

MODULATION, BUZZER.—The modulation of radio frequency oscillations by a buzzer which breaks up the sustained oscillations of a transmitter into audio frequency impulses.

MILLIHENRY.—The thousandth part of a *henry*.

MODULATION, CHOPPER.—The modulation of radio frequency oscillations by a chopper which breaks up the sustained oscillations of a transmitter into audio frequency impulses.

MODULATION, GRID.—The scheme of modulating an oscillator tube by connecting the secondary of a transformer, the primary of which is connected with a battery and a microphone transmitter, in the grid lead.

MODULATION, OVER.—See *Blub Blub.*

MODULATION, PLATE.—Modulating the oscillations set up by a vacuum tube by varying the current impressed on the plate.

MODULATOR TUBE.—A vacuum tube used as a modulator.

MOTION, WAVE.—(1) The to and fro motion of water at sea. (2) Waves transmitted by, in and through the *air,* or sound waves. (3) Waves transmitted by, in and through the *ether,* or *electromagnetic waves,* or *electric waves* for short.

MOTOR-GENERATOR.—A motor and a dynamo built to run at the same speed and mounted on a common base, the shafts being coupled together. In wireless it is used for changing commercial direct current into direct current of higher voltages for energizing the plate of a vacuum tube oscillator.

MULTI-STAGE AMPLIFIERS.—See *Amplifiers, Multi-Stage.*

MUTUAL INDUCTION.—See *Induction, Mutual.*

MUSH.—Irregular intermediate frequencies set up by arc transmitters which interfere with the fundamental wave lengths.

MUSHY NOTE.—A note that is not clear cut, and hence hard to read, which is received by the *heterodyne method* when damped waves or modulated continuous waves are being received.

NATIONAL ELECTRIC CODE.—See *Code, National Electric.*
NATIONAL ELECTRIC SAFETY CODE.—See *Code, National Electric Safety.*
NEGATIVE ELECTRICITY.—See *Electricity, Negative.*
NON-SYNCHRONOUS GAP.—See *Gap, Non-Synchronous.*

OHM.—The resistance of a thread of mercury at the temperature of melting ice, 14.4521 grams in mass, of uniform cross-section and a length of 106.300 centimeters.
OHM'S LAW.—The important fixed relation between the electric current, its electromotive force and the resistance of the conductor in which it flows.
OPEN CIRCUIT.—See *Circuit, Open.*
OPEN CORE TRANSFORMER.—See *Transformer, Open Core.*
OSCILLATION TRANSFORMER.—See *Transformer, Oscillation.*
OSCILLATIONS, ELECTRIC.—A current of high frequency that surges through an open or a closed circuit. (1) Electric oscillations may be set up by a spark gap, electric arc or a vacuum tube, when connected with a circuit having inductance and capacity, when they have not only a high frequency but a high potential, or voltage. (2) When electric waves impinge on an aerial wire they are transformed into electric oscillations of a frequency equal to those which emitted the waves, but since a very small amount of energy is received their potential or voltage is likewise very small.

Sustained.—Oscillations in which the damping factor is small.

Damped.—Oscillations in which the damping factor is large.

Free.—When a condenser discharges through an oscillation circuit, where there is no outside electromotive force acting on it, the oscillations are said to be *free*.

Forced.—Oscillations that are made to surge in a circuit whose natural period is different from that of the oscillations set up in it.

OSCILLATION TRANSFORMER.—See *Transformer.*

OSCILLATION VALVE.—See *Vacuum Tube.*

OSCILLATOR TUBE.—A vacuum tube which is used to produce electric oscillations.

OVER MODULATION.—See *Blub Blub.*

PANCAKE OSCILLATION TRANSFORMER.—Disk-shaped coils that are used for receiving tuning inductances.

PERMEABILITY, MAGNETIC.—The degree to which a substance can be magnetized. Iron has a greater magnetic permeability than air.

PHASE.—A characteristic aspect or appearance that takes place at the same point or part of a cycle.

PICK-UP CIRCUITS.—See *Circuits, Stand-by.*

PLATE.—One of the elements of a vacuum tube.

PLATE CIRCUIT.—The circuit in which the plate of a vacuum tube is connected.

PLATE CIRCUIT REACTOR.—See *Reactor, Plate Circuit.*

PLATE CURRENT.—See *Current, Plate.*

PLATE MODULATION.—See *Modulation, Plate.*

PLATE VOLTAGE.—See *Voltage, Plate.*

POLES, BATTERY.—The positive and negative terminals of the elements of a battery. On a storage battery these poles are marked + and — respectively.

POLES, MAGNETIC.—The ends of a magnet.

POSITIVE ELECTRICITY.—See *Electricity, Positive.*

POTENTIAL DIFFERENCE.—The electric pressure between two charged conductors or surfaces.

POTENTIOMETER.—A variable resistance used for subdividing the voltage of a current. A *voltage divider.*

POWER TRANSFORMER.—See *Transformer, Power.*

POWER TUBE.—See *Generator Tube.*

PRIMARY BATTERY.—See *Battery, Primary.*

PREVENTION, KICK-BACK.—A choke coil placed in the power circuit to prevent the high frequency currents from getting into the transformer and breaking down the insulation.

Q S T.—An abbreviation used in wireless communication for (1) the question "Have you received the general call?" and (2) the notice, "General call to all stations."

QUENCHED GAP.—See *Gap, Quenched.*

RADIATION.—The emission, or throwing off, of electric waves by an aerial wire system.

RADIO AMMETER.—See *Ammeter, Hot Wire.*

RADIO FREQUENCY.—See *Frequency, Radio.*

RADIO FREQUENCY AMPLIFICATION.—See *Amplification, Radio Frequency.*

RADIO FREQUENCY CURRENT.—See *Current, Radio Frequency.*

RADIO INSPECTOR.—See *Inspector, Radio.*

RADIOTRON.—The trade name of vacuum tube detectors, amplifiers, oscillators and modulators made by the *Radio Corporation of America.*

RADIO WAVES.—See *Waves, Radio.*

REACTANCE.—When a circuit has inductance and the current changes in value, it is opposed by the voltage induced by the variation of the current.

REACTANCE, CAPACITY.—The capacity reactance is the opposition offered to a current by a capacity. It is measured as a resistance, that is, in *ohms.*

REACTOR.—A coil wound on an iron core which opposes the flow of a current by its counter electro-motive force.

REACTOR, PLATE CIRCUIT.—A reactor connected in the plate circuit of a vacuum tube.

RECEIVING TUNING COILS.—See *Coils, Inductance.*

RECEIVER, LOUD SPEAKING.—See *Loud Speakers.*

RECEIVER, WATCH CASE.—A compact telephone receiver used for wireless reception.

Reactance, Inductive.—The inductive reactance is the opposition offered to the current by an inductance coil. It is measured as a resistance, that is, in *ohms*.

Reactor, Filter.—A reactance coil for smoothing out the pulsating direct currents as they come from the rectifier. A choke coil will act as a reactor.

Reactor, Plate Circuit.—A reactance coil used in the plate circuit of a wireless telephone to keep the direct current supply at a constant voltage.

Receiver.—(1) A telephone receiver. (2) An apparatus for receiving signals, speech or music. (3) Better called a *receptor* to distinguish it from a telephone receiver.

Rectifier.—(1) An apparatus for changing alternating current into pulsating direct current. (2) Specifically in wireless (*a*) a crystal or vacuum tube detector, and (*b*) a two-electrode vacuum tube used for changing commercial alternating current into direct current for wireless telephony.

Regenerative Amplification.—See *Amplification, Regenerative.*

Receptor.—A receiving set.

Receptor, Autodyne.—A receptor that has a regenerative circuit and the same tube is used as a detector and as a generator of local oscillations.

Receptor, Beat.—A heterodyne receptor.

Receptor, Heterodyne.—A receiving set that uses a separate vacuum tube to set up the second series of waves for beat reception.

Regenerative Action.—See *Feed-Back Action.*

Regenerative Amplification.—See *Amplification, Regenerative.*

Relay, Electron.—A vacuum tube when used as a detector or an amplifier.

Repeating Coil.—A transformer used in connecting up a wireless receiver with a wire transmitter.

Resistance.—The opposition offered by a wire or other conductor to the passage of a current.

RESISTANCE, AERIAL.—The resistance of the aerial wire to oscillating currents. This is greater than its ordinary ohmic resistance due to the skin effect. See *Resistance, High Frequency.*

RESISTANCE BOX.—See *Resistor.*

RESISTANCE BRIDGE.—An apparatus for measuring the resistance (in ohms) of a circuit.

RESISTANCE COIL.—A coil made of wire that has a high resistance, as German silver, and which is used to vary the strength of the current flowing through a circuit.

RESISTANCE COUPLING.—See *Coupling, Resistance.*

RESISTANCE, HIGH FREQUENCY.—When a high frequency current oscillates on a wire two things take place that are different than when a direct or alternating current flows through it, and these are (1) the current inside of the wire lags behind that of the current on the surface, and (2) the amplitude of the current is largest on the surface and grows smaller as the center of the wire is reached. This uneven distribution of the current is known as the *skin effect* and it amounts to the same thing as reducing the size of the wire, hence the resistance is increased.

RESISTIVITY.—The resistance of a given length of wire of uniform cross section. The reciprocal of *conductivity.*

RESISTOR.—A fixed or variable resistance unit or a group of such units. Variable resistors are also called *resistance boxes* and more often *rheostats.*

RESONANCE.—(1) Simple resonance of sound is its increase set up by one body by the sympathetic vibration of a second body. (2) By extension the increase in the amplitude of electric oscillations when the circuit in which they surge has a *natural* period that is the same, or nearly the same, as the period of the first oscillation circuit.

RHEOSTAT.—A variable resistance unit. See *Resistor.*

RHEOSTAT, CARBON.—A carbon rod, or carbon plates or blocks, when used as variable resistances.

RHEOSTAT, FILAMENT.—A variable resistance used for keeping the current of the storage battery which heats the filament of a vacuum tube at a constant voltage.

ROTATING COIL.—See *Coil.*

ROTARY GAP.—See *Gap.*

ROTOR.—The rotating coil of a variometer or a variocoupler.

RUHMKORFF COIL.—See *Coil, Induction.*

SATURATION.—The maximum plate current that a vacuum tube will take.

SENSITIVE SPOTS.—Spots on detector crystals that are sensitive to the action of electric oscillations.

SHORT WAVES.—See *Waves.*

SIDE WAVES.—See *Wave Length Band.*

SIGNALS, CONVENTIONAL.—(1) The International Morse alphabet and numeral code, punctuation marks, and a few important abbreviations. (2) Dot and dash signals for distress call, etc.

SKIN EFFECT.—See *Resistance, High Frequency.*

SOCKET POWER UNIT.—A device that will furnish "A," "B," and "C" battery power from the house-lighting line. Usually consists of a rectifier and filter.

SOFT TUBE.—A vacuum tube in which the vacuum is *low,* that is, it is not highly exhausted.

SPACE CHARGE EFFECT.—The electric field intensity due to the pressure of the negative electrons in the space between the filament and plate which at last equals and neutralizes that due to the positive potential of the plate so that there is no force acting on the electrons near the filament.

SPARK.—See *Discharge.*

SPARK COIL.—See *Coil, Induction.*

SPARK DISCHARGE.—See *Spark, Electric.*

SPARK FREQUENCY.—See *Frequency, Spark.*

SPARK GAP.—(1) A *spark gap,* without the hyphen, means the apparatus in which sparks take place; it is also called a *spark discharger.* (2) *Spark-gap,* with the hyphen, means the air-gap between the opposed faces of the electrodes in which sparks are produced.

Plain.—A spark gap with fixed electrodes.

Rotary.—A spark gap with a pair of fixed electrodes and a number of electrodes mounted on a rotating element.

Quenched.—A spark gap formed of a number of metal plates placed closely together and insulated from each other.

SPIDER WEB INDUCTANCE COIL.—See *Coil, Spider Web Inductance.*

SPREADER.—A stick of wood, or spar, that holds the wires of the aerial apart.

STAGGER WOUND COILS.—See *Coils, Inductance.*

STAND-BY CIRCUITS.—See *Circuits, Stand-By.*

STATIC.—Also called *atmospherics, grinders, strays, X's,* and, when bad enough, by other names. It is an electrical disturbance in the atmosphere which makes noises in the telephone receiver.

STATOR.—The fixed or stationary coil of a variometer or a variocoupler.

STRAIGHT LINE FREQUENCY.—See page 348.

STRAY ELIMINATION.—A method for increasing the strength of the signals as against the strength of the strays. See *Static.*

STRAYS.—See *Static.*

STRANDED WIRE.—See *Wire, Stranded.*

SUPER-HETERODYNE RECEPTOR.—See *Heterodyne, Super.*

SWINGING.—See *Fading.*

SWITCH, AERIAL.—A switch used to change over from the sending to the receiving set, and the other way about, and connect them with the aerial.

SWITCH, LIGHTNING.—The switch that connects the aerial with the outside ground when the apparatus is not in use.

SYMBOLS, APPARATUS.—Also called *conventional symbols.* These are diagrammatic lines representing various parts of apparatus so that when a wiring diagram of a transmitter or a receptor is to be made it is only necessary to connect them together. They are easy to make and easy to read. See *Page 315.*

SYNCHRONOUS GAP.—See *Gap, Synchronous.*

TELEPHONY, LINE RADIO.—See *Wired Wireless.*

TELEVISION.—Sight at a distance, literally. The name applied to a system of radio whereby the image of an object can be transmitted by electrical impulses from one point to another on a carrier wave.

THERMAL AMMETER.—See *Ammeter, Hot Wire.*

THREE ELECTRODE VACUUM TUBE.—See *Vacuum Tube, Three Electrode.*

TICKLER.—A third coil that forms part of the tuning coil and which feeds back part of the oscillating current to the detector tube in a regenerative receiving set.

TIKKER.—A slipping contact device that breaks up the sustained oscillations at the receiving end into groups so that the signals can be heard in the head phones.

TRANSFORMER.—A primary and a secondary coil for stepping up or down a primary alternating or oscillating current.

A. C.—See *Power Transformer.*

Air Cooled.—A transformer in which the coils are exposed to the air.

Air Core.—With high frequency currents it is the general practice not to use iron cores as these tend to choke off the oscillations. Hence the core consists of the air inside of the coils.

Auto.—A single coil of wire in which one part forms the primary and the other part the secondary by bringing out an intermediate tap.

Audio Amplifying.—This is a transformer with an iron core and is used for frequencies up to say 3,000.

Closed Core.—A transformer in which the path of the magnetic flux is entirely through iron. Power transformers have closed cores.

Microphone.—A small transformer for modulating the oscillations set up by an arc or a vacuum tube oscillator.

Oil Cooled.—A transformer in which the coils are immersed in oil.

Open Core.—A transformer in which the path of the magnetic flux is partly through iron and partly through air. Induction coils have open cores.

Oscillation.—A coil or coils for transforming or stepping down or up oscillating currents. Oscillation transformers usually have no iron cores when they are also called *air core transformers.*

Power.—A transformer for stepping down a commercial alternating current for lighting and heating the filament and for stepping up the commercial a.c., for charging the plate of a vacuum tube oscillator.

Radio Amplifying.—This is a transformer with an air core. It does not in itself amplify but is so called because it is used in connection with an amplifying tube.

TRANSMITTER, MICROPHONE.—A telephone transmitter of the kind that is used in the Bell telephone system.

TRANSMITTING TUNING COILS.—See *Coils, Inductance.*

TUNING.—When the open and closed oscillation circuits of a transmitter or a receptor are adjusted so that both of the former will permit electric oscillations to surge through them with the same frequency, they are said to be *tuned.* Likewise, when the sending and receiving stations are adjusted to the same wave length they are said to be *tuned.*

Coarse Tuning.—The first adjustment in the tuning oscillation circuits of a receptor is made with the inductance coil and this tunes them coarse, or roughly.

Fine Tuning.—After the oscillation circuits have been roughly tuned with the inductance coil the exact adjustment is obtained with the variable condenser and this is *fine tuning.*

Sharp.—When a sending set will transmit or a receiving set will receive a wave of given length only it is said to be sharply tuned. The smaller the decrement the sharper the tuning.

TUNING COILS.—See *Coils, Inductance.*

TWO ELECTRODE VACUUM TUBE.—See *Vacuum Tube, Two Electrode.*

VACUUM TUBE.—A tube with two or three electrodes from which the air has been exhausted, or which is filled with an inert gas, and used as a detector, an amplifier, an oscillator or a modulator in wireless telegraphy and telephony.

Amplifier.—See *Amplifier, Vacuum Tube.*

Amplifying Modulator.—A vacuum tube used for modulating and amplifying the oscillations set up by the sending set.

Gas Content.—A tube made like a vacuum tube and used as a detector but which contains an inert gas instead of being exhausted.

Hard.—See *Hard Tube.*

Rectifier.—(1) A vacuum tube detector. (2) a two-electrode vacuum tube used for changing commercial alternating current into direct current for wireless telephony.

Soft.—See *Soft Tube.*

Three Electrode.—A vacuum tube with three electrodes, namely a *filament*, a *grid* and a *plate.*

Two Electrode.—A vacuum tube with two electrodes, namely the *filament* and the *plate.*

VALVE.—See *Vacuum Tube.*

VALVE, FLEMING.—See *Fleming Valve.*

VARIABLE CONDENSER.—See *Condenser, Variable.*

VARIABLE INDUCTANCE.—See *Inductance, Variable.*

VARIABLE RESISTANCE.—See *Resistance, Variable.*

VARIOCOUPLER.—A tuning device for varying the inductance of the receiving oscillation circuits. It consists of a fixed and a rotatable coil whose windings are not connected with each other.

VARIOMETER.—A tuning device for varying the inductance of the receiving oscillation currents. It consists of a fixed and a rotatable coil with the coils connected in series.

VERNIER CONDENSER.—See *Condenser, Vernier.*

VOLT.—The electromotive force which produces a current of 1 ampere when steadily applied to a conductor the resistance of which is one ohm.

VOLTAGE DIVIDER.—See *Potentiometer.*

VOLTAGE, PLATE.—The voltage of the current that is used to energize the plate of a vacuum tube.

VOLTMETER.—An instrument for measuring the voltage of an electric current.

WATCH CASE RECEIVER.—See *Receiver, Watch Case.*

WATER-PIPE GROUND.—See *Ground, Water-Pipe.*

WATT.—The power spent by a current of 1 ampere in a resistance of 1 ohm.

WAVE, BROAD.—A wave having a high decrement, when the strength of the signals is nearly the same over a wide range of wave lengths.

WAVE LENGTH.—Every wave of whatever kind has a length. The wave length is usually taken to mean the distance between the crests of two successive waves.

WAVE LENGTH BAND.—In wireless reception when continuous waves are being sent out and these are modulated by a microphone transmitter the different audio frequencies set up corresponding radio frequencies and the energy of these are emitted by the aerial; this results in waves of different lengths, or a *band* of waves as it is called.

WAVE METER.—An apparatus for measuring the lengths of electric waves set up in the oscillation circuits of sending and receiving sets.

WAVE MOTION.—Disturbances set up in the surrounding medium as water waves in and on the water, sound waves in the air and electric waves in the ether.

WAVES.—See *Wave Motion.*

WAVES, ELECTRIC.—Electromagnetic waves set up in and transmitted by and through the ether.

Continuous. Abbreviated C.W.—Waves that are emitted without a break from the aerial. Also called *undamped waves.*

Discontinuous.—Waves that are emitted periodically from the aerial. Also called *damped waves.*

Damped.—See *Discontinuous Waves.*

Intermediate.—Waves from 600 to 2,000 meters in length.

Long.—Waves over 2,000 meters in length.

Radio.—Electric waves used in wireless telegraphy and telephony.

Short.—Waves up to 600 meters in length.

Wireless.—Electric waves used in wireless telegraphy and telephony.

Undamped.—See *Continuous Waves.*

WIRELESS TELEGRAPH CODE.—See *Code, International.*

WIRE, ENAMELLED.—Wire that is given a thin coat of enamel which insulates it.

WIRE, PHOSPHOR BRONZE.—A very strong wire made of an alloy of copper and containing a trace of phosphorus.

WIRED WIRELESS.—Continuous waves of high frequency that are sent over telephone wires instead of through space. Also called *line radio communication, carrier frequency telephony, carrier current telephony,* and *guided wave telephony.*

X's.—See *Static.*

ZINCITE.—See *Detector.*

STRAIGHT LINE FREQUENCY.—The term applied to condensers whose variable plates are cut in such a shape that if the frequency is plotted on graph paper against the dial settings the result will be a straight line. There are also dials for rotating the movable plates of the ordinary type of condenser, in such a way that the distance they move per scale unit varies throughout the length of the scale giving the same effect as a S.L.F. condenser.

WIRELESS DON'TS

Aerial Wire Don'ts

Don't use iron wire for your aerial.

Don't fail to insulate it well at both ends.

Don't have it longer than 75 feet for sending out a 200-meter wave.

Don't fail to use a lightning arrester, or better, a lightning switch, for your receiving set.

Don't fail to use a lightning switch with your transmitting set.

Don't forget you must have an outside ground.

Don't fail to have the resistance of your aerial as small as possible. Use stranded wire.

Don't fail to solder the leading-in wire to the aerial.

Don't fail to properly insulate the leading-in wire where it goes through the window or wall.

Don't let your aerial or leading-in wire touch trees or other objects.

Don't let your aerial come too close to overhead wires of any kind.

Don't run your aerial directly under, or over, or parallel with electric light or other wires.

Don't fail to make a good ground connection with the water pipe inside.

Transmitting Don'ts

Don't attempt to send until you get your license.

Don't fail to live up to every rule and regulation.

Don't use an input of more than ½ a kilowatt if you live within 5 nautical miles of a naval station.

Don't send on more than a 200-meter wave if you have a restricted or general amateur license.

Don't use spark gap electrodes that are too small or they will get hot.

Don't use too long or too short a spark gap. The right length can be found by trying it out.

Don't fail to use a safety spark gap between the grid and the filament terminals where the plate potential is above 2,000 volts.

Don't buy a motor-generator set if you have commercial alternating current in your home.

Don't overload an oscillation vacuum tube as it will greatly shorten its life. Use two in parallel.

Don't operate a transmitting set without a hot-wire ammeter in the aerial.

Don't use solid wire for connecting up the parts of transmitters. Use stranded or braided wire.

Don't fail to solder each connection.

Don't use soldering fluid, use rosin.

Don't think that all of the energy of an oscillation tube cannot be used for wave lengths of 200 meters and under. It can be if the transmitting set and aerial are properly designed.

Don't run the wires of oscillation circuits too close together.

Don't cross the wires of oscillation circuits except at right angles.

Don't set the transformer of a transmitting set nearer than 3 feet to the condenser and tuning coil.

Don't use a rotary gap in which the wheel runs out of true.

Don't fail to use alternating current for heating the filament where this is possible.

Receiving Don'ts

Don't expect to get as good results with a crystal detector as with a vacuum tube detector.

Don't be discouraged if you fail to hit the sensitive spot of a crystal detector the first time—or several times thereafter.

Don't use a wire larger than *No. 30* for the wire electrode of a crystal detector.

Don't try to use a loud speaker with a crystal detector receiving set.

Don't expect a loop aerial to give worthwhile results with a crystal detector.

Don't handle crystals with your fingers as this destroys their sensitivity. Use tweezers or a cloth.

Don't imbed the crystal in solder as the heat destroys its sensitivity. Use *Wood's metal,* or some other alloy which melts at or near the temperature of boiling water.

Don't forget that strong static and strong signals sometimes destroy the sensitivity of crystals.

Don't heat the filament of a vacuum tube to greater brilliancy than is necessary to secure the sensitiveness required.

Don't use a plate voltage that is less or more than it is rated for.

Don't connect the filament to a lighting circuit.

Don't use dry cells for heating the filament except in a pinch.

Don't use a constant current to heat the filament, use a constant voltage.

Don't use a vacuum tube in a horizontal position unless it is made to be so used.

Don't fail to properly insulate the grid and plate leads.

Don't use more than 1/3 of the rated voltage on the filament and on the plate when trying it out for the first time.

Don't fail to use a voltmeter to find the proper temperature of the filament.

Don't expect to get results with a loud speaker when using a single vacuum tube.

Don't fail to protect your vacuum tubes from mechanical shocks and vibration.

Don't fail to cut off the *A* battery entirely from the filament when you are through receiving.

Don't expect to get the best results with a gas-content detector tube without using a potentiometer.

Don't connect a potentiometer across the *B* battery or it will speedily run down.

Don't expect to get as good results with a single coil tuner as you would with a loose coupler.

Don't expect to get as good results with a two-coil tuner as with one having a third, or *tickler,* coil.

Don't think you have to use a regenerative circuit, that is, one with a tickler coil, to receive with a vacuum tube detector.

Don't think you are the only amateur who is troubled with static.

Don't expect to eliminate interference if the amateurs around you are sending with spark sets.

Don't lay out or assemble your set on a panel first. Connect it up on a board and find out if everything is right.

Don't try to connect up your set without a wiring diagram in front of you.

Don't fail to shield radio frequency amplifiers.

Don't set the axes of the cores of radio frequency transformers in a line. Set them at right angles to each other.

Don't use wire smaller than *No. 14* for connecting up the various parts.

Don't fail to adjust the *B* battery after putting in a fresh vacuum tube, as its sensitivity depends largely on the voltage.

Don't fail to properly space the parts where you use variometers.

Don't fail to put a copper shield between the variometer and the varicoupler.

Don't fail to keep the leads to the vacuum tube as short as possible.

Don't throw your receiving set out of the window if it *howls*. Try placing the audio-frequency transformers farther apart and the cores of them at right angles to each other.

Don't use condensers with paper dielectrics for an amplifier receiving set or it will be noisy.

Don't expect as good results with a loop aerial, or when using the bed springs, as an out-door aerial will give you.

Don't use an amplifier having a plate potential of less than 100 volts for the last step where a loud speaker is to be used.

Don't try to assemble a set if you don't know the difference between a binding post and a blue print. Buy a set ready to use.

Don't expect to get Arlington time signals and the big cableless stations if your receiver is made for short wave lengths.

Don't take your headphones apart. You are just as apt to spoil them as you would a watch.

Don't expect to get results with a Bell telephone receiver.

Don't forget that there are other operators using the ether besides yourself.

Don't let your *B* battery get damp and don't let it freeze.

Don't try to recharge your *B* battery unless it is constructed for the purpose.

Storage Battery Don'ts

Don't connect a source of alternating current direct to your storage battery. You have to use a rectifier.

Don't connect the positive lead of the charging circuit with the negative terminal of your storage battery.

Don't let the electrolyte get lower than the tops of the plates of your storage battery.

Don't fail to look after the condition of your storage battery once in a while.

Don't use a *6* volt storage battery for lighting the filaments of vacuum tubes that require only *1 1/2 or 4 volts.*

Don't fail to keep the specific gravity of the electrolyte of your storage battery between *1.225* and *1.300 Baumé.* This you can do with a *hydrometer.*

Don't fail to recharge your storage battery when the hydrometer shows that the specific gravity of the electrolyte is close to *1.225.*

Don't keep charging the battery after the hydrometer shows that the specific gravity is *1.285.*

Don't let the storage battery freeze.

Don't let it stand for longer than a month without using unless you charge it.

Don't monkey with the storage battery except to add a little sulphuric acid to the electrolyte from time to time. If anything goes wrong with it better take it to a service station and let the expert do it.

Extra Don'ts

Don't think you have an up-to-date transmitting station unless you are using *C.W.*

Don't use a wire from your lightning switch down to the outside ground that is smaller than *No. 4.*

Don't try to operate your spark coil with 110-volt direct lighting current without connecting in a rheostat.

Don't try to operate your spark coil with 110-volt alternating lighting current without connecting in an electrolytic interrupter.

Don't try to operate an alternating current power transformer with 110-volt direct current without connecting in an electrolytic interruptor.

Don't—no never—connect one side of the spark gap to the aerial wire and the other side of the spark gap to the ground. The Government won't have it—that's all.

Don't try to tune your transmitter to send out waves of given length by guesswork. Use a wavemeter.

Don't use *hard fiber* for panels. It is a very poor insulator where high frequency currents are used.

Don't think you are the only one who doesn't know all about wireless. Wireless is a very complex art and there are many things that those experienced have still to learn.

REGULATIONS OF THE NATIONAL BOARD OF FIRE UNDERWRITERS FOR ELECTRIC WIRING AND APPARATUS AS RECOMMENDED BY THE NATIONAL FIRE PROTECTION ASSOCIATION

American Standard Approved July 3, 1925, by American Engineering Standards Committee

Article 37. Radio Equipment

3701. *General.*

a. The requirements of this article shall not apply to equipment installed on shipboard, but shall be deemed to be additional to, or amendatory of, those prescribed in articles 1 to 19, inclusive, of this code.

b. Transformers, voltage reducers, keys and other devices employed shall be of types expressly approved for radio operation.

3702. *For Receiving Stations Only.*

a. Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b. Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

c. Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d. The preceding paragraphs, *a, b,* and *c,* shall not apply to light and power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

e. Lead-in conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

f. Lead-in conductors on the outside of buildings shall not come nearer than 4 inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g. Each lead-in conductor shall enter the building through a non-combustible, non-absorptive, insulating bushing slanting upward toward the inside or by means of an approved device designed to give equivalent protection.

h. Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

i. If an antenna grounding switch is employed, it shall in its closed position form a shunt around the protective device. Such a switch shall not be used as a substitute for the protective device.

It is recommended that the antenna grounding switch be employed, and that in addition a switch rated at not less than 30 amperes, 250 volts, be located between the lead-in conductor and the receiver set.

j. If fuses are used, they shall not be placed in the circuit from the antenna through the protective device to ground.

k. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The protective grounding conductor shall be not smaller nor have less conductance per unit of length, than the lead-in conductor and in no case shall be smaller than No. 14 if copper nor smaller than No. 17 if of bronze or copper-clad steel. The protective grounding conductor shall be run in as straight a line as possible from the protective device to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds, such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

l. The protective grounding conductor shall be guarded where exposed to mechanical injury. An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

m. The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs *k* and *l*, may be used as the operating ground.

It is recommended that in this case the operating grounding conductor be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, this operating grounding conductor being either bare or provided with an insulated covering.

n. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than 2 inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

o. Storage battery leads shall consist of conductors having approved rubber insulation. The circuits from storage batteries shall be properly protected by fuses or circuit breakers rated at not more than 15 amperes and located preferably at or near the battery.

3703. *For Transmitting Stations Only.*

a. Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b. Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

c. Splices and joints in the antenna and counterpoise span shall be soldered unless made with approved splicing devices.

d. Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.

e. Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted 5 inches clear of the surface of the building, on non-absorptive insulating supports such as treated pins or brackets, equipped with insulators having not less than 5 inches creepage and air-gap distance to inflammable or conducting material, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches.

f. In passing the antenna or counterpoise lead-in into the building a tube or bushing of non-absorptive, insulating material, slanting upward toward the inside, shall be used and shall be so insulated as to have a creepage and air-gap distance of at least 5 inches to any extraneous body, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches. If porcelain or other fragile material is used it shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing provided creepage and air-gap distance as specified above is maintained.

g. A double-throw knife switch having a break distance of at least 4 inches and a blade not less than 1/8 inch by 1/2 shall be used to join the antenna and counterpoise lead-in to the grounding conductor. The switch may be located inside or outside the building. The base of the switch shall be of non-absorptive insulating material. This switch shall be so mounted that its current-carrying parts will be at least 5 inches clear of the building wall or other conductors, except that for continuous wave sets of 1000 watts and less input to the transmitter, the clearance shall not be less than 3 inches. The conductor from grounding switch to ground shall be securely supported.

It is recommended that the switch be located in the most direct line between the lead-in conductors and the point where grounding connection is made.

h. Antenna and counterpoise conductors shall be effectively and permanently grounded at all times when station is not in actual operation and unattended, by a conductor at least as large as the lead-in and in no case smaller than No. 14 copper, bronze, or approved copper-clad steel. This protective grounding conductor need not have an insulated covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good permanent ground. Preference shall be given to water piping. Other permissible protective grounds are the grounded steel frames of buildings and other grounded metal work in buildings and artificial grounding devices such as driven pipes, rods, plates, cones, etc. The protective grounding conductor shall be protected where exposed to mechanical injury. A suitable approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping. Gas piping shall not be used for the ground.

It is recommended that the protective grounding conductor be run outside the building.

i. The operating grounding conductor shall be of copper strip not less than $3/8$ inch wide by $1/32$ inch thick, or of copper, bronze, or approved copper-clad steel having a periphery, or girth, of at least ¾ inch, such as a No. 2 wire, and shall be firmly secured in place throughout its length.

j. The operating grounding conductor shall be connected to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

k. Where the current supply is obtained directly from lighting or power circuits, the conductors whether or not lead covered shall be installed in approved metal conduit, armored cable or metal raceways.

l. When necessary to protect the supply system from high-potential surges and kick-backs there shall be installed in the supply line as near as possible to each radio-transformer, rotary spark gap, motor and generator in motor generator sets and other auxiliary apparatus one of the following:

1. Two condensers (each of not less than 1/10 microfarad capacity and capable of withstanding 600 volt test) in series across the line with mid-point between condensers grounded; across (in parallel with) each of these condensers shall be connected a shunting fixed spark-gap capable of not more than 1/32 inch separation.

2. Two vacuum tube type protectors in series across the line with the mid-point grounded.

3. Resistors having practically zero inductance connected across the line with mid-point grounded.

   It is recommended that this third method be not employed where there is a circulation of power current between the mid-point of the resistors and the protective ground of the power circuit.

4. Lightning arresters such as the aluminum cell type.

RADIO LAWS AND REGULATIONS OF THE UNITED STATES

AN ACT

For the regulation of radio communications, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act is intended to regulate all forms of interstate and foreign radio transmissions and communications within the United States, its Territories and possessions; to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. That no person, firm, company, or corporation shall use or operate any apparatus for the transmission of energy or communications or signals by radio (*a*) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or District; or (*b*) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (*c*) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (*d*) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (*e*) upon any vessel of the United States; or (*f*) upon any aircraft or other mobile stations within the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

Section 2. For the purposes of this Act, the United States is divided into five zones, as follows: The first zone shall embrace the States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, the District of Columbia, Porto Rico, and the Virgin Islands; the second zone shall embrace the States of Pennsylvania, Virginia, West Virginia, Ohio, Michigan, and Kentucky; the third zone shall embrace the States of North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Mississippi, Arkansas, Louisiana, Texas, and Oklahoma; the fourth zone shall embrace the States of Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Iowa, Nebraska, Kansas, and Missouri; and the fifth zone shall embrace the States of Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, the Territory of Hawaii, and Alaska.

Section 3. That a commission is hereby created and established to be known as the Federal Radio Commission, hereinafter referred to as the commission, which shall be composed of five commissioners appointed by the President, by and with the advice and consent of the Senate, and one of whom the President shall designate as chairman: *Provided,* That chairmen thereafter elected shall be chosen by the commission itself.

Each member of the commission shall be a citizen of the United States and an actual resident citizen of a State within the zone from which appointed at the time of said appointment. Not more than one commissioner shall be appointed from any zone. No member of the commission shall be financially interested in the manufacture or sale of radio apparatus or in the transmission or operation of radiotelegraphy, radiotelephony, or radio broadcasting. Not more than three commissioners shall be members of the same political party.

The first commissioners shall be appointed for the terms of two, three, four, five, and six years, respectively, from the date of the taking effect of this Act, the term of each to be designated by the President, but their successors shall be appointed for terms of six years, except that any person chosen to fill a vacancy shall be appointed only for the unexpired term of the commissioner whom he shall succeed.

The first meeting of the commission shall be held in the city of Washington at such time and place as the chairman of the commission may fix. The commission shall convene thereafter at such times and places as a majority of the commission may determine, or upon call of the chairman thereof.

The commission may appoint a secretary, and such clerks, special counsel, experts, examiners, and other employees as it may from time to time find necessary for the proper performance of its duties and as from time to time may be appropriated for by Congress.

The commission shall have an official seal and shall annually make a full report of its operations to the Congress.

The members of the commission shall receive a compensation of $10,000 for the first year of their service, said year to date from the first meeting of said commission, and thereafter a compensation of $30 per day for each day's attendance upon sessions of the commission or while engaged upon work of the commission and while traveling to and from such sessions, and also their necessary traveling expenses.

Section 4. Except as otherwise provided in this Act, the commission, from time to time, as public convenience, interest, or necessity requires, shall—

(*a*) Classify radio stations;

(*b*) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;

(*c*) Assign bands of frequencies or wave lengths to the various classes of stations, and assign frequencies or wave lengths for each individual station and determine the power which each station shall use and the time during which it may operate;

(*d*) Determine the location of classes of stations or individual stations;

(*e*) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein;

(*f*) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: *Provided, however,* That changes in the wave lengths, authorized power, in the character of emitted signals, or in the times of operation of any station, shall not be made without the consent of the station license unless, in the judgment of the commission, such changes will serve public necessity or the provisions of this Act will be more fully complied with;

(*g*) Have authority to establish areas or zones to be served by any station;

(*h*) Have authority to make special regulations applicable to radio stations engaged in chain broadcasting;

(*i*) Have authority to make general rules and regulations requiring stations to keep such records of programs, transmissions of energy, communications, or signals as it may deem desirable;

(*j*) Have authority to exclude from the requirements of any regulations in whole or in part any radio station upon railroad rolling stock, or to modify such regulations in its discretion;

(*k*) Have authority to hold hearings, summon witnesses, administer oaths, compel the production of books, documents, and papers and to make such investigations as may be necessary in the performance of its duties. The commission may make such expenditures (including expenditures for rent and personal services at the seat of government and elsewhere, for law books, periodicals, and books of reference, and for printing and binding) as may be necessary for the execution of the functions vested in the commission and, as from time to time may be appropriated for by Congress. All expenditures of the commission shall be allowed and paid upon the presentation of itemized vouchers therefor approved by the chairman.

Section 5. From and after one year after the first meeting of the commission created by this Act, all the powers and authority vested in the commission under the terms of this Act, except as to the revocation of licenses, shall be vested in and exercised by the Secretary of Commerce; except that thereafter the commission shall have power and jurisdiction to act upon and determine any and all matters brought before it under the terms of this section.

It shall also be the duty of the Secretary of Commerce—

(*A*) For and during a period of one year from the first meeting of the commission created by this Act, to immediately refer to the commission all applications for station licenses or for the renewal or modification of existing station licenses.

(*B*) From and after one year from the first meeting of the commission created by this Act, to refer to the commission for its action any application for a station license or for the renewal or modification of any existing station license as to the granting of which dispute, controversy, or conflict arises or against the granting of which protest is filed within ten days after the date of filing said application by any party in interest and any application as to which such reference is requested by the applicant at the time of filing said application.

(*C*) To prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such persons as he finds qualified.

(*D*) To suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy him that the licensee (*a*) has violated any provision of any act or treaty binding on the United States which the Secretary of Commerce or the commission is authorized by this Act to administer or by any regulation made by the commission or the Secretary of Commerce under any such Act or treaty; or (*b*) has failed to carry out the lawful orders of the master of the vessel on which he is employed; or (*c*) has willfully damaged or permitted radio apparatus to be damaged; or (*d*) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (*e*) has willfully or maliciously interfered with any other radio communications or signals.

(*E*) To inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements of this Act, the rules and regulations of the licensing authority, and the license under which it is constructed or operated.

(*F*) To report to the commission from time to time any violations of this Act, the rules, regulations, or orders of the commission, or of the terms or conditions of any license.

(*G*) To designate call letters of all stations.

(*H*) To cause to be published such call letters and such other announcements and data as in his judgment may be required for the efficient operation of radio stations subject to the jurisdiction of the United States and for the proper enforcement of this Act.

The Secretary may refer to the commission at any time any matter the determination of which is vested in him by the terms of this Act.

Any person, firm, company, or corporation, any State or political division thereof aggrieved or whose interests are adversely affected by any decision, determination, or regulation of the Secretary of Commerce may appeal therefrom to the commission by filing with the Secretary of Commerce notice of such appeal within thirty days after such decision or determination or promulgation of such regulation. All papers, documents, and other records, pertaining to such application on file with the Secretary shall thereupon be transferred by him to the commission. The commission shall hear such appeal de novo under such rules and regulations as it may determine.

Decisions by the commission as to matters so appealed and as to all other matters over which it has jurisdiction shall be final, subject to the right of appeal herein given.

No station license shall be granted by the commission or the Secretary of Commerce until the applicant therefor shall have signed a waiver of any claim to the use of any particular frequency or wave length or of the ether as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

Section 6. Radio stations belonging to and operated by the United States shall not be subject to the provisions of sections 1, 4, and 5 of this Act. All such Government stations shall use such frequencies or wave lengths as shall be assigned to each or to each class by the President. All such stations, except stations on board naval and other Government vessels while at sea or beyond the limits of the continental United States, when transmitting any radio communication or signal other than a communication or signal relating to Government business shall conform to such rules and regulations designed to prevent interference with other radio stations and the rights of others as the licensing authority may prescribe. Upon proclamation by the President that there exists war or a threat of war or a state of public peril or disaster or other national emergency, or in order to preserve the neutrality of the United States, the President may suspend or amend, for such time as he may see fit, the rules and regulations applicable to any or all stations within the jurisdiction of the United States as prescribed by the licensing authority, and may cause the closing of any station for radio communication and the removal therefrom of its apparatus and equipment, or he may authorize the use or control of any such station and/or its apparatus and equipment by any department of the Government under such regulations as he may prescribe, upon just compensation to the owners. Radio stations on board vessels of the United States Shipping Board or the United States Shipping Board Emergency Fleet Corporation or the Inland and Coastwise Waterways Service shall be subject to the provisions of this Act.

Section 7. The President shall ascertain the just compensation for such use or control and certify the amount ascertained to Congress for appropriation and payment to the person entitled thereto. If the amount so certified is unsatisfactory to the person entitled thereto, such person shall be paid only 75 per centum of the amount and shall be entitled to sue the United States to recover such further sum as added to such payment of 75 per centum which will make such amount as will be just compensation for the use and control. Such suit shall be brought in the manner provided by paragraph 20 of section 24, or by section 145 of the Judicial Code, as amended.

Section 8. All stations owned and operated by the United States, except mobile stations of the Army of the

United States, and all other stations on land and sea, shall have special call letters designated by the Secretary of Commerce.

Section 1 of this Act shall not apply to any person, firm, company, or corporation sending radio communications or signals on a foreign ship while the same is within the jurisdiction of the United States, but such communications or signals shall be transmitted only in accordance with such regulations designed to prevent interference as may be promulgated under the authority of this Act.

Section 9. The licensing authority, if public convenience, interest, or necessity will be served thereby, subject to the limitations of this Act, shall grant to any applicant therefor a station license provided for by this Act.

In considering applications for licenses and renewals of licenses, when and in so far as there is a demand for the same, the licensing authority shall make such a distribution of licenses, bands of frequency or wave lengths, periods of time for operation, and of power among the different States and communities as to give fair, efficient, and equitable radio service to each of the same.

No license granted for the operation of a broadcasting station shall be for a longer term than three years and no license so granted for any other class of station shall be for a longer term than five years, and any license granted may be revoked as hereinafter provided. Upon the expiration of any license, upon application therefor, a renewal of such license may be granted from time to time for a term not to exceed three years in the case of broadcasting licenses and not to exceed five years in the case of other licenses.

No renewal of an existing station license shall be granted more than thirty days prior to the expiration of the original license.

Section 10. The licensing authority may grant station licenses only upon written application therefor addressed to it. All applications shall be filed with the Secretary of Commerce. All such applications shall set forth such facts as the licensing authority by regulation may prescribe as to the citizenship, character, and financial, technical, and other qualifications of the applicant to operate the station; the ownership and location of the proposed station and of the stations, if any, with which it is proposed to communicate; the frequencies or wave lengths and the power desired to be used; the hours of the day or other periods of time during which it is proposed to operate the station; the purposes for which the station is to be used; and such other information as it may require. The licensing authority at any time after the filing of such original application and during the term of any such license, may require from an applicant or licensee further written statements of fact to enable it to determine whether such original application should be granted or denied or such license revoked. Such application and/or such statement of fact shall be signed by the applicant and/or licensee under oath or affirmation.

The licensing authority in granting any license for a station intended or used for commercial communication between the United States or any Territory or possession, continental or insular, subject to the jurisdiction of the United States, and any foreign country, may impose any terms, conditions, or restrictions authorized to be imposed with respect to submarine-cable licenses by section 2 of an Act entitled "An Act relating to the landing and the operation of submarine cables in the United States," approved May 24, 1921.

Section 11. If upon examination of any application for a station license or for the renewal or modification of a station license the licensing authority shall determine that public interest, convenience, or necessity would be served by the granting thereof, it shall authorize the issuance, renewal, or modification thereof in accordance with said finding. In the event the licensing authority upon examination of any such application does not reach such decision with respect thereto, it shall notify the applicant thereof, shall fix and give notice of a time and place for hearing thereon, and shall afford such applicant an opportunity to be heard under such rules and regulations as it may prescribe.

Such station licenses as the licensing authority may grant shall be in such general form as it may prescribe, but each license shall contain, in addition to other provisions, a statement of the following conditions to which such license shall be subject:

(*A*) The station license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies or wave length designated in the license beyond the term thereof nor in any other manner than authorized therein.

(*B*) Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of this Act.

(*C*) Every license issued under this Act shall be subject in terms to the right of use or control conferred by section 6 hereof.

In cases of emergency arising during the period of one year from and after the first meeting of the commission created hereby, or on applications filed during said time for temporary changes in terms of licenses when the commission is not in session and prompt action is deemed necessary, the Secretary of Commerce shall have authority to exercise the powers and duties of the commission, except as to revocation of licenses, but all such exercise of powers shall be promptly reported to the members of the commission, and any action by the Secretary authorized under this paragraph shall continue in force and have effect only until such time as the commission shall act thereon.

Section 12. The station license required hereby shall not be granted to, or after the granting thereof such license shall not be transferred in any manner, either voluntarily or involuntarily, to (*a*) any alien or the representative of any alien; (*b*) to any foreign government, or the representative thereof; (*c*) to any company, corporation, or association organized under the laws of any foreign government; (*d*) to any company, corporation, or association of which any officer or director is an alien, or of which more than one-fifth of the capital stock may be voted by aliens or their representatives or by a foreign government or representative thereof, or by any company, corporation, or association organized under the laws of a foreign country.

The station license required hereby, the frequencies or wave length or lengths authorized to be used by the licensee, and the rights therein granted shall not be transferred, assigned, or in any manner, either voluntarily or involuntarily, disposed of to any person, firm, company, or corporation without the consent in writing of the licensing authority.

Section 13. The licensing authority is hereby directed to refuse a station license and/or the permit hereinafter required for the construction of a station to any person, firm, company, or corporation, or any subsidiary thereof, which has been found guilty by any Federal court of unlawfully monopolizing or attempting unlawfully to monopolize, after this Act takes effect, radio communication, directly or indirectly, through the control of the manufacture or sale of radio apparatus, through exclusive traffic arrangements, or by any other means or to have been using unfair methods of competition. The granting of a license shall not estop the United States or any person aggrieved from proceeding against such person, firm, company, or corporation for violating the law against unfair methods of competition or for a violation of the law against unlawful restraints and monopolies and/or combinations, contracts, or agreements in restraint of trade, or from instituting proceedings for the dissolution of such firm, company, or corporation.

Section 14. Any station license shall be revocable by the commission for false statements either in the application or in the statement of fact which may be required by section 10 hereof, or because of conditions revealed by such statements of fact as may be required from time to time which would warrant the licensing authority in refusing to grant a license or an original application, or for failure to operate substantially as set forth in the license, for violation of or failure to observe any of the restrictions and conditions of this Act, or of any regulation of the licensing authority authorized by this Act or by a treaty ratified by the United States, or whenever the Interstate Commerce Commission, or any other Federal body in the exercise of authority conferred upon it by law, shall find, and shall certify to the commission that any licensee bound so to do, has failed to provide reasonable facilities for the transmission of radio communications, or that any licensee has made any unjust and unreasonable charge, or has been guilty of any discrimination, either as to charge or as to service or has made or prescribed any unjust and unreasonable classification, regulation, or practice with respect to the transmission of radio communications or service: *Provided,* That no such order of revocation shall take effect until thirty days' notice in writing thereof, stating the cause for the proposed revocation, has been given to the parties known by the commission to be interested in such license. Any person in interest aggrieved by said order may make written application to the commission at any time within said thirty days for a hearing upon such order, and upon the filing of such written application said order of revocation shall stand suspended until the conclusion of the hearing herein directed. Notice in writing of said hearing shall be given by the commission to all the parties known to it to be interested in such license twenty days prior to the time of said hearing. Said hearing shall be conducted under such rules and in such manner as the commission may prescribe. Upon the conclusion hereof the commission may affirm, modify, or revoke said orders of revocation.

Section 15. All laws of the United States relating to unlawful restraints and monopolies and to combinations, contracts, or agreements in restraint of trade are hereby declared to be applicable to the manufacture and sale of and to trade in radio apparatus and devices entering into or affecting interstate or foreign commerce and to interstate or foreign radio communications. Whenever in any suit, action, or proceeding, civil or criminal, brought under the provisions of any of said laws or in any proceedings brought to enforce or to review findings and orders of the Federal Trade Commission or other governmental agency in respect of any matters as to which said commission or other governmental agency is by law authorized to act, any licensee shall be found guilty of the violation of the provisions of such laws or any of them, the court, in addition to the penalties imposed by said laws, may adjudge, order, and/or decree that the license of such licensee shall, as of the date the decree or judgment becomes finally effective or as of such other date as the said decree shall fix, be revoked and that all rights under such license shall thereupon cease: *Provided, however,* That such licensee shall have the same right of appeal or review as is provided by law in respect of other decrees and judgments of said court.

Section 16. Any applicant for a construction permit, for a station license, or for the renewal or modification of an existing station license whose application is refused by the licensing authority shall have the right to appeal from said decision to the Court of Appeals of the District of Columbia; and any licensee whose license is revoked by the commission shall have the right to appeal from such decision of revocation to said Court of Appeals of the District of Columbia or to the district court of the United States in which the apparatus licensed is operated, by filing with said court, within twenty days after the decision complained of is effective, notice in writing of said appeal and of the reasons therefor.

The licensing authority from whose decision an appeal is taken shall be notified of said appeal by service upon it, prior to the filing thereof, of a certified copy of said appeal and of the reasons therefor. Within twenty days after the filing of said appeal the licensing authority shall file with the court the originals or certified copies of all papers and evidence presented to it upon the original application for a permit or license or in the hearing upon said order of revocation, and also a like copy of its decision thereon and a full statement in writing of the facts and the grounds for its decision as found and given by it. Within twenty days after the filing of said statement by the licensing authority either party may give notice to the court of his desire to adduce additional evidence. Said notice shall be in the form of a verified petition stating the nature and character of said additional evidence, and the court may thereupon order such evidence to be taken in such matter and upon such terms and conditions as it may deem proper.

At the earliest convenient time the court shall hear, review, and determine the appeal upon said record and evidence, and may alter or revise the decision appealed from and enter such judgment as to it may seem just. The revision by the court shall be confined to the points set forth in the reasons of appeal.

Section 17. After the passage of this Act no person, firm, company, or corporation now or hereafter directly or indirectly through any subsidiary, associated, or affiliated person, firm, company, corporation, or agent, or otherwise, in the business of transmitting and/or receiving for hire energy, communications, or signals by radio in accordance with the terms of the license issued under this Act, shall by purchase, lease, construction, or otherwise, directly or indirectly, acquire, own, control, or operate any cable or wire telegraph or telephone line or system between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any foreign country, or shall acquire, own, or control any part of the stock or other capital share of any interest in the physical property and/or other assets of any such cable, wire, telegraph, or telephone line or system, if in either case the purpose is and/or the effect thereof may be to substantially lessen competition or to restrain commerce between any place in any State, Territory, or possession of the United States or in the District of Columbia and any place in any foreign country, or unlawfully to create monopoly in any line of commerce; nor shall any person, firm, company, or corporation now or hereafter engaged directly or indirectly through any subsidiary, associated or affliated person, company, corporation, or agent, or otherwise, in the business of transmitting or receiving for hire messages by any cable, wire, telegraph, or telephone line or system (*a*) between any place in any State, Territory, or possession of the United States or in the District of Columbia and any place in any other State, Territory, or possession of the United States; or (*b*) between any place in any State, Territory, or possession of the United States, or the District of Columbia, and any place in any foreign country, by purchase, lease, construction, or otherwise, directly or indirectly acquire, own, control, or operate any station or the apparatus therein, or any system for transmitting and/or receiving radio communications or signals between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any foreign country, or shall acquire, own, or control any part of the stock or other capital share or any interest in the physical property and/or other assets of any such radio station, apparatus, or system, if in either case the purpose is and/or the effect thereof may be to substantially lessen competition or to restrain commerce between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any foreign country, or unlawfully to create monopoly in any line of commerce.

Section 18. If any licensee shall permit any person who is a legally qualified candidate for any public office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the licensing authority shall make rules and regulations to carry this provision into effect: *Provided,* That such licensee shall have no power of censorship over the material broadcast under the provisions of this paragraph. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

Section 19. All matter broadcast by any radio station for which service, money, or any other valuable consideration is directly or indirectly paid, or promised to or charged or accepted by, the station so broadcasting, from any person, firm, company, or corporation, shall at the time the same is so broadcast, be announced as paid for or furnished, as the case may be, by such person, firm, company, or corporation.

Section 20. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

Section 21. No license shall be issued under the authority of this Act for the operation of any station the construction of which is begun or is continued after this Act takes effect, unless a permit for its construction has been granted by the licensing authority upon written application therefor. The licensing authority may grant such permit if public convenience, interest, or necessity will be served by the construction of the station. This application shall set forth such facts as the licensing authority by regulation may prescribe as to the citizenship, character, and the financial, technical, and other ability of the applicant to construct and operate the station, the ownership and location of the proposed station and of the station or stations with which it is proposed to communicate, the frequencies and wave length or wave lengths desired to be used, the hours of the day or other periods of time during which it is proposed to operate the station, the purpose for which the station is to be used, the type of transmitting apparatus to be used, the power to be used, the date upon which the station is expected to be completed and in operation, and such other information as the licensing authority may require. Such application shall be signed by the applicant under oath or affirmation.

Such permit for construction shall show specifically the earliest and latest dates between which the actual operation of such station is expected to begin, and shall provide that said permit will be automatically forfeited if the station is not ready for operation within the time specified or within such further time as the licensing authority may allow, unless prevented by causes not under the control of the grantee. The rights under any such permit shall not be assigned or otherwise transferred to any person, firm, company, or corporation without the approval of the licensing authority. A permit for construction shall not be required for Government stations, amateur stations, or stations upon mobile vessels, railroad rolling stock, or aircraft. Upon the completion of any station for the construction or continued construction of which a permit has been granted, and upon it being made to appear to the licensing authority that all the terms, conditions, and obligations set forth in the application and permit have been fully met, and that no cause or circumstance arising or first coming to the knowledge of the licensing authority since the granting of the permit would, in the judgment of the licensing authority, make the operation of such station against the public interest, the licensing authority shall issue a license to the lawful holder of said permit for the operation of said station. Said license shall conform generally to the terms of said permit.

Section 22. The licensing authority is authorized to designate from time to time radio stations the communications or signals of which, in its opinion, are liable to interfere with the transmission or reception of distress signals of ships. Such stations are required to keep a licensed radio operator listening in on the wave lengths designated for signals of distress and radio communications relating thereto during the entire period the transmitter of such station is in operation.

Section 23. Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency or wave length specified by the licensing authority, with apparatus capable of transmitting and receiving messages over a distance of at least one hundred miles by day or night. When sending radio communications or signals of distress and radio communications relating thereto the transmitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference which may thus be caused.

All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies or wave lengths which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

Section 24. Every shore station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

Section 25. At all places where Government and private or commercial radio stations on land operate in such close proximity that interference with the work of Government stations can not be avoided when they are operating simultaneously such private or commercial stations as do interfere with the transmission or reception of radio communications or signals by the Government stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time.

The Government stations for which the above-mentioned division of time is established shall transmit radio communications or signals only during the first fifteen minutes of each hour, local standard time, except in case of signals of radio communications relating to vessels in distress, and vessel requests for information as to course, location, or compass direction.

Section 26. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

Section 27. No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substance, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect, or meaning of the same or any part thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided,* That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

Section 28. No person, firm, company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

Section 29. Nothing in this Act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Section 30. The Secretary of the Navy is hereby authorized unless restrained by international agreement, under the terms and conditions and at rates prescribed by him, which rates shall be just and reasonable, and which, upon complaint, shall be subject to review and revision by the Interstate Commerce Commission, to use all radio stations and apparatus, wherever located, owned by the United States and under the control of the Navy Department (*a*) for the reception and transmission of press messages offered by any newspaper published in the United States, its Territories or possessions, or published by citizens of the United States in foreign countries, or by any press association of the United States, and (*b*) for the reception and transmission of private commercial messages between ships, between ship and shore, between localities in Alaska and between Alaska and the continental United States: *Provided,* That the rates fixed for the reception and transmission of all such messages, other than press messages between the Pacific coast of the United States, Hawaii, Alaska, the Philippine Islands, and the Orient, and between the United States and the Virgin Islands, shall not be less than the rates charged by privately owned and operated stations for like messages and service: *Provided further,* That the right to use such stations for any of the purposes named in this section shall terminate and cease as between any countries or localities or between any locality and privately operated ships whenever privately owned and operated stations are capable of meeting the normal communication requirements between such countries or localities or between any locality and privately operated ships, and the licensing authority shall have notified the Secretary of the Navy thereof.

Section 31. The expression "radio communication" or "radio communications" wherever used in this Act means any intelligence, message, signal, power, pictures, or communication of any nature transferred by electrical energy from one point to another without the aid of any wire connecting the points from and at which the electrical energy is sent or received and any system by means of which such transfer of energy is effected.

Section 32. Any person, firm, company, or corporation failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the authority of this Act or of any international radio convention or treaty ratified or adhered to by the United States, in addition to any other penalties provided by law, upon conviction thereof by a court of competent jurisdiction, shall be punished by a fine of not more than $500 for each and every offense.

Section 33. Any person, firm, company, or corporation who shall violate any provision of this Act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by this Act, or shall knowingly swear falsely to a material matter in any hearing authorized by this Act, upon conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than $5,000 or by imprisonment for a term of not more than five years or both for each and every such offense.

Section 34. The trial of any offense under this Act shall be in the district in which it is committed; or if the offense is committed upon the high seas, or out of the jurisdiction of any particular State or district, the trial shall be in the district where the offender may be found or into which he shall be first brought.

Section 35. This Act shall not apply to the Philippine Islands or to the Canal Zone. In international radio matters the Philippine Islands and the Canal Zone shall be represented by the Secretary of State.

Section 36. The licensing authority is authorized to designate any officer or employee of any other department of the Government on duty in any Territory or possession of the United States other than the Philippine Islands and the Canal Zone, to render therein such services in connection with the administration of the radio laws of the United states as such authority may prescribe: *Provided,* That such designation shall be approved by the head of the department in which such person is employed.

Section 37. The unexpended balance of the moneys appropriated in the item for "wireless communication laws," under the caption "Bureau of Navigation" in Title III of the Act entitled "An Act making appropriations for the Departments of State and Justice and for the judiciary, and for the Departments of Commerce and Labor, for the fiscal year ending June 30, 1927, and for other purposes," approved April 29, 1926, and the appropriation for the same purposes for the fiscal year ending June 30, 1928, shall be available both for expenditures incurred in the administration of this Act and for expenditures for the purposes specified in such items. There is hereby authorized to be appropriated for each fiscal year such sums as may be necessary for the administration of this Act and for the purposes specified in such item.

Section 38. If any provision of this Act or the application thereof to any person, firm, company, or corporation, or to any circumstances, is held invalid, the remainder of the Act and the application of such provision to other persons, firms, companies, or corporations, or to other circumstances, shall not be affected thereby.

Section 39. The Act entitled "An Act to regulate radio communication," approved August 13, 1912, the joint resolution to authorize the operation of Government-owned radio stations for the general public, and for other purposes, approved June 5, 1920, as amended, and the joint resolution entitled "Joint resolution limiting the time for which licenses for radio transmission may be granted, and for other purposes," approved December 8, 1926, are hereby replaced.

Such repeal, however, shall affect any act done or any right accrued or any suit or proceeding had or commenced in any civil cause prior to said repeal, but all liabilities under said laws shall continue and may be enforced in the same manner as if committed; and all penalties, forfeitures, or liabilities incurred prior to taking effect hereof, under any law embraced in, changed, modified, or repealed by this Act, may be prosecuted and punished in the same manner and with the same effect as if this Act had not been passed.

Nothing in this section shall be construed as authorizing any person now using or operating any apparatus for the transmission of radio energy or radio communications or signals to continue such use except under and in accordance with this Act and with a license granted in accordance with the authority hereinbefore conferred.

Section 40. This Act shall take effect and be in force upon its passage and approval, except that for and during a period of sixty days after such approval no holder of a license or an extension thereof issued by the Secretary of Commerce under said Act of August 13, 1912, shall be subject to the penalties provided herein for operating a station without the license herein provided.

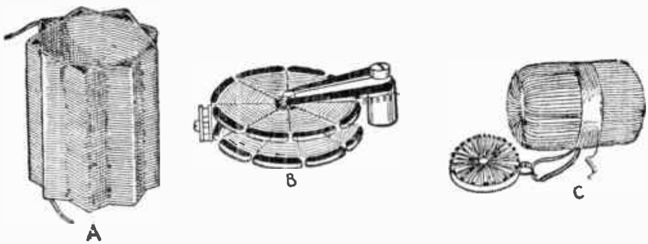
Section 41. This Act may be referred to and cited as the Radio Act of 1927. (Approved Feb. 23, 1927).

SUPPLEMENTARY INFORMATION

By GEORGE C. BAXTER ROWE
Assistant Editor *Radio News*

Radio Frequency Amplification

The majority of radio frequency transformers that are employed in receivers using this type of amplification are extremely simple in construction. There are several different styles of windings used on the coils forming the



Basket-weave   Spider Web   Toroidal

FIG. 101.—Types of Inductance Coil Windings.

primary and secondary of these transformers, such as the basket-weave, the pan-cake, the spider-web, the toroidal and the cylindrical, but the last one mentioned is not only thoroughly efficient electrically, but has the added advantage of being easily constructed. For different styles of windings see Fig. 101.

It should be borne in mind that when very small electrical currents, such as are present in the radio frequency amplifier, are being dealt with, it is of the utmost importance that all possible losses should be reduced to a minimum. One of the largest losses met with in radio receivers generally is that of high resistance in connection wires and in coils. Coils may be wound of No. 22 B. & S.

Fig. 102.—Straight Line Wave Length Condensers.

gauge D.C.C. wire and in some cases No. 18 bell wire may be employed. In using wire of this size, not only will the resistance of the coils be lower, but a minimum of in-

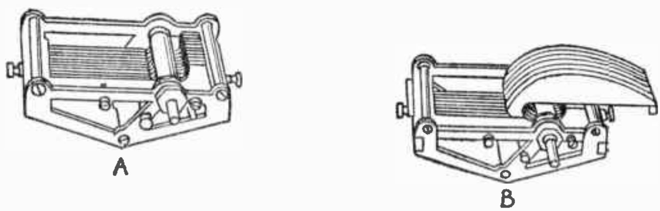


Fig. 103.—Straight Line Frequency Condensers.

sulation tubing will be necessary as the coils can be made self-supporting.

Generally the secondaries of radio frequency transformers are shunted by a variable condenser in order to have each stage exactly in resonance with the others. The condensers that are used have in general 23 plates, which means that the capacity of the condenser is approximately .0005 mf.

As in the case of the coils there are different types of condensers used; i.e. straight line capacity, straight line wave-length and straight line frequency. (See Figs. 102 and 103.) These titles mean that if the dial settings of the condensers are plotted on graph paper against the capacity, wave-length or frequency as the case may be, the points obtained would fall on a straight line. Each of these three types of condensers has its own advantage, but for radio frequency receivers the last one mentioned is superior, because the dial settings of the stations received are spread over a greater range, making the tuning of the set much easier.

A Tuned Radio Frequency Receiver

There are a great many variations of this type of circuit and the majority of the higher-priced receivers employ it, as it is excellent for distant reception as well as volume of reproduction. It will be noticed that there is a similarity between the circuit in Fig. 104 and the Neutrodyne shown on page 114, the main difference being in the addition of a 400 ohm potentiometer, which replaces the neutralizing condensers.

In tuning this receiver, the three variable 23 plate condensers are placed at approximately the same dial readings. When a station is heard the quality of reception can be brought to maximum by varying the potentiometer, which varies the grid bias of the first two tubes. The volume of the loud speaker can be regulated by changing the filament rheostat of the last two tubes.

The Parts and How To Connect Them.—You will require (1) 3 radio frequency transformers; (2) 3 23 plate variable condensers, (.0005 mfd.) preferably of the straight line frequency type; (3) 2 fixed condensers, (.00025 mfd.) and (.001 mfd.); (4) a grid leak, 2 megohms; (5) 4 amplifier vacuum tubes; (6) 1 detector vacuum tube; (7) 5 tube sockets; (8) a potentiometer, 400 ohms; (9) 3 filament

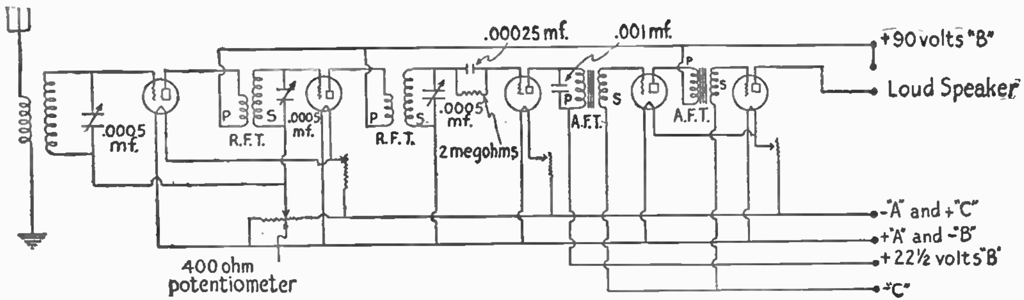


FIG. 104.—Tuned Radio Frequency Receiver.

rheostats; (10) 2 audio frequency transformers, ratios of 5 to 1 and 3 to 1; (11) an "A" battery; (12) a "B" battery capable of delivering 90 volts; (13) a "C" battery of 4½ volts; (14) a pair of head-phones or loud speaker.

The radio frequency transformers can be wound by the constructor. Procure sufficient hard rubber or bakelite tubing, 3 inches in diameter, for the three transformers and a ¼ lb. of No. 22 B. & B. gauge D.C.C. wire. The secondary winding consists of fifty turns of the wire and the primary, which is wound over the secondary and in the same direction, has ten turns. The ends of the coils should be securely fastened to the tubing. Fig. 104 shows the diagram of connections. If the oscillations, or howls, cannot be eliminated completely by means of the potentiometer, try reversing the leads to the radio frequency transformers.

The Regenerative Interflex

This is one of the most interesting circuits that has been brought to the public's attention recently and although only the fundamental circuit is shown in Fig. 104A it is an extremely simple matter to add audio frequency amplification to its output.

The Parts and How to Connect Them.—You will require one vacuum tube socket; one S.L.F. .0005 mf. variable condenser; one 6 ohms rheostat; one .00025 mf. fixed condenser; one 2-20 mmf. variable condenser; one 25 turn honeycomb coil; one fixed carborundum detector; one 201-A vacuum tube; one 3-inch bakelite tube; No. 22 D.C.C. wire for winding the inductances; "A" and "B" batteries.

The two inductances are wound on the same 3-inch tube with ¼ inch between them. The 25-turn honeycomb coil is mounted inside this tube so that it can be raised and lowered with respect to the 46 turns of the secondary. This is done by fitting a piece of hard rubber 3/16 by ½ inch in the diameter of the tube and a hole drilled through it to take a threaded rod to the end of which is fastened the tickler, i.e., the honeycomb coil. Two guide rods are also used on which the tickler slides without turning.

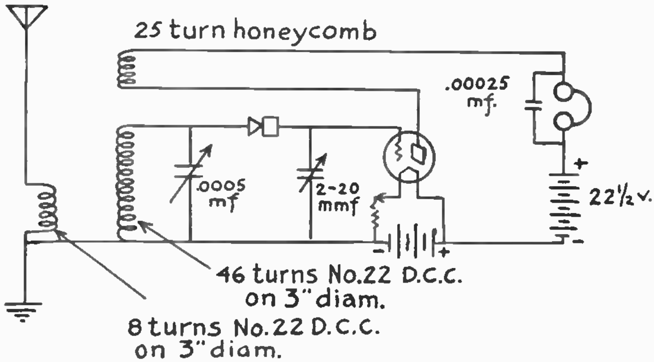


FIG. 104A.—Regenerative Interflex Receiver.

The circuit, which has but a single control, will not squeal or howl when it is properly adjusted; loud speaker operation is possible on local stations; with two stages of audio-frequency amplification a 1,000 mile loud speaker range is possible and the set tunes with extreme sharpness.

When the set has been tested a station is tuned in and the tickler varied up and down and the rheostat varied until there are no howls when the condenser is varied. A fixed crystal detector is used to eliminate trouble with the adjustable types. After the adjustments mentioned above have been made it is unnecessary to touch the rheostat and the tickler, the variation of the condenser being the only thing needed to tune stations in.

If audio-frequency amplification is added, any one of the systems mentioned in the section devoted to that subject may be used, the input of the amplifer being connected to the output of the detector circuit, which is in this case the headphones.

An Interbalanced R.F. Regenerative Receiver

The circuit which is shown in Fig. 104B has several unique features. It has a stage of radio-frequency amplification, a regenerative detector, and three stages of resistance-coupled audio-frequency amplification. The regenerative action of the detector and the coupling between the radio-frequency and detector tubes are controlled by the same adjustment, i.e., the 10,000-ohms resistor in the plate circuit of the first tube, The action of this resistor is aided by the resistance and condenser enclosed by the dotted line, this combination being called a "phasatrol"—a phase shifting device.

The Parts Needed and How to Connect Them.—The following apparatus is required: L1, antenna coupler; L2, R.F. transformer; L3, tickler coil; two .0005 mf. variable condensers (connected in tandem); C, midget balancing condenser; RFC, R.F. choke coil, 85 millihenries; two 5 mf. by-pass condensers; one .00025 mf. fixed condenser; one .002 mf. fixed by-pass condenser; one variable resistor, 0-10,000 ohms; R4, two filament ballasts, 5 volts, 1/4 ampere; R5, one filament ballast, 5 volts, 1 ampere; one grid leak, 2 megohms; one Phasatrol; one resistance coupled A.F. amplifier (this may be purchased complete); two coil shields; one filament switch, SW; two UX-type sockets; one dial; one panel, 7 × 18 × 3/16 inches; two 201-A vacuum tubes; two high-mu vacuum tubes for first two stages of A.F. amplifier; one power tube for last stage; "A," "B" and "C" batteries.

The inductances, L1 and L2, are constructed in the same manner. On a form 2 3/4 inches in diameter are first wound 55 turns of No. 22 D.S.C. wire. Over the lower part of these turns are wound two or three layers of paper or insulating cloth, over which is wound the primary of 10 turns of the same size wire. For the fixed tickler coil, L3, 15 turns of No. 24 D.S.C. wire is wound on a 2-inch

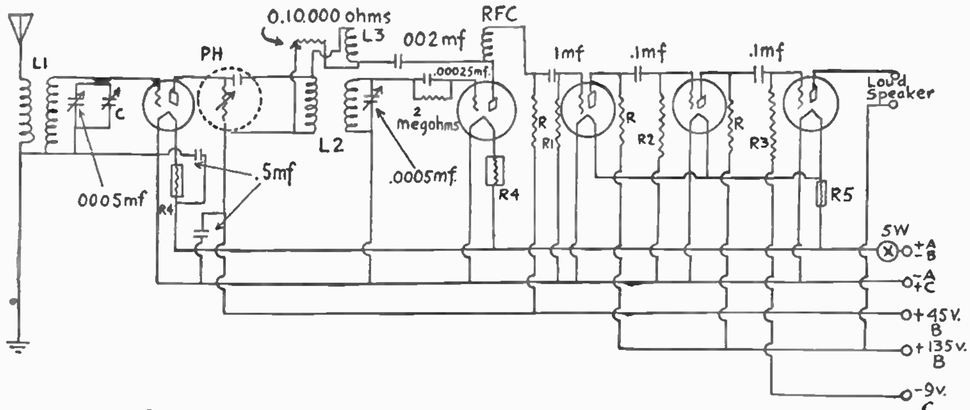


Fig. 104B.—Interbalanced Radio-Frequency Regenerative Receiver.

form that is 1½ inches in length. This is mounted inside the R.F. transformer, L2.

The only apparatus that need be mounted on the panel of the set are the gang condenser, the midget balancing condenser and the 10,000 ohms resistor, the remainder of the parts being mounted on the baseboard. No rheostats are required as the filament ballasts fulfill the duties of these devices automatically.

Shields are used around the R.F. inductances in order that there may be eliminated all possibility of feed-back and interaction between the R.F. coils and the detector inductances. It is very important that these aluminum cans be of such a size that they do not come too close to the coils, for in that case they would be worse than useless, as they would absorb more of the energy than they would keep out.

The tuning of this receiver is extremely simple after the initial adjustments have been made on the phasatrol, the 10,000 ohms resistor and the balancing condenser.

40-Meter Transmitter

Amateurs are doing more and more work on low wave lengths under 100 meters. One of the most satisfactory wave lengths for distance and general reliability is 40 meters and the constants for the circuit in Fig. 104C are for that number of meters. This circuit, which was developed by John L. Reinartz, is one which has been the subject of a great amount of experimenting and should prove satisfactory, not only because of its relatively low cost but on account of its efficiency.

The inductances are of ⅜-inch copper ribbon 7 inches in diameter and the turns are spaced with ¼-inch glass beads. The radio-frequency chokes, RFC, consist of 70 turns of No. 24 D.C.C. wire wound on a tube 2 inches in diameter. Any power vacuum tube may be used; the size and necessary equipment for its operation depending on the constructor's pocketbook.

The apparatus can be easily mounted on three 4-inch boards 16 inches long fastened to two 1¼-inch square

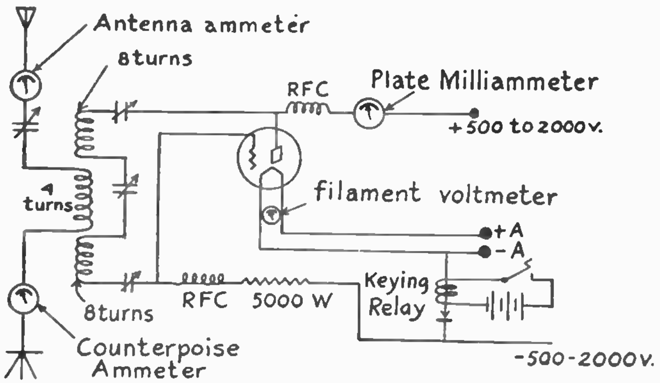


FIG. 104C.—40-Meter Transmitter.

uprights 24 inches long. On the upper board can be placed the antenna and the counterpoise ammeters with the antenna condenser; on the middle board the three other condensers and on the bottom one, the other two meters with the necessary binding posts. The vacuum tube is mounted on a shelf at the rear together with the choke coils.

The Parts and How to Connect Them.—You will require four 250 mmf. variable condensers; two ammeters; one 15-volts A.C. voltmeter; one 250 milliammeter; three inductances (See Fig. 104C for sizes); two radio-frequency choke coils; one keying relay; one vacuum tube and apparatus for its operation. The information regarding the necessary equipment for operating the tube can best be had from the dealer who supplies you with the tube, as for some types a storage battery and dry-cell plate batteries are sufficient, while with the higher-powered tubes a motor-generator set is imperative.

The antenna should be a vertical wire 40 feet long and the counterpoise, which is horizontal, should be about 20 feet in length. There are several precautions to observe. The antenna ammeter must be between the antenna condenser and the point where the antenna is connected to the set. The condenser side of the antenna inductance should be next to the grid inductance, thus eliminating harmonics. The information given in other sections of this book should be read and digested before this circuit is tried, the circuit being given here because it is new.

Short Wave Receiver

One of the most remarkable circuits for the reception of short waves is that shown in Fig. 104D, this being also developed by John L. Reinartz. With an antenna only about 15 or 20 feet long amateur stations all over the world have been received and the set itself is extremely simple to construct.

The Parts and How to Connect Them.—The following apparatus will be required, two .00025 mf. variable condensers; one 55 mmf. variable condenser; one 6:1 ratio audio-frequency transformer; one .0005 mf. fixed condenser with grid leak mounting; one 7 megohms grid leak; one 6-ohm rheostat; two UX-type sockets; one single-circuit jack; one 201-A and one 112-type vacuum tubes; one radio-frequency resistor, 1,000 ohms; one panel $7 \times 11 \times 3/16$ inches; No. 16 D.C.C. wire for coils; eleven binding posts.

When a set is operated at waves under 100 meters it is necessary to have a set of coils for the different wave bands. Coils may be wound according to the following table which covers wave lengths from about 15 meters to approximately 190 meters.

Wave Length	*Coils*	*L1*	*L2*	*L3*	*L4*
20 Meters	....	4	2	2	..
40 Meters	....	8	4	4	..
80 Meters	....	16	8	8	4
150–200 Meters	....	16	16	8	8

The coils are bunch wound, i.e., they are wound with no thought of keeping the turns side by side. Their diameter

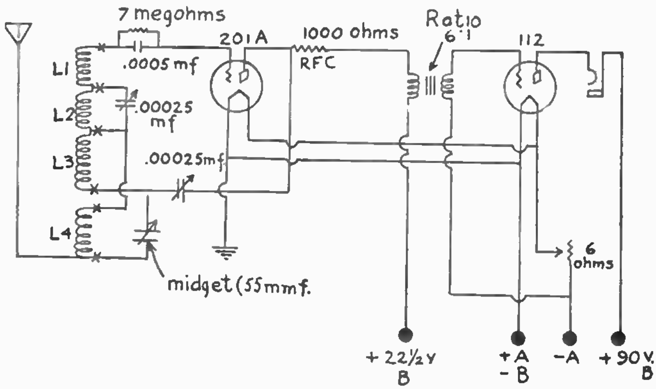


FIG. 104D.—Short Wave Receiver.

is approximately 3 inches and the turns are held in place by a few turns of tape. These coils are connected to binding posts (indicated by X in Fig. 104D) which are mounted on the front of the panel.

The simplest way to mount the apparatus is to place it all on the panel. A tube socket is placed in each of the upper corners, so that the tube will be horizontal. The transformer is mounted between them with the midget condenser on one side of it and the grid condenser and leak on the other. In the two lower corners are mounted the two variable condensers and between them the rheostat. The panel may be kept in an upright position by making two feet of 1/16-inch brass and fastening them to the condensers.

It will be noticed that for the 20 and 40 meters bands there are only three coils required. This is because the set operates more efficiently with the 55 mmf. condenser in series with L3 at these high frequencies. The 1000 ohms choke coil, RFC, is an inductive resistance, the coil being embedded in a porcelain tube. Only one stage of audio frequency amplification is needed as headphones are used almost entirely.

Audio Frequency Amplifiers

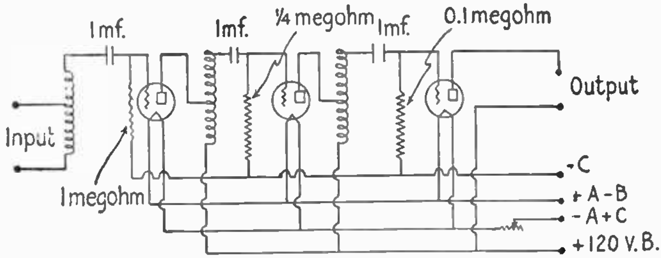
This type of amplification can be divided into four groups, as follows:

a. Transformer coupled.
b. Impedance coupled.
c. Resistance coupled.
d. Push-pull.

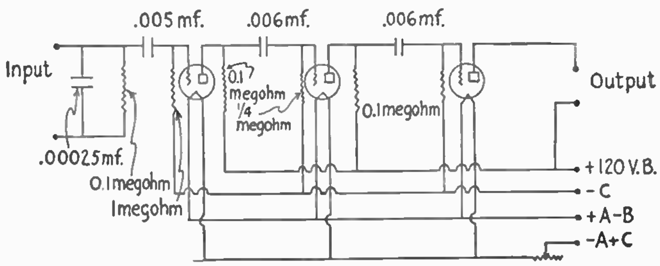
Two of these types of amplifiers are covered in the text on pages 119 to 128.

Each of these four styles of amplification has its own advantages and disadvantages. The first one mentioned, transformer coupled, is the one that is most frequently used, as the cost is relatively low for the necessary apparatus and the results are generally satisfactory.

The second type, impedance coupled, uses an autotransformer, a high capacity condenser and a resistor in each stage. The advantage of this type of coupling is that a higher plate voltage may be used on the amplifying tubes, which results in greater volume. However this type is more or less subject to the disadvantages of transformer coupling, because of the difficulties experienced in the construction of transformers that will have a uniform distor-



A. Impedance Coupled A.F. Amplifier.



B. Resistance Coupled A.F. Amplifier.

Fig. 105.—Audio Frequency Amplifiers.

tionless range. Another drawback is that as the tubes alone amplify the signals, there being no turns ratio of transformers to aid them, there should be three stages used in this type in order to get good volume. See Fig. 105A for circuit of impedance coupled amplification.

The advantages of the resistance coupled type of amplifier is in its low initial cost, the high plate voltages that may be used and its relatively distortionless output. The disadvantage is the same as that mentioned last in the previous paragraph, the use of three stages of amplification being almost imperative.

The push-pull amplifier (see page 120) is conceded to be the best all-around type, but the initial and upkeep costs should be considered.

The Parts and How They are Connected.—For the impedance coupled type of amplifier you will need the following parts, (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) 3 impedances or autoformers; (4) 3 grid resistors, values 0.1, 0.25 and 1 megohm; (5) 3 condensers, fixed type, 1 mf. capacity; (6) a 4.5 volts "C" battery; (7) an "A" battery; (8) a "B" battery capable of delivering 120 volts; (9) a rheostat for the "A" battery; (10) a loud speaker.

The circuit of the impedance coupled amplifier is shown in Fig. 105A. This circuit can be employed with any type of detector by connecting the plate of the detector tube to the center tap of the impedance coil and the positive "B" detector plate voltage to the end of the same coil. These connections are shown at Input in the diagram.

The Parts and How They are Connected.—You will require the following parts for a resistance coupled amplifier, (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) 3 resistors, values 0.1 megohm; (4) 4 fixed condensers, capacities; .00025 mf., .005 mf., and two of .006 mf.; (5) 3 grid resistors, values 0.1, 0.25 and 1 megohm; (6) a "B" battery capable of delivering 135 volts; (7) an "A" battery; (8) a 4.5 volts "C" battery; (9) a rheostat for the "A" battery; (10) a loud speaker.

The connections for this amplifier are shown in Fig. 105B. As in the case of the impedance coupled type, this amplifier can be used with any type tuner, the connections being made to the Input terminals.

It should be noticed that when amplifiers are spoken of as being "distortionless" it means only that they will reproduce exactly what is put into them. Do not expect audio frequency amplifiers to take howls out of oscillating radio frequency amplifiers or squealing regenerative detectors.

Recently there has been announced a new system of audio frequency amplification, which is called double impedance coupling. In Fig. 105C is shown the circuit of an amplifier of this type. This amplifier can be so adjusted that it

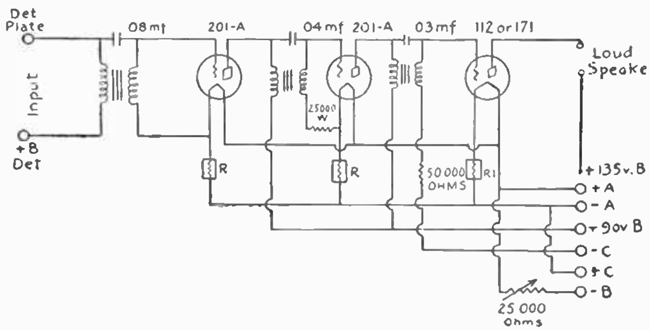


Fig. 105C.—Double Impedance Audio-Frequency Amplifier.

compensates for any discrepancies in the loud speaker, the result being reproduction of the highest quality.

The Parts and How to Connect Them.—You will need the following parts; three double impedance units; three fixed coupling condensers, values being .08, .04 and .03 mf.; two ¼ ampere, 5 volt filament ballasts; one ½ ampere, 5 volt filament ballast; one fixed resistor, 25,000 ohms; one fixed resistor, 50,000 ohms; one variable resistor, 25,000 ohms, three vacuum tube sockets; two 201-A vacuum tubes; one 112 or 171 power amplifier; "A," "B" and "C" batteries.

The quality of reproduction that may be had with this amplifier is due to the fact that use is made of regeneration, which is usually the curse of amplifiers. This is adjusted by means of the resistors in the grid return leads of the second and third tubes. These are shown as fixed resistances in the diagram, for the values given have been determined as being about correct for the average loud speaker. If the experimenter wishes to better his results and to learn something more about the amplifier, variable resistors can be inserted instead of the fixed ones. The coupling condensers in some cases come in the same case as the impedance unit and in that case, of course, the ones shown are not included in the circuit.

Loud Speakers

The loud speaker is one of the parts of a radio receiver that is too often blamed for faulty reproduction. If the music or speech is harsh or distorted, there is an excellent chance that the trouble is somewhere in the set itself, for today loud speakers are rapidly approaching the acme of perfection.

There has been no radical change in design of loud speakers lately, but great improvements have been incorporated in the two main types of speakers, i.e., the cone and the horn. It has always been the goal of engineers working on loud speaker problems to reproduce the bass notes with the same fidelity with which the treble notes are. To a great extent this has now been accomplished.

The average size loud speaker using a paper diaphragm to move the column of air has been in the neighborhood of eighteen or twenty inches in diameter. This size cone was found to be entirely too small and almost perfect reproduction is being obtained now with diaphragms that are thirty to thirty-six inches in diameter. Improvements in the design of actuating units have also been made as well as methods of attaching them to the paper. This loud speaker was designed by Clyde Fitch. (See Fig. 106.)

This cone speaker has a diameter of thirty-six inches and uses but a single sheet of heavy paper. The driving unit is extremely simple, being no more than a bar magnet, the flux of which is changed by the field set up by the changes in the coil caused by the variations in the plate current of

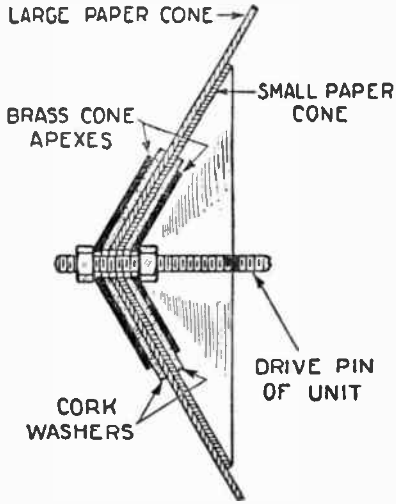


Fig. 106.—Fitch Loud Speaker.

the last tube in the receiver. The driving rod of the unit is fastened to the paper cone by means of the two small metal cones which are glued to the larger one.

Another advance in design has been the work done on horns. It was found that a horn which expanded in a certain ratio, that followed the exponential law, reproduced the bass and treble notes with equal faithfulness. The length of these horns also was found to be a function of the reproduction. Without going into the mathematics of design it may be said that if an exponential horn, whether it have a round, square or oblong cross section, be six feet in length with a throat about one-half inch in area and a mouth about four square feet in area, it should reproduce all the frequencies that the ordinary receiving set will pass. This is provided, of course, that there is a good unit at the throat. It must not be expected that if an inferior grade of unit is used first-class music will result.

While on the subject of loud speakers it might be fitting to mention something about the power tubes that have been introduced. These tubes are capable of handling much more power than the 201-A tubes and they are used in the last stage of the audio-frequency amplifier. With the UX-171 type there is used about 180 volts on the plate and 40 volts negative bias on the grid; sometimes the plate voltage is even higher. With a tube of this type in a set it is possible to pass to the loud speaker a greater amount of current than has hitherto been done and this without distortion.

Here another problem presented itself to the designing engineers. If a large current and voltage were needed to operate these power tubes it would doubtless burn out the windings of the loud speaker coils which are of relatively fine wire. In order to overcome this two means were at hand: an output transformer or an output filter circuit. The former is no more than a transformer having an iron core and whose turns have a 1:1 ratio. The secondary of the transformer is connected directly to the loud speaker terminals and all the heavy current goes through the primary windings.

The filter type is no more than an audio-frequency choke coil and a condenser, the latter being placed in the circuit between the plate of the tube and the loud speaker windings. Either of these types have proved to be thoroughly efficient.

Another innovation is the loud speaker developed by Messrs. Rice and Kellogg of the General Electric Co. This instrument has also a paper cone that is used as a diaphragm, but that is the only similarity. As can be seen from Fig. 107 the larger diameter of the cone, which is about eight inches, is attached to the baffle wall, or panel, by means of a very thin rubber membrane. This permits

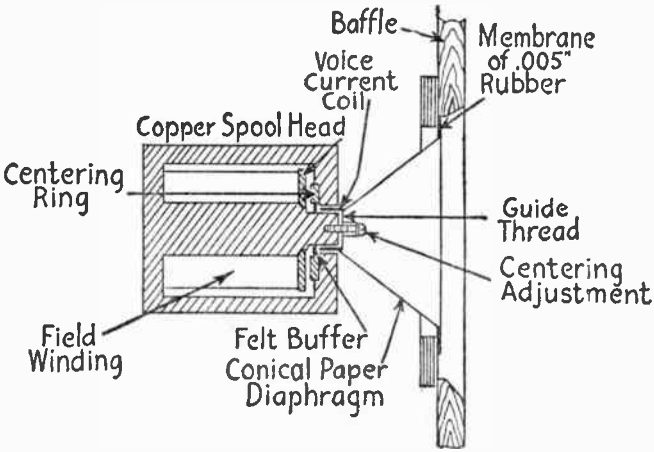


FIG. 107.—Construction of Free Edged, Coil-Driven, Conical Diaphragm Loud Speaker. (General Electric Co.)

the cone to vibrate back and forth with hardly any mechanical resistance. On the smaller diameter of the cone there is a coil of wire in which are induced currents by the magnetic field surrounding it and set up by the field winding.

This loud speaker is capable of producing enormous volume with a minimum of distortion. In the same cabinet with it is a special audio-frequency amplifier and also a rectifier for converting 110 volts A.C. to direct current for the various requirements of the vacuum tubes. This speaker reproduces the low tones of the bass notes as faithfully as the high treble.

Another departure from conventional design is in the loud speaker shown in Fig. 108. The diaphragm of this instrument is a thin sheet of aluminum that is loosely supported between two pan-cake type coils. The magnetic field that is set up by these coils is so controlled that there is almost a uniform force over the whole diaphragm. This is the induction type of loud speaker invented by Dr. C.

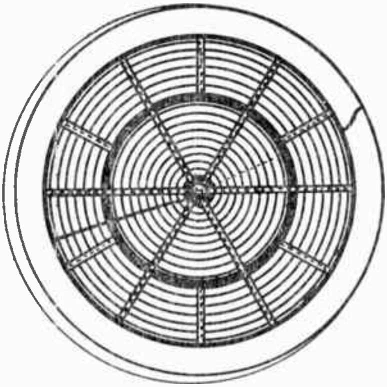


FIG. 108.—Hewlett Induction Type Loud Speaker.

W. Hewlett and they have been made up to about three feet in diameter, being capable of delivering a tremendous volume of music. There is no horn used with this loud speaker, the vibrations of the diaphragm being sufficient to set up sound waves of great intensity.

The main thought of the designers of loud speakers has been to reproduce with equal efficiency and quality all the tones and overtones of the whole musical scale. It is relatively simple to design an instrument that will faithfully reproduce a certain band of notes, but it is another matter to be able to hear the low notes of the bass viol as well as the treble notes of the flute. Before a loud speaker is purchased it would be well to listen to the different types of reception, as instrumental and vocal music, speeches, etc., in order to ascertain the merits of each.

"A" and "B" Socket Power Units

One of the greatest problems that radio designing engineers have been confronted with is the elimination of the different batteries, substituting in their place some device which will supply the necessary power from the house lighting circuit. It was simple enough to arrange a system of rectification from the A.C. lines stepping the power either up or down, but the main difficulty was getting rid of the humming noise made by the 60 cycles alternating current.

Filters of all kinds were devised to be used with transformers, but still the hum persisted. Then the rectifying tube was introduced and to some extent this eliminated the hum, but insufficient power was passed. However, all these obstacles have now been overcome with the result that to-day it is possible to supply filament, plate and grid bias for almost any receiver directly from the 110 volt. 60 cycles A.C. house-lighting mains.

Unquestionably this revolution in radio has been brought about through the perfecting of the rectifier tubes. One of the best is a "full-wave" rectifier, developed by the Raytheon Mfg. Co. The term "Full wave" will perhaps need some explaining. Ordinary 60 cycle current, such as the majority of us get from our light sockets, if viewed through an oscillagraph—an instrument that enables you to see the wave form of an electrical current—would appear like the cross section of a water wave or to be more exact and mathematically speaking, a sine wave. The function of the rectifier tube is to smooth out the ripples in this wave and transform it into a current that is as near D.C. as possible. This is done in the rectifier due to the fact that in one direction current can easily flow but in the opposite

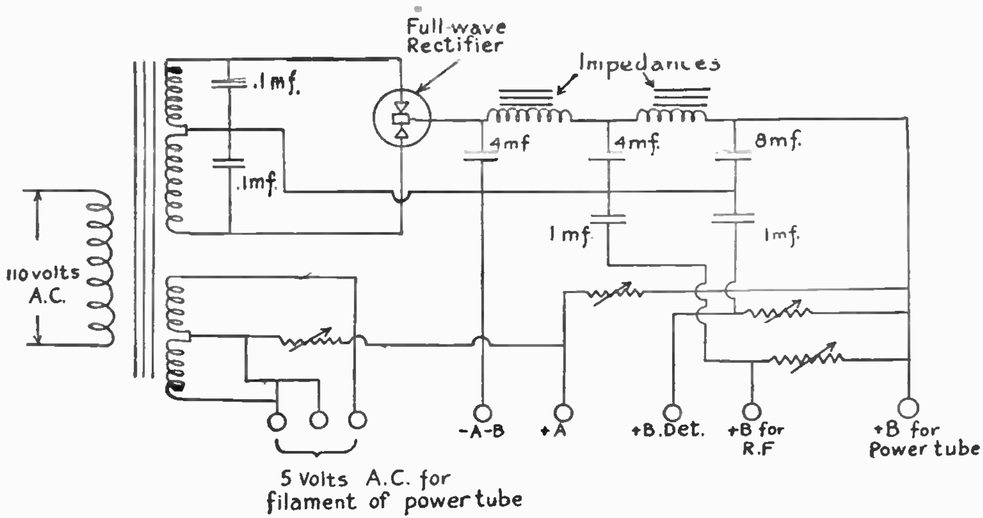


Fig. 100.—Circuit Diagram of an "A" and "B" Socket Power Unit.

direction there is practically no flow whatsoever. This is in brief what happens in a "half wave" rectifier. In a "full wave" rectifier tube both halves of the A.C. wave are smoothed out, thus getting twice as much power as with the other type.

The system for the most part consists of a power transformer with a secondary in one, two or three sections, depending on the nature of the unit with which it is to be used. Across the output of the rectifying tube are connected some sort of an impedance and a heavy duty condenser bank, these being to take out all the ripples, which would produce a humming noise in the loud speaker. Suitable resistances are placed across the output of this filtering system so that the several voltages can be adjusted to whatever values it is desired. Such a rectifier circuit is shown in Fig. 109. Such a system as is shown is relatively costly to construct and rather difficult to adjust properly, therefore no constants are given. It is recommended that if the reader wishes one of these socket power units he will go to some reliable dealer and purchase it complete.

It might be also well to mention the new vacuum tubes that have recently been introduced which need no rectifier for their filament voltage. These tubes instead of the usual filament have a small cylinder of some substance that emits electrons freely when heated. The heat is supplied to this cathode by means of a heater wire coiled within the cylinder and current is supplied to it from the A.C. mains sometimes stepped down to 6 volts or lower. Due to the heavy heater consumption of current the voltage is sometimes about 1½ volts and the current, 2½ amperes. In a case such as this the heater elements of the tubes are connected in series in order that an ordinary transformer can supply the current without overheating.

Light Sensitive Crystals

Due to the great progress recently made in the transmission of pictures and scenes by radio much interest has been shown by experimenters in this phase of the field. It has been thought that in order to do any experimenting along these lines expensive apparatus was necessary, but this is not the case. With a comparatively small outlay of capital it is possible to perform most interesting experiments that will demonstrate the principles involved in television and furnish a great amount of food for thought to the intelligent worker.

First of all it is imperative that some type of a light sensitive cell be obtained. At present there are several companies throughout the country where photoelectric cells may be purchased at a very reasonable figure. However, if the experimenter would prefer to construct his own cell, while it may not have the sensitivity that one purchased might possess, it will give very good results.

The most sensitive cell within the means of the experimenter to construct is one in which the substance used that is sensitive to light rays, is the selenium cell. This selenium, which appears like a stick of black sealing wax, is melted on to a sheet of mica over which has been wound two No. 28 bare copper, brass, or German silver wires spaced about 1/32 inch. See Fig. 110. It is necessary to get a very thin coating of selenium on this base and this is done easiest in the following manner: The wire-wound mica sheet, which is about one by two inches in area, is placed on a copper plate over a Bunsen burner. The proper temperature of the mica sheet is about 425 degrees Fahr. The selenium will act like sealing wax and can be easily spread if the temperature is correct.

When a satisfactory thin surface has been spread over the mica the latter is transferred to another copper plate to cool, while the burner is turned down to a temperature about 250 degrees Fahr. When the mica sheet is again

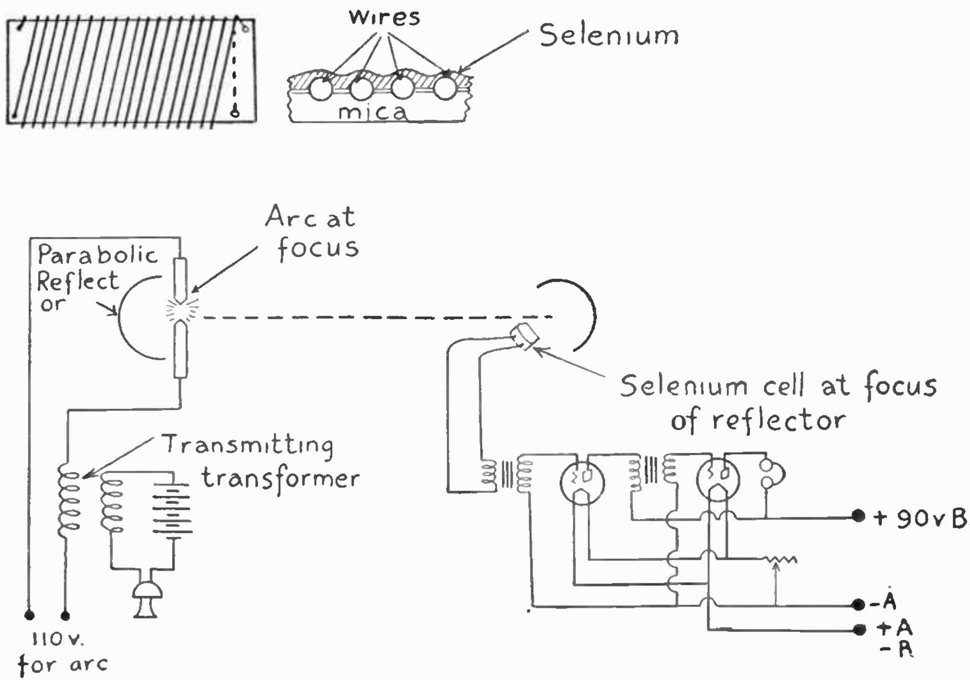


FIG. 110.—Details of Selenium Cell and Diagram of Apparatus Used for Talking Over a Beam of Light.

placed on the copper plate it has cooled quite a bit below the temperature at which the burner now is. After heating it for awhile it will be noticed that the surface of the selenium will turn gray. Then the temperature is increased until the selenium shows signs of melting. The heat is at once removed and the edges of the selenium watched until they again turn to their original color. The burner after being turned down is replaced under the copper plate and the cell carefully watched for signs of melting. When the temperature is just under the melting point the cell is allowed to stand for three or four hours under these conditions. The cell is then cooled off by turning the burner down gradually for over a period of an hour.

When the cell has been finally cooled it may be mounted in a small box having a glass cover, which has binding posts on the outside to which the leads are brought from the cell. This is the most convenient way for preserving the cell.

It need hardly be mentioned that the main property of selenium is that it changes its electrical resistance with the intensity of light that falls upon it; that is, the more light that falls on it the lower the resistance.

One interesting experiment that can be performed is illustrated in Fig. 110. By means of the selenium cell it is possible to transmit speech over a beam of light. Two parabolic reflectors are needed; at the focal point of one a source of light is placed, as an arc lamp, and at the focal point of the other, the selenium cell. In the circuit of the arc light is connected a telephone transmitter as shown and to the selenium cell is connected a pair of phones or if desired the output of the cell may be put through an audio frequency amplifier. The reflectors are placed in such a position that the light beam falls exactly in the middle of the second one.

If the apparatus is properly adjusted and the connections made as indicated, it should be possible to transmit speech over a light beam for a distance of several hundred feet.

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