SIMPLICITY OF RADIO

POWEL CROSLEY, JR.

THE BLUE BOOK OF RADIO

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FOREWORD

A MYSTERIOUS power that brings the talents of the world to your door; an inexhaustible source of entertainment, education and information; a fascinating game played by young and old—that is what radio is today. A few years ago radio was chiefly valuable in saving ships in distress at sea. You may remember, for instance, Jack Binns' famous SOS call from the S. S. Republic. From that stage, wireless telegraphy, and the more recent development, radio telephony, have progressed to usefulness in many fields—in business as a means of communication across the ocean; in the home as a means of education and entertainment.

In this booklet the author tells you, as simply as possible, just what radio is and how it works. A certain amount of technical explanation is necessary. Don't let that worry you as far as enjoying radio is concerned. Radio is now on such a practical basis that all you do in order to enjoy its possibilities is to turn a few dials. You need not bother about what is inside the cabinet in order to have the pleasure of listening to the broadcast programs. If, however, the receiving set arouses your curiosity, you will find on the following pages a simple explanation of what it is and how it works, together with a number of practical suggestions that may help you.

The booklet is divided into two parts for the convenience of two classes of readers. Those who desire a simple, non-technical discussion, which will give them a general, comprehensive view of the subject, will find Part I adapted to their needs. Those who desire to go more fully into the details of construction and operation of the set and its various parts, will find that Part II covers these subjects rather completely, in a manner somewhat more technical than Part I, yet not beyond the grasp of the reader without a technical education.

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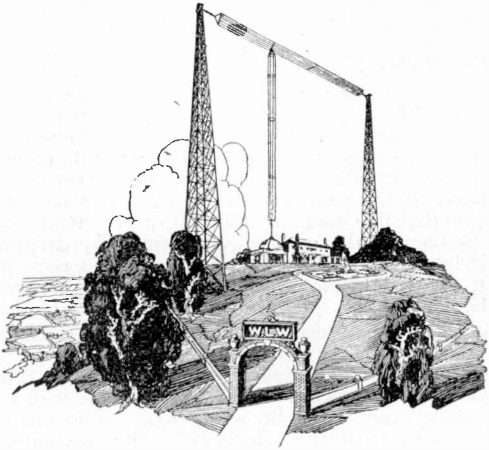
PART I

WHAT RADIO IS



A THUMBNAIL SKETCH OF RADIO

HIGH in the air, stretched between two steel towers, is a span of wires from which a single strand runs to a building below. Behold a Radio Broadcasting Station

In a studio in the building a famous band is playing a popular air. The sound waves produced by the various instruments strike a device like a telephone transmitter, which transfers them into electrical energy. The electrical energy passes through various complicated electrical equipment to the single strand of wire, and along it to the system of wires between the towers. From these wires, in the form of electric waves, it travels through the invisible ether in all directions at a speed of 186,000 miles per second. Think of it! A distance almost as great as that from the earth to the moon—more than seven times the distance around the world—in a single second of time.

Hundreds of miles away you sit in your home with your family and friends about you. The radio-electric waves sent from the broadcasting station are picked up by a wire, or wires, erected for the purpose, and travel down to your receiving set. There they undergo various electrical changes and are finally transformed into sound. You and your family hear the music just as it is being played at the broadcasting station.

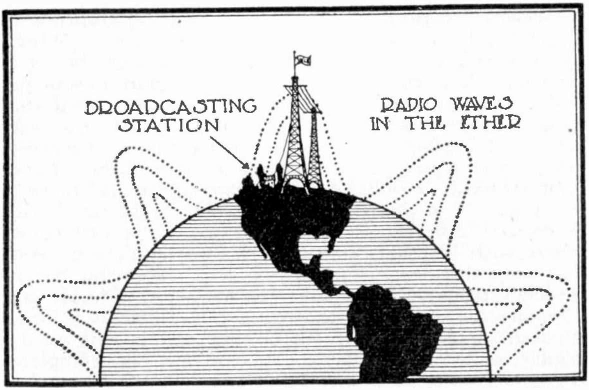
RADIO WAVES

The word "radio" comes from "radiate," which means the giving off of something (such as energy) in every direction. From the sending station, or broadcasting station (as sending stations devoted to public entertainment and information are called), energy is sent out in all directions in the form of electromagnetic waves in the ether, an invisible medium filling all space. Radio waves may be compared to the waves formed by dropping a pebble into a pool of water. These water waves spread out in every direction, traveling until finally they reach the shore.

The fact that you can't see, or hear, or feel radio waves may make it difficult for you to think about them. But when you talk into a telephone you can't see, or hear, or feel the electrical energy travelling along the wire to the other party, can you? So why should radio seem any more strange than the telephone? The mechanism in your telephone transmitter transfers the sound energy of your voice into electrical energy, and this travels along the wire to the other end of the line, where it is transformed into sound. In like manner, the broadcasting station changes the sound energy into radio energy, which travels out in every direction in the form of waves, is picked up by receiving sets, and changed back into sound.

The broadcasting station may be likened to a pebble dropped into a pool of water, the radio waves likened to the water waves made by the pebble, and the receiving sets likened to corks scattered about on the pool, bobbing up and down as the waves strike them. The corks resemble receiving sets in that they are caused to bob up and down by the water waves just as the receiving sets are caused to give out sound by the radio waves.

Many of the everyday experiences of life are due to some sort of wave motion. Heat, light, and X-rays, as



well as radio, for instance, are supposed to travel as waves. Sound is known to be due to vibrations, or waves (a wave may be said to be simply a travelling vibratory motion) in the air and other material substances. Strike a key on the piano and with your finger you can feel the string vibrate as it gives out the musical note. So the idea of wave motion is by no means confined to radio and water waves alone.

RADIO WAVES AND TUNING

Did fourteen or fifteen cats ever sit on your back fence and yowl at the same time as if their lives depended on keeping you awake? If these cats were trying to talk to one another in cat language they must have had a hard time understanding what one another said. Perhaps you wonder if you wouldn't have just as much trouble as the cats did, trying to single out the broadcasting station you want and listen to it alone, when there is always a continual chorus of several of the five hundred or so broadcasting stations in the United States sending out programs at the same time. When you use the telephone, you have wires to guide the energy where you want it to go, and an exchange girl to connect you with the party with whom you wish to talk. There are no wires to guide the energy and no exchange girls to give you the proper connection in radio, but there is a process that takes the place of the wires and exchange girl. It is called "tuning".

Perhaps the principle of tuning can be appropriately illustrated by a fact well known to army men. When troops of soldiers are marching across a bridge they are always made to break step, for if they step in unison the bridge is quite liable to swing up and down until the strain becomes too great and it collapses. If you ever have used a swing—a rope swing, porch swing, or garden swing—you know that if you keep giving it pushes at the right intervals it will keep swinging higher and higher. If you push it at the wrong times, however, the result will be entirely different—it will act like a sailor just come ashore, with "sea legs," careening this way one instant and that way the next. That is because the swing has a tendency to move back and forth at a certain fixed rate (the rate depending on the manner in which it is constructed) and pushing it out of time will give it an irregular motion. The time required for one complete swing, or cycle, back and forth is called the "period," and the period to which any particular object tends naturally to respond is called its "natural period."

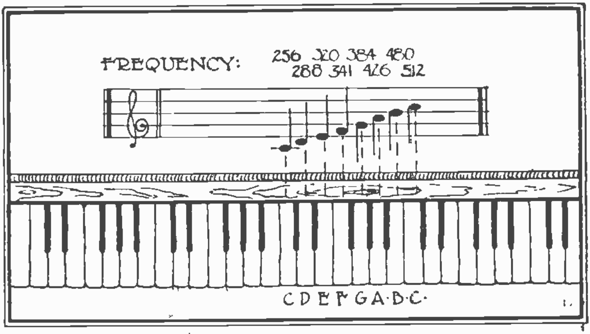
As for soldiers keeping step when marching over a bridge—if they should happen to be marching at just the right tempo, the bridge would sway up and down a little farther each time they put their feet down, until finally the strain would be too great, and the army and bridge would crash into the river. This is called the principle of "resonance". The marching tempo of the soldiers is said to be in resonance with the bridge when it has the maximum effect in causing the bridge to swing up and down.

A little story may help further to drive home the principle of resonance. Picture a great auditorium—rows upon rows of people sitting as still as statutes, like little waxen images from the hands of a master sculptor, forgetful of everything but the beautiful voice of the opera singer on the stage before them. It is as if she were an enchantress and her voice a magic wand with which to cast a spell over the multitude. Higher and higher soars her voice, until away up, higher then we believed anyone could ever sing, she holds a note. It seems that she will hold it forever—the fitting climax of a perfect aria. Suddenly there is a splitting sound. With one agonized crack, the roof pulls apart, revealing a jagged line of sky.

Now sound, as already stated, is transmitted through the air by means of vibrations, or waves. The auditorium roof had a certain natural vibrating period. The note sung by the artist was, by chance, of a similar period (that is, it was in resonance with the roof), so that it kept giving the roof little pushes, always at just the right moment, causing it to swing up and down, farther and farther, until finally it swung too far and broke.

The waves sent out by the broadcasting station are of a certain definite period—that is, waves are sent out at certain definite intervals. The number of waves starting out per second is called the "frequency"; the distance between corresponding portions of two waves next to each other is called the "wave-length". You can notice a similar condition in the example already used—the case of waves formed when you drop a pebble into a pool of water. These all travel with a certain speed and are a definite distance apart, a foot or two feet perhaps. New ones start out at regular intervals, the length of the intervals depending upon a variety of factors. The distance between succeeding crests is called the wave-length.

Now, just as one has to give a swing pushes of a certain frequency in order to get any appreciable movement, just as an army has to march at a certain tempo in order to make a bridge collapse, just as an artist has to sing a note with a certain period of vibration to crack a roof, so the radio set has to be adjusted to the period, or frequency, of the waves sent out by the broadcasting station in order properly to receive them. No two broadcasting stations, unless hundreds of miles apart operate on the same frequency at the same time, so that by tuning to the frequency of the station you want, you can receive it and



eliminate all others. Just how this tuning is accomplished will be explained later.

If you have a piano and a stringed instrument, such as a guitar or violin, you can try a simple experiment to demonstrate the principle of tuning. Tightening up a string causes it to vibrate more rapidly, giving out a shorter wave-length and a note of higher pitch. If, now, you loosen all of the strings on your stringed instrument until they hang with practically no tension, they will not vibrate when you strike a key on your piano, for their wave-length will be much too long to be in resonance with the piano note. If, however, you tighten up one of the strings gradually, it will eventually begin to vibrate in resonance with the piano note. By tightening it further the vibrations will be caused to die out.*

Wave-length is equal to the velocity (or speed in a given direction) divided by the number of waves sent out per second (that is, by the frequency.) In other words, there is a certain definite relation between the frequency and wave-length of radio waves (for the velocity, of radio waves, is always constant—186,000 miles per second, the same as the velocity of light.) Now the frequency of radio waves runs into the hundreds of thousands per second, while the wave-length (of the average broadcasting station) is but a few hundred meters‡, so that it is more convenient to speak of wave-length than of frequency when discussing radio tuning.

*If it is tightened still further, to a note one octave higher than that to which it originally responded, it will again begin to vibrate. This is the phenomenon of harmonics. Notes an octave apart have a frequency ratio of two to one. That is, the higher note has a frequency twice that of the lower. Naturally, strings tuned to these notes will respond to each other, though not so noticeably as though they were tuned to the same frequency. The greatest response is always obtained when the two notes are of the same frequency, or in unison. The original note or frequency is called the fundamental. Other frequencies which also respond to it, such as two times the fundamental, one-half the fundamental, etc., are called harmonics. The ratio between these notes and the fundamental need not always be so simple as 2 to 1, 3 to 1, or 4 to 1. Harmonic ratios of 3 to 4, 2 to 3, and the like, are quite common.

Some difficulties are encountered in radio transmission because the quality, or timbre, of musical instruments and of the human voice depends so much on the harmonics present. It is difficult to design and construct the apparatus, and so coordinate it throughout, that these harmonics will be faithfully reproduced at the receiving station. The same problem confronted designers of phonographs for years and still receives a large part of their attention. Harmonics of the radio waves themselves are not of sufficient importance to be considered in detail here.

‡The meter, the French standard of measurement equal to 39.37 inches, is used to measure radio waves.

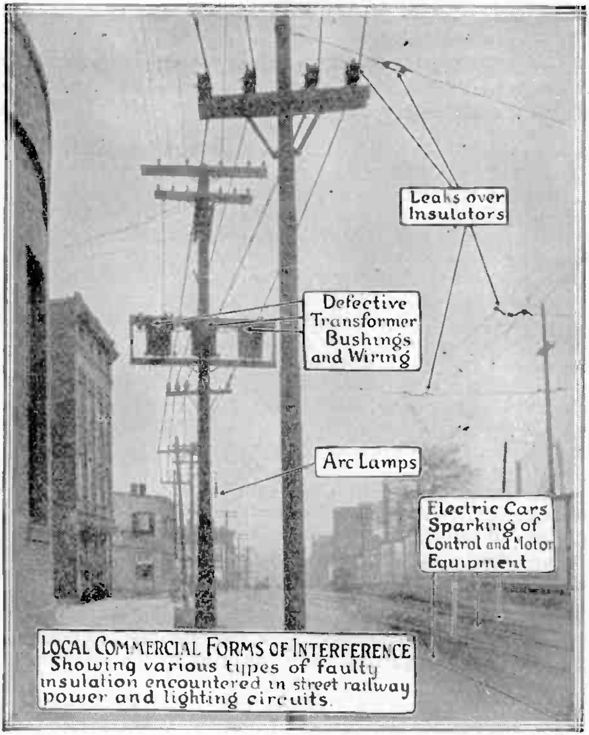
INTERFERENCE WITH THE RECEPTION OF RADIO WAVES

Interference may be divided into three classifications: (1) that due to transmitting or broadcasting stations other than the one from which it is desired to receive, (2) that due to alternating current electric transmission lines and various other alternating current electric devices, and (3) that due to electrical storms.

Perhaps the cats on the back fence, yowling at one another, are just as good an illustration of interference of the first sort as any. Three or four broadcasting stations being received at the same time would produce an equally annoying effect. Selectivity is the measure of the ability of a set to tune out these undesired stations and receive only the one that you wish to hear. It is also called "sharpness of tuning." Well-designed receiving sets will tune out completely stations operating on a wave-length differing but a few meters from that of the desired station. Even when another station is heard at the same time, its signals are usually so faint as to cause no inconvenience. Interference from broadcasting stations is called "station interference."

Electric power plants in the immediate vicinity, light and power transmission lines, trolley wires, X-ray machines, vibrators, elevated railways, transformers on poles, and various other apparatus employed in the production, transmission, or use of alternating electric current, sometimes cause a continual "humming" sound in the headphones or loud speaker. This second class of disturbance is called "local interference." It may be guarded against by taking certain precautions outlined in the section on aerials.

The third class of interference is due to electrical storms and atmospheric electricity. Electrical storms set up waves of the same kind as radio waves, and these sometimes cause clicking, hissing, and crashing sounds in the headphones. Such interference is called "static." Despite the fact that "static-eliminators" are often advertised, and freak sets, purporting to do away with static, frequently mentioned in various periodicals, there has not, as yet, been found a means of entirely overcoming this interference. Most broadcasting stations however, are so powerful that they can be heard plainly even when static is quite severe. In a few more years we will probably have forgotten that there ever was such a thing as



LOCAL COMMERCIAL FORMS OF INTERFERENCE
Showing various types of faulty insulation encountered in street railway power and lighting circuits.

static—as the present tendency is toward the erection of much more powerful broadcasting stations, of such enormous power as to drown out totally interference of this sort.

YOUR RECEIVING EQUIPMENT

THE first time you walk into a home where there is a radio set and hear music or voices coming from the loud speaker as clear and distinct as though the performers were in the next room, the radio set seems a very strange and mysterious piece of apparatus. But if you investigate you will find that there are really only a few simple units to your equipment and that they are all designed to do certain definite things.

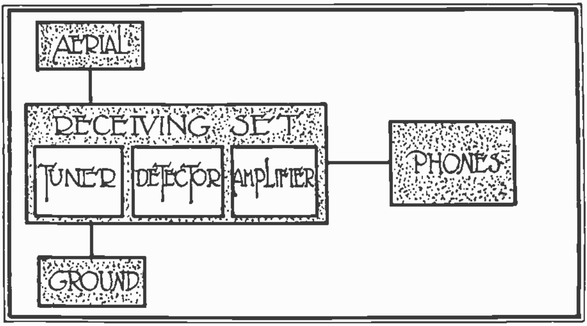
THE EQUIPMENT NECESSARY

First, there is the receiving set with which you tune to the particular wave-length desired. It contains in addition to the tuning unit certain apparatus for modifying the received electrical energy (as will be explained later) so that it is capable of operating headphones or a loud speaker. This apparatus is called a "detector" and is usually either a vacuum tube or crystal. The set may also contain additional vacuum tubes arranged to amplify the incoming radio energy.

Either a pair of headphones or a loud speaker is necessary for changing the received electrical energy into sound. Headphones are telephone receivers especially designed for radio work, and extremely sensitive. Most loud speakers consist of single receivers of this type, designed to give an especially great volume of sound, and equipped with horns for amplifying the sound.

Next, there is some sort of arrangement to intercept the radio waves. This ordinarily consists of a span of one or more wires suspended some distance above the ground and called an "aerial" or "antenna." The word "aerial" means "suspended high in the air"; the word "antenna" is applied to the long feelers common among insects, and may be as appropriately applied to a radio aerial because that is, in a way, the feeler of the radio receiving station, since it "picks up" the radio waves.

Lastly, there is a connecting wire from the receiving set to the earth or ground. The average radio set will give no results at all unless it has a good ground. It is sometimes possible to receive with a ground alone—that is, without an aerial. When it is impractical to make a connection direct to the earth, the counterpoise system is often used. This is described in the section on *grounds*.



Schematic Diagram of Receiving Equipment.

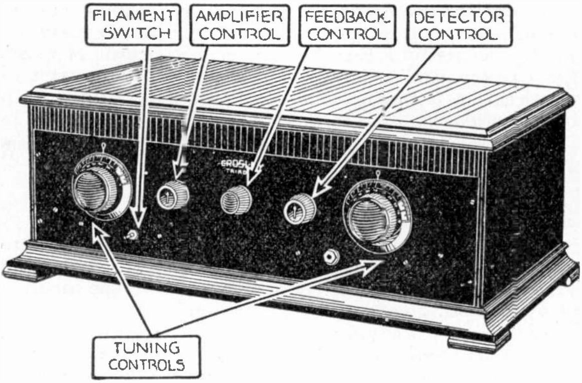
THE RECEIVING SET AND HEADPHONES OR LOUD SPEAKER

The receiving set may be divided into three distinct units, according to the function performed. First, there is the apparatus for tuning; second, the detector, a device which so modifies the received electrical energy as to enable it to operate a headset or loud speaker; and third the vacuum tube amplifying unit which, while not necessary to the operation of a set, greatly increases the volume of sound obtainable and the distances that may be covered.

The tuning unit consists of certain electrical equipment that makes it possible for you to receive one broadcasting station or another, as you wish, by merely turning the tuning control dials on your panel. The fundamental principle on which tuning depends is described in a previous division entitled *Radio Waves and Tuning* The theory and construction of the electrical devices by means of which tuning is accomplished will be discussed in Part II.

The detector is usually a vacuum tube or a crystal. The name that was first applied to vacuum tubes used as dectectors, may give you a hint as to the detector's action. The first tubes invented were called "valves" a term still used in Great Britian. This name was selected because their function was to allow the electric current to flow in but one direction.

A radio vacuum tube looks very much like an ordinary light bulb, but it contains, besides a filament, one or more



Receiving Set, Showing Controls.

additional elements. An "A" Battery is used to light the filament, just as a storage battery in an automobile is used to light the filament of the headlight bulbs. The radio waves that reach your receiver hundreds of miles from the powerful broadcasting transmitter, are not one-millionth as strong as when they started out. They may be likened to a marathon runner after the race—much in need of food and stimulation to bring back his strength. The "B" Battery used with a vacuum tube, supplies this stimulating energy to the radio-electric current in the receiving set. By its means the electric current is boosted up until it is many times as strong as the original received current. A small switch, called a "filament switch," is often provided for cutting off the "A" and "B" Batteries when the set is not in use. Several vacuum tubes may be connected in tandem, one after the other, and used further to boost or amplify the electric current. Tubes used in this way are called "amplifiers." A detector—either vacuum tube or crystal — is *necessary*, for without it the received current will not operate headphones or loud speaker. Amplifiers, while not necessary, are very desirable. By an ingenius method of wiring, the detector is often used as an amplifier as well, making it practically equivalent to two tubes used in the ordinary way—a detector tube and an amplifier tube. This system is called regeneration and is patented and manufactured under special license by a limited number of concerns of which the Crosley Radio Corporation is one. The amount of regeneration is controlled by the regeneration, or "feed-back," control.

Vacuum tubes, batteries, headphones, and loud speakers are described in detail in Part II.

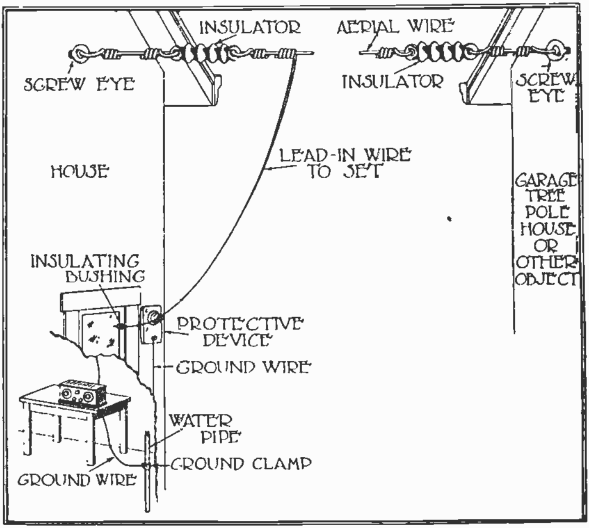
THE AERIAL

The Aerial is to a receiving set what your mouth is to food. It swallows up the radio energy from the ether and turns it over to the radio set, which performs the function of a stomach, digesting it into audible form.

The first consideration in erecting an aerial is where to put it. The most usual type of aerial consists of one or more wires stretched horizontally some distance above the ground. One end is often suspended from the house, and the other attached to a garage, tree, or pole somewhere in the yard. Sometimes both ends are attached to poles on the roof, or to high poles in the yard. It really doesn't matter much what manner of suspension is used. The aerial is even sometimes stretched indoors, in the attic, for instance. This should not be done if the house is of metal construction or has a metal roof. A single wire aerial should be 35 or more feet high and 60 to 90 feet long. An aerial of two or more wires should be equally high and 40 to 60 feet long. Single wire aerials are quite satisfactory, though if it is necessary to make the aerial excessively short, two or three wires should be used. No. 18 bare copper wire is quite satisfactory for use in making an aerial. Any strong copper wire will do. Wire that is covered or insulated, is as effective as bare wire, but has no advantage over bare wire for this purpose and costs considerably more.

Those substances through which the electric current will flow are called conductors and those through which it will not flow (with any comparative ease) are called insulators. Now it is important that the aerial, and the wire connecting it to the receiving set, be protected from coming in contact with anything, so that the electric current may be prevented from leaking off the aerial onto other objects, thus dissipating the received radio energy.

For this reason, especially designed insulators are used between the aerial wires and the supporting ropes or other supports, and the wire connecting the aerial to the receiving set is brought into the house through an insulating tube.



Method of Erecting an Aerial.

The aerial wire system should not, for purposes of safety, pass near enough to high-voltage light and power wires so that there is any danger that it might accidentally come in contact with them.

To avoid local interference, described in the section on interference, the aerial should, wherever possible, be placed perpendicular to nearby (that is, those within a hundred feet or so) power and trolley wires.

When very little space is available, or for some other reason it is inconvenient to erect one of any other kind, a "loop aerial" is often used. This is merely a coil of several turns of wire, a few feet in diameter, stretched on an insulating frame. A wooden frame is often used. It is then best to insulate the wire from the frame. Loop aerials are especially convenient for use with portable receiving sets, or in places where another type of aerial cannot be employed. Of course, for best results the loop receiving set should be especially designed for use with a loop aerial. Sensitive loop receiving sets give fairly good resuts, even over long distances.

Many other devices are employed as aerials. Sometimes the antenna wire is concealed behind picture moulding. Light sockets provided with special plugs, bedsprings, window screens, and telephone wires are often used as aerials. These devices should only be resorted to when the construction of an aerial of the ordinary type is impractical.

The wire connecting the aerial to the receiving equipment is called the "lead-in." It should be soldered to the aerial and firmly clamped to the receiving set. The lead-in should be of copper or copper-clad steel, which will not corrode excessively, and should not be smaller than No. 14, except that No. 17 copper-clad steel wire may be used. Do not allow the lead-in wire to come nearer than 4 inches to electric light or power wires, for reasons mentioned above. Where it passes into the building, it must be insulated by means of an insulating tube or some other device.

The lead-in should be equipped with some sort of approved protective device (for protection against lightning), properly connected and located as near as possible to the point where the wire enters the building. It may be either inside or outside of the building. As shown in the illustration, one contact or terminal (the insulated one) is connected to the lead-in, and the other terminal is connected to a protective ground wire.

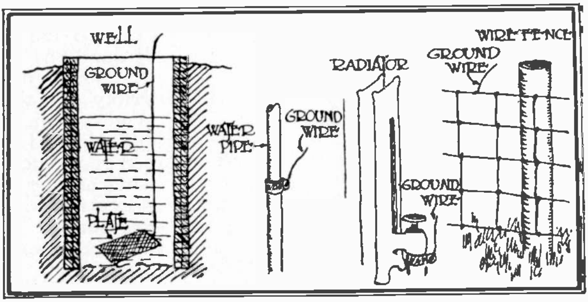
A "ground" wire must be run from the protective device to the ground, so that electricity will be harmlessly carried away should lightning strike the aerial. It may be either a bare or insulated copper wire, No. 14, or a No. 17 copper-clad steel wire. It must be run in as straight a line as possible to a good ground, preferably water-piping.

THE GROUND

Poor grounds and poor ground connections probably cause more trouble to the operators of radio sets than any one other factor. A large radio service company in New

York City recently made an investigation and found that in over nine-tenths of all the cases in which trouble was experienced, poor grounds were the cause.

The ground wire used with the aerial protective device may also be used for the receiving set, or a separate ground wire may be run for the receiving set, if that is more convenient. In city installation, a water pipe is perhaps the best object to use for a ground. Water piping is a good



Types of Grounds.

conductor of electricity, and, as it runs for miles and miles through the earth, it is sure of making a good connection with the ground. Water that seeps out at the pipe joints moistens the surrounding earth and helps to insure a good earth connection. You should connect the ground wire to the pipe as near as possible to where the pipe enters the building. If the water meter is located in the building, connect the wire to the pipe on the far side of the meter. Steam or hot-water heating systems are connected to the water supply, and may therefore serve as grounds. However, it is best to go direct to the water system if possible. While gas pipes often serve quite satisfactorily as grounds, they are seldom as efficient as water-pipes. As in the case of water pipes, the wire should be connected to the gas pipe as near as possible to the point where it enters the building, and on the far side of the meter.

Where a piping system is not available, a ground may be obtained by dropping a copper plate to the bottom of a well. Do not attempt to use a cistern, as in all probabilities it will have a concrete or brick lining which will prevent the cistern water from coming in contact with the ground and thus making an electrical ground connection (concrete and brick are insulators.) A rod, pipe, or plate may be buried deep in moist soil, to serve as a ground. This system is usually quite unsatisfactory because it is difficult to penetrate the earth far enough to make contact with ground water and the comparatively dry soil close to the surface of the earth is a very poor electrical conductor. Frequently such grounds become absolutely worthless in dry weather. Do not attempt to use a lightening-rod ground, or the telephone ground, as in practically all cases they are worthless. If you have not a piping system available, you will probably get the best results with a counterpoise. This is a system of wires stretched underneath the aerial, parallel to it and to the ground, a few feet off the ground or buried in a trench. The counterpoise should be of one or two wires and be as long or slightly longer than the aerial. Connecting your ground wire to a wire fence serves the same purpose.

Be sure to make a good connection between the ground wire running to the radio set and the pipe, metal plate, or other object used as a ground. Scrape the object until it is absolutely clean and solder the connecting wire to it. If this cannot be done, use a ground clamp and fasten it tightly to the brightened metal.

IF YOU HAVE ANY TROUBLE

If you have any difficulties, *remember that in practically nine hundred and ninety-nine cases out of every thousand, troubles with radio receiving outfits are due to one of four causes*:

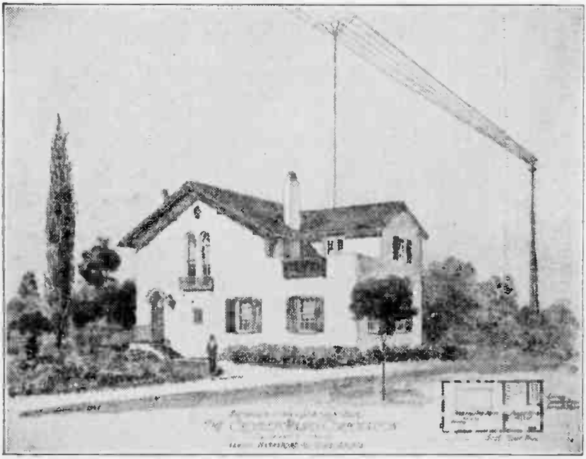
1. To a bad ground.
2. To run-down batteries.
3. To burnt out tubes.
4. To a fault in the aerial or lead-in.

There is practically nothing inside your receiving cabinet that can go wrong unless a wire or connection breaks. The chance of either of these happening is just as small as the chance of a stranger meeting you on the street and persuading you to buy the County Court House from him for a quarter.

BROADCASTING

IF you ask Bill Jones, when you meet him on the street, what he thinks of radio, Bill won't stop to consider its value in saving ships at sea or in sending radiograms across the ocean. The first thing that occurs to him will be the entertainment and educational programs sent out by broadcasting stations all over the country. That is the big feature of radio that appeals to everyone today. That

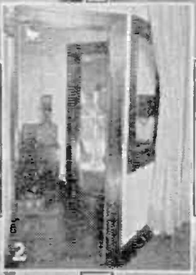
Sidney Smith, creator of "Andy Gump" welcomed to the WLW Studio by Powel Crosley, Jr.



Architect's drawing of New WLW Transmitting Station.

is what makes a radio set in your home equivalent to a phonograph, a player-piano, a newspaper, and a seat in the first row at the opera, combined.

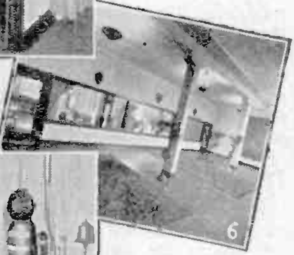
The few broadcasting stations which were in existance two or three years ago sent out concerts of reproduced music from phonographs and player-pianos. Today, powerful stations in almost every big city have daily programs of two and three hours duration. You and your family, sitting comfortably in your own home, may have the pleasure of listening to great artists giving vocal and instrumental solos, nationally known orchestras playing both popular and classical music, eminent authorities making speeches on educational and instructive subjects, reports of market and weather conditions, and church services. Radarios, or plays written especially for radio, take their place with the broadcasting of theatrical performances direct from the theatre. It is interesting that W. L. W., The Crosley Radio Corporation, was the first broadcasting station to introduce radarios to the public. It is possible to broadcast from the stage of a theatre, from an auditorium, a dance hall or, any gathering, no matter where located.



1. Solo studio and office of the Director.

2. Room between the studios for control of the microphones and amplifier. Telephone lines carry the voice or music to the tranemitting station some miles away.

3.—The ensemble studio will accomodate a large orchestra or group of singers. It is draped with Monk's cloth and the ceiling is especially constructed to be acoustically efficient.



4.—View of the studios from the auditorium. A glass partition between the studios and auditorium enables visitors to watch the artists. Loud speakers in the auditorium permit the visitors to hear the program.

5.—Powel Crosley Jr., President of the Crosley Radio Corporation.

6.—View of the auditorium, giving some indication of its great size.

7.—Rear of the auditorium showing some of the antique furnishings. The sidewalls are covered with medieval tapestries.

WLW Broadcasting Studios and Auditorium

THE BROADCASTING STUDIOS

The broadcasting studios are the rooms in which the broadcast programs are given. They are often many miles from the broadcasting station. the program being carried by telephone lines from the studio to the station. They are usually furnished very beautifully. Of greatest importance, however, is the necessity of building them with the proper sound, or acoustic, properties, so that none of the qualities of the voices and instruments of the performers will be modified, or lost, Sound from the outside, such as that caused by passing trolleys, automobiles, etc., must be excluded. Lining the walls with cork or felt, providing double partitions with air spaces between, and using double windows with similar airs paces, helps in overcoming these noises. Bare walls are liable to cause objectionable echo effects, so that it is often found desirable to drape them with thick hangings.

Placed at some convenient spot in the broadcasting studio is the microphone, an instrument which controls the strength of the electrical energy sent out by the broadcasting transmitter in accordance with the sounds in the studio impressed upon it. This instrument is nothing more than a specially designed and super-sensitive telephone transmitter, such as you speak into whenever you carry on a telephone conversation.

THE BROADCASTING TRANSMITTER

In some other room close by, or perhaps in a special building some distance away, is housed the transmitting equipment for sending out the program in the form of radio waves. It consists of apparatus for generating high-frequency alternating current, a tuning unit (necessary to adjust the wave length to conform to that allotted to the particular station by the Government), and other equipment necessary to the operation of the station. The source of high-frequency electrical current may be any one of a number of devices—though most stations now employ vacuum tubes (similar to those used in receiving sets but much larger) for this purpose, (see section on *vacuum tubes* for further details.) The tendency today is to build larger and more powerful stations, in order that static and other forms of interference may be effeetively overcome.

Towering high above the station building is the aerial, from which the radio waves travel out. It is like the

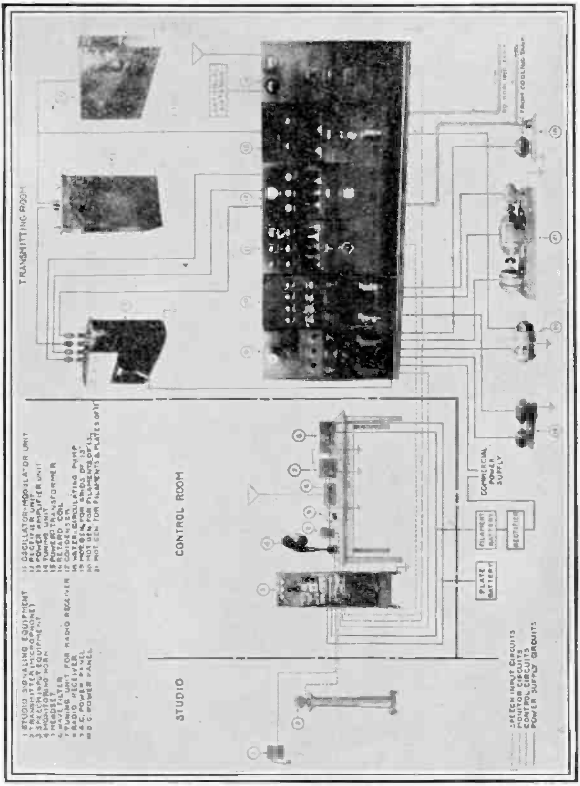
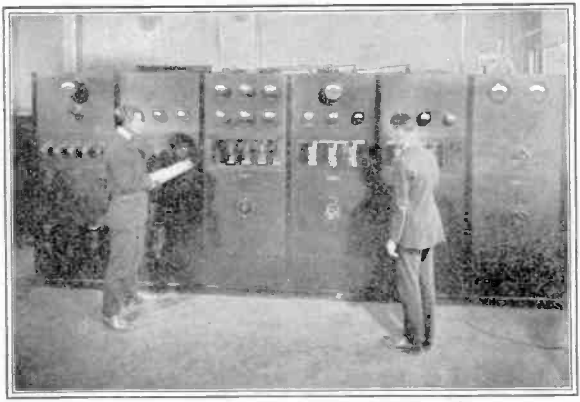
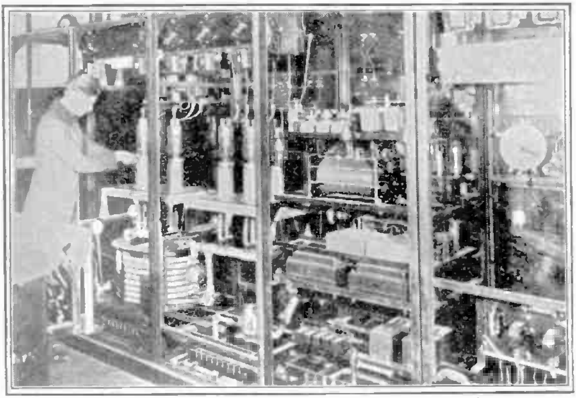


Diagram of Broadcasting Equipment

mouth whence comes a great voice, calling around the earth to millions of receiving sets everywhere.



Front of Transmitter Panel

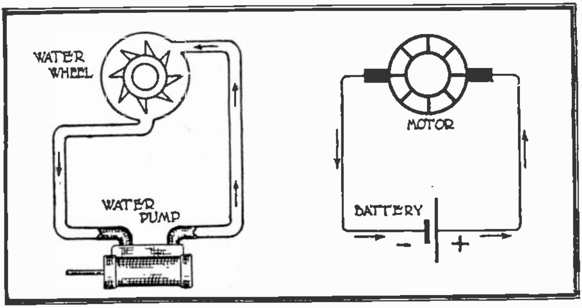


Rear of Transmitter Panel

PART II.

FUNDAMENTAL FACTS OF ELECTRICITY

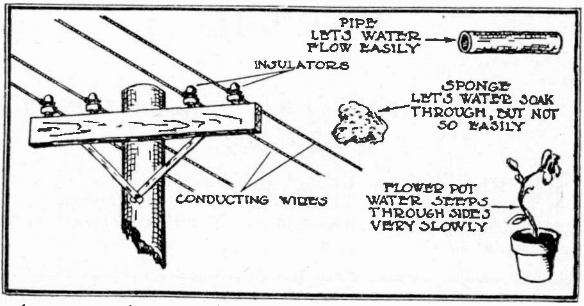
THERE are a few elementary, fundamental facts of electricity that you must know before you can very well understand the functioning of the different parts of a radio set.



In many ways electricity seems to behave like a fluid, such as water. If, for instance, you connect a battery to a motor by a system of wiring, as shown in the drawing, the battery may be likened to a pump, the motor, to a waterwheel, and the wire, to a system of piping going from the pump outlet to the intake of the waterwheel and back again, from the waterwheel outlet to the intake of the pump. As long as the pump is in operation there will be a continuous flow of water through the system. As long as the battery functions there will be a continuous flow of electricity in the electric circuit.

CONDUCTORS AND INSULATORS

Substances through which the so-called electric current can flow are called "conductors". Those through which it cannot flow are called "insulators". In reality every substance conducts electricity to some extent, but those



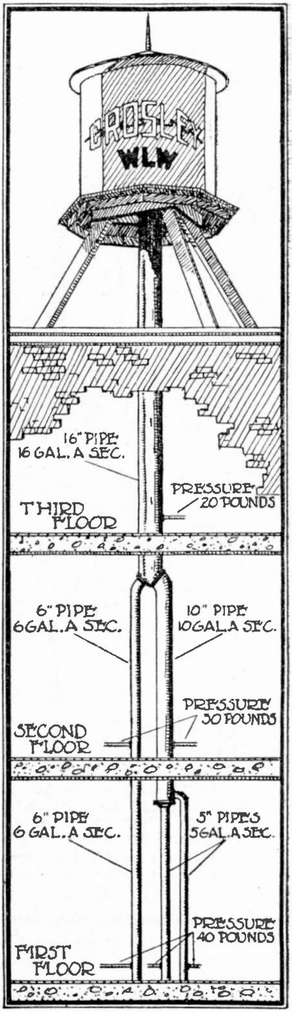
substances that conduct it very slightly are called "insulators". The opposition to the electric flow due to the material of the conductor is called "resistance". The unit of resistance is called the "ohm". The greater the cross-sectional area of the conductor the less the resistance. Other things being constant, resistance is directly proportional to the length of the conductor. Turning again to our analogy—a pipe is a good conductor of water, a sponge not nearly so good, and a flower pot might be called an insulator, although water really does soak through unglazed pottery. The friction of the pipe, opposing the flow of water, corresponds to the electrical resistance. The bigger the pipe the less will be this opposition to the flow and the longer the pipe the greater it will be.

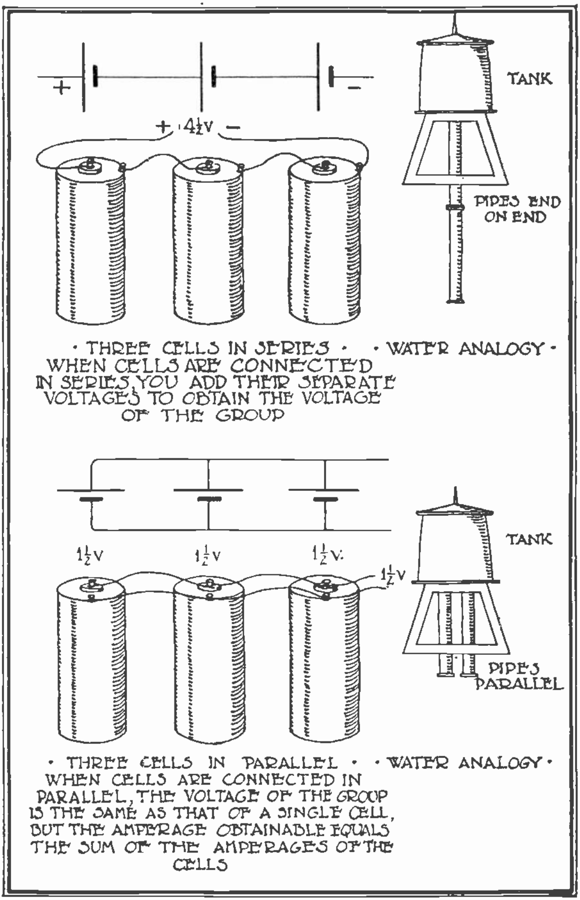
CURRENT AND POTENTIAL

You measure the speed with which water flows in gallons per minute. Now you can't measure electricity in gallons, so you must use another quantity, called the ampere, to measure its rate of flow. One ampere is a flow of unit quantity of electricity per second. In order for the water to flow in a given direction, there must be some sort of pressure in that direction, usually measured in pounds. The electrical potential, corresponding to the water pressure, is measured in volts. The current of electricity flowing in a circuit is proportional to the potential across that circuit divided by the resistance of the circuit. Amperes of current equal volts potential divided by ohms resistance. This is called Ohm's Law. It follows, from it, that when there are two or more conducting paths over which the current may flow, it will divide itself in inverse proportion to the resistances. That is, the greatest current will be in the conductor of least resistance and vice-versa. The accompanying drawing of a standpipe shows how water divides in an analogous manner when several paths are open to it.

Sometimes a loose wire or piece of metal accidently comes in contact with two parts of an electric circuit—as with the lead wires from a battery, for instance—and provides an easy, low-resistance path over which the electric current can flow, deflecting most of it from the path it was intended to follow. Such a condition is called a "short-circuit". Poorly insulated battery lead wires sometimes rub together and form a short-circuit, quickly discharging the battery.

The direction in which the current is said to flow is called the "positive" direction. The opposite direction iscalled "negative" The battery or generator terminal from which the current flows is called the "positive terminal". The one toward which it flows is called the "negative terminal". Current always flows from the positive to the negative—from the point of high potential to the point of low potential.





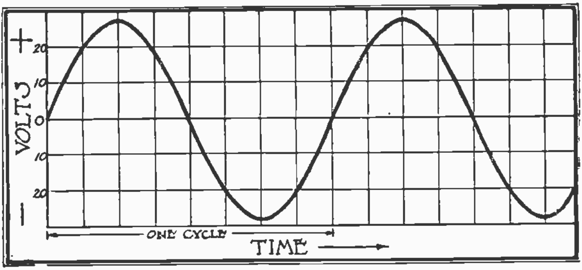
Battery Connections

Dry cells and storage cells are the two sources of electric current most frequently used in the operation of radio sets. A single, new dry cell has a voltage of one and one-half, and will give a momentary current of 20 to 30 amperes—though it should not be used to supply a steady current greater than a quarter of an ampere as otherwise it will be too quickly discharged. A single, charged, acid storage cell has a voltage of about two (the Edison alkaline storage cell has a voltage somewhat lower). Several amperes current may be drawn from a single storage cell without evil consequences (see section on *Batteries*).

If more voltage is desired than that obtainable from a single cell, several cells may be connected in series—that is, the positive pole of each one connected to the negative pole of the next, and the positive pole at one end of the group and the negative pole at the other end of the group, connected to the circuit. The voltages will then add up, just as pressures add up when water pipes are stacked end on end (see drawing of stand pipe).

If more amperage is desired than that obtainable from a single cell, several cells may be connected in parallel—that is, all of their positive poles connected together and all of their negative poles connected together. There are then several sources of electricity sending their energy into the same channels, so that the obtainable current is proportionally increased.

DIRECT AND ALTERNATING CURRENT



Graph of an Alternating Current.

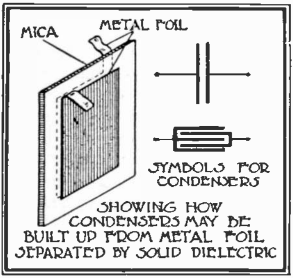
A quantity of electricity that is not in motion along a conductor is called a charge. If it is moving along a conductor, it is called a current. In the case that we have been considering, the current is continuously flowing in one direction, and is called a "direct current" (abbreviated, D. C.). If, however, it periodically changes in direction of flow, it is called an "alternating current" (abbreviated, A. C.). This change back and forth does not usually take place abruptly, but the current builds up from zero to a maximum in one direction, dies down again to zero, builds up to a maximum in the other direction, and dies again to zero—these complete sets of changes, each one of which is called a "cycle," being repeated periodically. The number of cycles per second is called the "frequency."

HIGH-FREQUENCY OSCILLATIONS

When these alternations are of very high frequency, they cause electric waves in the ether in the vicinity of the apparatus. This is the principle upon which radio depends. High-frequency alternations generate the electric radio waves. We must, therefore, have some sort of apparatus at the radio station to set up high-frequency electric current, or high-frequency oscillations, as they are called. We must also have apparatus for tuning—that is, apparatus for controlling the frequency of the oscillations in the sending circuit, and thus the frequency of the resulting waves sent out into the ether. Now it so happens that an electric circuit has a natural period, just as did the swing, and the auditorium roof, and the bridge, so that a current will tend to oscillate in it with a certain particular frequency. Thus by controlling the natural period of the electric circuit, we can control the frequency of the oscillations in the circuit and thus tune to the frequency, or wave-length desired. The natural period of an electric circuit depends upon two factors—capacity and inductance.

CAPACITY

What is capacity? Crudely speaking, capacity might be said to be to electricity what a sponge is to water. It soaks up and stores it until at some later instant something happens to release it. This analogy is by no means accurate—in many ways it would be more true to liken capacity to an air, or gas, tank, as will be explained later. Capacity depends upon the fact that like charges

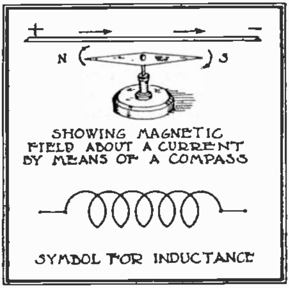


of electricity (that is, two positive or two negative charges) repel each other, while unlike ones attract each other. The amount of attraction or repulsion varies inversely as the square of the distance—that is, it is greater the less the distance and vice-versa. When a wire carrying a positive charge is placed close to a wire carrying a negative charge, these charges will attract each other, and it will therefore be possible to store up a considerable amount of electricity on the two wires (by connecting them respectively to a positive and negative source of electricity). A piece of apparatus for supplying capacity in a circuit is called a condenser.

Capacity depends upon three factors—the area of the oppositely charged surfaces exposed to each other, the distance between these surfaces, and the material between them. Condensers are usually made of flat plates placed very close together, so that maximum capacity may be had in minimum space. Mica, glass, and many other substances, when used to separate the plates, give the condenser many times the capacity it would have if air were used. Such materials are convenient in building compact condensers of high capacity.

INDUCTANCE

Inductance depends upon the fact that a magnetic field is always set up about a current of electricity. This magnetic field opposes any change in the current—when the current is building up the inductive magnetic field opposes the increase in current, when the current is dying down the magnetic field opposes the decrease. Thus inductanec

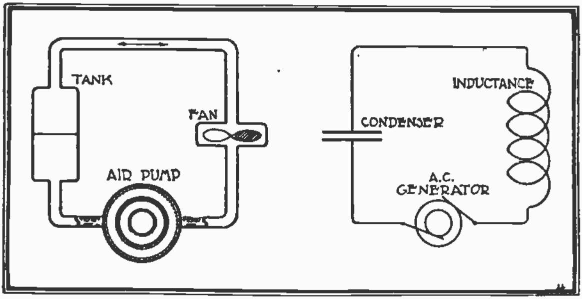


has the effect of holding back or retarding the cycle of changes of an alternating current.

Inductance depends largely on the shape of the conductor. In a coil of wire, for instance, the magnetic fields due to each of the turns of wire are all concentrated together in a very small space, so that the total magnetic field is very great and the resulting inductance very large. It is therefore customary to make inductances in the form of closely wound coils. Of course inductance has no effect on a steady direct current, as it only opposes changes in current.

INDUCTANCE AND CAPACITY IN A CIRCUIT

Just what effect inductance and capacity have in an electric circuit may best be explained by reference to the accompanying drawing. The air pump represents a source of alternating electric current, the tank, with its two compartments closed off from each other, represents

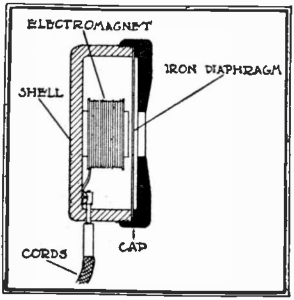


a condenser, and the fan represents an inductance. It will take some energy and some time to speed up the fan just as it takes some time and some gasoline to speed up an automobile. But after the fan is once speeded up it will keep on running, "coasting" as we say, if the force is removed. Thus it will always oppose and retard any increase or decrease in the current of air flowing by. Just how difficult it will be to start and stop the fan depends upon its mass. For instance, it requires a less powerful engine to accelerate quickly a small, light automobile than to accelerate a large, heavy automobile up to the same speed in the same length of time.

The tank compartments will always aid the flow instead of retarding it, because their back pressure will always be less than the pressure due to the pump when the latter is forcing air into them, and greater than the pressure due to the pump when it is forcing air in the opposite direction. For the pressure of the tank must be less than that due to the pump for air to be forced into it, and greater than that due to the pump for air to be sucked out of it. The back pressure from the tank will, of course, keep on increasing as more and more air is pumped into the compartment, until, if the pump is kept going in that direction long enough, the back pressure will be the same as that of the pump and no more air will be pumped into the compartment. The quantity of air that must be pumped into the compartment to raise its back pressure a certain amount depends directly upon the size of the compartment. This quantity corresponds to the capacity of a condenser. The back pressure corresponds to the back potential (or back electromotive force, as it is frequently called.)

Now if the pump is made to reverse in direction periodically, corresponding to the alternator in an electric circuit, the fan will oppose these changes, or alternations, and the tank will aid them. The amount that the fan opposes the changes is proportional to the speed with which the changes take place—that is, the fan will give more resistance to them if the alternations are rapid than if they are slow. This corresponds to our analogy of the automobile, for the more quickly we try to accelerate it up to speed, the more powerful an engine we must have. It is thus apparent that there must be some speed, or frequency, of alternations at which the opposing pressure of the fan will just equal the aid given by the tank. At this frequency the current will, of course, be greatest, because the actions of the fan and tank will neutralize each other, and there will be no energy wasted in starting and stopping the fan. Thus, by regulating the size of the fan, or the size of the tank, we can regulate the frequency at which the greatest current of air will flow. Or, in the words of electricity, by regulating the inductance and capacity we can regulate the frequency to which that circuit will best respond, giving the most current for a given impressed potential, whether that potential be due to an alternating current generator of some sort in the circuit, or to radio waves causing alternations to be set up in the circuit.

WHY HAVE A DETECTOR?



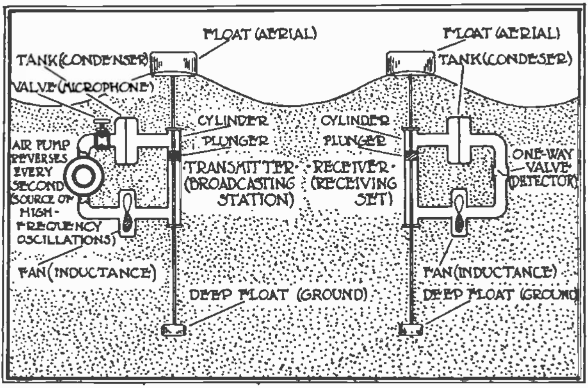
Now it has several times been said that in addition to some device for tuning you need a device called a detector, for making the radio oscillations capable of operating headphones. It has not been explained, however, just why this detecting device is necessary.

A headphone or telephone receiver consists of a little electromagnet placed so as to attract an iron disk or diaphragm whenever a current passes through the electromagnet. The pull that the magnet exerts on the diaphragm is proportional to the amount of current flowing through the electromagnet coils. If the current is alternating, for instance, the diaphragm will vibrate back and forth, corresponding to the current changes. But radio oscillations are of such very high frequency (hundreds of thousands of cycles per second, as before mentioned) that an iron diaphragm could by no means respond to them. Their effect, if sent directly into a set of headphones, would be nil as far as producing sound is concerned. For that reason, a device called a detector, which corresponds to a one-way valve in a water pump—a device that will let the oscillations flow in but one direction, is used to cut out one half of each alternation. This makes the resulting current almost equivalent to a steady current in one direction—for though there are continuous pulsations, or building ups and dying downs, in that direction, these take place so rapidly that the average effect is almost the same as though the current were steady. This is especially true if a little condenser, called a phone condenser, is placed across the phone terminals, storing up some electricity at the height of the alternations and giving out some electricity when the oscillations approach zero, so that the average effect is that of a steady current.

RADIO TELEPHONE COMMUNICATION

Now a steady direct current will not cause the diaphragm of the headphone receiver to move, and when no one is talking at the sending station you don't hear anything in your headphones, even though the station is continuously sending out high frequency waves of constant amplitude. But when someone talks into the microphone at the sending station, this instrument varies the strength of the oscillating current in the sending circuit in accordance with the variations of the sound waves of the voice. When the resulting radio waves reach the receiving circuit, they set up current oscillations there which vary in strength in the same way, and when these oscillations are rectified by the detector they become a uni-directional current of varying strength, the variations corresponding exactly to those originally caused in the sending circuit by the action of the voice waves on the microphone. This varying, uni-directional current causes the headphone diaphragms to vibrate back and forth, reproducing the sounds made at the sending station.

Thus we have the complete process of radio transmission and reception analyzed. We may illustrate the whole process by a diagram showing our analogy fully worked out.



SELECTIVITY

In the preceding analogy, the current of air is greatest when the sizes of the fan and tank are just right for the particular frequency at which the air pump is operating. If the frequency of the air pump were changed from this value without altering the size of the fan or tank, the current of air would rapidly fall off as the frequency differed more and more from its original value. Just so, when a radio receiving circuit is tuned to some station—say at 500 meters—the current it receives will rapidly fall off if the wave-length of the incoming signal is shifted from this value without a corresponding change being made in the tuning controls of the receiving set. Thus, if the receiving set is kept adjusted to 500 meters, a signal at 495 meters will give less results, one at 490 meters still less results, and so on.

The effect on the strength of the received signal of a small change in the signal wave-length is a measure of the selectivity or sharpness of tuning—that is, it is a measure of the ability of the receiving set to respond only to the wave-length to which it is adjusted. A difference of one or two meters in signal wave-length may make a considerable difference in signal strength if a selective receiving set is being used, while it may make practically no difference at all if a broadly-tuned, non-selective set is being used.

THE VACUUM TUBE

ELECTRON EMMISSION

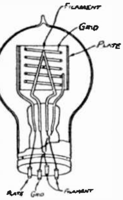
THE modern idea of electric current flow in metal assumes that a current of electricity is a flow of little negative particles of electricity through the conductor. These little negative particles are called "electrons." They are always present in the metal, but ordinarily move about in all directions in zig-zag paths, colliding with the atoms of the metal, and, in effect, getting no where. If however, an electromotive force is applied to the conductor, they will (since they are negative particles) be attracted toward the positive end of the conductor and flow in that direction. This is the phenomenon known as an "electric current."

The velocity with which the electrons travel over their zig-zag paths when no electromotive force is being applied to the metal is proportional to the temperature of the metal. When it is very hot, their velocity will be so great that a number of them will be continually shooting off into space from the surface of the metal, just as sparks shoot off from a burning iron wire. As these electrons shoot off, however, they leave the hot metal positivley charged, so that unless some means is taken to prevent their so doing, they will be drawn back into it If a positively charged conductor is placed in the neighborhood of the hot metal, a large number of the negative electrons will be continually drawn to it, forming a continual flow of negative particles from the hot body to the positive conductor.

THE TWO ELEMENT VACUUM TUBE

The first vacuum tubes, called "valves," contained a filament, which, when heated served as a source of electrons, and a small metal plate that was kept positively charged, and served to cause a steady stream of electrons to flow from filament to plate. The filament was heated by a battery, called an "A" battery. Another battery (called a "B" battery) was connected between the plate and filament; its positive pole to the plate and its negative pole to the filament, serving to keep the plate at a positive potential. The electron stream completed the circuit (called the plate circuit,) so that there was a continual flow of electric current; the negative particles going from the battery to the filament, thence, by means of the electron stream to the plate, and finally back to the battery. As fast as electrons were shot off from the hot filament they were supplied to it by the "B" battery. If the tubes were connected so that the incoming radio signals had to flow between the filament and plate before reaching the headphones, the signals would be rectified, that is, made uni-directional, because the electron stream would allow them to flow in but one direction. Not only radio signals, but any alternating current may be rectified in this way. In fact, the two element vacuum tube has come into considerable vogue as a rectifier for use in charging storage batteries from alternating current circuits.

THE THREE ELEMENT VACUUM TUBE

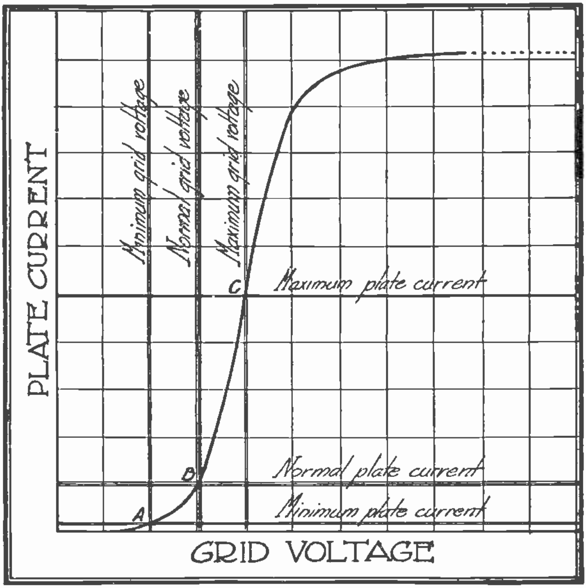


If a third metallic element of grid-like, or screen-like, structure be placed between the plate and the filament it will act as a control for the electron stream. The grid is nearer the filament than the plate is, so a small change in its potential will have a greater effect than the same change in plate potential, in changing the electron flow. If the grid is made slightly positive it will attract and aid the electron flow to the plate, while if it is made sufficiently negative it may repel the electrons so effectively as to cause all of them to be drawn back into the filament as fast as they are shot off.

Now the current in the plate circuit (that is, the circuit from "B" battery to plate, to filament—through the tube—and back to the "B" battery again) is, of course, directly controlled by the electron flow, for the electron stream is part of the plate circuit. So if the incoming signals are made to act upon the grid, slight changes in their strength will cause a correspondingly large change in the plate circuit current, resulting in an amplified replica of the grid current, in the plate circuit. Of course the current in the plate circuit is supplied by the "B" battery, the signals in the grid circuit acting merely as a sort of trigger. In a similar manner, the current in the plate circuit may be impressed upon the grid circuit of another vacuum tube and still further amplified. As many tubes may be connected one after another in this way, as desired—though certain electrical and other considerations place a limit on the number of tubes that may be practically used under given circumstances.

CHARACTERISTICS OF VACUUM TUBES

The rectifying action of three element vacuum tubes depends upon a certain peculiar relation between the grid potential and plate current. The grid potential may be made considerably negative before it entirely stops the plate current flow. Thus both positive and negative sides of the alternations of the received signal will affect the plate current. When the signal alternations are negative they will decrease the plate current and when positive they will increase it. Thus their effect will be to cause a continuous fluctuating current in the plate circuit.



Characteristic Curve of a Vacuum Tube.

However, every change in grid potential does not cause the same change in plate current. A grid change from four to five volts may cause almost the same change as from five to six volts, while a change from two to three, or six to seven volts may not have one-tenth that effect. A curve showing the ralation between grid potential plate and current is called a characteristic curve.

THE THREE ELEMENT VACUUM TUBE AS A DETECTOR

If, now, the vacuum tube is operated in the section of the curve a-b-c, a decrease in grid potential will cause a small change in plate current, while an increase in grid potential will cause a relatively large change in plate current. In other words, the negative portion of the signal alterations will be effectively blotted out, and only their positive portion will cause much change in plate current. The result is, in effect, the rectification of the incoming signals.

In order to operate the tube on a knee of the curve, the grid potential must be kept in the neighborhood of some certain amount. This may be done by inserting a battery in the grid circuit and adjusting its voltage to the right valve. . Such a battery is called a "C" battery. "C" batteries are used with some types of amplifier tubes. It is customary to use, instead, with detector tubes a small condenser, called a grid condenser.

The grid condenser accumulates a charge as the tube continues in operation. This accumulated charge acts in very much the same manner as the impressed potential of the "C" battery. In some cases, too great a charge collects, causing the tube to operate away off on the horizontal portion of the curve, where changes in the grid potential have practically no effect on the plate current. This effect, called "blocking," may be prevented by connecting a small high resistance unit, called a "grid leak," across the terminals of the grid condenser. The grid leak allows the condenser charge to slowly leak away. Blocking is an effect which depends largely on the construction of the tube, and when it is necessary to use a grid leak with a vacuum tube the manufacturer so specifies in his instructions, recommending the proper value.

VACUUM TUBES AS AMPLIFIERS

If the tube is operated on the nearly vertical portion of the curve, both sides of the alternations in the grid circuit will be faithfully reproduced in the plate circuit. The tube then acts merely as an amplifier. Several tubes may be connected one after another—the plate circuit of each one connected to the grid circuit of the next by a small transformer (see section entitled *Coupled Inductances*)—and the current further amplified.

When the incoming signals are amplified before being rectified, the process is known as "radio-frequency" amplification. Each circuit should, for best results, be tuned to the frequency of the incoming waves. Radio-frequency amplifying transformers are therefore often constructed so that they can be tuned, (that is, so that their inductance can be changed at will.)

Amplification after rectification is called "audio-frequency," or "tone-frequency," amplification, as the fluctuations of the current after rectification correspond to the fluctuations of the voice or music at the broadcasting station.

THE DEFLECTRON TUBE

The third element or grid, need not necessarily be placed between the filament and the plate. If it is placed at one side of the filament, it will deflect the electron stream out of its ordinary path when it is positively and negatively charged. and will thus control the number of of electrons reaching the plate by deflecting them, instead of by blocking their path. This is the principle upon which the deflectron tube depends.

REGENERATION

By connecting the plate circuit of the detector tube to its grid circuit, by means of an air-core transformer, the change in current in the plate circuit may be impressed on the grid circuit, the energy run through the tube again, and further amplified. This system, called "regeneration" is one of the great advances in the development of radio communication.

REFLEX CIRCUITS

Modern ingenious circuits make it possible to run the signals through the same tube twice, as in the Trirdyn circuit, for instance, in which the first tube acts as a radio-frequency amplifier, the second tube as a regenerative detector, after which the signals are reflexed, or again run through the first tube, this time as an audio-frequency amplifier, and finally are sent through a third tube as a second audio-frequency amplifier. Thus, the first tube acts as both an audio-frequency and a radio-frequency amplifier, performing the functions of two tubes.

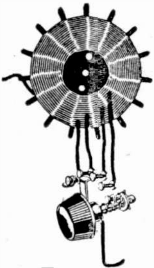
THE FOUR ELEMENT TUBE

Recently vacuum tubes with four elements have come into vogue. Special circuits have been designed for their use, such as the Solydyne, for instance

THE PARTS OF A RECEIVING SET

TUNING INDUCTANCES

INDUCTANCES are made in the form of coils of wire, as already explained. If it is desired to vary the inductance, for purpose of tuning, a tap switch may be provided — a small rotary switch with a number of contacts, called taps, connected in at different parts of the "coil", so that by rotating the switch arm the number of turns of wire in the circuit may be changed. As the inductance of a coil depends on its number of turns, this is a simple means of varying it.

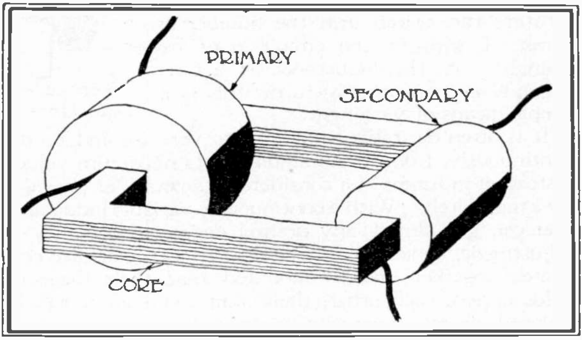


Tapped Inductance

It is often desirable to be able to vary the inductance continuously, from its minimum to its maximum values, instead of in jumps of a considerable amount, as provided by a tap switch. With a continuously variable inductance you can get almost any desired degree of accuracy of adjustment, hence the advantage. If two coils are connected together and so mounted that their magnetic fields oppose each other, their joint inductance may be reduced almost to zero by bringing them close together, so that the opposition of the fields is greatest, or it may be increased from this value to nearly the sum of their separate inductances by removing them sufficiently far apart so that the fields have little effect on each other. Such an instrument is called a "variometer". A coil of wire carrying a current is just as much a magnet as a compass needle. It has a north and south pole, like any other magnet. Keeping this in mind may help you to understand the variometer principle. The variometer coils are sometimes placed one within the other so that the inner one can be rotated and the relation of the fields changed in that way. Another popular arrangement consists of two flat coils hinged together at one edge so that they can be moved closer together or farther apart like the leaves of a book.

COUPLED INDUCTANCES

If two coils of wire connected to different circuits are placed close enough to each other and an alternating current, or pulsating direct current, is sent through one of them, the fluctuating magnetic field about this coil, interlinking with the turns of the other coil, will cause a like current to be set up in it. Just as variations in the current in a conductor will cause a fluctuating magnetic field about it, so a fluctuating magnetic field about a conductor will set up pulsating or alternating currents in the conductor. Two coils inductively connected in this manner are called "coupled inductances," and their inductive connection is called "mutual inductance."



Construction of a Transformer

The transformers that you see on telephone poles about the city consist of two coils mounted together on an iron core. Iron magnetizes many hundreds of times as easily as air, so that the inductive effect of the coils is much greater when an iron core is used. One of the coils is connected to the high-voltage power lines from the central generating station; the other coil is connected to lighting and power circuits in the neighboring homes and factories. Now when alternating current is transformed from one coil to another by means of inductive coupling, the ratio of the voltage in the two coils depends upon the ratio of their inductances. Or, since when other things are kept equal, inductances depends upon the number of turns of wire in the coil, the ratio of the voltages of the two coils depends very largely on the ratio of their number of turns. In other words, if the coil connected to the house wiring has one-tenth as many turns as the coil connected to the high-voltage wires, the voltage induced in the house-lighting circuit will be approximately one-tenth that in the high-voltage circuit. The current will be correspondingly increased, that is, it will be ten times as great as in the high voltage circuit. As the electrical power is a product of the voltage and current, their is no power lost in this transformation. Actually there is a small power loss in transformers, due to heating of the wires and core.

You can see how convenient this means of transforming alternating current is, for by this method electricity may be transmitted for miles about the generating station at a very high voltage with a correspondingly low current, requiring but small wires, and in the vicinity of the dwelling or factory where it is consumed it may be transformed into a low-voltage high-amperage current that will not hurt anyone if he accidentally comes in contact with it. If it were necessary to transmit the low-voltage, high-amperage current all the way from the generating station to the consumer, very heavy wires would have to be used to keep the heavy current from heating the wire too much and dissipating energy in the form of heat. These wires would be so costly that in many instances, as where electric power is transmitted for a hundred miles or so, the project would be totally impractical.

When the coils are placed far apart so that their is little mutual inductive effect, the coupling is said to be "loose." When they are placed close to one another, so that the inductive effect is great, the coupling is said to be "tight."

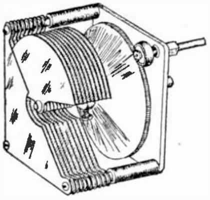
Coupled Inductance

The "Varind" is a coupled inductance made of two coils wound "flat lattice" fashion. One of them slides back and forth on a shaft passing through the other coil, thus enabling the operator to change the distance between the coils, or the coupling. The fixed coil is provided with a tap switch for varying its self-inductance. The flat lattice form of winding provides air spaces between the turns of wire, and removes them from each other, so that there is little capacity effect between one turn and the next. This capacity between different parts of a coil, or of a circuit, is called "distributed capacity", and is to be avoided as much as possible because it reduces the selectivity of the set.

VARIABLE CONDENSERS

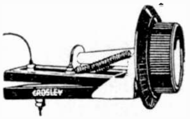
The capacity of a condenser depends on the area of the oppositely charged surfaces, the distance between them, and the material between them. Condensers of variable capacity are made by varying these factors.

One common type of variable condenser consists of two sets of semi-circular plates, one set stationary and the other made to rotate and interleave with it. Thus by rotating one set of plates, so as to change the amount of opposing plate area, the capacity is correspondingly varied.



Rotary Plate Variable Condenser.

The book-type variable condenser consists of two moulded insulating plates coated with metallic foil and hinged together at one edge so that they can be swung toward or away from each other like the leaves of a book. A cam, mounted on a shaft passing through a bearing in the condenser frame, and provided with a knob and dial, offers the mechanical means of adjusting this condenser. A thin sheet of mica is mounted between the plates in order that the capacity may be sufficiently high without making the plates excessively large, and so there will be no danger of short-circuiting no matter how close together the plates are pressed.



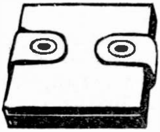
Book Type Variable Condenser

For very fine adjustment, condensers are often provided with verniers. These consist usually of a large gear mounted on the condenser shaft, meshing with a pinion controlled by a small knob. The control knob must be turned around several times to move the condenser plates a small amount, and it therefore serves as an extremely accurate means of adjustment for final tuning.

There is a certain amount of power loss in condensers due to the dielectric or insulating material used. Air has the least loss, and this accounts for the general preference for air condensers. Mica is next in the list and is the favorite solid dielectric. Often insulating frames are responsible for a very high loss, and well-designed condensers have as little of such insulating material in the neighborhood of the plates as possible.

Sometimes difficulty is encountered in tuning a set because there is a large capacity effect between your body and the part of the set. When you have your hands on the controls, near the instrument, this capacity is greatest, and after having tuned in the set with this capacity present, you remove your hands, and with them the body capacity, so that the set is immediately out of tune. Such trouble may be guarded against by shielding the parts of the set by a metal screen, or sheet of metal foil, connected to the ground and fastened to the back of the panel between the instruments and your hands. Care should be taken not to short-circuit any of the wiring of your set with this screen. Some condensers, such as the Crosley book-type, are provided with metal frames which when grounded make them free from body capacity effects.

FIXED CONDENSERS



Fixed Condenser.

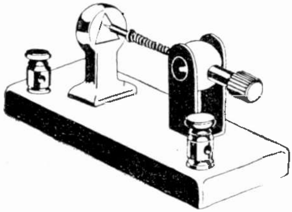
Condensers of fixed capacity are required for a variety of purposes. For instance, they are often used across the terminals of headphones, as explained earlier in this booklet. A "grid condenser" is usually used in the grid circuit of a vacuum tube detector, as was explained in the theoretical section on *Vacuum Tubes.*

A fixed condenser for radio reception is usually made of sheets of metal foil—copper, aluminum, or lead (commonly called tinfoil)—insulated from each other by thin sheets of mica or paraffin paper.

Condensers for radio transmitting sets are required to stand much higher voltages without puncturing—that is without having the electric charge break down the insulating material and jump across from one plate to another. They are usually made up of metal plates, insulated from each other by thin mica sheets, plates of glass, or insulating oil.

CRYSTAL DETECTORS

Some crystals of certain substances exhibit the remarkable property of conducting electricity very readily in one direction, and conducting it hardly at all in the opposite direction. This enables them to be used in radio circuits to detect, or rectify, the high frequency oscillations, so that they are capable of operating the headphones. The crystal detector usually consists of a cup, in which the crystal is mounted, and a wire contact ("cat-whisker"), arranged so that it can be brought to bear on any point of the exposed surface of the crystal. It is necessary to find a sensitive spot by trial, as some portions of the crystal are many times more effective than others. At one time, carborundum, silicon, iron pyrites, galena, and a number of other substances were popular for use as radio detector crystals, but galena has almost displaced all others, and is the present favorite.



Crystal Detector.

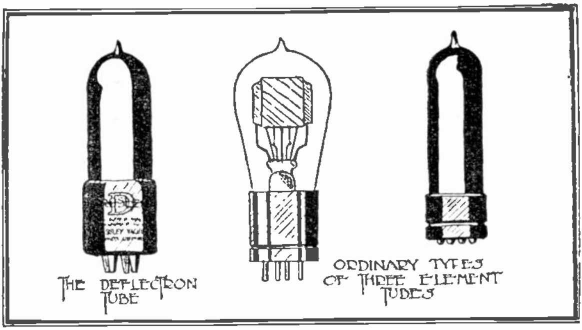
"Fixed" crystal detectors have brush like contacts of several wires, instead of the single wire catwhisker. Among these many wires, some are sure to bear on a sensitive spot. However, carefully adjusted catwhisker detectors are generally more sensitive than fixed-crystal detectors.

Some crystal detectors employ a second crystal, bearing on the first, instead of the catwhisker or brush of wires. These double-crystal detectors were at one time in more general use than they are today.

VACUUM TUBES

Most vacuum tubes for receiving purposes are of about the same general type. They are somewhat smaller than the ordinary pear-shaped electric light bulb, and contain three elements, instead of just a filament.

The smaller tubes are intended for operation on dry "A" batteries, and the larger ones for operation on storage "A" batteries. Tubes for use as amplifiers are generally slightly different from those intended to be used as de-



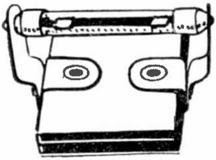
Type of Vacuum Tubes.

tectors. The amplifier tubes are usually exhausted to a higher vacuum than the detector tubes.

The theoretical operation of vacuum tubes is fully described in a previous section.

GRID LEAK

There is sometimes a tendency for the charge on the grid condenser to build up to such an extent that the detector tube is unstable and erratic in operation. This condition commonly known as "blocking", may be guarded against by providing a very high resistance unit, called a "grid leak," across the grid condenser terminals, as explained in the section on *Vacuum Tubes*. The grid leak allows the condenser charge to leak slowly away when the applied potential is removed. In its most convenient form, it consists of a little glass cartridge containing a high resistance unit (usually a lead-pencil line or India ink line on a piece of paper.) You can easily construct one yourself, but it is better to purchase one known to be of the proper resistance, as each type of vacuum tube requires a particular grid leak resistance value.

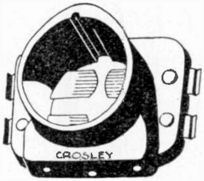


Grid Leak mounted on Fixed Condenser.

There are several variable grid leaks on the market that by suitable adjustment may be used with any tube.

VACUUM TUBE SOCKETS

Vacuum tubes are provided with a base having four prong contacts, and it is necessary to have some kind of a socket or receptacle to hold them. Most sockets are made of either moulded composition or porcelain. Such sockets are superior to those having metal receptacles, as capacity effect between the tube and neighboring metal is undesirable.



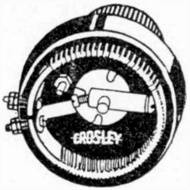
Tube Socket.

Adapter

Certain tubes have a base smaller than the standard socket size, and if you wish to use these in a standard socket you must use an adapter with them.

RHEOSTATS

Rheostats are variable resistances for controlling the amount of current flowing in a circuit. Vacuum tube filament rheostats usually consist of a coil of resistance wire and a rotating switch lever that slides over the turns and makes contact with them. One terminal of the circuit is connected to the switch lever and the other is connected to an end of the coil, so that by rotating the switch lever any desired number of the coil turns may be brought into the circuit, and the resistance thus regulated.



Rheostat.

It is necessary to have some means of regulating the filament current, first, because different tubes require different amounts of current, and second, because the batteries used to light the filament are much stronger when first put into operation than after an extended period of use. In fact there is such a great difference in the current requirements of various tubes that no ordinary rheostat is adapted to the needs of all of them. The Multistat, however, solves this problem.

The Multistat has two coils of resistance wire, connected in series. One is of comparatively low resistance, the other comparatively high. By rotating the switch lever from the zero, or "off", position, both coils are first brought into the circuit, the lever making contact with the high-resistance coil, which provides the fine adjustment necessary for certain tubes. As the lever rotates still further it makes conatct with the low-resistance coil, and the high-resistance coil is cut out of the circuit, providing the required resistance for tubes using high filament current.

Care should always be taken to adjust the filament rheostat so that the tube filaments do not burn too brilliantly, as otherwise the life of the tube will be considerably shortened.

"A" BATTERIES

"A" batteries, for lighting the filaments of vacuum tubes may be either dry cells or wet, storage cells, (a cell is one of the complete units that make up a battery—a battery consists of a number of separate cells connected together). If the tube requires a filament current of more than 0.25 ampere (which would be a rather heavy drain on a dry cell) it is more economical to use a storage battery, as these may be recharged inexpensively from the ordinary electric light circuit when they lose their strength, whereas when dry cells once lose their strength they are of no further use and must be thrown away and new ones purchased. Storage batteries have another advantage in that their voltage does not begin to fall off rapidly until they have been considerably discharged, while the voltage of a dry cell begins to fall immediately after it is put into service. On the other hand, dry batteries occupy less space, are more convenient to handle, and require less attention than storage batteries.

Dry "A" Battery

The smaller tubes are especially designed to be used with dry cell "A" batteries. The ordinary No. 6 dry cell is quite satisfactory, though there are certain cells on the market, designed especially for "A" battery radio use, for which the manufacturers claim a much longer life. Each cell gives 1.5 volts potential, and by connecting a number of cells in series, any required voltage may be obtained.

Storage "A" Battery.

Storage batteries are rated in ampere-hour capacity. If, for instance, a storage battery is said to have a 100 ampere-hour capacity, that means that when fully charged it is capable of delivering a current of 1 ampere for 100 hours. or of ½ ampere for 200 hours, or 2 amperes for 50 hours, etc., before being recharged. However, storage cells should always be recharged before they are completely discharged. In fact, to let a storage battery stand for some time in a nearly discharged condition is quite liable to ruin it.

The condition of the storage cell may be determined from time to time by means of a hydrometer—a syringe-like instrument with a tubular glass body containing a weighted float scale. The end of the hydrometer is inserted in the filler hole on the top of the battery, after removing the filler cap, and the solution sucked up into the tube. If the battery is fully charged, the float will sink to a point where the top surface of the liquid corresponds to a reading of 1250 to 1300 on the float scale. When this scale reading is as low as 1100 the battery should be immediately recharged.

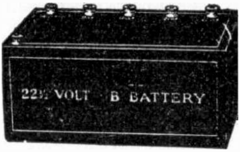
There should always be sufficient solution in the battery to cover the tops of the plates. If, when examining the battery through the filler caps, you find the tops of the plates exposed, add distilled water until they are covered. Only pure, distilled water should be used for this purpose. It may be obtained at any drugstore or battery service station. Remember that the solution is easily spilled.

LIGHT CIRCUIT SUPPLY

There are several devices now on the market designed to take the place of "A" and "B" batteries, operating the vacuum tubes directly off the lighting circuit. These consist of some sort of rectifier and a step-down transformer.

"B" BATTERIES

The current required from the "B" battery is not nearly so great as that required from the "A" battery, but the required "B" battery voltage is much greater, ranging from 22 to 120 volts and sometimes even higher. As a good dry "B" battery will last six months or more if not abused, it is economical to use dry cells for this purpose. The most common form of dry "B" battery is made up in 22½ volt units, composed of 15 little dry cells connected in series and sealed together in a single container. When voltages greater than 22½ are required, a number of these batteries may be used, connected in series. These 22½ volt "B" battery units are made in different sizes and shapes to fit different conditions.



Dry "B" Battery.

Storage "B" Battery Cell

Storage "B" batteries are usually assembled in 24 volt units. They are much more costly than dry "B" batteries, but have the advantage of eliminating certain troubles sometimes encountered in dry "B" batteries as they approach the end of their useful life, due to internal chemical actions. When these particular internal chemical actions take place they cause the dry "B" battery to give an unsteady current, which results in annoying sounds in the headphones.

"C" BATTERIES

"C" batteries, required, as explained above, by some tubes when used as amplifiers, are practically always dry cells. The required voltage is from 1.5 to 6, and the current used is so small that storage cells are of no advantage.

BATTERY CHARGERS

If the home is supplied with a direct current lighting circuit, storage batteries may be charged directly from this circuit. With town lighting circuits of 120 or 220 volts a lamp bulb or some other resistance must be used in series with the battery to reduce the current flow Information as to the size of bulb best adapted to your needs may be obtained from the dealer from whom you purchase your battery, or from the manufacturer. The positive terminal of the battery should be connected to the positive side of the circuit and the negative terminal to the negative side of the circuit. It is very important to get these connections right.

If you have a farm lighting plant, you can charge your battery directly from this plant without using any resistance in series. Simply be careful to get the connections right, positive to positive and negative to negative.

Most homes, however, are supplied with 110 volts alternating current, at 60 cycles frequency. Some form of rectifying and current-reducing device must be used to charge batteries from these circuits. There are three main types of battery chargers now on the market. Mechanical chargers have a vibrating contact that makes and breaks the current at the proper times, so that only one half of the alternation is allowed to pass, and a small transformer for stepping down the current. Electronic rectifiers use the vacuum tube for rectification and a small transformer for stepping down the current. Electrolytic rectifyers employ a pair of metal plates immersed in a chemical solution, for purposes of rectification, and usually either obtain sufficient resistance for current reduction in this solution itself, or by means of an external series resistance. They are sometimes used with step-down transformers. A choice among these three types is largely a matter of the personal preference and pocketbook of the user. All three types will give good service.

HEADPHONES

Headphones are all constructed, as previously explained, of small electromagnets arranged to attract iron armatures when a current flows through them. The armature may be either an iron diaphragm, which sets up the sound waves directly, or a small piece of iron connected by a lever to a mica diaphragm so that a small armature movement will cause a relatively large diaphragm movement and a correspondingly loud sound. This latter principle is made use of in one type of so-called "amplifying headphones."

Headphones.

It is very important that the headphones be well constructed, as they are a vital part of the receiving set.

LOUD SPEAKERS

As before mentioned, loud speakers usually consist of an especially sensitive headphone receiver unit to which is attached a sound-amplifying horn, corresponding to

Loud Speaker.

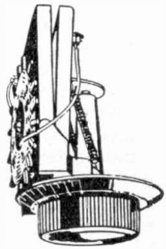
the tone-arm and horn chamber of your phonograph. The volume of sound which can be obtained from a loud speaker depends greatly on the proper design of these two units. Some loud speakers employ an ordinary headphone receiver and a small, poorly designed horn, and do not give much volume of sound.

Sometimes a sound reflecting board or chamber takes the place of this horn. Loud speaker receiver units can also be obtained for connecting directly on the tone arm of your phonograph—using its sounding chamber to amplify the sound.

One type of loud speaker on the market replaces the headphone receiver unit with a specially designed sounding unit depending on certain electrodynamic principles. A separate battery is required for its operation.

RADIO-FREQUENCY AMPLIFYING TRANSFORMERS

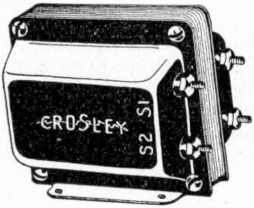
For transferring the energy from the plate circuit of one tube to the grid circuit of the next, in radio-frequency amplification, a small radio-frequency amplifying transformer is generally used, as explained in the section on *Vacuum Tubes.* As each radio-frequency circuit must be tuned to the frequency of the incoming oscillations for effective results, some means of tuning the radio frequency amplifying circuits should be provided. For this purpose a variometer is often placed in the transformer circuit. The Crosley tuned radio-frequency transformer employs a condenser for varying the wave-lengths.



Crosley Tuned R.F. Transformer

AUDIO-FREQUENCY AMPLIFYING TRANSFORMERS

Transformers for transferring the energy from the plate circuit of the detector tube to the grid circuit of an audio-frequency amplifier tube, or from the plate circuit of one stage of audio-frequency amplification to the grid circuit of the next, as explained in the section on *Vacuum Tubes* are called "audio-frequency amplifying transformers."



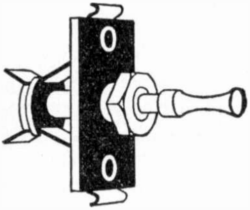
A. F. Amplifying Transformer.

The transformer must transfer this energy as efficiently as possible and with minimum distortion. There must be no particular notes to which it is especially responsive, and it should not introduce any harmonics. The primary winding must be of sufficiently large wire to carry the plate current of the vacuum tube to which it is connected, and the insulation must be capable of withstanding the "B" battery voltage. It is desirable to enclose the core and windings in an iron shell so that the magnetic field will not stray to other parts of the circuit. The Sheltran transformer is provided with a protective casing of this sort.

The ratio of the number of turns of wire in the secondary to the number of turns in the primary must be proper for the circuit used. Ordinarily, audio-frequency transformers ratios are from 3 to 1, to 9 to 1.

FILAMENT SWITCH

For convenience in cutting off the "A" and "B" batteries from the circuit when the set is not in operation, a small filament switch is often provided. If your set has no filament switch, the wires from these batteries should be disconnected when not using the set, as in that way their life will be considerably prolonged. The Crosley filament switch connects or disconnects both "A" and "B" Batteries with the circuit. and is a great convenience, especially as by merely pushing



Filament switch

a little knob the circuit is opened or closed. If you are listening to any particular station and wish to leave your set and come back later, you may cut off the battery current in this way, without changing any of the controls, and at any subsequent time you may merely close the switch and the station will be heard, if it is in operation.

CABINETS AND PANELS

The parts of a receiving set are usually mounted on the rear of a panel of formica, bakelite, or other insulating material, on the front of which are the controlling knobs and dials, phone jacks, filament switch, etc. This panel

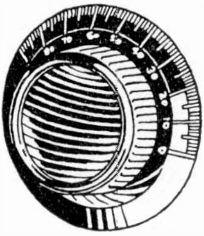
Trirdyn Special Cabinet and Panel

is generally mounted in a wood cabinet for the purpose of protecting the instruments and of giving the set a pleasing appearance. The present tendency is toward self-contained sets in which the batteries and even the loud speaker unit are enclosed in the cabinet.

JACKS AND PLUGS

These are convenient devices for quickly connecting the headphones or loud speaker to the detector circuit, or in any desired stage of amplification. A plug, provided with two contacts is fastened to the telephone cords, and this slips into a tubular receptacle, provided with the proper contacts. This receptacle is called a "jack". Jacks are often arranged to accomplish a variety of purposes, as for instance, to close the battery circuits when the phone plug is inserted and, open them when it is removed.

KNOBS AND DIALS



Knob and Dial.

The present tendency is to make dials with especially large knobs so as to facilitate fine adjustment. Knobs are usually made of moulded insulating material. Dials are made either of the same material, or of celluloid, or metal. Metal dials are often objectionable because of the capacity effect between them and other parts of the set.

BINDING POSTS

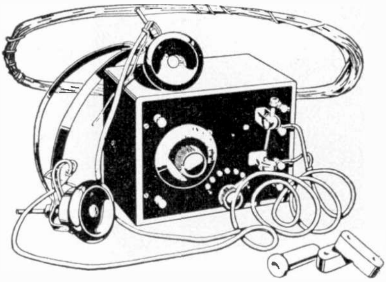
Binding Post

Binding Posts are used for making connections at the set to the wires from all necessary external equipment, such as batteries, ground, aerial, etc. They consist of some kind of thumbscrew or spring clip arrangement for firmly clamping the wire. You should always take care to see that the insulation is well removed from the end of the wire before clamping it in the binding post, as a bad electrical connection at this point may be the cause of the failure of your set to function. It is best to scrape the wire clean with a knife until the metal appears quite bright, and to clamp it as tightly as possible in the binding post.

RECEIVING SETS

CRYSTAL RECEIVING SETS

CRYSTAL Receiving Sets are the simplest of all. They consist merely of a crystal detector and some kind of tuning device—usually an inductance coil with a tap switch or sliding contact, or a variable condenser. There is little choice, as far as sensitiveness is concerned, among the many crystal receiving sets on the market, but some of them are much better constructed then others, and employ much more selective circuits.



Crystal Receiving Set.

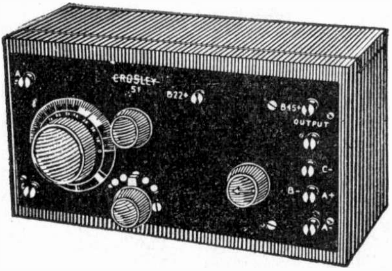
Crystal sets are used for reception from local broadcasting stations or other stations in the immediate vicinity. Under fair conditions they will give good audibility in the headphones when receiving from stations as far away as twenty-five miles. They are practically never capable of operating loud speakers. Vacuum tube audio-frequency amplifiers may be used in conjunction with crystal receiving sets, in which case the audibility of the incoming signals is increased many times, and it is possible to receive far away stations whose signals would otherwise be too weak to hear. However, this is seldom done, except in special circuits, as it is considerable bother to adjust a crystal detector for maximum sensitiveness, and for a slight additional cost a vacuum tube detector, which is more sensitive and more stable in operation, may be purchased.

VACUUM TUBE RECEIVING SETS

First under this classification might be put the non-regenerative receiving set, consisting of a tuning unit and a vacuum tube detector. This is the simplest form of vacuum tube receiving set and has little advantage over the crystal set except in stability of operation and greater selectivity of the circuits usually employed.

REGENERATIVE RECEIVING SETS

The Armstrong regenerative receiver, the principle of which was explained in the section on vacuum tubes, is so



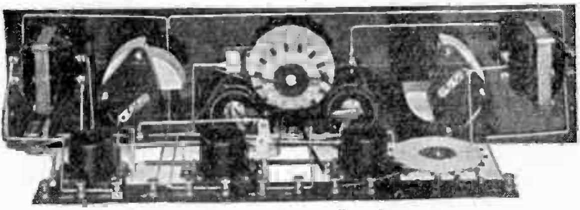
Two Tube Regenerative Receiver.

many times more sensitive than the non-regenerative receiver as to be in an entirely different class as far as signal strength is concerned.

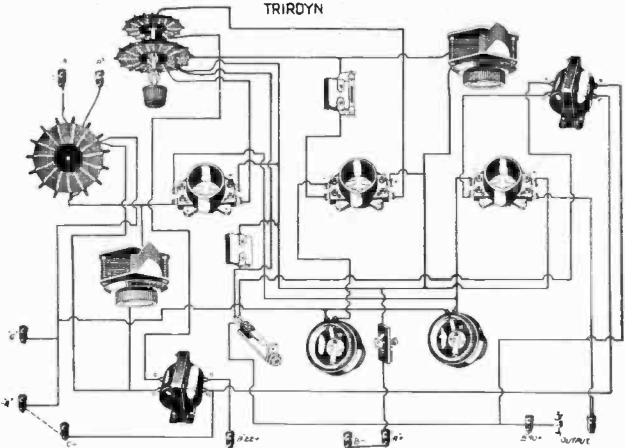
MULTIPLE TUBE RECEIVING SETS

First among these may be classed the Armstrong regenerative receiver with one or two stages of audio-frequency amplification. Next we have multiple tube receiving sets employing one or more stages of radio-frequency amplification and a vacuum tube detector. Radio-frequency amplification is notably free from distortion and gives a faithful reproduction of the sound sent out at the sending station. Lastly, may be classed multiple tube receivers employing both radio-frequency and audio-frequency amplification, in combination with a vacuum tube detector. These are the last word in volume of sound, clearness of reproduction, and selectivity.

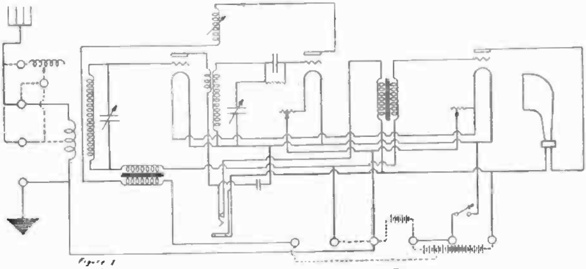
A great many circuits now popular make use of the



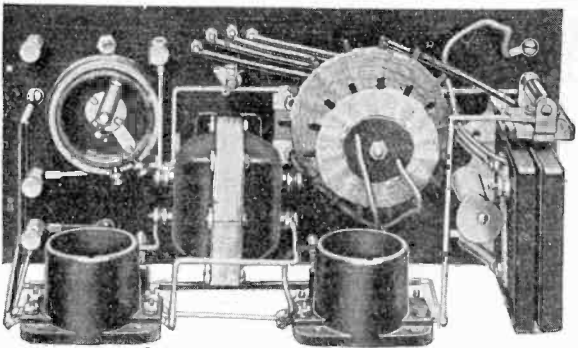
Rear of Trirdyn Panel



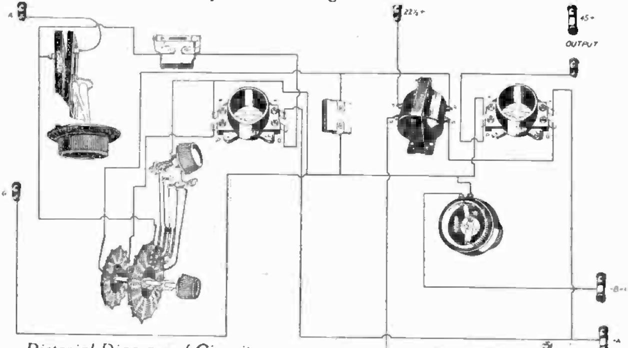
Pictorial Diagram of Trirdyn Circuit



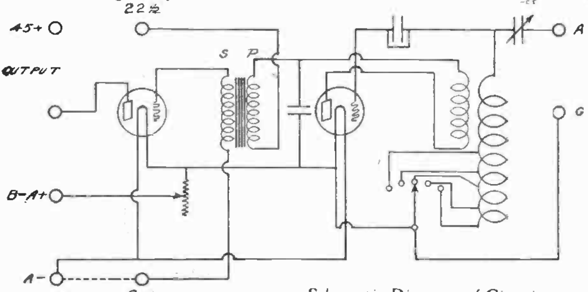
Schematic Diagram of Trirdyn Circuit



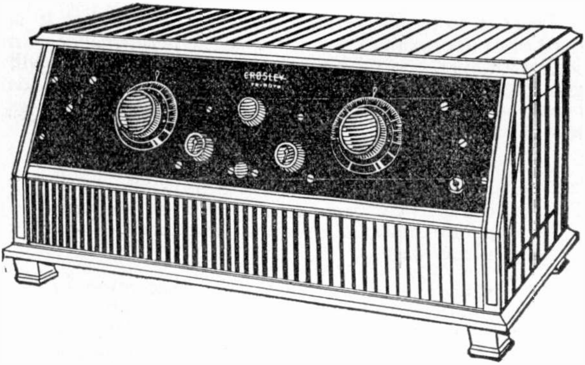
Rear of Two Tube Regenerative Panel



Pictorial Diagram of Circuit



Schematic Diagram of Circuit



The Trirdyn, a Three Tube Receiver Employing Tuned Radio Frequency, Regenerative, and Reflex Principles.

reflex principle, explained in the *Vacuum Tube* section, by which the effective signal strength is greatly increased.

DISTANCES THAT MAY BE COVERED

People often ask how far a certain set will receive. That is a difficult question to answer, even approximately, as there are so many factors involved. Some of the conditions on which the distance of reception depend are:

1. The power output of the transmitting station.
2. The sensitiveness of your receiving set.
3. The type, size, height, and insulation of your aerial.
4. The efficiency of your ground connection.
5. Atmospheric conditions (reception is better at night than in the daytime, etc.)
6. The nature of the surrounding country (over flat country greater distances can often be covered than over hilly country, and reception is much better over water than over land.)
7. Surrounding buildings (tall buildings in the vicinity often seriously interfere with reception, especially if they are considerably higher than your aerial and of metal construction.)

There is so much variation in these factors that it is hard even approximately to predict the performance of a set. However, the following conservative estimates will give you an idea of what you may expect from the various types of sets. Under good conditions, these estimates will often be greatly exceeded.

Crystal Set: Reception of local broadcasting stations a maximum distance of 10 to 25 miles away according to conditions, with sufficient strength to operate headphones. You cannot expect to use a loud speaker.

Single Tube Regenerative Set: Reception of local stations 10 to 25 miles away with sufficient strength to operate a loud speaker. Under good conditions, reception of stations within a radius of two or three hundred miles with sufficient strength to operate headphones.

Two Tube Regenerative Set: Reception of stations within a radius of a hundred miles with sufficient strength to operate a loud speaker. Reception of stations several hundred miles away with sufficient strength to operate headphones.

Three Tube Regenerative Set: Reception of stations several hundred miles away with loud speaker volume. Reception of stations 1000 miles or more away with sufficient strength to operate headphones.

Sets of More than Three Tubes, and Three Tube Reflex Sets: With a set of this type, such as the Trirdyn, for instance, you should be able consistently to receive stations as far away as half across the continent with sufficient strength to operate a loud speaker.

TROUBLE HUNTING

The following *Trouble Chart* and *Outline of Trouble* will enable you quickly to find the part affected and the proper remedy when something goes wrong. Be sure to read the last paragraph of Section I, however, entitled *If You Have Any Trouble*, before using this chart and outline.

I. TROUBLE CHART. *NOTE: The letters and numerals refer to the paragraphs in the Outline of Troubles.*

General Ailment	Particular Symptom	Probable Cause	Possible Cause
No signals.	Tubes do not light.	**A1 or A2** **C1**	**F.** **O.** **G.** **H.**
	Tubes light but no click in phones when plug is removed from jack.	**B1 or B2**	**O.** **G.** **H.** **I.** **J.** **K.**
	Tubes light, phones click when plug is removed from jack.	**E1 or E2** **D1**	
	Reception O. K. on detector but no signals on first stage of amplifier.	**A3** **B3**	**O.** **L.**
	Reception O. K. on first stage of amplifier, but no signals on second stage.	**L.**	
Weak Signals.	Set appears to be O. K.	**D1** **E1 or E2**	
	Rheostat must be all the way on for best results.	**A2**	
	No Regeneration.	**B2**	
	With Crystal Set.	**P.**	
	Regeneration very critical.	**Q.**	
	Set will not tune.	**D1** **E1 or E2**	**M or M3**

TROUBLE CHART—Continued.

General Ailment	Particular Symptom	Probable Cause	Possible Cause
Fluctuating Signals or Noisy Reception.	Signal strength normal when tubes are just turned on, but rapidly falls. off.	A2.	
	Signals interupted by clicks, and tubes flicker in brilliancy, especially when the set is jarred.	B1.	
	Clicks heard when tuning controls are adjusted.	M2. N.	
	Clicks heard when potentiometer is adjusted.	S1.	
	Clicks heard when phone cords are hit or shaken, or at other times that cannot be connected with any particular operation or adjustment.	K3.	O.
	Signals fade out and come back in again, perhaps accompanied moderate clicks.	D1 or D2.	
	Clicks when tap switch is adjusted.	M3.	
	Set howls sometimes and not at other times No consistency.	T.	
	Continuous squeal in set regardless of amplifier rheostat adjustment.	U.	
	Ringing sound in phones, which gradually dies out.	C2.	
	Steady low hum, present almost all of the time.	R.	
	Interference from other stations.	M4.	

TROUBLE CHART—Continued.

General Ailment	Particular Symptom	Probable Cause	Possible Cause
Distortion of Signals.	Far away stations better than local ones.	F2.	
	Distortion when coupling is great. Not distorted when coupling is loose.	I2.	
	Self Oscillation.	F2.	B4. S2.
	Good reception with one set of phones. Bad with another. (Same applies to loud speaker.)	J. K2.	
	Moderate distortion. No regeneration.	A4.	

II. OUTLINE OF TROUBLES

A. *"A" BATTERY.* 1. *Bad connections.* Examine connections and lead wires carefully to see that all contacts are good and that there is not a broken wire. 2. *Discharged.* After testing connections and lead wires, insert a tube that you know to be good in the socket and see if it lights to proper brilliancy without turning rheostat on "full." If you must turn the rheostat all the way on to get proper brilliancy, the chances are that the battery is too far discharged for good results. If tube does not light, try short-circuiting the terminals of the battery with a wire (just touch the terminals instaneously.) If there is no spark, or but a very feeble one, the battery is dead. In either this or the preceding case, the battery must be replaced, if of the dry cell type, or recharged, if of the storage type. 3. *Separate amplifier "A" battery.* When a separate amplifier "A" battery is used, the same rules in Section 2 above apply to it, as well as to the detector "A" battery. 4. *Reversed "A" battery leads* sometimes cause this trouble. Try reversing the leads.

B. *"B" BATTERY:* 1. *Bad connections.* Examine connections and lead wires carefully to see that all contacts are good and there is not a broken wire. 2. *Discharged.* Touch the phone clips lightly to the cell terminals, *one cell at a time.* Don't get your fingers on the terminals unless you want a shock. If no click is heard in the phones, or only a weak click, the batteries are dead and must be replaced, if of the dry cell type, or recharged, if of the storage cell type. 3. *If separate amplifier "B" batteries are used,* these are governed by the rules given in Sections 1 and 2. 4. *Too great voltage.* Too great "B" battery voltage often causes local oscillations in the receiving set, interfering with clear reception. Try reducing the "B" battery voltage.

C. *VACUUM TUBE:* 1. *Burnt out.* If you know the "A" battery to be O. K. and the wiring and connections to be without fault, the chances are that the vacuum tube filament is burnt out. In this case the tube must be replaced. 2. *Microphonic action.* Jarring of the apparatus sometimes causes the elements of the vacuum tube to vibrate, resulting in a ringing sound in the receivers. Try mounting the set in a steadier position, and if this fails to remedy the trouble, try other tubes.

D. AERIAL: 1. Bad lead-in connection or connection to aerial. Examine this and repair if found faulty. 2. *Swinging aerial.* If aerial is hanging with considerable slack, tighten up the supporting ropes until this slack is taken up.

E. GROUND: 1. Bad ground connection. This is so often the seat of trouble that it should be very carefully examined. 2. *Bad ground.* Try some other ground system.

F. RHEOSTAT: 1. Burnt out. This may be tested by placing it in series with a pair of headphones across the terminals of a *single dry cell.* Just make the connection for an instant with all of the rheostat resistance in the circuit, and unless a click is heard in the receivers when the connection is made and broken, the rheostat is burnt out. In this case it must either be replaced or rewound. 2. *Improperly adjusted.* Sometimes the signals from nearby stations are so strong as to overload the headphones and cause distortion. This may often be overcome by reducing the filament current, that is, by turning the rheostat toward the "off" position. Often local oscillations in the tube circuit may be overcome in this way.

G. SOCKETS: Bad contacts. This may be determined by examination, and remedied.

H. JACKS: Examine the jack for *poor contacts,* and adjust them if found necessary.

I. TICKLER COIL: 1. Burnt out. This is not very liable to occur. You may test the coil by connecting it in series with a *single cell* of dry battery and a set of headphones, making and breaking the connection and listening for clicks when this is done. If no clicks are heard, the coil is burnt out and must be rewound, or a new one substituted 2. *Wrong adjustment.* Excessive regeneration effects which interfere with reception are often caused by the ticker coil coupling being adjusted too tight, that is, by the tickler coil being too close to the variocoupler secondary. The tickler control may be marked "tickler" on your set, or (especially if the set is of the single circuit type) it may be marked "coupling." The tickler control on Crosley sets is a small knob attached to a shaft that slides in and out of the panel.

J. LOUD SPEAKER: Some loud speakers considerably distort the sound waves because of *faults in the design and construction* of their various parts. If your loud speaker is of a reliable make, you are not liable to experience trouble of this sort. However, there is always a possibility that this is the seat of distortion. It is best to use a good loud speaker.

K. PHONES: 1. Burnt out. Phones are not liable to burn out, unless they are accidently connected to some source of high-voltage, high-amperage electric current. They may be tested by touching their terminals lightly to the terminals of a *single cell* of dry battery. If no clicks are heard in the phones, they are burnt out and must be repaired or replaced. 2. *Adjustment.* Tightening or loosening the receiver cap sometimes clears up distortion due to improper tension on the receiver disphragm. 3. *Cords broken.* These may be tested by disconnecting them from the headphones and touching them lightly across the terminals of a *single cell* of dry battery. They should only be touched to the battery terminals for an instant. If no spark occurs (the battery being known to be a good one) the cords are burnt out and must be replaced.

L. AUDIO FREQUENCY TRANSFORMER: Burnt out. This is the only trouble that you are liable to incur from an audio frequency transformer, and it happens very seldom. Both primary and secondary windings of the transformer may be tested by means of a pair of phones connected in series with a single cell of dry battery, as described under Section II.

M. TUNING INDUCTANCE: 1. Wire broken in coils. Use test described in Section I. If coil is burnt out is must be rewound or replaced. *2. Coil Mountings.* When contact with the ends of the coil is made through the coil mountings, or bearings, these may become loose, making the contact a poor one. If found to be loose, tighten these contacts in some way. *3. Tap switch.* Faulty contact may cause trouble. If contact between spring lever and contact points is loose, bend spring so as to tighten it and scrape contact until they are bright. *4. Coupling.* Too tight coupling may cause this difficulty. Try adjusting the coupling contact.

N. TUNING CONDENSERS: A rotary plate condenser may be *short-circuiting* by having some of the plates come in contact with one another as they are rotated. Connect a single dry cell and set of headphones in series with the condenser. If clicks are heard as the condenser dial is turned, the condenser is short-circuiting and must be repaired or replaced.

O. WIRING: Broken wire may be discovered by tracing all connections. The remedy is obvious. Make a soldered splice at the break. Short-circuits from touching wires often cause trouble. Examine and repair if found faulty.

P. CRYSTAL: Out of adjustment. Try other spots on the crystal surface.

Q. GRID LEAK: Wrong value. Try other values of grid leak unless you are using the value specified by the manufacturers of your tube.

R. POWER LINE: Too close to power line. Try placing antenna perpendicular to the power line.

S. POTENTIOMETER: 1. Contact. Adjust the contact lever so that it bears with more pressure on the resistance unit. *2. Adjustment.* Try varying the potentiometer control.

T. NEIGHBOR'S SET: Other receiving sets in the neighborhood sometimes cause this trouble.

U. "C" BATTERY: Run down or connection bad. Replace battery or tighten connections.

A GLIMPSE OF THE FUTURE

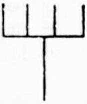
COULD we but glance into a crystal ball and see therein the future of radio, what marvelous sights we would behold. If past history be any indication of what is to happen in the years to come, we may expect new wonders that seem almost too strange even for us to imagine.

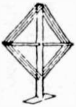
When ships are lost far out at sea, their captains need no longer fear, for the radio compass—made possible by directional radio, or the radio beam—guides them to shore. Someday this principle of directional radio may be extended even to the aid of the wanderer in the desert and the automobile traveller lost on some lonesome road.

The transmission of photographs by radio is already an accomplished fact. The process takes time, and the picture is transmitted and reproduced part by part. Who knows but that in a few years we will be able to look into some sort of radio device and see, at will, sights in the far corners of the earth.

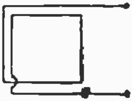
Much progress has been made toward the transmission of electric power by radio. What does this mean? It means that some day farmers in the most outlying districts, far from the electric wires and generating plants of urban centers, will be able to have electric lights, and the hundreds of other electrical appliances, as easily as the city folks have them today. It means that ocean liners will take their power from generating plants on the shore—travelling everywhere with their holds free to stow away cargo instead of loaded down with tons of coal. It means that automobiles need never run out of gas—motoring the simple, clean, electric way, by radio power. It means that trains may be run across the continent without coal or electric trolley wires; it means that houses may be heated thousands of miles away from the generating stations—in short, it means an age as far in advance of this one, as we are in advance of our monkey ancestors.

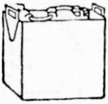
Aerial or Antenna—a system of wires for intercepting the radio waves.



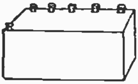


Loop Aerial—A special form of aerial designed to occupy little space, consisting of turns of wires wound on a frame.

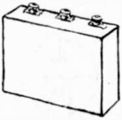




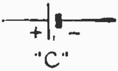
"A" Battery—The source of current for heating the filament of a vacuum tube.

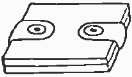


"B" Battery—The source of plate current for a vacuum tube.

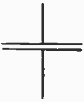


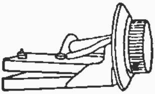
"C" Battery — Sometimes used in the grid circuit of the amplifier tubes.



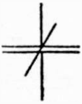


Fixed Condenser — A condenser of fixed capacity.

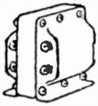




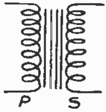
Variable Condenser—A condenser whose capacity may be varied between limits.

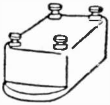


Headphones—Specially designed telephone receivers for radio use.

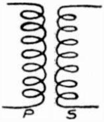


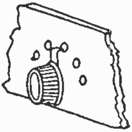
Audio - Frequency Transformers—Small transformers used to connect amplifier tubes in tandem for amplifying the signals after they have passed through the detector.



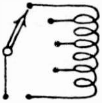


Radio-Frequency Transformers—Small transformers for connecting tubes in tandem where they are used to amplify signals before they pass through the detector.

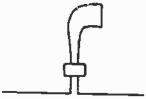


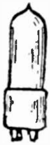


Tap Switch—A multiple contact switch for connecting various portions of an inductance into the circuit.

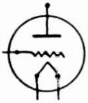


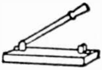
Loud Speaker—A special designed headphone receiver unit with a sound-amplifying horn, for giving great volume of sound.





Vacuum Tube—An electronic device for dedetecting and amplifying the radio signals.

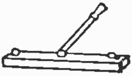




SPST

Single Pole Single Throw Switch—A device for opening or closing one circuit.

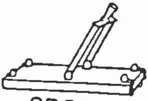
SPST



SPDT

Single Pole Double Throw Switch—A device for connecting one circuit to either of two different wires.

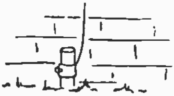
SPDT



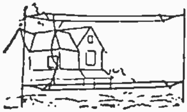
DPDT

Double Pole Double Throw Switch—A device for connecting two circuits to either of two different pairs of wires.

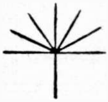
DPDT

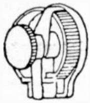


Ground—An earth or ground connection.

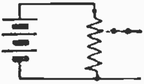


Counterpoise—A substitute for a ground connection consisting of a wire or wires stretched above the ground.

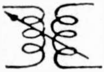


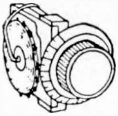


Potentiometer.—A device for controlling the "B" battery voltage.

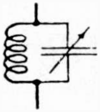


Variocoupler—A coupled inductance by which two circuits may be placed in a variably coupled inductive relation to each other.

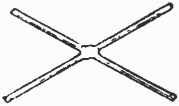




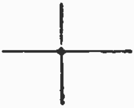
Tuned Radio-Frequency Transformer—A radio-frequency transformer whose natural period can be changed.

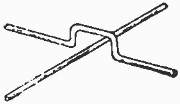


Grid Leak—A high resistance unit used to provide a path for the grid condenser charge to slowly leak away.



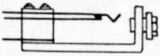
Connection—Two crossing wires making, electrical contact.



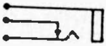


Non-Connection—Two crossing wires insulated electrically from each other.

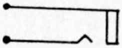
Phone Plug—A device used instead of binding posts (which are less convenient) for connecting receiving phones to the circuit.



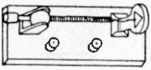
Phone Jack — (closed circuit)—The receptacle for the phone plug permanently connected in the circuit. The closed circuit jack is used to connect in the receiving phones some place before the final amplifier tube.



Phone Jack—(open circuit)—An open circuit jack is used as the receptacle for the phone plug at the final stage of amplification.

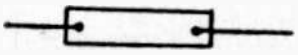


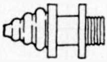
Binding Posts—A device for connecting external circuits to circuits within the apparatus.



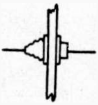
Crystal Detector—A radio detector depending upon the rectifying action of a crystal.

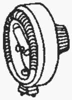
Insulator — A device which will not readily conduct electric currents.





Leadin Bushing—A hollow insulator through which the lead-in wire is brought into the building.





Rheostat— A variable resistance for controlling the amount of current flowing in a circuit.

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

Used in 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 ——••

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

Period	•• •• ••
Semicolon	—•—•—•
Comma	•—•—•—
Colon	———•••
Interrogation	••——••
Exclamation	——••——
Apostrophe	•————•
Hyphen	—••••—
Bar indicating fraction	—••—•
Parenthesis	—•——•—
Inverted comma	•—••—•
Underline	••——•—
Double dash	—•••—
Distress Call	•••———•••
Attention	—•—•—
General inquiry call	—•—• ——•—
From (de)	—•••
Go Ahead (Transmit)	—•—
Warning (high power)	——••——
Question (please repeat after)	••——••
Wait	•—•••
Break (Bk) (double dash)	—•••—
Understand	•••—•
Error	••••••••
Received (O. K.)	•—•
Position report (to precede all position reports)	—•—•
End of each message (cross)	•—•—•
Transmission finished (end of work)	•••—•—

In Conclusion

"'Of making many books," twas said,
'There is no end', and who thereon
The ever-running ink doth shed
But proves the words of Solomon."

THE author hopes that this little book is something more to you than just another one of the millions the printing presses grind out each year and add to the other millions that have gone before. He hopes that it has been to you an entertaining journey into that enchanted land of mysteries—the Radio World. He hopes that it will serve the purpose of a reference book as well—answering your questions when you seek information and helping you out of difficulties.

The spirit of service, in which this book is written, is the spirit upon which the success of The Crosley Radio Corporation is founded.

CONDENSED LIST OF

BROADCASTING STATIONS

Call Letter	Broadcasting Station	City and State	Wave Length	Kilo Cycles
CFAC	Calgary Herald	Calgary, Alb.	440	682
CFCA	The Star	Toronto, Ont.	400	750
CKAC	LaPresse	Montreal, Que.	430	697
CKCD	Vancouver Province	Vancouver, B. C.	410	732
CYL	Mexico City	Mexico City	500	600
KDKA	Westinghouse	Pittsburgh, Pa.	326	920
KFI	E. C. Anthony—Herald Examiner	Los Angeles, Cal.	469	640
KFKX	Westinghouse	Hastings, Neb.	341	880
KGO	General Electric Co.	Oakland, Cal.	312	960
KGW	The Oregonian	Portland, Ore.	492	610
KHJ	Times-Mirror	Los Angeles, Cal.	395	760
KLZ	Reynolds Radio Co.	Denver, Col.	360	833
KPO	Hale Brothers, Inc.	San Francisco, Cal.	423	709
KSD	Post-Dispatch	St. Louis, Mo.	546	549
KYW	Westinghouse	Chicago, Ill.	536	560
PWX	Cuban Telephone Co.	Havana, Cuba	400	750
WBZ	Westinghouse	Springfield, Mass.	337	890
WBAP	Star-Telegram	Fort Worth, Texas	476	630
WBAV	Erner & Hopkins Co.	Columbus, O.	423	759
WBAY	Western Electric Co.	New York City	492	610
WCX	Free Press	Detroit, Mich.	517	580
WCAP	C. & P. Tel. & Tel. Co.	Washington, D. C.	469	640
WCBD	Wilbur G. Voliva	Zion Ill.	345	870
WCCO	Washburn Crosby	Minneapolis, Minn.	417	720
WCNY	City of New York	New York	526	570
WDAF	Star	Kansas City, Mo.	411	730
WDAR	Lit Brothers	Philadelphia, Pa.	395	760
WEAF	Amer. Tel. & Tel. Co.	New York City	492	610
WFAA	News & Journal	Dallas, Texas	476	630
WFI	Strawbridge & Clothier	Philadelphia, Pa.	395	760
WGI	Amer. Research Corp.	Medford Hills, Mass.	360	833
WGN	Chicago Tribune	Chicago, Ill.	370	670
WGR	Fed. Tel. & Tel. Co.	Buffalo, N. Y.	319	940
WGY	General Electric Co.	Schenectady, N. Y.	380	790
WHAS	Courier-Journal	Louisville, Ky.	400	750
WHAZ	Rennselaer Politechnic Inst.	Troy, N. Y.	380	790
WHB	Sweeney School	Kansas City, Mo.	411	730
WHAM	University of Rochester	Rochester, N. Y.	283	1060
WHO	Bankers' Life Co.	Des Moines Ia.	526	570
WIP	Gimbel Bros.	Philadelphia, Pa.	509	590
WJAX	Union Trust Co.	Cleveland, O.	390	769
WJY	Radio Corp. of America	New York City	405	740
WJZ	Radio Corp. of America	New York City	455	660
WKAQ	Radio Corp. of Porto Rico	San Juan, P. R.	360	833
WLS	Sears-Roebuck	Chicago, Ill.	345	870
WLW	**THE CROSLEY RADIO CORP.**	**Cincinnati, Ohio**	423	709
WMAQ	Daily News	Chicago, Ill.	448	670
WMC	Commercial Appeal	Memphis, Tenn.	500	600
WOAI	So. Equip. Co.	San Antonio, Texas	385	779
WOAW	Woodmen of the World.	Omaha, Neb.	526	570
WOC	Palmer School	Davenport, Ia.	484	620
WOO	Wanamaker Store	Philadelphia, Pa.	509	590
WOR	L. Bamberger & Co.	Newark, N. J.	405	740
WRC	Radio Corp. of America	Washington, D. C.	469	640
WSAI	U. S. Playing Card Co.	Cincinnati, Ohio	309	970
WSB	Atlanta Journal	Atlanta, Ga.	429	700
WTAM	Willard Storage Battery Co.	Cleveland, O.	390	769
WWJ	News	Detroit, Mich.	517	508