PRACTICAL RADIO

INCLUDING THE TESTING OF RADIO RECEIVING SETS

BY

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PREFACE TO SECOND EDITION

Remarkable development of radio equipment and rapidly increasing demand have brought many changes within a few months. Experimental work with short wave lengths and super-power radio broadcasting stations has opened new fields for the use of radio communication for greater distances than before and with less interference.

Among the subjects which have been added in this edition are the following: Radio direction finding and directional distortion caused by buildings and other structures, new types of radio receiving sets, especially Browning-Drake and improved super-heterodynes, super-power broadcasting stations and their effects on distance, fading, interference, and static. Practical methods of reactivation of vacuum tubes are explained in detail.

Another important addition is a Radio Trouble Chart, similar to those in books on automobile operation, to show at a glance the probable cause of the most common troubles and the remedies when these are not obvious from the nature of the defect in the receiving set or its auxiliary equipment.

Another chart shows the important characteristics of various types of radio receiving sets, indicating by the words, "excellent," "good," "fair," and "poor," the relative desirability of the various types.

THE AUTHORS.

STATE HOUSE,
BOSTON, MASSACHUSETTS,
January, 1926.

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PREFACE TO FIRST EDITION

Radio is an electrical science; but its development, unlike that in most branches of science during recent years, has been more or less by "hit-or-miss" methods. Many accomplishments of first importance in radio were obtained for the first time as a result of chance or unorganized experiment. This groping progress of radio science is, however, rapidly giving way to systematic research; and the many problems which remain to be solved will doubtless receive the concentrated attention of experts.

Popular interest in radio has been established mainly through the introduction of radio broadcasts. This form of communication has been developed to such an extent that in nearly every large city there are powerful transmitting stations which broadcast for the benefit of millions of receiving sets distributed all over the country. In addition, a chain of very large transmitting stations, circling the globe, has been organized to give a thoroughly dependable world-wide communication by radio, twenty-four hours a day, the year around.

Much that has been written on the subject of radio has been so technical, so brief, that the average reader is unable to get a clear understanding of even the fundamental principles. It is the object of this book to present the fundamentals of the subject so simply and clearly that any person of average training will be able to read, understand, and apply them. Above all, the intention has been to make this book practical, as the name indicates; and in furtherance of this idea, in one of the chapters, working drawings are given for a number of popular, typical radio receiving sets. All of these receiving sets have been actually constructed so that there can be no question as to the exactness of details. It is believed

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also that sufficiently complete information is given so that the reader will have very little difficulty in constructing his own receiving set if he wishes to do so.

The authors are especially indebted to Charles W. Hobbs, Massachusetts Division of University Extension, and to Professor Raymond U. Fittz of the Engineering Department of Tufts College at Medford Hillside, Massachusetts, where so much pioneer work in radio investigation and broadcasting has been done. Acknowledgment should also be made to Ralph Greenleaf and Miss Helen Meinhold for assistance in the preparation of drawings and manuscript.

The authors are always glad to answer correspondence with teachers in regard to the difficulties of students in understanding this subject.

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STATE HOUSE,
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CHAPTER I

WHAT IS RADIO?—AN EXPLANATION

Electricity in its most familiar form is the electric current carried by wires to light buildings and streets and to operate machinery, telegraphs, and telephones. Radio, another kind of electricity, has in recent years attracted wide-spread attention, and this form of electricity, like the lightning of a thunder storm, goes through the air in waves extending in every direction, without the assistance of wires; for this reason the transmission of telephone and telegraph messages by radio waves is sometimes referred to as *wireless*. Because of its freedom from wire connections, radio has almost unlimited possibilities, as compared with the telephone and telegraph. It has possibilities of the same magnitude that the airplane has in comparison with a railroad train on tracks.

Radio waves are much like sound waves in that they also spread out through the air in all directions, and can be heard at the same time by any number of listeners within the range of the radio transmitting station. Light, also, is like radio, but where we can detect light or sound directly by means of our eyes or ears, radio waves can be detected only by special receiving apparatus. The effect of radio, for all practical purposes, is instantaneous, since it travels at the speed of 186,000 miles per second, which is the same as the speed of light.

Later it will be shown how the action of an electric current in the apparatus at a transmitting station produces radio waves. If the electric current at a radio transmitting station is varied as it is by the transmitter of a telephone or according

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to the dots and dashes used in the telegraphy, the resulting radio waves will have similar variations.

Radio and Sound Waves Interchangeable.—In the ordinary telephone the sound of the speaker's voice at the transmitting end produces certain variations in an electric current. This variable current flows along the connecting wires to the receiver at the other end, and the receiver changes the variable current back again into sound. The radio process is similar to this, since at the transmitting end sound is changed into radio waves and at the receiving end, radio waves are changed back again into sound. The great difference, however, is that its action depends upon the radio waves which pass through the air[1] instead of the electric current which goes along a telephone wire.

Radio Broadcasting.—The most important use of radio is for broadcasting the human voice. Indeed radio did not attract the interest of the general public until it began to be utilized for broadcasting definite programs, and this interest grew as the scope of the service was increased. For years government stations have sent out in the Morse code weather forecasts and market information by radio telegraph (wireless). Recently, however, the government stations began to transmit such information for farmers by radio telephone; and manufacturing concerns, newspapers, schools, and others, seeing the possibilities in this form of service, obtained permission to broadcast music and lectures. Radio broadcasting is now carried on at regular schedules by various stations which are so distributed that in most sections of the country an

[1] In these introductory pages, for the sake of simplicity of statement, radio waves are represented as passing through air. Obviously, however, these radio waves pass readily through material objects and liquids as well. Radio transmission is sometimes referred to as wave propagation through the *ether*.

Steinmetz and some other scientists have stated that there are no ether waves. They believe light and radio waves to be merely properties of an alternating electro-magnetic *field of force* extending around the earth. Einstein, however, in a lecture on the ether and the theory of relativity has stated that according to the general theory of relativity space is endowed with physical qualities, and that in such a sense the ether exists, because without it propagation of light would be impossible.

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interesting program may be received on relatively cheap and simple radio receiving apparatus. By the use of amplifiers and loud speakers this service may also be made available to large gatherings of people.

The ideal night to establish long-distance radio records is during the time in winter when the days are shortest and there is a cold, clean atmophere just after a storm when the low hanging clouds have cleared away. Broadcasting just at dusk, during cloudy conditions, which may have covered a radius of three hundred miles, may be followed less than an hour later, after darkness has set it, by broadcasting from the same transmitter which may be heard for one thousand miles. Moonlight has a slight tendency to weaken signals. Aurora borealis has only a slight effect upon radio transmission.

Kinds of Broadcasting.—Many stations now broadcast music, lectures, theatrical entertainments, speeches, church services, weather forecasts, market prices, sporting events and time signals. By sending out entertaining programs, radio has become a valuable supplement to the music hall, the newspaper, the theater, the phonograph, and the classroom. Indeed several colleges now offer correspondence courses in which the instruction material is transmitted by radio.

A few years ago, before there was such demand for radio services, government information was transmitted at one radio wave length and all popular programs were sent out at a standard wave length. As the number of transmitting stations increased, it became necessary to assign different wave lengths to the various stations in order to reduce the interference of one station with another. Receiving sets must now be sufficiently selective so that, over a wide range of wave lengths, any one transmitting station may be picked up and all others excluded. This is made possible by *tuning* the receiving set. The effect of tuning is that, by turning a dial or dials on the receiving set to different positions, the operator can make his set respond to waves of different lengths.

Wave Length Explained.—The general idea of wave length can be understood readily by comparison with water or sound waves, or even with the wave in a rope as shown in Fig. 1,

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where the wave travels from one end of the rope to the other. We cannot see radio waves as we see the waves on a pond, but neither can we see sound waves. Yet we know that when a tuning fork is struck it gives off sound waves which travel out into the air in all directions. These sound waves are caused by the to-and-fro motion, or vibration, of the prong of the tuning fork. As the prong vibrates it causes the air next

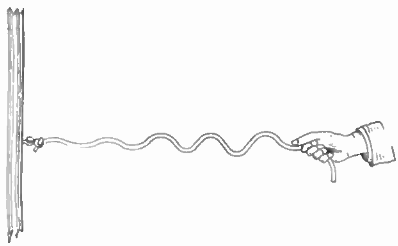

FIG. 1.—Example of wave motion.

to it to vibrate. This vibration is passed on to the surrounding air. Just as the tuning fork causes a to-and-fro motion, or alternating motion, of the air surrounding it, so an alternating electric current flowing in a wire causes an alternating electric pressure in the air around the wire, which spreads out in the same way as a sound wave.

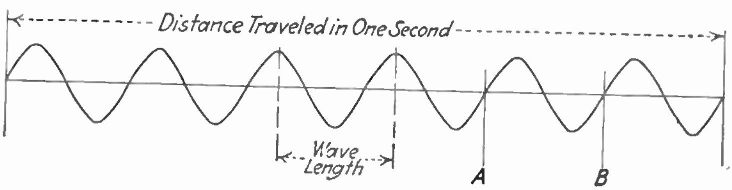

FIG. 2.—Wave cycle.

One complete to-and-fro motion or alternation is called a *cycle* and the number of these cycles per second is called the *frequency* of the wave. Wave length is the distance, measured in meters[1] from the top of one wave to the top of the next wave. If we represent a wave motion as in Fig. 2, then the wave will pass through one cycle when it has gone through

[1] A meter is approximately 39 inches.

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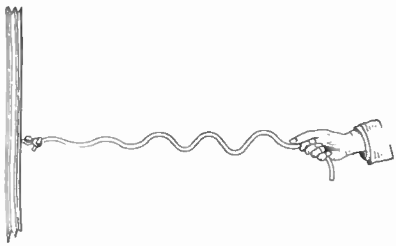

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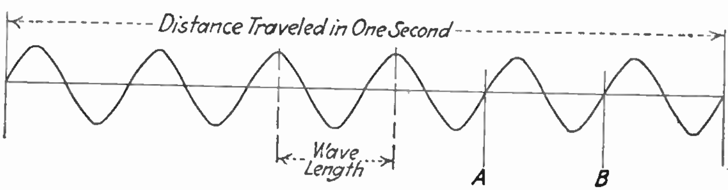

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[1] A meter is approximately 39 inches.

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the changes shown between any two points such as *A* and *B*. This wave has a frequency of 6, since there are six cycles or alternations in one second. The wave length[1] is shown clearly.

At the suggestion of the United States Bureau of Standards, the Second National Radio Conference which met in March, 1923, introduced the *kilocycle* method of designating radio waves. The word kilocycle, which is formed by combining "kilo" which means one thousand and "cycle" which is the unit of frequency, means that the electric current goes through *one thousand cycles per second.* The wave length in meters of a transmitting station can readily be converted into equivalent kilocycles per second thus:

$$\text{Kilocycles (kc.)} = \frac{300{,}000}{\text{meters (wave length)}}.$$

All radio and other electric waves travel through the air at a speed of 300,000,000 meters per second, but at different frequencies. The difference in their frequencies gives to each its characteristic properties. The higher the frequency the more effectively the waves radiate and spread out. High frequencies, therefore, must be employed in radio so that a wave will travel most effectively through the air.

Essential Parts of a Radio Receiving Set.—No matter how simple the type of apparatus it is necessary to have the following parts: (1) The *antenna,*[2] a wire or group of wires without insulating covering which must be elevated from the ground and which may be located either out-of-doors on poles or may

[1] Numerically, the length of a wave is equal to its velocity divided by its frequency. Since the velocity of all electric waves is 186,000 miles or 300,000,000 meters per second, the wave length in meters equals 300,000,000 divided by *frequency.* Thus, a radio wave of 400 meters goes through 750,000 frequency alternations or cycles per second, that is, the frequency is 750,000 cycles per second. Electric currents in ordinary telephone service have wave lengths of between 100,000 and 20,000,000 meters, so that the corresponding frequencies of ordinary telephone messages vary from 15 to 3,000. In this connection it is interesting to note that the frequencies of heat, light, and x-rays vary from trillions to quintillions of cycles per second.

[2] Sometimes it is possible to substitute for the outdoor antenna, a radio loop which will be described in another chapter. No ground wire is required when a loop is employed.

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be suitably suspended from insulators inside a building. Its purpose is to intercept from the air the radio waves. (2) The *lead-in*, which is an insulated wire and should always be soldered to the antenna, usually at the end nearest the receiving set. This wire is used to carry the feeble radio electric currents from the antenna to the receiving set. The lead-in wire should be soldered to the antenna so as to make a metallic connection, as otherwise there would be oxidation or rusting where the joint is made and eventually poor contact with consequent weakening of the current coming to the receiving set. (3) The *ground connection*, which should be an insulated wire having a foot or more of bare wire at the end to be connected to a water pipe, steam pipe, or other metallic object embedded in moist earth. (4) A device for adjusting the receiving set to different wave lengths so that radio waves of any desired frequency may be intercepted to the exclusion of radio waves of some other frequency. This adjustment of the receiving set for a desired wave length is called *tuning*. (5) The "*detector*" for changing the frequency of the radio waves at the receiving set from high frequency (too high to be heard) to audio frequency (audible frequency so that they may be heard). The "detector" which accomplishes these changes of frequency may be a crystal or a vacuum tube. (6) A means for changing the audio-frequency current delivered by the crystal or vacuum tube and making it audible to the human ear. This is accomplished through a telephone *headset* or a *loud speaker* or *horn*.

The antenna is preferably a single wire set up so as to be electrically insulated at both ends and elevated preferably more than 30 feet from the ground and having a length between insulators of between 75 and 150 feet.

Experience has shown that for ordinary radio work the best results are obtained when antennas are used whose length comes within the above limits. The reasons for t[illegible]ent will be explained in a later chapter.

Calcatiulon of Wave Length.—Wave length in *meters* may be calculated approximately by adding the length in *feet*, of the antenna, the lead-in, and the ground wire, then multiply-

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ing the total length of all three by 1.5. For example if the antenna is 100 feet long, lead-in 30 feet, and ground wire 20 feet, the total length is 150 feet. Multiplying the 150 by 1.5, the result is 225, the natural period or wave length of the antenna in meters.

QUESTIONS

1. In what way is a radio wave similar to a sound wave?
2. How fast does a radio wave travel?
3. Explain and illustrate the term *wave length.*
4. What is the meaning of *cycle* and *frequency?*
5. Name the essential parts of a radio receiving set and describe the purpose of each one.

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CHAPTER II

THE ANTENNA

In radio communication it is necesary to have a single wire or a set of wires for broadcasting radio waves into the air at the transmitting station, and also for picking up these waves from the air at the receiving instrument. This wire or set of wires is now usually called an *antenna*, although many people still call it an *aerial* especially when it is of the elevated outside variety. Generally the location in which the antenna is to be erected determines its form and dimensions. An antenna may

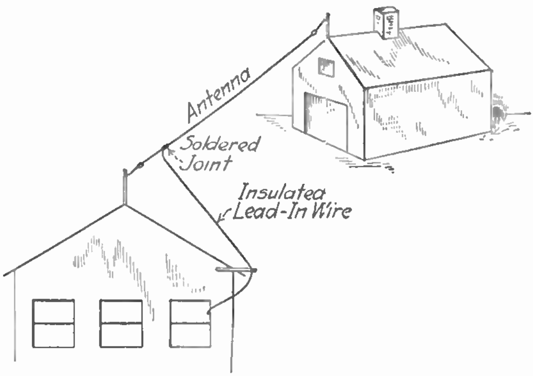

Fig. 3.—Simple outside antenna.

be either the ordinary elevated outside wire type, or the coil or loop type. There are, of course, many variations of each of these types. In the construction of an antenna, the only information required is about the length, size, material, and insulation of the wire used, the ground connections, and lightning protection.

For use at the receiving instrument, the elevated outside wire is usually most satisfactory. A good form of such an

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antenna is a single wire about 75 to 100 feet long and raised 30 to 50 feet above the ground (Fig. 3). The greater the height, the better. With this construction, the addition of more wires is not of much advantage. If the antenna must

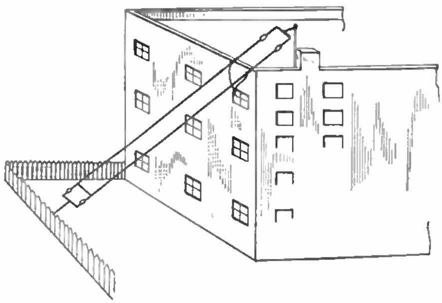

FIG. 4.—Double wire antenna.

be shorter than 75 feet, it may be made with two parallel wires spaced about 3 feet apart, as in Fig. 4. In this case the wires at each end of the line should be connected together as shown.

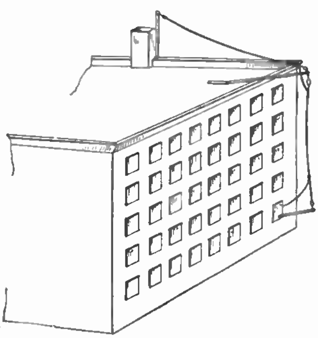

FIG. 5.—Typical outside antenna.

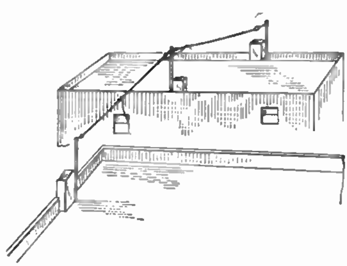

FIG. 6.—Typical outside antenna.

The *lead-in* wire, which goes to the binding post marked *antenna* on the receiving set, is soldered to the antenna at the near end as shown in Fig. 3. Sometimes it is necessary to attach the lead-in at the center of the antenna. When this

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is done the effective length of the antenna is decreased and other means must be used to offset the reduction in length, such as more turns on the coils of wire in the receiving set. Nevertheless, the strength of the radio waves will be lessened somewhat. Several other ways of setting up antennas are

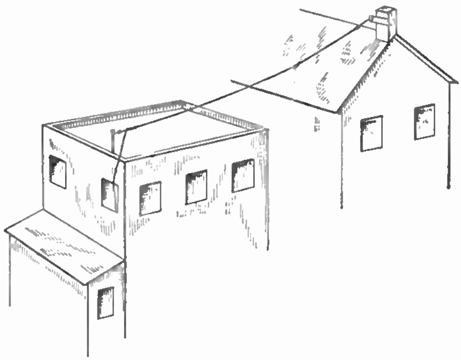

FIG. 7.—Typical outside antenna.

shown in Figs. 5 to 9. When the wires are placed *inside the house* as in a garret, they should be kept away from surrounding objects as much as possible. The antenna wire should never be run close to electric power lines, as the greater the

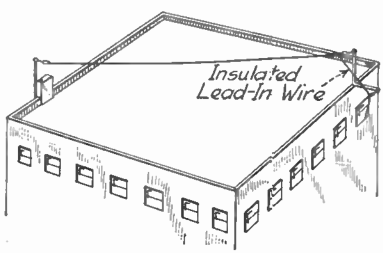

FIG. 8.—Typical outside antenna.

distance from such lines, the less will be the interference from that source.

Very frequently a braided, seven-strand, No. 22 wire of hard drawn copper, or of phosphor bronze, is used for the antenna. A No. 14 or larger solid copper wire also has proved satis-

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factory. To prevent rusting it is best to use *tinned* wires. Enameled wires are equally good but are more expensive. Between each end of the antenna wire and the supports to which it is fastened insulators must be placed in order to prevent current leakage. An insulator is made of some material which is a non-conductor of electricity, such as glazed porcelain, glass, or wood (especially prepared by soaking in melted paraffin). Any material which will absorb moisture is not suitable for insulation. It should be remembered also that an insulator must be strong enough mechanically to stand the strain put upon it, especially in windy or icy weather.

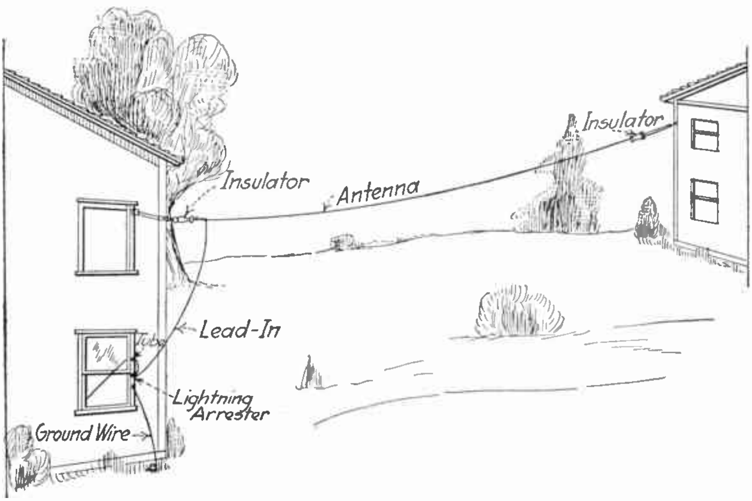

FIG. 9.—Typical outside antenna.

Figure 9 shows some details of a single-wire antenna. If the antenna is not accessible from a window, one end (beyond the insulator) has sometimes a rope and pulley arrangement by which the antenna may be raised or lowered. The lead-in wire is kept well away from the building and must pass through some form of hollow insulator where it enters the building. Usually a porcelain tube, placed in a hole drilled through the wall or window sash is easily installed. Remember, however, that the hole should be bored at such an angle that

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the outside end of the insulator tube which is exposed to the weather is lower than the end inside the building. This

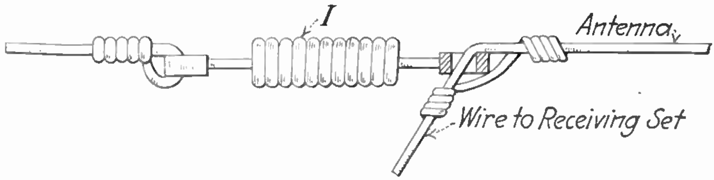

FIG. 10.—Extension antenna used as lead-in wire.

downward slant prevents rain from entering the building by way of the insulator tube. When a covered lead-in wire is

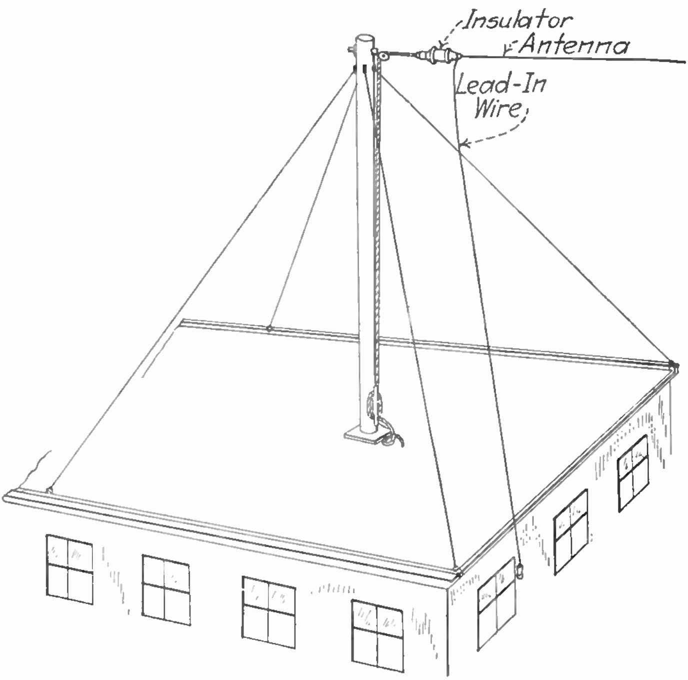

FIG. 11.—Substantial pole for attachment of antenna.

used instead of the bare wire, the same precautions as to insulation must be observed because it is not safe to rely upon the

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covering of the wire. The receiving apparatus should be placed as near as possible to the place where the lead-in wire enters the room. Figure 10 shows a way of passing the antenna wire through the insulator I, which avoids the necessity of soldering a lead-in wire to the end of the antenna. Sometimes it becomes necessary to use a pole for a support. Such a pole should be of sufficient strength for this purpose, not only to secure durable construction but to do away with the sagging and slip-shod appearance when too small a pole is used for a support. Figure 11 shows a safe method to follow.

Soldered Wire.—All wire connections in radio work should be soldered, except where connections are made by means of screws and nuts in which case the nuts may be turned up so tightly as to bite into the metal and thus make a perfect electrical contact. Merely twisting wires together is not sufficient as radio currents are very small and anything short of perfect metallic connection is likely to interrupt them altogether. Especially is this true of antenna and ground connections. Radio soldering is not difficult if certain precautions are taken. It is a good idea to practice a little on odds and ends of wire before actually beginning on a real job.

Ground Wire.—Most receiving sets have a binding post or terminal marked *ground* from which a wire must be led to some object or structure which is connected with the earth. The purpose of the ground wire is to complete the electrical circuit for the radio waves. This circuit is from the transmitting station through the air to the antenna, and parts of the receiving set, through the ground wire to the ground, which takes the minute electric currents back to a similar ground wire connected to the transmitting set. A good ground connection is obtained by attaching the ground wire to a water pipe or to a metal structure which itself is *grounded*, that is, embedded in the earth. In some cases the use of several different ground connections may result in louder signals. It has been found, however, that when one of the several ground wires is very long and makes a poor connection, the strength of the radio current may be weaker than if a single wire with a reasonably good ground connection were used. A pipe or rod, driven

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into moist earth, makes a satisfactory ground, but if the soil around the pipe becomes dry, the connection will not give good results. The ground wire should be as short as possible, avoiding any sharp bends or turns, and to get good electrical contact, the connection between ground wire and the pipe or other object to which it is connected should be soldered. It is advisable always to scrape or sandpaper both the wire and the surface on the grounding system, where the connection is made. When an approved ground connecting clamp is used, soldering is not necessary. A gas-pipe system must not be used as a ground.

Counterpoise.—Where a good *ground* is not convenient, it may be replaced by a *counterpoise*. This consists of a set of wires which is similar in dimensions and construction to the antenna. Sometimes the counterpoise is made by running the wires out in several directions from the radio set, supported about a foot above the ground and insulated from it. The wires are placed below the antenna and should cover an area at least as great as that of the antenna. As a protection against lightning, both the antenna and counterpoise wires must be grounded through some approved protective device. The counterpoise may be used with good results in places where the ground is very dry or when a receiving set is located near the top of a tall building where the distance to the ground is considerable. However, the counterpoise device is used more commonly at transmitting than at receiving stations. Sometimes the conditions of the surroundings at a transmitting station are such that both a ground connection and a counterpoise may be used to advantage.

It has been observed that a long, low antenna has some directional action; that is, the signal strength is improved when the lead-in end of the antenna points toward the station from which radio currents are received. This action is not noticeable in short antennas, which may point in any direction with equally good results.

Inside Antennas.—Wires may be looped back and forth across a room close to the ceiling or run around the picture moulding to make a satisfactory indoor antenna. A so-called

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"talking-tape" has been used successfully in this way. Insulation in such cases is just as important as for outside

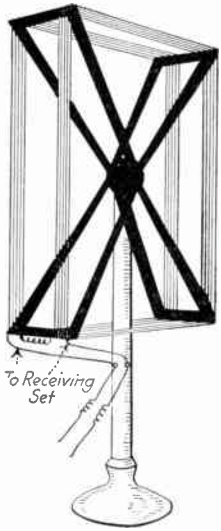

FIG. 12.—Typical radio loop.

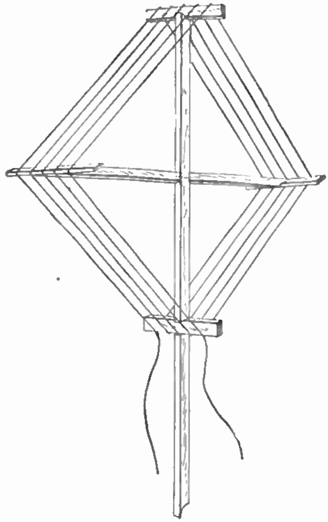

FIG. 13.—Typical radio loop.

antennas. Electric light wires in a building have been used in some cases under favorable circumstances as collectors of radio waves. One method of employing the house lighting wires is by the use of a special connection to be inserted into an electric light socket by means of an "antenna plug." This apparatus is merely an electric condenser which allows the high-frequency radio currents to pass to the receiving set but prevents the low-frequency lighting current.

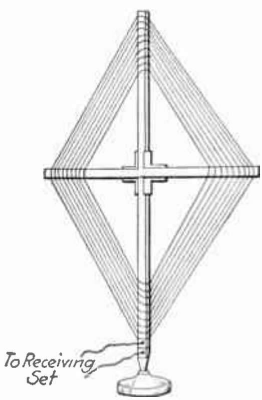

FIG. 14.—Typical radio loop.

Loop Antenna.—Under some conditions the *coil* or *loop* gives satisfactory reception. This type of antenna construction consists of several turns of wire wound on a wooden

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frame varying in size from about 1 foot to 4 feet square. Such an antenna requires no ground connections. Figures 12, 13, 14, and 15 show the loop construction. Because of its small size, the loop cannot be used for receiving from distant stations unless some kind of signal amplifier or magnifier is used with it. The loop has, however, several good features to recommend its use on nearby stations, especially where ampli-

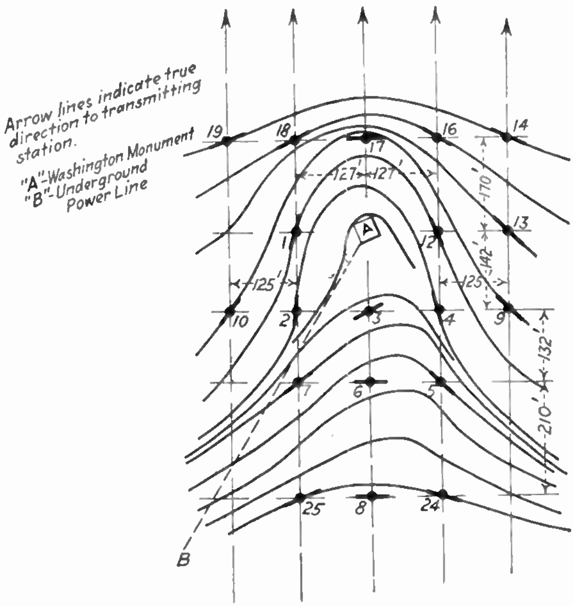

FIG. 14a.

fication is available. Its most important advantage is its adjustability to *directional action.* Thus, the signal strength is loudest when the loop is turned so that its plane is pointed in the direction of the transmitting station. If the plane of the loop is at right angles to this direction, very weak radio currents, or none at all, are received. Thus, messages may be received from one station while those from another are avoided, even though both stations are transmitting on the same wave length. The amount of electrical energy received

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by a loop is very small, but, because of its greater freedom from interference, this energy may usually be sufficiently amplified to give clearer radio reception waves than can be received by any other type of antenna.

Directional Effects of Loops.—Theoretically a wire loop for radio should give its maximum reception strength when its edge (plane of any one of the loops) is turned toward the transmitting station, and under ideal conditions, there should be no reception from radio waves when the loop is turned so that the loop is at right angles to the direction of the transmitting station. In or near any building or similar structure there will always be distortional effects which practically vitiate this principle. In fact, in many cases entirely dif-

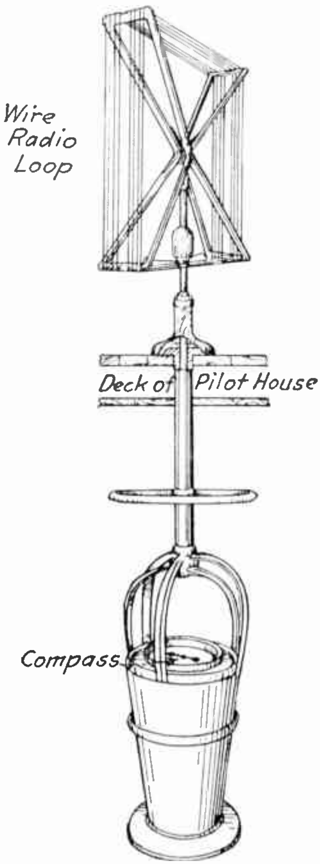

Fig. 14b.

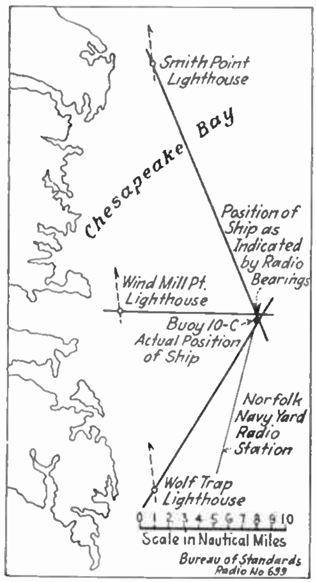

Fig. 14c.

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ferent or no directional effects will be produced. For example, in a fireproof apartment house or office building, the planes of the loops point toward the centre of gravity of the building for maximum strength of radio reception, irrespective of the direction of the transmitting station. A loop loses its directional effect when it is near to an outdoor antenna and lead-in wire, whether or not these are connected to the receiving set. Under these circumstances, when the directional action of a

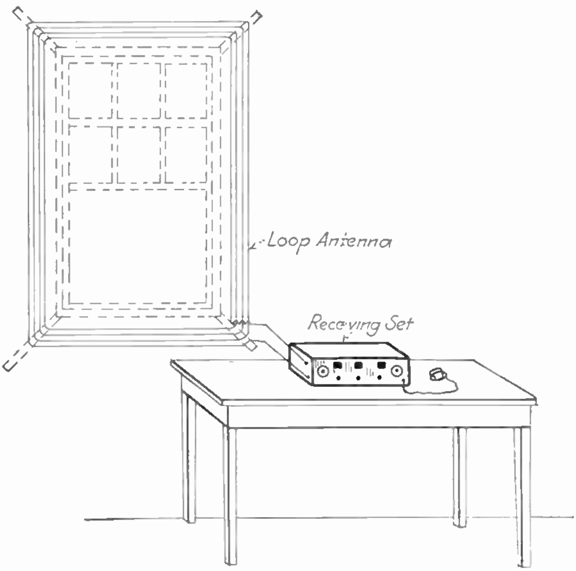

Fig. 15.—Typical radio loop around a window.

loop cannot be effective, an indoor antenna stretched around the sides of a room gives better results than a loop.

Distortion of radio waves causing abnormal directional action of a loop for radio reception as produced by the nearness of large structures of metal and other energy-absorbing materials is shown in Fig. 14*a*. The curves in this figure show

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the distortion of radio waves near the Washington Monument in the District of Columbia. The monument is about 555 feet high and has within it an elevator and stairway which form what may be considered a fairly efficient antenna. The maximum distortion occurs at a wave length of about 800 meters, which appears to be, therefore, the natural wave length of the monument. In other words, the Washington Monument considered as an antenna is in resonance or in tune at this wave length.

Radio Loop for Direction Finding.—An application of a wire radio loop for direction finding on shipboard is shown in Fig. 14*b*. The loop consists of 11 turns of insulated wire wound on a rigid skeleton frame 4 feet square. The loop is supported on a vertical shaft which extends into the pilot house. The shaft is held in position on ball bearings in order to permit ease and uniformity of rotation, and it is attached at its lower end to the framework carrying the ship's magnetic compass. The loop can be rotated from within the pilot house by means of the handwheel and the direction of the signaling station is read directly on the usual card, showing directions, which is beneath the compass. The accuracy with which the position of a ship may be determined by means of the radio direction finder is shown in Fig. 14*c*, which is an actual case where radio bearings were taken on a naval vessel from each of three radio signalling stations.

Lightning Arrestors.—The installation of an approved device for protection against lightning is required by the Fire Underwriter's rules which may be found at the end of this chapter. As shown in Fig. 16, a lightning arrester *L* is attached to a bared (uninsulated) portion of the lead-in wire *A*, and has an outside ground connection which serves in case of lightning storms, to carry electric discharge directly from the antenna into the ground.

If the receiving set is near the place where the lead-in enters, the arrester may be mounted on the set, although this method is not recommended. A single-pole double-throw knife switch may be used in addition to, but not in place of,

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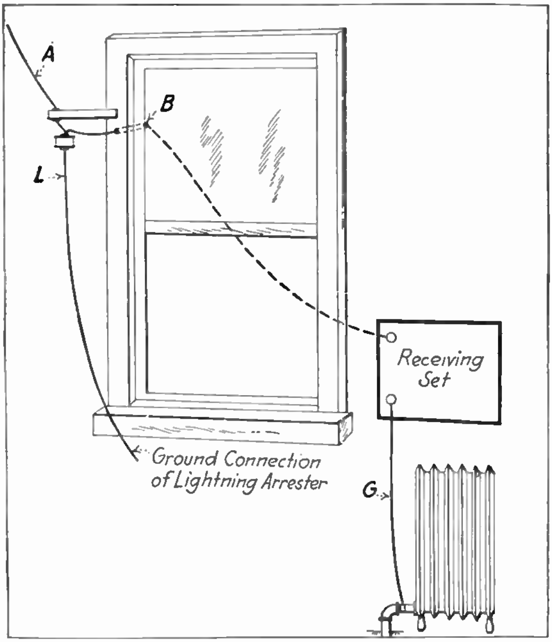

FIG. 16.—Method of attachment of lightning arrester.

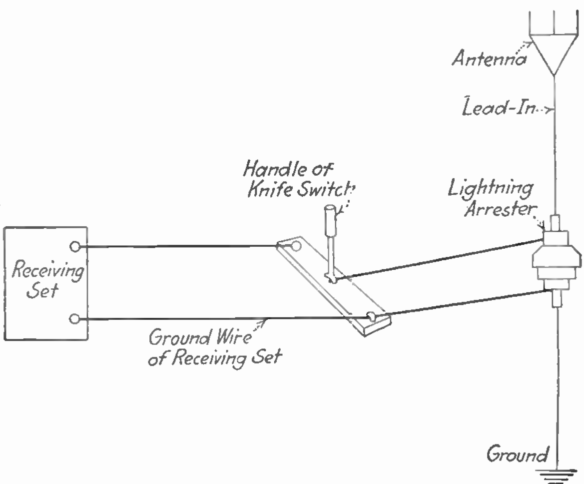

FIG. 17.—Combined knife-switch and lightning arrester.

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the lightning arrester. The connections for such an installation are shown in Fig. 17.

Transmitting Antenna.—A radio transmitting station requires a more complicated antenna (sometimes called *aerial*) than a receiving set. Transmitting antennas are made in several forms as shown in Fig. 18. They generally consist of several long parallel horizontal wires with the lead-in wire attached either at the middle or at one end of the antenna wires.

When the lead-in wire is attached at the middle of the horizontal antenna wires, because of its resemblance to the letter T, the arrangement is called a *T*-antenna; and when attached to one end an *L-antenna*. A fan or harp antenna is made of a number of wires spreading upward from a common point. Where tall supporting structures are available, a good arrangement is the cage antenna. This is made of a number of parallel wires separated by spreaders or by a hoop, and may be placed either vertically or horizontally. For receiving, none of these types are better than the single wire. When the same antenna must serve for both receiving and transmitting, the usual construction is the flat-top multiple-wire type with either the *T* or *L* connections.

Transmitting antennas must be insulated very carefully because of the high voltages which are produced in the antenna. The antenna and lead-in must be supported at least 5 inches away from the building. A lightning arrester is not required on transmitting sets but a ground switch must be used which will carry a current of 60 amperes and has a space of 5 inches or more from the knife hinge to the end clip.

FIRE UNDERWRITERS' REGULATIONS FOR RADIO EQUIPMENT (1926)

The requirements of this article shall not apply to equipment installed on shipboard. Transformers, voltage reducers, keys and other devices employed shall be of types expressly approved for radio operation.

For Receiving Stations Only.—Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

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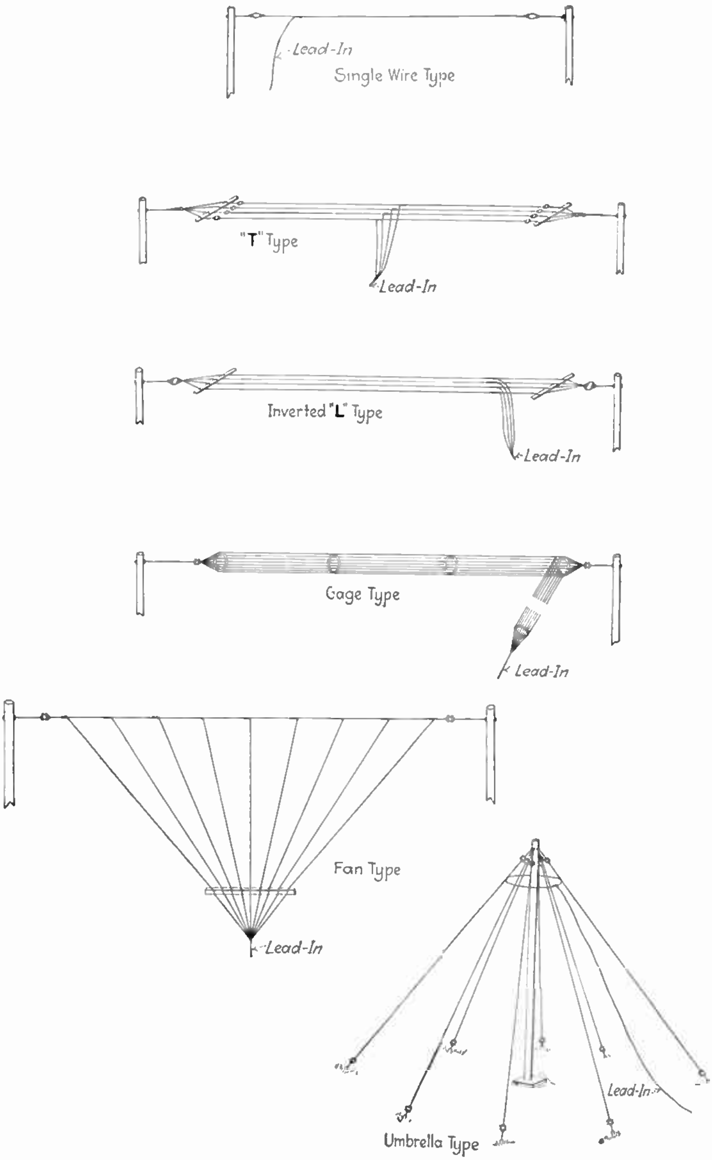

FIG. 18.—Forms of transmitting antennas.

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Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

The preceding paragraphs shall not apply to light and power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

Lead-in conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

Lead-in conductors on the outside of buildings shall not come nearer than 4 inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

Lead-in conductors shall enter the building through a non-combustible, non-absorptive insulating bushing slanting upward toward the inside, or by means of an approved device designed to give equivalent protection.

Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitible stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

If the antenna grounding switch is employed it shall in its closed position form a shunt around the protective device. Such a switch shall not be used as a substitute for the protective device.

It is recommended that an antenna grounding switch be employed, and that in addition a switch rated at not less than 30 amperes, 250 volts, be located between the lead-in conductor and the receiver set.

If fuses are used, they shall not be placed in the circuit from the antenna through the protective device to ground.

The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The protective grounding conductor shall be not smaller nor have less conductance per unit of length than the lead-in conductor and in no case shall be smaller than No. 14 if copper, nor smaller than No. 17 if of bronze or copper-clad steel. The protective grounding conductor shall be run in as straight

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a line as possible from the protective device to a good permanent ground. Preferance shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

The protective grounding conductor shall be guarded where exposed to mechanical injury. An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs may be used as the operating ground.

It is recommended that in this case the operating grounding conductor be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, the grounding conductor being either bare or provided with an insulating covering.

Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than 2 inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire. Storage battery leads shall consist of conductors having approved rubber insulation. The circuits from storage batteries shall be properly protected by fuses or circuit breakers rated at not more than 15 amperes and located preferably at or near the battery.

For Transmitting Stations Only.—Antenna and counterpoise outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

Splices and joints in the antenna and counterpoise span shall be soldered unless made with approved splicing devices.

Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.

Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted 5

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inches clear of the surface of the building, on non-absorptive insulating supports such as treated pins or brackets, equipped with insulators having not less than 5 inches creepage and air-gap distance to inflammable or conducting material, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches. Suspension type insulators may be used.

In passing the antenna or counterpoise lead-in into the building a tube or bushing of non-absorptive insulating material, slanting upward toward the inside, shall be used and shall be so insulated as to have a creepage and air-gap distance of at least 5 inches to any extraneous body, except that the creepage and air-gap distance for continuous wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches. If porcelain or other fragile material is used it shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing provided 5 inches creepage and air-gap distance, as specified above, is maintained.

A double-throw knife switch having a break distance of at least 4 inches and a blade not less than 1/8 inch by 1/2 inch shall be used to join the antenna and counterpoise lead-in to the grounding conductor. The switch may be located inside or outside the building. The base of the switch shall be of non-absorptive insulating material. This switch shall be so mounted that its current-carrying parts will be at least 5 inches clear of the building wall or other conductors, except that for continuous wave sets of 1000 watts and less input to the transmitter, the clearance shall be not less than 3 inches. The conductor from grounding switch to ground shall be securely supported.

It is recommended that the switch be located in the most direct line between the lead-in conductors and the point where grounding connection is made.

Antenna and counterpoise conductors shall be effectively and permanently grounded at all times when station is not in actual operation and unattended, by a conductor at least as large as the lead-in and in no case smaller than No. 14 copper, bronze, or approved copper-clad steel. This protective grounding conductor need not have an insulated covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good permanent ground. Preference shall be given to water piping. Other permissible protective grounds are the grounded steel frames of building and other grounded metal work in buildings and artificial grounding devices such as driven pipes, rods, plates, cones, etc. The protective grounding conductor shall be protected where exposed to mechanical injury. A suitable approved ground clamp shall be used where the protective ground conductor is connected to pipes or piping. Gas piping shall not be used for the ground.

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It is recommended that the protective ground conductor be run outside the building.

The operating grounding conductor shall be of copper strip not less than 3/8 inch wide by 1/32 inch thick, or of copper, bronze, or approved copper-clad steel having a periphery, or girth of at least 3/4 inch, such as a No. 2 wire, and shall be firmly secured in place throughout its length.

The operating grounding conductor shall be connected to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

When the current supply is obtained directly from lighting or power circuits, the conductors whether or not lead covered shall be installed in approved metal conduit, armored cable or metal raceways.

When necessary, to protect the supply system from high-potential surges and kick-backs there shall be installed in the supply line as near as possible to each radio-transformer, rotary spark gap, motor and generator in motor-generator sets and other auxiliary apparatus one of the following:

1. Two condensers (each of not less than 1/10 microfarad capacity and capable of withstanding 600-volt test) in series across the line with mid-point between condensers grounded; across (in parallel with) each of these condensers shall be connected a shunting fixed spark-gap capable of not more than 1/32 inch separation.
2. Two vacuum tube type protectors in series across the line with the mid-point grounded.
3. Resistors having practically zero inductance connected across the line with mid-point grounded.

   It is recommended that this third method be not employed where there is a circulation of power current between the mid-point of the resistors and the protective ground of the power circuit.
4. Lightning arresters such as the aluminum-cell type.

QUESTIONS

1. Write briefly on the following topics pertaining to the straight-wire antenna: number, length, size, position and insulation of wires.
2. (*a*) Why is it necessary to solder the joints?
   (*b*) Where should the lead-in be connected to the antenna?
3. How should the ground connection be installed?
4. What device is required as protection against lightning and how may it be installed?
5. What are the advantages of a loop antenna?

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6. Explain directional action of a radio loop.
7. What is Fire Underwriters' regulation regarding the size of fuse which is required to protect the wires leading from a storage battery?

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CHAPTER III

RADIO ELECTRICITY EXPLAINED

Radio waves are produced by an electric current at the transmitting station and, at the receiving set, these waves are changed into an electric current again. Indeed one cannot go far in the study of radio without understanding the action of electric currents.

Electric Currents.—When the two ends of a piece of wire are connected to the terminals of an ordinary dry cell battery, an electric current is said to flow in the wire. But no current will flow unless there is a continuous or uninterrupted path for the current to flow in; under such conditions the path or electrical circuit is said to be *closed.* That is, the connections must be such that current can flow out from one terminal of the battery, through the wire, and back to the battery at the other terminal. Conversely, when the path is interrupted, or broken, the circuit is said to be *open.*

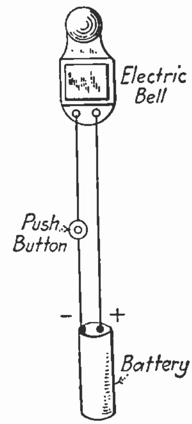

FIG. 19.—Electric bell and battery.

If a bell and battery are connected as in Fig. 19, the current will always flow out from the *positive* (+) terminal of the battery, through the wire to the bell, through the bell, and through the wire to the *negative* (−) terminal of the battery. If the ends of the wires at the battery terminals are interchanged, the current will flow through the bell circuit in the opposite direction. The push button is used to control the ringing of the bell, since when it is *on*, the circuit is closed and when it is *off*, the circuit is open.

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Amperes.—A useful illustration of an electric circuit is a closed pipe line, full of water, and provided with a pump, as shown in Fig. 20. Electricity in a circuit acts much like the water in the pipe line. With a water meter we can easily measure the quantity of water flowing through the pipe in a certain time and express it as so many gallons per second for example. In electrical work, the quantity of electricity flowing per second is indicated by an instrument called an ammeter.

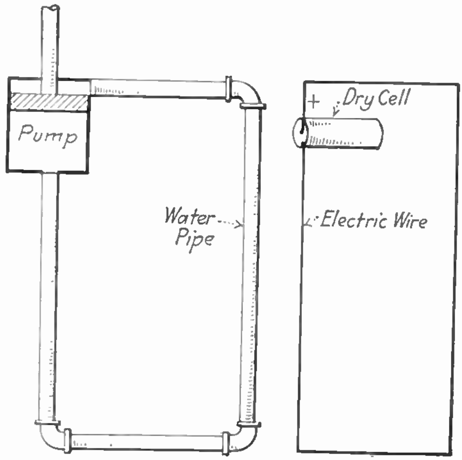

FIG. 20.—Pump and pipe line to illustrate electric circuit.

Thus a reading of 5 on such an instrument means that electricity is flowing at the *rate* of 5 amperes. An ammeter, indicating rate of flow in amperes, corresponds to a speedometer indicating speed in miles per hour. If the terminals of an ammeter are touched to the terminals of a dry cell, a reading of 25 to 35 amperes will be observed.

Volts.—So far we have said nothing about what makes the electricity flow. In the pipe line (Fig. 20) the water will not flow unless some force such as the pump pushes it. Likewise, electricity will not flow in a circuit unless there is, in the circuit, a source of electrical pressure, such as a battery. If the pressure of the pump is increased more water will flow and if more batteries are connected into the circuit, more electricity

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will flow. This electrical pressure or voltage is measured in *volts* by an instrument called a voltmeter. If the terminals of a voltmeter are touched to the terminals of a new dry cell the reading ought to be 1.5 volts.

Resistance—Ohms.—The water pressure at the end of a long pipe line is much less than at the pump. This loss in pressure is due to the friction or resistance of the pipe. And we have noticed also that we can cut down on the quantity

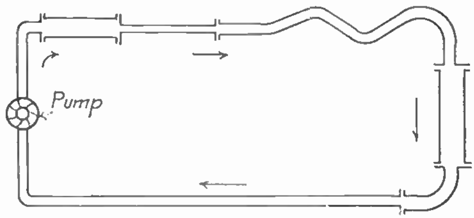

FIG. 21.—Pipes connected in series.

of water flowing by introducing more resistance as by partly closing a valve or faucet. In an electric circuit this friction is called *resistance*, and it causes a voltage drop and acts as a control on the current flow. The resistance of a wire depends upon the material of which it is made and varies directly with the length, but inversely with the cross-section. The unit of resistance is the *ohm*. The three quantities, pressure, current and resistance, are so related that pressure equals the product of current and resistance, or, in terms of the units,

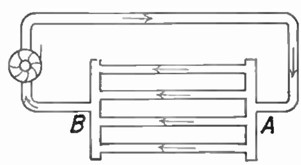

FIG. 22.—Pipes connected in parallel.

$$\text{volts} = \text{amperes} \times \text{ohms}$$

This equation holds true for any circuit or part of a circuit. When the equation is used for a part of a circuit, the values of voltage, current and resistance must apply to that part only. The flow of current in a circuit may be increased by either increasing the voltage or decreasing the resistance, or both.

Series and Parallel Circuits.—In radio work the units of apparatus may be connected in series or in parallel. If the various parts of a circuit are connected in such a way that the *total* current must flow through each part, the parts are said to be in *series*. This corresponds to the pipe line shown in Fig. 21, in which pipes of various sizes and lengths are connected in series. If the various parts are connected in such a way that the total current is subdivided, the parts are said to be in *parallel*. The corresponding condition in the pipe line is shown in Fig. 22. If each of the four paths offer the same resistance to current flow, then the total current at *A* will be divided into four equal parts, which come together again at *B*.

Direct Current.—The electric current which is supplied by all kinds of batteries is direct current. That is, it flows in one direction through the circuit. In Fig. 19, for instance, if the pressure or voltage of the battery is steady, the current will be steady and will flow from the + terminal of the battery, through the circuit to the − terminal of the battery. If the voltage is *pulsating*, that is, if it rises and falls in strength, but acts in one direction only, then the current also rises and falls in strength and is called a *pulsating current.*

Alternating Current.—When radio waves are changed into an electric current by means of the receiving apparatus, this current instead of flowing in one direction, not only changes its direction at a definite rate, but also varies in strength. Such a current is called an *alternating* current. If there is an alternating voltage in a circuit, the variations in both strength and direction of the electric current correspond to the variations of the voltage. The flow of an alternating current is like the flow of water which would be produced in the pipe line in Fig. 20, when the water is agitated by a paddle moving back and forth rapidly over a short distance. In that case, the water simply surges, first in one direction, then in the other direction. It no sooner gets up speed in one direction than it is compelled to slow up and then get up speed in the opposite direction, and so on, over and over again. An object placed in the water will not travel around the pipe circuit, but simply oscillates back and forth.

The alternating current which is used for electric lights changes it direction, or alternates, 60 times per second.

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That is, it is said to have a frequency of 60 cycles per second. The radio currents most used, however, may have frequencies ranging from 10,000 to 30,000,000, corresponding to wave lengths of 30,000 and 10 meters, respectively.

In order to distinguish the directions of flow, we call one direction the *positive* (+), and the other the *negative* (−) direction. During the flow in one direction, the strength of the current varies from zero to a maximum and back to zero again. Figure 23 shows a simple way of indicating the variations in strength, direction and time when an alternating current is considered. The *positive* direction of flow is from *A* to *C*; the *negative* from *C* to *E*. During the flow from *A* to

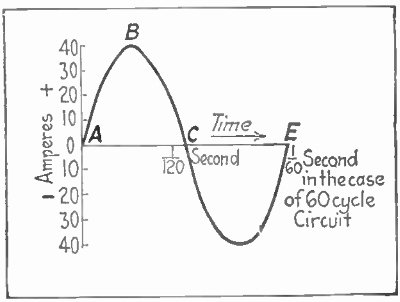

Fig. 23.—Variations in strength and direction (positive and negative) of alternating current.

C, the strength of the current varies from zero to a maximum, and again to zero, as shown by the curve *ABC*.

Magnetic Field.—It is well known that an ordinary horseshoe magnet will attract a piece of iron or steel. If iron filings are sprinkled on a piece of paper placed over a magnet, they act in a way which proves the existence of a condition, in the space or region all around the magnet, which is called a *magnetic field*. The presence of this field can be shown also by the behavior of the needle of a compass when brought near the magnet. Whenever an electric current flows in a wire, there is a magnetic field around the wire as shown in Fig. 24.

The importance of the magnetic effect of an electric current cannot be overestimated. Magnetic action makes possible

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the operation of the telephone and telegraph, as well as electric bells, electric motors and the like.

Induction.—If the current in a wire is steady then the magnetic field will also be steady, that is, its strength will not vary. If the current varies the magnetic field will vary also. It is obvious, therefore, that an alternating current will produce a magnetic field which is also of alternating strength, meaning that it acts first in one direction, then in the other, varying in magnetic strength at the same time. If a wire is moved through a magnetic field, or if a magnetic field is moved

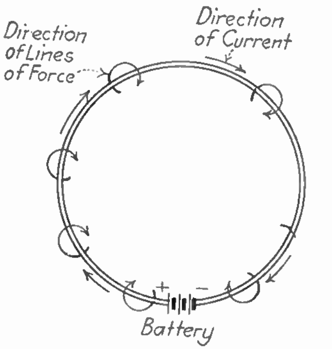

Fig. 24.—Magnetic field produced by electric current in a wire.

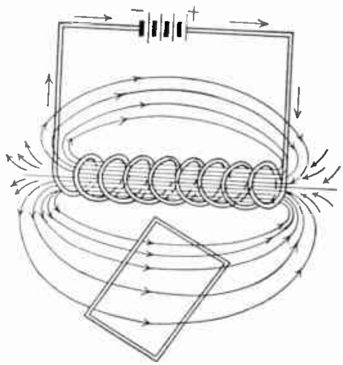

Fig. 25.—Electric current induced in a wire by a magnetic field.

so that it passes over a wire, a voltage is *induced* in the wire and will cause a current to flow. This effect is called *induction.*

The practical application of this principle of induction is as follows: If a single closed circuit which forms a loop is moved through a magnetic field, as in Fig. 25, a voltage is produced or *induced* in the circuit and causes a flow of current in the circuit.[1] The same result would be obtained if the magnetic field is moved over the loop. As we shall see later, this explains the action of the antenna.

[1] If a length of wire is wound in the form of a coil, the character of the magnetic field resulting from current flow may be represented as in Fig. 25. The direction of the field is such that if you look at one end of the coil and observe that the current is flowing in a clockwise direction (like the hands of the clock), then the end next to you is the south pole of the magnetic field.

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Inductance.—When an alternating current passes through a coil of wire, it *induces* a *back voltage* in the coil. This induced voltage acts to resist the flow of current.[1] This property of a circuit is called its *inductance*. In fact, a coil called a *choke coil* may be made with enough turns of wire so that its inductance will entirely prevent the flow of very high-frequency currents (called radio frequency), but will permit the flow of relatively low-frequency currents (called audio frequency, because the frequency is low enough to make sounds audible to human ears). If, however, a choke coil is poorly designed the

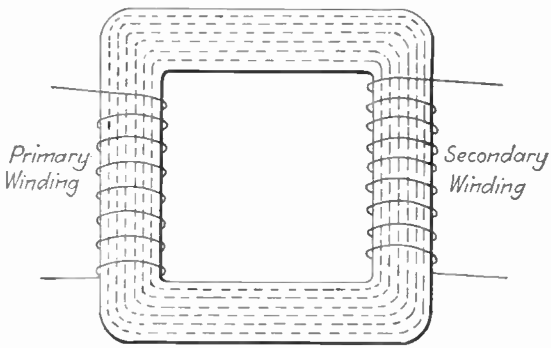

FIG. 26.—Simple transformer.

very high-frequency (radio frequency) currents may pass through it. Inductance is measured in units called *henries*.[2]

Transformers.—If a coil carrying a current is placed near another coil, it is possible to transfer electrical energy from the first coil to the second, even though there is no wire or other electrical conductor connecting the coils. A very important application of this is the *transformer*, a simple form of which

[1] Actually the changes in the current *lag behind* the changes in voltage.

[2] A coil of wire (without iron) has an inductance of one microhenry (one-millionth henry) when one microvolt is induced in it when the current is changing at the rate of one ampere per second.

In a circuit containing inductance (L) only it can be shown that $E = I \times 2\pi fL$ where E is in volts, I in amperes, L in henries. The term $2\pi fL$ in which $\pi = 3.142$ and f = frequency, is called *inductive* reactance and is measured in ohms. Thus, if an alternating voltage of constant effective value is applied to a circuit, the effective value of current will increase as L or f are decreased.

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is shown in Fig. 26. In most cases, a transformer is used to change or transform alternating current of low voltage and comparatively large current to alternating current of high voltage and small current and *vice versa*.[1]

Condensers.—A simple electric condenser consists of two metal plates separated by some insulating material. Figure 27 shows a diagram of a simple type of condenser and Fig. 28 is

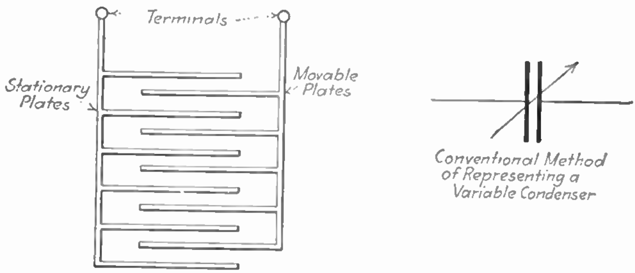

Fig. 27.—Diagram of a simple condenser.

an illustration of a commercial type with several movable plates (with only air for the insulating material). The effectiveness of a condenser to store electricity is called *capacity*. Since an insulator (air or electric insulating material) is between every two adjoining plates, it is easy to see that there is no flow of electric current through a condenser. With direct current this is literally true, that is, no current can flow past the condenser, but with alternating current there is an *apparent* flow. This action of a condenser is similar to the conditions which exist in the pipe line as shown in Fig. 29.

[1] The action of a transformer may be expressed by the equation

$$\frac{N_1}{N_2} = \frac{E_1}{E_2} = \frac{I_2}{I_1}$$

in which

N_1 = number of turns on the primary coil,
N_2 = number of turns on the secondary coil,
I_1 = primary current, amperes,
I_2 = secondary current, amperes,
E_1 = voltage induced in the primary, volts,
E_2 = voltage induced in the secondary, volts.

From this it is obvious that $E_1 \times I_1 = E_2 \times I_2$.

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The system is full of water and as the piston in the cylinder moves back and forth, it pushes the water first in one direction and then in the other. There is no flow past the partition but due to the pressure of the water in the direction *A* to *B*,

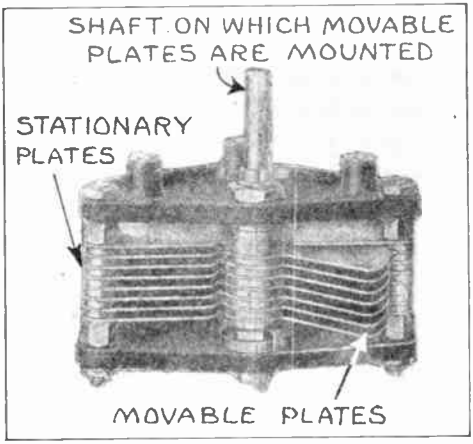

FIG. 28.—Commercial type of condenser.

the partition stretches toward *B* as shown. When the piston moves in the opposite direction, the partition stretches toward *A*. Thus there is a surge of water back and forth through the

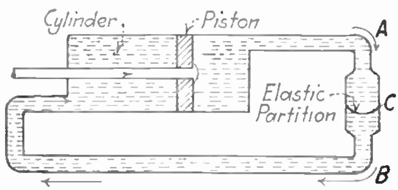

FIG. 29.—Partition in a pipe line to illustrate action of a condenser.

pipe line. The insulating material of a condenser corresponds to this partition. The comparison helps to show that while there is no flow of current, the current does alternate in the circuit itself.[1]

[1] When an alternating voltage is impressed on a condenser, the current reaches its maximum value before the voltage and we say the current *leads* the voltage. In other words, the *capacity effect of the*

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Capacity is measured in units called *farads*. But this unit is too large for practical radio work, so we use the *microfarad* (*mf.*) which is one-millionth of a farad. *Since capacity in a circuit produces an effect which is the opposite of the effect produced by inductance, the amounts of inductance and capacity may be proportioned so that one will just neutralize the other. When this is done, the only limitating influence to the flow of current is the resistance.*

Commercial Types of Condensers.—A *fixed condenser* is one in which the value of capacity stays constant while a *variable condenser* has a large range of capacity.

QUESTIONS

1. Explain the terms, *electric current, ampere, volt* and *resistance*, by comparison with the flow of water.
2. State the relation between volts, amperes and ohms.
3. (*a*) Draw a series connection of three coils of wire.
   (*b*) Draw a parallel connection of four wires.
4. (*a*) What is the difference between direct current and alternating current?
   (*b*) Draw a diagram to represent an alternating current.
5. Mention a few properties of a magnetic field.
6. Explain induction and show how it applies to the transformer.
7. (*a*) When inductance is introduced into a circuit what effect has it upon the relation between current and voltage?
   (*b*) How is this relation affected by the introduction of capacity?

---

condenser is just the opposite of the inductance effect which causes the current to *lag* behind the voltage.

When an alternating current is applied to a circuit containing only capacity, it can be shown that $E = \frac{I}{2\pi fC}$ where C is the capacity in farads and the other units are used as before. The term $2\pi fC$ is measured in ohms and is called the *capacity reactance*. If the value of voltage is kept constant, then the value of the current varies directly with the frequency and capacity. When a circuit contains resistance R, inductance L, and capacity C, the relation between voltage and current may be shown by the equation

$$E = I \times \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

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CHAPTER IV

TELEPHONE RECEIVERS AND CRYSTAL RECEIVING SETS

These principles of inductance and capacity as explained in Chap. III will now be applied in studying the practical operation of a radio receiving set. When radio waves cross a wire, a voltage is induced in that wire and causes a radio current to flow if the circuit is complete. This explains how an electric current is produced in the antenna wire. This radio current will have a frequency which is the same as that of the radio wave carrying it. A telephone receiver, however, would not respond to such a radio current if it were connected directly to the lead-in wire of an antenna. In order to understand

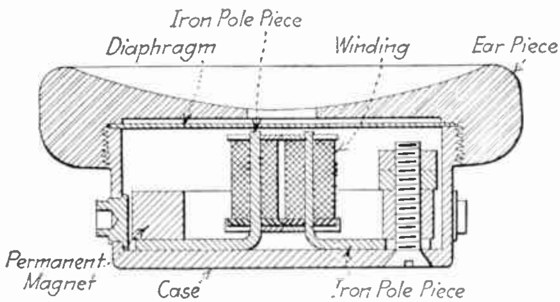

FIG. 30.—Typical telephone receiver.

this, we must examine carefully the operation of the telephone receiver in relation to radio waves.

Figure 30 shows the construction of a typical telephone receiver. It has two coils of wire each wound in many layers around an iron core to produce two electromagnets. A metal diaphragm is so supported that it may be attracted by the magnet poles or released depending upon the strength of magnetism in the poles. An increase of current through the

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windings causes the diaphragm to be attracted and a decrease of current causes it to be released, because the strength of the magnetic attraction is likewise increased and decreased. When the diaphragm is alternately attracted and released it will vibrate, and if the *frequency* of vibration is between 15 and 15,000 vibrations per second, the air waves created will be audible. In other words, electric current vibrations between 15 and 15,000 per second are *audio*-frequency vibrations. Higher frequencies (not audible) are *radio*-frequency vibrations. The more rapid the vibration, the higher the pitch of the sound produced.

Telephone receivers designed for radio service have more wire wound on the magnets than those used in ordinary telephone service, so that a small current will produce a louder sound. As a measure of the amount of wire used, telephone receivers are rated by the resistance (ohms) of the winding. Thus there are 1,000, 2,000 and 3,000 ohm receivers. It is not possible to judge performance by resistance alone, however, as many other factors must be considered in determining the most effective operation.

Alternating electric currents having a high frequency of vibration as in radio waves would tend to cause motion of the diaphragm of the telephone receiver, but the diaphragm cannot be made to follow the very rapid back and forth variations of such a current. Alternating current has the effect of tending to make the diaphragm go both ways at once, because the current alternates in direction so rapidly, with the result that no appreciable motion takes place.

Crystal Detector.—Our problem, then, is to change alternating radio current in such a way that the diaphragm of the telephone receiver will be attracted in only one direction. This is accomplished by putting into the circuit, including the antenna and the telephone receivers, a device which permits the radio current to flow in one direction only, that is, making it direct current. A *crystal detector* acts in this way and consequently the radio current flowing from the detector to the telephone receivers is really a pulsating direct current. For all practical purposes, this action may be represented as in Fig. 31. It will

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be noticed that even now the variation of the telephone current is so rapid that the diaphragm cannot follow it exactly. Actually, however, one-half of a cycle of current variation will produce only a small effect on the diaphragm of a telephone receiver compared with the effect of a complete cycle of current variation. Thus the net effect of a series of current changes on the movement of the diaphragm is shown by the dotted line in the chart marked *B* in this figure, and the full line in the chart marked *C*.

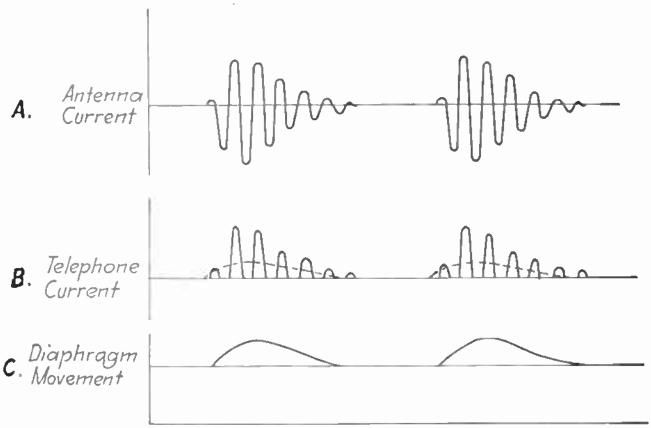

FIG. 31.—Action of crystal detector on radio currents.

Assume, for example, that a radio current is induced in the antenna of a broadcasting station, which has a frequency of 1,000,000 cycles per second and then on this radio current a sound frequency of 400 vibrations per second is impressed. Assume also that a device is inserted in this circuit which will allow only the current flowing in one direction to pass through and act on the diaphragm of a telephone receiver and which will prevent the current flowing in the other direction. Then, during each 1/400 of a second, the diaphragm will be acted on by 2,500 impulses acting in the same direction. The cumulative effect of these impulses will be to pull the diaphragm in only one direction, and the sound transmitted will thus be made audible. A device operating in this way with respect

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to the high-frequency currents is called a *detector*. Not every piece of this material is suitable for detectors and satisfactory pieces are obtained only by careful selection where it is sold in bulk. This difficulty has been largely overcome, however, as most crystals are mounted and tested when sold. Crystals may lose their sensitivity by the application of heat. They are generally mounted in an alloy which has a very low melting point, such as Wood's metal, solder being unsuitable for this purpose. Repeated contact with the fingers may cause a loss of sensitivity owing to the formation of a thin film of grease on the crystal. This film may be removed by washing the crystal in alcohol.

Points on the surface of a piece of radio-sensitive mineral, will usually vary in sensitivity. A sensitive spot on a crystal will last only a short time, and it is then necessary to move the contact around on the surface of the mineral until another sensitive spot is found.

Simple Receiving Equipment.—The simplest radio receiving equipment consists obviously of a *detector* and a *telephone receiver*. The detector of course is a device which changes the incoming radio waves so that they may be heard in the telephone receiver.

Crystal Receiving Sets.—The least complicated and most inexpensive radio outfit is the so-called crystal receiving set, which makes use of a crystal mineral having the property of changing the high-frequency radio waves to electric impulses of varying strength, traveling in one direction, and capable of operating a telephone receiver. The crystal mineral which is most used in galena (lead sulphide). This is a silver-gray mineral, which breaks in squares with mirror-like surfaces.

In its essential parts a *crystal detector* consists of a piece of galena crystal mounted in such a way that a fine piece of wire attached to a flexible handle can be made to touch the surface of the mineral. Crystals of this mineral are not uniformly sensitive so that there are some spots which are not as sensitive as others. In the operation of a crystal detector, therefore, the wire must be shifted with its flexible handle on the surface of the galena, until a highly sensitive contact is

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found. If, however, the instrument is jarred the sensitive contact may be lost and even with use, the sensitiveness of any particular spot is likely to change. No adjustment for receiving radio currents from only one transmitting station (tuning) is possible with a simple crystal receiving set as all near-by signals come in at the same time. There are usually, however, few difficulties in its use because its range is very limited. On the other hand, it is very satisfactory for picking up radio broadcasting from powerful nearby stations.

The simplest type of radio receiving set consists of an antenna, lead-in wire, crystal, telephone receiver and ground wire. The lead-in wire is fastened to the crystal and the flexibly supported wire resting on the surface of the crystal is connected to the telephone receivers. In this apparatus the circuit of the radio (alternating) current is from the antenna and lead-in wire to the surface of the crystal. The flexibly supported wire on the crystal takes the radio current now changed to direct current to the telephone receivers, to which also the ground wire is connected. Finally the radio current (although changed to direct current) from the ground wire finds its way back to the transmitting station through the ground, thus completing the circuit.

In radio telephony the electric generator (dynamo) at a transmitting station furnishes an antenna current having constant amplitude, or strength, which produces a so-called continuous wave called the *carrier wave* of radio, and the sound waves of the voice or of music are used to modify this continuous wave so that the resultant wave is similar to that shown in Fig. 32. The alternating current which produces the carrier wave must have a higher frequency than that to which the ear will respond (radio frequency). Otherwise a sound would be produced at the transmitting instruments which would interfere with the spoken words or music which are being transmitted. The frequency of sound waves created by the human voice *averages* around 800 per second, but constantly increases and decreases with the pitch of the tone. In the case of music every change in tone also means a change in the frequency. If the sound of the vowel *a* as in *father* is

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spoken, the sound wave is as illustrated in Fig. 33. The result of superimposing such a voice wave upon the radio-frequency carrier wave is given in Fig. 32. The alternations of the radio wave are shown by full lines and the dotted out-

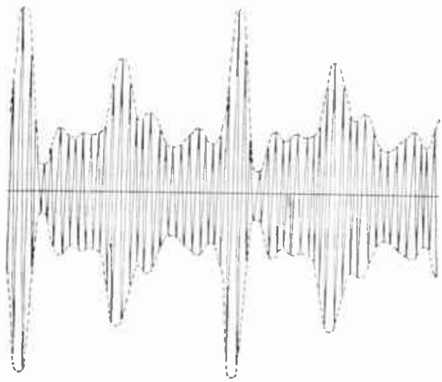

FIG. 32.—Carrier radio wave modulated by sound waves.

line shows how the amplitude or strength of the radio wave is made to vary in accordance with the voice wave.

Tuning.—In general, radio waves from any particular transmitting station have only one wave length, and the

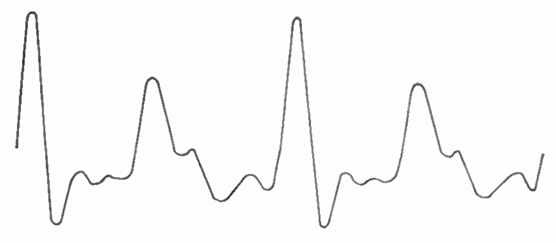

FIG. 33.—Sound wave of letter "*a*."

frequency of the *antenna current* at the receiving set is the same as that of the radio waves. But unless the *antenna circuit* is *tuned* to this same frequency, the radio current will not have its maximum strength. That is, the receiving circuit must be arranged to respond to the frequency of the transmitting circuit and of its radio waves. This idea of tuning

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may be illustrated by the use of two tuning forks of the same pitch, or frequency of vibration. If one is struck and caused to vibrate, the other will vibrate also, producing a note having the same pitch as that of the first tuning fork. Now, if the second fork is put out of tune with the first, as, for example, by sticking on a piece of wax, the second fork will not respond when the first is made to vibrate. You can see then that, if the receiving circuit is so arranged that it can be tuned to various frequencies, it may be possible to pick out any desired radio wave to the exclusion of all other waves of different frequencies, and, at the same time, get the greatest possible strength of that wave.

Tuning with an Inductance Coil.—By providing a simple tuning device the efficiency of a crystal detector and telephone receiver can be very much improved. One of these tuning devices is a single tuning inductance coil which consists of a large number of turns of bare copper wire wound in a single layer on a suitable tube, with provision for varying the number of turns of wire which are to be used. When such a coil is used in a simple crystal detector set the lead-in wire is connected to one end of the coil and the other end is attached to the wire connected to the crystal. In some devices of this kind a *sliding contact* is provided which may be moved over the bare section of the wire. A coil of this kind is shown in Fig. 34.

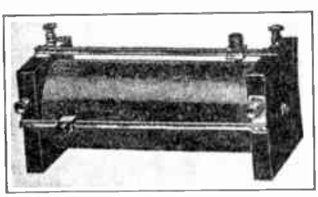

Fig. 34.—Simple inductance coil for tuning antenna circuit.

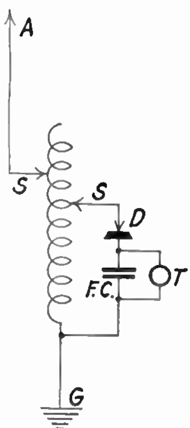

Fig. 35.—Diagram of connections of inductance coil for tuning.

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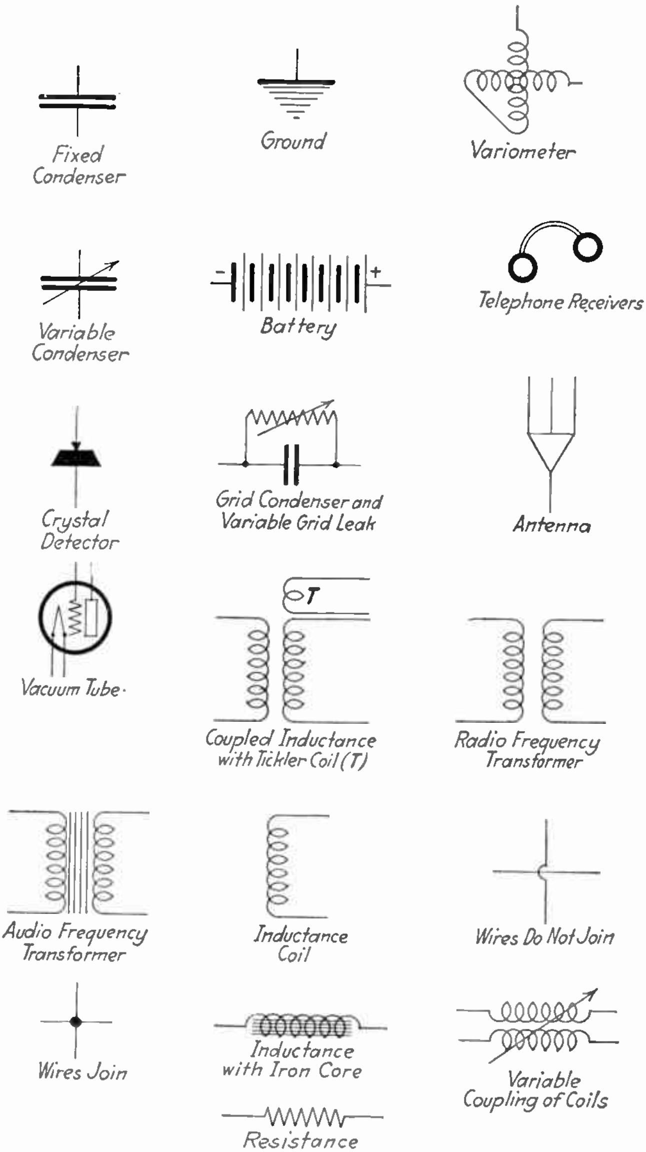

FIG. 36.—Conventional radio symbols.

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Another method of using a tuning inductance coil is in connection with a switch with contact points so arranged as to cut out, say, every ten turns of wire. A tuning inductance coil may be connected conveniently, as shown in Fig. 35. In this way there are two sliding contacts, which really have the effect of making two separate circuits; one for the crystal and one for the *antenna to ground*. Usually a small *fixed* condenser is placed across the telephone receiver. The *reason for using the condenser* is that the telephone offers too much resistance to the passage of high-frequency current from the crystal, and the use of a condenser has the effect of reducing this resistance. A list of the symbols used in radio work is given in Fig. 36 and should be consulted freely.

Tuning with a Variometer.—The tuning device shown in Fig. 37 is called a *variometer*, and consists of a fixed set of coils

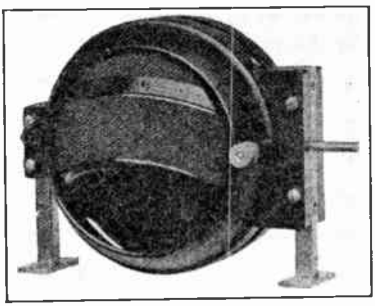

FIG. 37.—Variometer for tuning antenna circuit.

and a movable set of coils. The movable coils are attached to a graduated dial. When the dial of the variometer is turned, the position, with respect to each other, of the fixed and the movable coils is changed. At the maximum reading of the dial, which usually is marked 180, the coils are so arranged that the current will flow in the same direction in each set of coils, thus adding wave length to the circuit, in which the variometer is used. On the other hand, when the dial is set at zero, the fixed and the movable coils will be arranged so that the current will flow in opposite directions, and in this position they carry opposing currents or are *bucking* each other, so that

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the inductance of the coils is greatly reduced and consequently the wave length is also reduced. A considerable variation in the wave length can thus be obtained by moving the dial of the variometer. With a properly designed apparatus of this kind, it is usually possible to get relatively fine adjustments.

Inductance and Capacity Combined.—The frequency[1] of

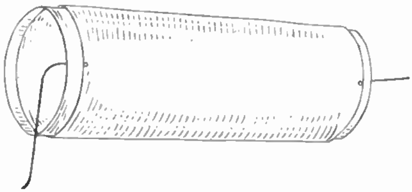

FIG. 38.—Fixed type of inductance coil.

any circuit depends upon *inductance L* and *capacity C*. A condenser is used to introduce capacity into a circuit, and a coil of wire is used to introduce inductance. Inductance may be either fixed or variable; the fixed types are shown in Figs. 38 to 40, and variable types in Figs. 41 and 42. The addition of inductance increases the natural wave length of a circuit. Thus by adding inductance to a circuit, as in Fig. 43, it may be tuned to various wave lengths. But even under the best con-

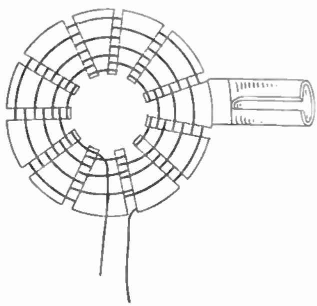

FIG. 39.—Fixed type of inductance coil.

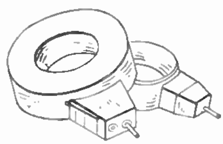

FIG. 40.—Fixed type of inductance coil.

[1] It can be shown that the natural frequency of a circuit containing L and C in series is $f = \frac{1}{2\pi\sqrt{LC}}$ where L is the inductance in henries and C is the capacity in farads. Another way of expressing this is, wave length $= 1{,}884\sqrt{LC}$, where L is in microhenries and C is microfarads, and wave length is in meters.

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ditions the current which will flow is small because both the crystal and the telephone receivers offer a high resistance. A condenser, however, offers low resistance to radio-frequency

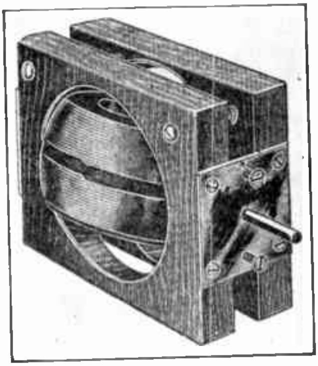

FIG. 41.—Variable type of inductance coils.

currents. If then, a fixed condenser is connected across, or in parallel with the telephone receivers, the resistance to the flow of the high-frequency current is reduced, and a greater

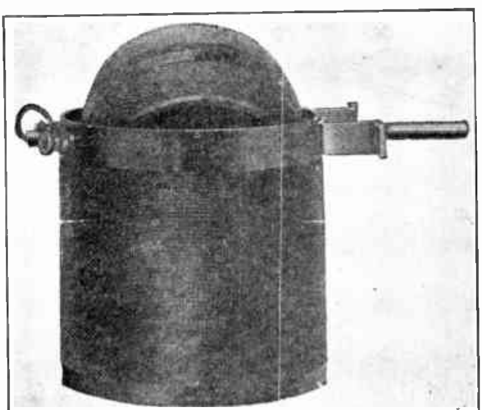

FIG. 42.—Variable type of inductance coils.

current will flow. A condenser in parallel with the telephone receivers, in some cases, is considered as a storage for electricity with an action as follows: When current flows through the

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crystal the condenser accumulates a charge of electricity which discharges through the telephone receivers during the interval when no current flows through the crystal. This action occurs once in every cycle and its effect is to increase the strength of the current. A telephone cord, which consists of two insulated wires, has some condenser action and this may be sufficient for some cases so that no additional condenser effect is required.

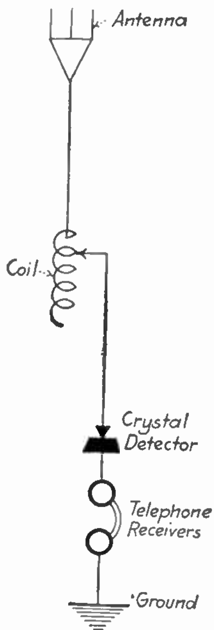

FIG. 43.—Inductance coil in antenna circuit for tuning.

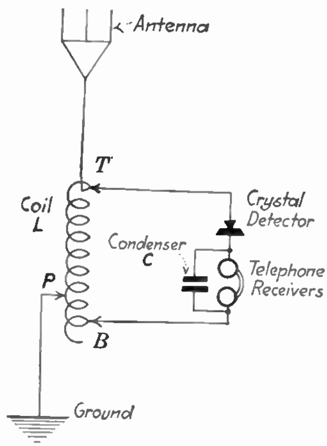

FIG. 44.—Crystal detector in secondary circuit.

Since the crystal of a detector has a high resistance, and is in the direct path of the antenna current, better results will be obtained by having the crystal and telephone in a circuit by themselves, as in Fig. 44. Here the antenna circuit includes all the turns of wire on the coil between *T* and *P* while the secondary circuit, containing the crystal and telephone receivers includes the turns between *T* and *B*. By this

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arrangement both the antenna and the secondary circuits may be tuned to the proper frequency.[1]

Double Circuit Wiring Diagram.—A circuit has now been described which operates very well except when very close tuning is necessary to separate signals from two stations on nearly the same wave lengths. This difficulty can be overcome by separating entirely the antenna circuit and the secondary circuit as indicated in Fig. 45. This arrangement is called a

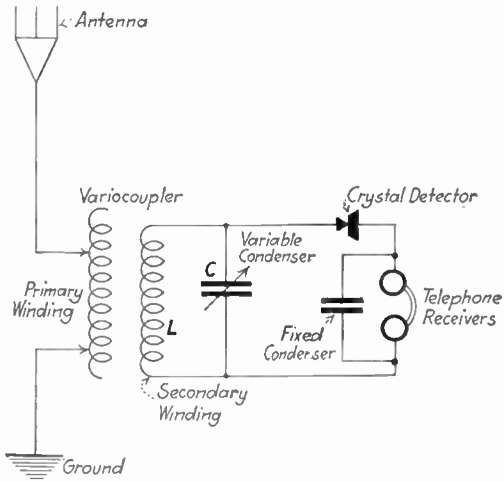

FIG. 45.—Diagram of primary circuit (antenna) and secondary circuit (including inductance, capacity and telephone receivers).

double circuit to distinguish it from the single circuit considered above. Energy is transferred by induction from the primary to the secondary circuit. The variable condenser C which is placed across the secondary coil gives sharp tuning because it makes possible a very fine adjustment of the frequency of the secondary circuit. When the circuit con-

[1] In order to understand the action we need only to apply the conception of voltage drop. Since there is a current flowing in the antenna circuit, we know from the relation $E = IR$ (where R is the resistance to alternating current) that there will be a certain drop in voltage across the coil. The location of the point B determines the value of the voltage which is used to force a current through the secondary circuit.

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taining the inductance L and the capacity C is tuned exactly, the voltage across its terminals will be a maximum and will cause a maximum current to flow in the telephone receivers.

Coupling.—In comparing the single and double circuits, we must first consider the *purpose of this tuning system.* This has two objects; first, to adjust the frequency of the primary circuit, and second, to provide the proper *transformer action* so that the greatest possible amount of energy is transferred to the secondary circuit. In the single circuit, the *frequency adjustment* depends upon the *amount* of inductance L and capacity C, while the *transformer adjustment* depends upon the *ratio* of L to C. This is true also for the double circuit with the advantage that the *transformer action* may be adjusted also by the *coupling*, that is, by the relative position of the two coils, meaning the primary and secondary of the tuner. It is important to remember that when the distance between these coils is increased, the coupling is *loose* and sharper tuning results than with *close* coupling. The process of coupling may be looked upon as a sort of *filtering* scheme. The antenna circuit partly filters out the desired wave and the process of filtering is carried still further by the secondary circuit. The single circuit gives comparatively loud signals with poor selectivity. The double circuit, with loose coupling, has good selectivity, but will give a weaker signal than the single circuit unless the voltage actuating the secondary circuit is increased enough by having a large number of turns on the secondary coil to offset the effect of loose coupling.[1]

Variable Condenser in Series and Parallel Circuits.—If it is desired to receive radio currents of a wave length shorter than the wave length corresponding to the length of the antenna and coil, a variable condenser must be connected in *series*

[1] From the relations E varies as $\frac{1}{R_p}$, for the single circuit, in which E is the voltage acting and R_p the resistance of the primary, and the relation E varies as $\frac{1}{\sqrt{R_p \times R_s}}$ for the double circuit, in which R_s is the resistance of the secondary circuit, it can be seen that by reducing the secondary resistance better results will be obtained with the double circuit, for given antenna circuits.

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with the ground lead, as shown at C_1 in Fig. 46. As the capacity of this condenser is decreased, that is, as the plates are moved farther apart, the wave length of the circuit decreases. If, on the other hand, the antenna circuit is short, and, even with the antenna inductance coil, will not tune up to a high wave length, it is necessary to use a variable condenser connected in *parallel*[1] with the coil as shown by the dotted line at C_2.

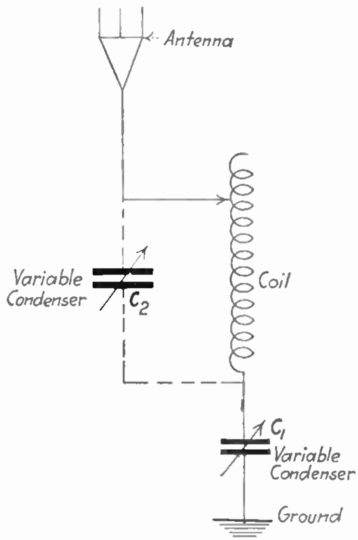

FIG. 46.—Variable antenna condensers for tuning.

By keeping these relations in mind, and remembering that the antenna to ground circuit forms a condenser with one plate (antenna) connected to one side of the receiving set and the other plate (ground) to the other side of the set, it is easy to understand the effect of *series* and *parallel condensers* in the antenna circuit on wave length. Thus, a parallel condenser

[1] It is interesting to note that the total capacity of two condensers C_1 and C_2, connected in parallel, is equal to $C_1 + C_2$, while the total capacity for a series connection of C_1 and C_2 is $\frac{C_1 + C_2}{C_1 \times C_2}$. This is just the opposite of the case with inductance, or resistance.

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increases the capacity and consequently the wave length, while the opposite is true for the series condenser. In determining upon the size of a condenser, use the smallest size which will do the work. A larger size will serve, but will be harder to adjust. The smaller condenser, not so critical in adjustment, adds capacity more slowly and brings in a given signal over a wider adjustment of the plates. In a crystal set the antenna condenser may be placed in the ground lead with the movable plates grounded.

QUESTIONS

1. Explain how an electric current is produced in the antenna.
2. Why is a detector necessary in a receiver?
3. Tell what you can of the process by which a sound wave at the transmitting station is sent out as a radio wave and changed into a sound wave again at the receiving station.
4. What happens when you tune your receiver?
5. How are inductance and capacity used in tuning?
6. Describe the purpose of the telephone condenser.
7. Why do we use a separate circuit for the detector and telephone receivers?
8. Explain the meaning of *double circuit* and *coupling*.
9. If it is necessary to change the wave-length range of a circuit how would you connect a variable condenser in the circuit to get
   (*a*) a lower minimum?
   (*b*) a higher maximum?

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CHAPTER V

VACUUM-TUBE RECEIVING SETS

The operation of the *vacuum tube* as used in radio sets was discoverd by Edison. He learned that when an electric lamp filament is cold no current passes through the vacuum between the *filament* and an extra wire or *plate* inserted in the bulb, but that when a lamp filament of this kind is brought up to incandescence, a current passes readily through the vacuum between the filament and the extra wire or plate. An electric current, however, can pass through a vacuum tube in only one direction, and for this reason the tube is called a *rectifier* of alternating current. It allows the electric current to flow in one direction only, and therefore converts alternating current into pulsating direct current. Vacuum tubes for this purpose are made, however, with still one other part, which is called the *grid*. The grid surrounds the filament and is thus a separating surface between the filament and the plate. Now, if the wire at the base of the vacuum tube, which is connected to the grid, is connected to a source of electricity, as for example a dry cell, it will be possible by this means to control of the flow of electricity. The *grid* is usually a piece of wire bent in a zig-zag form or it may be a wire in the shape of a spiral spring so placed as to surround the filament and act as a separating surface between the filament and the plate.

A vacuum tube is so sensitive that when there is even a small change in the voltage in the wire connected to the *grid*, it may produce a considerable change in the amount of current flowing between the filament and the plate. This, therefore, is the general method adopted in radio practice to regulate a large current by means of a small current. In this case, a small current is due to the radio waves which are brought from the antenna by the lead-in wire to the grid, where it serves to con-

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trol the amount of current which passes through the vacuum tube to the telephone receivers. In this way the radio waves are changed into audible sounds which may be heard in the telephone receivers of the headset. Thus, much louder and clearer signals are obtained by the use of vacuum tubes than could possibly be secured with any of the simple devices in which a crystal detector is used.

The construction of a typical vacuum tube is shown in Fig. 47. It resembles an ordinary electric light bulb. In addition to the *filament*, it contains a spiral wire, previously described

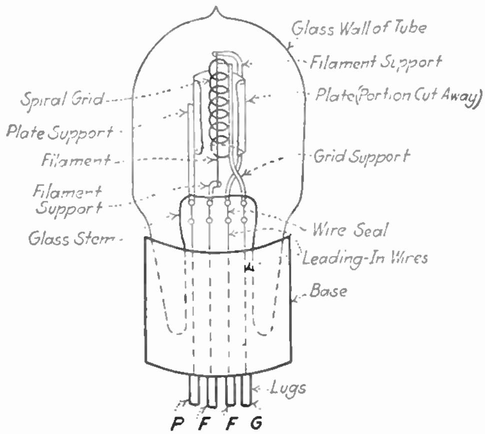

Fig. 47.—Typical vacuum tube.

as the *grid* which surrounds the filament, and a cylindrical metal *plate*, which surrounds both the grid and filament. The tube from which all the air possible is drawn (hence the name—*vacuum tube*) is provided with a base which fits into sockets of standard size. At the bottom of the base, there are four terminal lugs, two of which (marked *F*) lead to the ends of the filament, a third (marked *G*), leads to the grid, and the fourth (marked *P*) leads to the plate. The conventional way of representing a vacuum tube is shown in Fig. 48.

"A" and "B" Batteries.—The vacuum tube requires for its operation a *filament* or "A" *battery* and a *plate* or "B" *battery*. In the action of the vacuum tube the electric energy of a

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"B" battery is used to increase the *effect* of radio waves. The "A" battery is used to heat the filament of the vacuum tube to incandescence, and thus permit weak radio waves received from the antenna circuit to serve only as a control on the electric energy taken from the "B" battery. The diagram of a vacuum tube with the necessary "A" and "B" batteries is shown in Fig. 49.

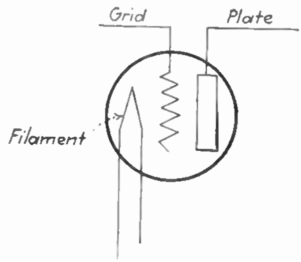

FIG. 48.—Conventional representation of vacuum tube.

In order to understand what a vacuum tube does when it is connected with a radio receiving set, the action of the tube itself must be explained. When its filament is heated by the current from the "A" battery, and when the "B" battery is connected so that its positive terminal is attached to the plate P of the vacuum tube and its negative terminal to the filament F, the electric force (voltage) at the plate is positive with respect

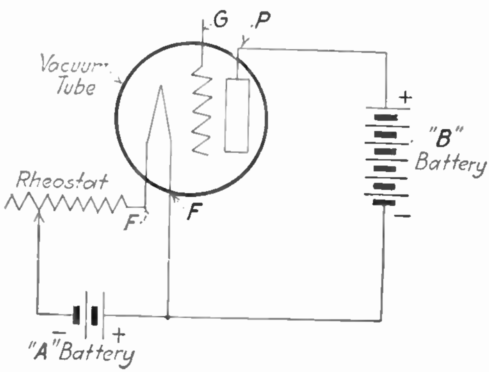

FIG. 49.—Vacuum tube with connections to "A" and "B" batteries.

to the filament, and a current will flow through the tube. The paths followed by the plate and filament currents are indicated in Fig. 50.

It will be noticed that *one side of the filament circuit carries both the filament and the plate currents.* The plate current can

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be increased by either increasing the "B" battery voltage, or by increasing the filament current from the "A" battery, which is controlled by a variable resistance called a *rheostat*. If the plate voltage is too high there will be a blue glow inside the vacuum tube; and when this occurs, the action of the tube is very erratic, and the volume of sound in the telephone receivers is reduced. Too much plate voltage shortens the life of the tube; in fact, if the blue glow is allowed to remain, the tube will burn out. Likewise, the filament current cannot be increased very much without injuring temporarily or burning out the filament. In its practical operation, the filament is heated to

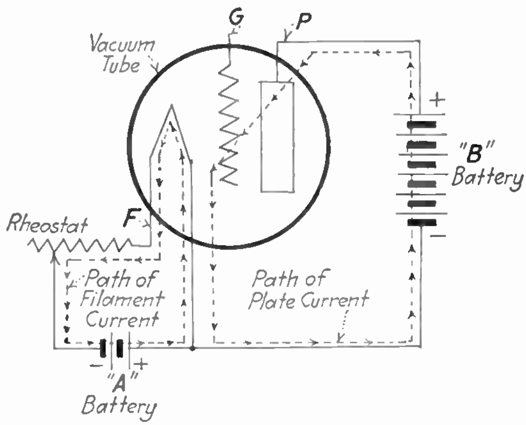

FIG. 50.—Plate and filament currents in vacuum tube.

a moderate temperature, as determined by the manufacturer, and the plate voltage is adjusted for best results by variation of the voltage of the "B" battery.

If, however, the negative terminal of the "B" battery is connected to the plate, there will be no current flowing in the plate circuit. When the direction of the electric force (voltage) between the plate and the filament is thus changed, there is no flow of current. Thus the action of the tube, so far, is similar to that of the crystal detector, since it will allow current to flow in one direction only.

The grid is placed between the filament and the plate to increase the power of the vacuum tube. Since the grid and

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filament are very much nearer together than the plate and filament, it can be seen that when an electric force (voltage) is established between the grid and the filament, it will have more effect upon the plate current than when there is the same electric force between the plate and filament. As a result of this, a small electric force between grid and filament controls a comparatively large flow of current in the plate circuit. It is this effect which makes the tube far more sensitive as a detector than the crystal. In a crystal set, only the original current produces sounds in the telephone receivers, while in a vacuum-tube set, the incoming radio current merely *controls* a much stronger current.

Probably in most cases, the "A" battery is rated at 5 or 6 volts, as 5-volt vacuum tubes are used a great deal. A battery of this kind as a rule consists of a storage battery of three cells each giving 2 volts, making a total of 6 volts, or four dry cells, each giving 1½ volts when new, making 6 volts in all. There are, however, some vacuum tubes which operate on very low voltages from 1.1 to 1.4 volts, and use only ¼ ampere of current. Vacuum tubes of this low voltage are ideally suited for operation with a single dry cell for the "A" battery. Very many vacuum tubes rated at 5 volts require a current of one ampere, and when tubes of this large capacity are used, it is extravagant to operate with dry cells, because with a 1-ampere current drawn from the battery no dry cell will last long. For any receiving set, having more than one vacuum tube it is generally considered economical to use a storage battery for the "A" current supply.

Storage Batteries.—It is desirable that storage batteries used for radio work, should be in rubber boxes or cases so as to prevent leakage of acid upon floors, rugs and carpets, and also to avoid the noises caused by leakage of acid either from one of the cells to the ground or from one cell to another cell. Storage batteries for radio service may well be made somewhat smaller in capacity than those used for automobile starting and lighting. These small sizes are cheaper and more convenient to handle than the larger ones ordinarily used in automobiles. Also, when electric lighting current is avail-

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able, it is desirable to have a recharging device for the storage battery if the radio set includes several vacuum tubes. A number of vacuum tubes are a considerable drain on the battery and unless provision is made for more or less constant recharging, there will be a great deal of inconvenience and expense when the storage battery must be taken out frequently for recharging. Further, with a recharging apparatus always at hand the storage battery will be kept well charged and its life and general serviceability will be very much increased.

The "B" battery, or high-voltage battery, is now generally made in compact units of 22½ volts, and these units are made in both small and large sizes and the large sizes should, by all means, be used where there is a more or less constant use of the receiving set. Most small-size units have no provision for taking less than 22½ volts from the unit, while the large units are generally made with a suitable number of lugs or binding posts which are arranged to permit a considerable variation of voltage which is taken from the cells. This variable type of "B" battery is especially useful for vacuum tubes requiring fine adjustment of the "B" voltage. Each of these units, whether large or small, consists of 15 dry cells each intended to give 1½ volts when new.[1]

Uses of Vacuum Tubes.—A vacuum tube as used in radio sets for both receiving and transmitting purposes has a number of uses. The most important of these are the following:

1. Changing the alternating current to pulsating direct current.

2. Controlling a large electric current by means of a relatively small current.

The first of these uses has been clearly explained in the preceding pages. The second use is, however, just as important and in general is referred to as *amplification*, which means that a weak current, brought to the receiving set from the

[1] In a receiving set consisting of a simple detector having a single vacuum tube one "B" battery (22½ volts) is sufficient, but if there is also an amplifier used in connection with the detector, two of these units (45 volts) are needed. If a loud speaker is also a part of the equipment, in addition to the amplifier, three or four units (67½ or 90 volts) may be needed.

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antenna, may have its characteristics impressed on a current several times as powerful, usually called "B" current, in such a way that the powerful current will communicate to a telephone receiver all the characteristics of a weak current. The principle of amplification is the same as that applied in telephone repeaters which are employed in long-distance telephone lines for the purpose of receiving a telephone message with a weak current and sending it on at a much stronger current to a great distance.

Vacuum tubes are made in a number of sizes and with slightly different characteristics, depending upon the service for which they are to be used. The smallest vacuum tubes use about ¼ ampere at 1.1 volts which means that these smallest tubes are rated about ¼ watt, and the largest tubes are rated at about 250 watts.

Storage Batteries for "B" Currents.—The "B" batteries referred to in the preceding explanation consist of dry cells. Instead of the compact units of dry cells just referred to, some "B" batteries which are in almost constant use consist of storage batteries. Such storage batteries may be recharged from time to time with the same recharging apparatus that is used for "A" batteries. It is claimed that the operating cost of "B" storage batteries is less than when dry cells are used. Dry cells of course, when they become reduced in voltage are practically valueless and are usually thrown away.[1]

A receiving set provided with a vacuum tube and "A" and "B" batteries is shown in Fig. 51. In the operation of this set, the antenna circuit is first tuned to the radio waves from a transmitting station by manipulation of the dials, so that a maximum current flows in the primary circuit. Then, by induction in the transformers, the electric energy is transferred to the secondary circuit. When the secondary circuit *LC* is tuned, a maximum current will flow in it and the voltage across the terminals of the condenser *C* will likewise be a

[1] When the voltage of a 22½-volt dry cell unit becomes lower than 17 volts it is not very satisfactory and begins to make trouble particularly in the way of increasing unpleasant noise during reception. When the voltage has been reduced to this amount, however, these units may be satisfactorily used for electric bell and private telephone circuits, as well as for regulators for thermostatic controls.

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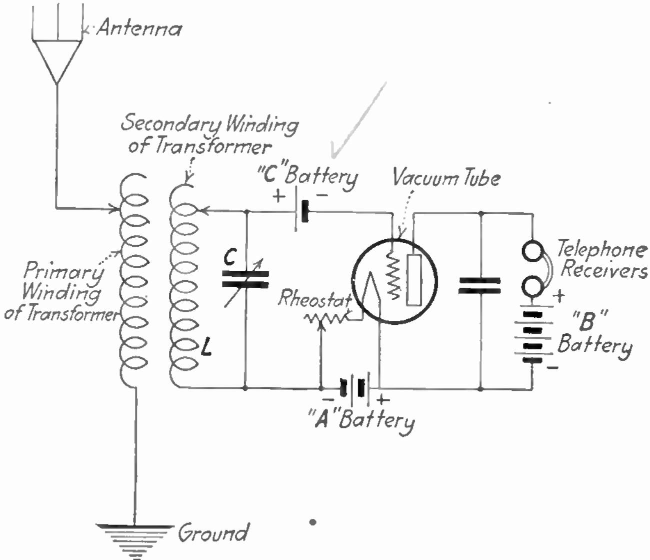

FIG. 51.—Simple vacuum tube receiving set with "A" and "B" batteries.

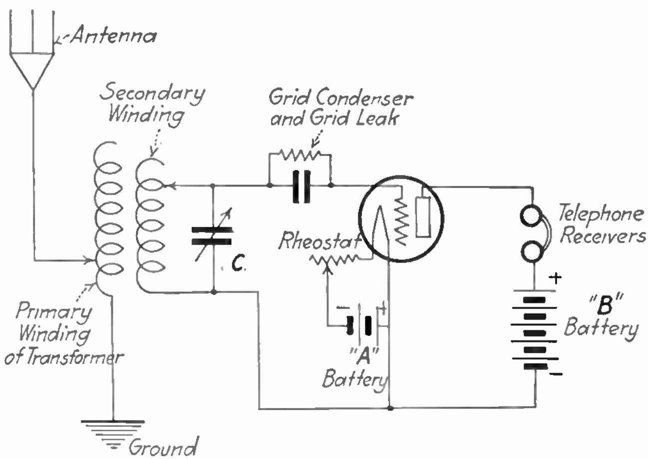

FIG. 52.—Diagram illustrating use of grid leak and grid condenser.

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maximum. This alternating voltage being impressed on the grid-filament circuit will act, as explained before, so as to control the flow of current in the plate circuit. In this way, the alternations of the grid voltage resulting from the original weak current in the antenna, will cause corresponding fluctua-

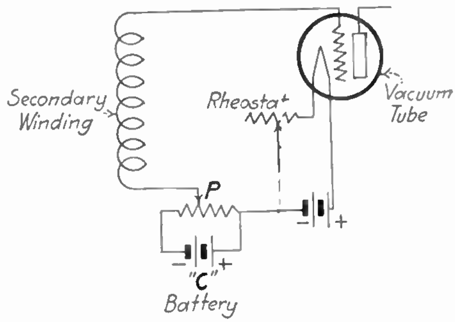

FIG. 53.—Combined use of potentiometer and "C" battery.

tions in the much stronger current flowing from the "B" battery through the plate circuit.

In the diagram (Fig. 51), the electric force between plate and filament acts in a direction which is called positive. The force between grid and filament will be positive during the interval

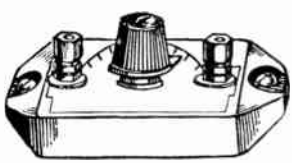

FIG. 54.—Combined grid leak and grid condenser.

FIG. 55.—Combined grid leak and grid condenser.

of time when the impressed alternating voltage is positive, and, during this interval, it will act in connection with the positive *plate to filament* voltage to increase the flow of *plate* current. Likewise, during the interval when the impressed voltage is negative, the *grid to filament* voltage will be negative and will act in the opposite direction to the positive *plate to filament* voltage, to decrease the flow of *plate* current. The difficulty

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comes from the fact that since the grid periodically becomes positive with respect to the filament, it will at those periods allow a current to flow in the grid circuit. This is not desirable because it causes distortion[1] and weakens the action of the vacuum tube. With many tubes, louder signals result when a *grid leak* and *grid condenser* are used as in Fig. 52. Two types of a combination grid leak and grid condenser are shown in Figs. 54 and 55. Two types of rheostats are shown in Figs. 56 and 57.

FIG. 56.—Typical resistance rheostat.

FIG. 57.—Typical resistance rheostat.

"C" Battery.—The primary purpose of a "C" battery is to put an electric current in the negative direction on the grid element of a vacuum tube, thus preventing a flow of current from the filament to the grid. It reduces the "B" battery drain considerably and produces a saving in the cost of "B" batteries. It also affords clearer reception by reducing somewhat the noises in a set. A "C" battery is used to advantage only in cases where the "B" battery voltage is in excess of

[1] Sound distortion caused by periodic changes of voltage direction in the grid may be prevented by connecting the grid-circuit return to the negative end of the filament in order to produce a permanent negative force at the grid to insure that the grid will never become positive due to the impressed voltage. If this does not prove sufficient it may be necessary to use a "C" battery as shown in Fig. 51, or in combination with a potentiometer *P*, as in Fig. 53.

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50 volts. It is most commonly used on amplifier tubes, and the amplifier circuit is usually arranged so that but one "C" battery takes care of two stages of amplification.

Vacuum Tubes for Alternating Current.—Considerable progress has been made in the improvement of radio vacuum tubes for use with alternating current, but results are not as satisfactory as with tubes operating with direct current from batteries. These tubes will, in many cases, give satisfactory service for radio reception when a loud speaker is included in the receiving set, but when telephone headsets are used, the results are not nearly so good, because of interference, due to humming noises. It has been observed that in some receiving sets in which alternating current tubes are used, the humming noises are not nearly as troublesome when the tubes are new, as when they have been in use for some time. There is, therefore, considerable room for improvement in these tubes, both in their operating characteristics and uniformity. It should be noted, also, that in order to use these alternating current vacuum tubes, it is necessary to make slight changes in the wiring of the receiving set. In other words, a special "hook-up" is necessary in connection with any of the standard lay-outs of wiring.

"A" and "B" Battery Current from Alternating Current Supply.—Modified and improved forms of the chemical type of alternating current rectifiers have been recently introduced for use with radio receiving sets in place of the usual "A" and "B" batteries. The alternating current of the ordinary lighting circuit passes first through a transformer by which the voltage is reduced to the required amount. The current then passes on to a series of chemical rectifier cells, each cell containing one plate of lead and two plates of a metal having electrical properties similar to aluminum and its alloys in permitting the flow of only one-half of an alternating current cycle between this metal and the lead when plates of both metals are immersed in a borax solution. In other words, the aluminum or similar metal in conjunction with lead and a borax solution forms a means for "rectifying" alternating current. The pulsating (direct) current thus obtained is then

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further changed into non-pulsating direct current by the use of a system of condensers and inductance coils. By this method, the objectionable humming noise of the ordinary types of rectifiers is eliminated. Satisfactory "A" and "B" battery eliminators are now made which use vacuum tubes for rectification of alternating current.

Current from Electric Lighting Circuits.—In some cities where direct current is distributed for lighting purposes those operating radio receiving sets have been tempted to try to use the city current for the "A" and "B" current, but such attempts have not yet been successful. The reason is that in making radio adjustments very small variations in current and voltage are necessary. For example, if the voltage of the "A" or filament current varies even the slightest amount from instant to instant there will be disagreeable noises in the telephone receivers. In order to secure quiet radio service, it is necessary to have a steady supply of direct current. In any event, the direct current from a lighting circuit has much too high voltage to be applied directly and there would always be a very large loss in reducing the relatively high voltage to the voltage required for receiving sets.

Soft and Hard Vacuum Tubes.—Vacuum tubes which require adjustment of voltage to suit the service for which they are used are called *soft* or gas-content tubes. Such tubes are particularly suited for use in detectors. On the other hand, vacuum tubes which are not intended to require adjustment of voltage are called *hard* tubes and are best suited for use in amplifiers. Soft tubes require critical adjustment of both the "B" or plate voltage and of the "A" or the filament current. When such tubes are properly adjusted for voltage and current they tend to make the operation of a detector very sensitive. The amount of the "A" or filament current is usually varied as necessary for best results by means of a rheostat which is nothing more than a variable type of electrical resistance, which is placed in series with the circuit carrying the current which lights the filament of the vacuum tubes. The "B" or plate voltage is not so conveniently

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adjusted as it must be varied as a rule in steps of 1.5 volts, the voltage of a single dry cell.[1]

The voltage from the "B" battery which will give the best result can only be determined by actual trial, that is by the method of temporarily touching the wire from the *plate* of the vacuum tube to the various lugs or terminals of the 22½-volt unit, and thus finding by trial the position for the attachment of this wire to the lug which gives the greatest sensitiveness of the detector. After this best position of sensitiveness has been determined, as a rule, no further adjustment of the "B" or plate voltage will be necessary for some time. Most of the vacuum tubes intended for use in detectors operate best when the "B" voltage is between 16½ and 22½ volts, and in "B" batteries of the variable voltage type, variations of voltage between these limits are obtained by attachment to any one of the intervening lugs, or outer terminals, which are provided. Very many operators, however, get satisfactory results by using a fixed voltage "B" battery on detector tubes, but obviously they get their best results when the tube happens to be one that gives its best service at 22½ volts or some multiple of that number of volts.

So-called hard vacuum tubes which are also called amplifier tubes, are exactly like the soft or detector tubes, as regards external appearance, and differ only in electrical characteristics; and the most important of these characteristics is the absence of critical adjustment in the hard tubes. As a rule, hard or amplifier tubes operate successfully on plate voltages varying from 40 to 90 volts.[2] In receiving sets having three or four vacuum tubes it may be necessary to use three or four 22.5-volt units connected in series, with the connecting wires so arranged that the full voltage will be impressed on the vacuum

[1] There are usually 15 of these cells in a 22½-volt unit, but the adjustment of voltage is usually only between 16½ and 22½ volts.

[2] Some receiving sets are operated with plate voltages on the tubes of the amplifier receiving electric current at more than 100 volts with the result that they get very loud reception, but there is also the disadvantage that such a high voltage also increases the noises which may be very objectionable, especially in the telephone receivers.

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tubes in the amplifiers while a variable voltage from this same series of batteries will be used for the detector tube.

The "soft" tube, which is recommended for use as a detector, does not have a high degree of vacuum and hence contains some gas. The "hard" tube, which is used both as a detector and as an amplifier, has a high vacuum and needs a higher plate voltage. The terms "hard" and "soft" as applied to vacuum tubes originated with the development of the *x*-ray tube. An *x*-ray tube which produces feeble rays and contains some gas is said to be a "soft" tube. An *x*-ray tube which produces very penetrating rays ("hard" rays) and has a high vacuum is said to be a "hard" tube and needs a higher plate voltage.

In the case of the *soft* vacuum tube, the presence of gas in the tubes changes the action. The grid current in a *soft* tube tends to flow at a much lower value of positive force between the grid and filament. Although a grid current is necessary, too much is harmful and for this reason the return wire from the grid is connected to the negative side of the "A" battery. The proper connections for the various cases are given in the following table:

	Use	With grid condenser and grid leak	Without grid condenser and grid leak
Hard tube...	Detector	Grid return to *positive* of "A" battery	Grid return to *negative* of "A" battery
	Amplifier	....	Grid return to *negative* of "A" battery
Soft tube....	Detector	Grid return to *negative* of "A" battery	Grid return to *negative* of "A" battery

In all cases the rheostat is to be connected to the negative terminal of the filament.

When a grid condenser and grid leak are used, no "C" battery is required with most of the vacuum tubes sold com-

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mercially. This feature, together with the fact that operation is satisfactory over a considerable range of plate voltage, is decidedly in favor of this arrangement.

A soft or detector tube which does not have a critical adjustment of plate voltage and filament current is defective and should be returned to the dealer. A good tube of this kind should have easily recognized maximum sound strength, when the critical plate voltage and filament current are obtained. On the other hand, a hard or amplifier tube which requires a critical adjustment of plate voltage and filament current will not give satisfactory results in an amplifier and should be used instead only in a detector. In some receiving sets consisting of a detector and an amplifier, the makers recommend the use of hard or amplifier tubes in both the detector and amplifier for the reason that the wiring has been laid out in such a way that the detector and amplifier use the same plate voltage and filament current. The object of this arrangement is to simplify the construction and the operation of the set, but simplification of wiring is accomplished only with the sacrifice of most efficient operation.

Grid Leak.—In many of the simple types of receiving sets a very high-resistance [redacted] called a *grid leak* together with a small fixed condenser are placed in series with the *tuner*. In all cases when a vacuum tube is to be connected into a radio circuit it is very necessary that careful attention be given to connecting the positive and negative terminals of both the "A" and "B" batteries to the proper points in the circuit where they are intended to be used.

Loose Couplers and Vario Couplers.—In many receiving sets the relatively weak antenna current scarcely more than gets to the operating parts of the receiving sets; that is, the antenna current enters from the lead-in wire, passes through a single coil in the receiving set, and then passes out through the ground wire. When this is the case, the relatively weak current in the antenna circuit is made to develop an induced current in another winding very close to the one carrying the antenna current. One form of such windings in close contact with each other is called a *loose coupler*, and another

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form is called a *vario coupler.* The *loose coupler* consists of a large tube on which a large number of turns of wire are wound. This winding is called the primary coil, and in a detector is connected at one end with the antenna by means of the lead-in wire and at the other to the ground wire. Inside this larger tube is a smaller tube on which there are wound very many turns of wire and this smaller tube with its winding is arranged to slide in and out of the larger tube. A *vario coupler* differs from the loose coupler just described in that it consists of a large tube on which are wound a large number of turns of wire, to which the antenna is connected by means of the lead-in and the other end is connected to the ground wire. Inside this large tube is a ball or a similarly shaped form, made usually of wood or fibre on which very many turns of wire are wound. The ball with its winding is mounted on a small shaft which has a suitable handle for rotation. In either of these devices, the wire on the large tube is called the primary coil and, the wire on the smaller tube or ball, is called a secondary coil, which is connected (in a receiving set equipped with vacuum tubes) to the wires leading to the tubes and related apparatus.

Honeycomb and Spider-web Inductance Coils.—Until recently most forms of inductance coils were large and clumsy, but recently such coils have been developed which are quite compact and therefore much more convenient to use than the older forms. One kind of this compact inductance coil, is the *honeycomb coil,* shown in Fig. 40. Each coil of this kind is fixed as regards its wave-length value, but there are usually several coils of this kind which may be used interchangeably so that the operator may shift from one coil to the other and thus vary the wave length in large amounts, and depend for smaller variations of wave length on the use of the variometer or a variable condenser.

Compact inductance of still another type, called *spider-web* inductance is shown in Fig. 39. In essential parts this form of inductance consists of a sheet of insulating material such as fiber or hard rubber in which radial slots have been cut and the wire to carry the current is wound in a compact spiral in

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and out of these slots. Because of its shape it is also sometimes called a pancake inductance. Two inductance sheets of this form make a satisfactory loose coupler when mounted so that one sheet is fixed and the other hinged so that the distance between them may be varied.

Descriptions of Radio Receiving Sets.—It will be remembered that the *plate current* in a simple detector set having a single vacuum tube is at radio frequency, but is varied at audio frequency or voice rate; and that the telephone receivers of the head set respond to the audio variations but not to the radio-frequency variations.

The following descriptions of radio receiving sets are detailed and in many respects somewhat technical. On this account they are not intended for detailed study or for special attention on the part of the readers. The information given here regarding these sets is especially for those making a study of one of the sets described.

Feed Back Regeneration.—In a *regenerative receiving set*, radio-frequency current is used to increase considerably the strength of the sounds in the telephone receivers by being *fed back* to the grid circuit. It has been shown that any variation in the voltage impressed on the grid produces a corresponding variation of the plate current and hence if one unit of the radio current received from the antenna is thus *fed back* to the grid circuit, several times that amount—say ten times—may be available in the plate circuit. Now, if we so arrange the parts of a radio receiving set that part of the current in the plate circuit is impressed back on the grid circuit, the sound effects in the telephone receivers will be nearly doubled. This action can be repeated and thus enormously increases the volume of speech or music in the telephone receivers. The limit is reached when so much of the plate current is fed back to the grid circuit that very objectionable noises result.

Tickler Coil Regeneration.—This *feed back* of the plate current to the grid circuit is accomplished by coupling the plate circuit to the grid circuit either by induction or by capacity effects. The action is easily understood by consider-

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ing the double circuit shown in Fig. 58, in which the plate circuit is *coupled by induction* to the secondary of the tuning device. In this arrangement an extra *tickler coil* is connected to the plate circuit so that it may be brought near to the primary winding of the detector circuit. The current flowing in this *tickler coil* sets up a magnetic field which, by induction, reacts upon the coil in the grid circuit and induces in it a voltage. This voltage is such that it adds its effect to that already acting in the grid circuit, and the result is

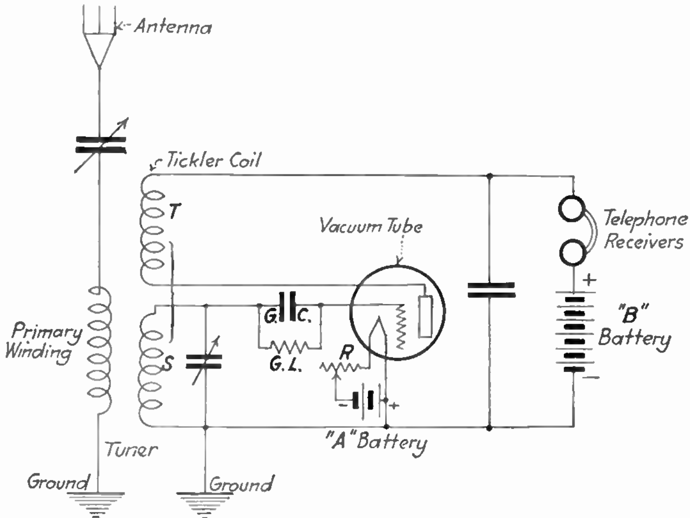

FIG. 58.—Plate circuit coupled by induction to secondary winding.

that the variations in plate current are increased. This increased plate current again reacts on the grid which again increases the plate current. This amplifying action will continue until the limit is reached when the tube starts to oscillate or act as a generator of electric current on its own account. The regenerative action is controlled by the tickler coil coupling, which is made variable, and is increased by increasing the coupling. To obtain maximum voltage on the grid, the grid circuit should have large inductance and small capacity, for this particular type of coupling.

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The *tickler coil* may be the movable coil of a vario coupler, or one of a set of honeycomb, or spider web coils. In order, then, to get regeneration, the plate current must pass through the tickler coil in such a direction that the voltage induced in the grid circuit will increase the voltage already impressed on the grid. If it is not flowing in this direction, its effect will be to decrease the voltage on the grid, and so reduce the strength of the sounds in the telephone receivers. If this happens with a coil which cannot be rotated, it is necessary merely to interchange the wires leading to and from the tickler coil. It will be noticed that as the coupling effect is increased, the radio currents become more and more distorted because the amplification due to the *feed back* is uneven. If the coupling effect is increased still more, a dull click will be heard and the signals will probably disappear. This indicates that the tube is *oscillating or acting as a generator*. This oscillating action is not difficult to understand. We have seen how starting with a given amount of energy in the grid circuit, some of the plate circuit energy can be fed back thus increasing the plate current. If this action is increased more and more, and then if the original source of energy which supplies the grid circuit, be removed, the tube will continue to operate and, essentially, its action is that of a generator. The alternating current thus produced in the plate circuit will have a frequency determined by the values of inductance and capacity in the grid circuit. From this viewpoint, the tube may be considered as a converter of direct-current energy, supplied by the battery, into alternating-current energy.

If the original source of energy is not removed, as would be the case when we are receiving signals, then we have several currents flowing in the apparatus. One current is that due to the incoming signal, a second current is the local one which is produced when the tube begins to oscillate, and the third current is the result of interaction between the other two. This action will be considered more in detail when the superheterodyne receiving set is discussed.

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Oscillating Tubes.—The oscillation[1] of a tube may be started by several causes, such as, a slight jar, the effect of body capacity, a sudden change in the signals, stray currents picked up by the antenna, or most commonly, by an increase in the inductance or capacity of the plate current when the regenerative action is already strong. In other words, the regeneration is so great that the feed back becomes violent upon a slight variation of grid voltage. When a receiving set is adjusted to this oscillating condition it may become a very troublesome source of interference to receiving stations near by, since it is then acting as a weak transmitter.

Experiments have been made which would seem to indicate that a one-tube regenerative set using a tickler coil gives about the same response as a two-stage radio-frequency amplifier with detector. A number of ways of obtaining feed back have been employed, but the most satisfactory and popular forms are by tickler coil regeneration which has just been explained, and by tuned plate regeneration, which we shall now consider.

Tuned Plate Regeneration.—Regeneration with a tuned plate circuit is obtained from the arrangement shown in Fig. 59. Any form of variable inductance may be used, in series with the plate circuit, for regeneration, but the *variometer* is most popular because of the smooth and fine control it gives of the inductance. Likewise there are many forms of double-circuit and of single-circuit inductance which can be used for the tuning arrangement shown here. With this arrangement, feed back takes place, not by inductive coupling, as with a tickler, but by capacity coupling. In a tube the conducting wires which connect to the grid, the filament and the plate, are sealed into the glass at the base, fairly close together, with a layer of glass between. This produces a considerable capacity effect as illustrated by the dotted lines in Fig. 60. In a tube, the capacity between filament and grid is coupled to the capacity between filament and plate, and thus the grid and plate circuits are coupled together. The feed-back action

[1] Oscillaton of a vacuum tube circuit does not mean that there is any physical "oscillation" of the filament, plate or grid in the tube.

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depends also upon the capacity of grid to plate, and often may be improved by connecting a variable condenser of about

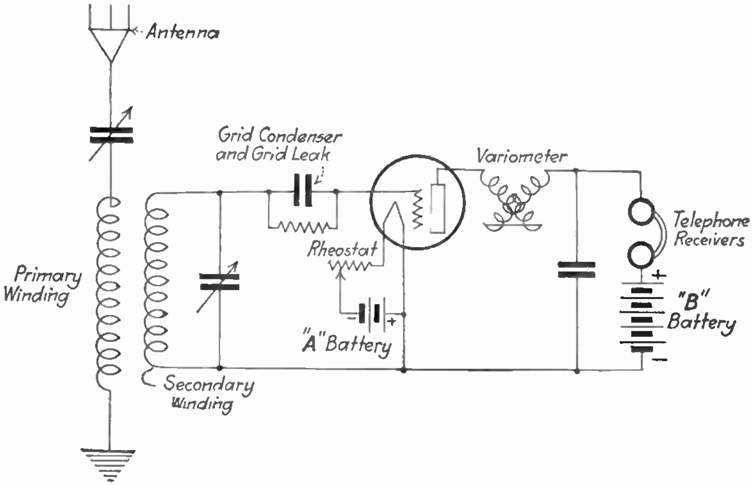

FIG. 59.—Regeneration with tuned plate circuit.

0.0001 microfarad, as in Fig. 61. One disadvantage of the tuned plate method of obtaining regeneration is that the adjustments for regeneration and for tuning are not entirely

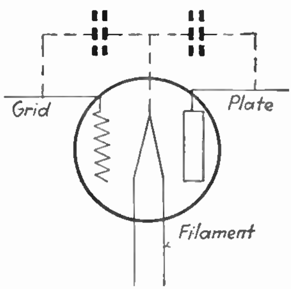

FIG. 60.—Capacity effect in vacuum tube.

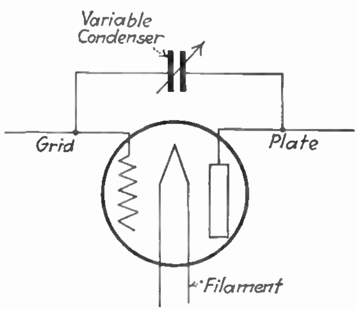

FIG. 61.—Variable condenser for increasing feed-back action.

independent of each other. This does not apply to the tickler coil circuit in which the plate inductance does not vary.

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Armstrong Super-regenerative Receiver.—A super-regenerative set compares favorably with sets using radio-frequency amplification and produces the same results with fewer tubes. The set is so sensitive and powerful, that noises from both within and without the apparatus cause some interference. The use of a loop is advisable because it increases the selectivity and reduces the re-radiation as compared with the antenna. It must be stated here that the adjustment and operation of this set is rather complicated and that not many experimenters have been able to duplicate the results obtained by Armstrong.

In ordinary regeneration, the amplification of the sound in the telephone receivers increases as the amount of feed-back coupling is increased, up to the point where the vacuum tube starts to oscillate and beyond this point the speech and music in the telephone receivers are distorted and these sounds may disappear entirely. In super-regeneration the feed back can be carried much farther than the point at which oscillation starts in a regenerative set. Investigation proved that the oscillation current does not reach its final value instantly, but requires a definite time to build up. The problem, then, was to control the feed back in such a way that the benefit of the high feed-back current was retained but that the tube did not oscillate. This is done by varying the amount of feed back above and below the amount required for oscillation. Thus, the feed back is first increased so that the current builds up almost to the point of oscillation. In the simple regenerative set it is impossible to control the circuit so near the point of oscillation, and the operation is necessarily so far below that the full value of the action is lost.

In the super-regenerative set, however, the control is so accurate that the current builds up to a much greater amount. Before the tube begins to oscillate the feed back is reduced and the current begins to decrease. This variation in the feed back takes place so rapidly that it does not interfere with the signal.

The amount of feed back may be controlled in several ways. Thus, a decrease in plate voltage below a certain point will decrease the feed back and an increase will cause the current to

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build up. Also, if the grid voltage is alternately made positive and then negative with respect to its normal value, the feed back will alternately become greater and smaller.

In order to preserve clarity of tone it is essential that the time between the building up periods be very short. The necessarily rapid variations in grid voltage or plate voltage are obtained most conveniently by using a vacuum tube acting as an oscillator at the required frequency. The variation in grid voltage is accomplished by the arrangement shown in Fig. 62. In this circuit the two tubes are in parallel, that is, the grid and the filament of one tube are "shunted" with the grid and filament of the other. The circuit of tube *O* is so

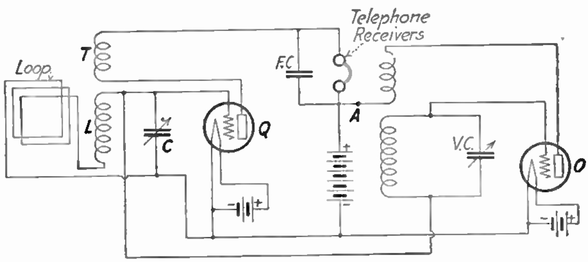

FIG. 62.—Vacuum tube acting as oscillator in super-regenerative circuit.

adjusted that the tube generates current at a frequency which is lower than that being received, while the first tube acts as a regenerator and detector. A grid or "C" battery of 2 to 6 volts may be necessary and should be connected between the grid terminal of the tube and the secondary condenser in such a way that the grid is negative. At the instant when the grid of tube *O* is negative, it acts to increase the grid voltage of tube *Q* in a negative direction, and likewise when the grid of tube *O* is positive, the voltage of tube *Q* will be increased in a positive direction. Tube *Q* is adjusted so that it will cause an increase in the feed back action of its grid voltage is increased in the positive direction but the feed back will decrease if its grid voltage is increased in the negative direction. Thus the signal that is present at the instant when the grid voltage

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begins to increase positively will be amplified until the action is stopped by the decrease in grid voltage.

The telephone receivers might also be placed at the point *A*. in which case, tube *O* would act as both oscillator and detector, In fact super-regeneration may be used in a variety of forms. The duties of regenerator, oscillator, and detector may each be performed in separate tubes; they may be combined in various ways, or they may all be performed by one tube. The frequency of the oscillator must be as low as possible, in order that enough time may be allowed for building up the current yet not so low as to produce noises in the telephone receivers.

Instructions for Operation of Receiving Sets.—In order to save both time and patience, it is desirable to write down the settings of the various dials for stations of different wave lengths. In most sets, when a station is located in this way, it can always be found again at the same setting.

Before starting to operate a set, it is necessary to make sure that antenna and ground connections are made. In a crystal set, the crystal can be adjusted later, by trial. In a vacuum-tube set, the tube is lighted by turning the rheostat knob, or, in some cases, by inserting the phone plug. In no case should the voltage on the filament be increased beyond the manufacturer's recommendations. A voltmeter is useful in locating the position of the rheostat which gives this allowable voltage. If no voltmeter is available, increase the brightness until a faint hiss is heard in the telephone receivers and then turn back the rheostat slightly until the noise is gone. It is important to remember that excessive filament current will shorten the life of the tube and that the tube should be operated at the lowest temperature that will give satisfactory results. For a given value of filament current there is a value of plate voltage which will give best results, so that it is advisable to adjust the plate voltage after the filament current is fixed. However, whenever one is changed, the other should be changed also. Adjustment of plate voltage finer than the taps on the "B" battery may be obtained by the use of a *potentiometer P* connected as shown in Fig. 63. Since this potentiometer connec-

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tion draws current, one end of the "A" battery should be disconnected when the set is not in use.

In a single-circuit crystal set, having a single control the only care necessary in tuning is to make changes gradually so that one does not pass over a transmitting station. The double-circuit crystal set usually has two controls, one for the antenna circuit which we shall call the primary, and one for the coupled circuit, which we shall call the secondary. When the coupling is fixed, the range of broadcasting wave lengths may be explored by moving the primary control slightly each time and the secondary control over the whole range for

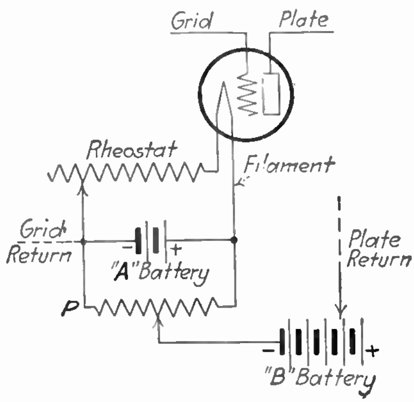

FIG. 63.—Potentiometer for fine adjustment of plate voltage.

each setting of the primary. If the coupling effect is variable, the first move is to get maximum coupling, that is, to get the coils as close together as possible. Then proceed as above for the double-circuit set. After a transmitting station has been located, a decrease in the coupling effect will help to tune out interference from other stations. The primary and secondary controls may then be readjusted slightly until best results are secured.

In tuning a three-circuit set (tuned plate) there are four adjustments to make after the tube filament current is regulated. The first step is to set the coupling control at about midway. Then the primary control is adjusted approximately.

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Finally, using both hands, the secondary and the plate controls are moved over the entire range. It will be noticed that for a given setting of the secondary there is a definite position of the plate control at which the set will oscillate, that is, produce a sort of sizzling or roaring sound. After a little experience the operator can become familiar with these relative settings so that he will rotate both controls over the entire range and keep them at the proper relation so that oscillation is avoided. Then the primary control is again moved slightly and the secondary and plate controls rotated. After a signal is located, the coupling is reduced until the signal is faint, and the primary control changed until the signal is clear of interference. Then the adjustment for volume is made by the coupling control.

In a set which has a tickler coil control, this should be in its minimum position until tuning is completed. When a signal has been located, the volume of sound is increased by turning the tickler control towards maximum, until distortion begins. The control should then be turned back enough to get rid of the distortion.

Super-regenerative Set Operation.—It is not possible to give operating details for the super-regenerative set, since local conditions will affect these to a considerable extent. In general, the tuning of the first vacuum tube is accomplished by means of the turns of wire on the loop and the secondary condenser. The grid battery voltage must be adjusted carefully to the type of tube used. The coupling on all the coils is very close. The proper frequency of the oscillating device is obtained by adjustment of the inductance and capacity in the circuit containing the oscillating tube.

A *vernier* is used to make fine adjustments in tuning. It may consist of a slow-motion attachment on either the inductance or capacity controls, or it may be a small additional condenser which allows small changes in capacity for relatively large movements of the control. After the operator has become familiar with the controls, a little experimenting with the grid leak may improve results. The changes should be

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small and considerable time should elapse between adjustments in order that the results may be compared effectively.

QUESTIONS

1. Expain the detector action of a vacuum tube.
2. (*a*) Why are batteries used with a vacuum tube?
   (*b*) Show by means of a sketch how these batteries are connected to the tube.
3. Draw a diagram of a complete receiving set using a vacuum tube as a detector and tell what happens when a signal is received.
4. What is the difference between a *soft* and a *hard* tube?
5. Where would you connect the grid return wire of a circuit in which a hard tube is used as an amplifier?
6. Name and illustrate two forms of inductance used in radio work.
7. How does *regeneration* in a regenerative receiving set increase the volume of sound?
8. (*a*) Name two methods by which regeneration may be obtained.
   (*b*) Draw a diagram of a circuit using one of these methods.
9. What is meant by an *oscillating* tube?
10. Describe briefly the steps which are necessary in the operation of a regenerative receiving set having a tickler coil.

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CHAPTER VI

SOURCES OF ELECTRICITY FOR VACUUM TUBES

In the application of vacuum tubes to receiving sets, electricity is required to *light the filament* and also to *make the plate of the tube positive* in voltage. Electricity for this purpose may be obtained usually by the use of some kind of battery, the action of which depends upon the chemical energy of the substance employed.

Filament or "A" Battery.—A battery for electric service consists of a number of units called cells. Each cell is composed of two terminals and a supply of chemicals. When the terminals are connected by a wire, an electric current flows in the wire. The two kinds of batteries most commonly used are the *dry* battery and the *storage* battery.

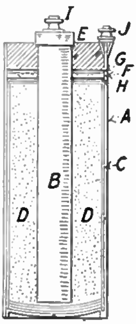

Fig. 64.—Construction of ordinary dry cells.

Actually the dry battery is not dry since it is filled with a material moistened with the active liquid. The center terminal which is made of carbon, is positive; and the side terminal, which is negative, is connected to the zinc container. The most common form of dry cell as shown in Fig. 64, is 2½ inches in diameter and about 6 inches high, known as the No. 6 size. In this figure *A* is the zinc container; *J* is the negative terminal; *B* is the carbon rod; *C* is a pulp board lining; *D* is a mixture of powdered carbon and manganese dioxide moistened with a solution of salammoniac; *E* is a water-tight seal; *F* is a layer of paper (for expansion); *G* is a layer of sand; *H* is a layer of sawdust. The positive terminal is marked (+) and the negative terminal (−). A dry cell has an open-circuit voltage of about 1.5 volts and the maximum of

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short-circuit current is 25 to 35 amperes. Dry cells are intended primarily for intermittent use, but may be used continuously for small currents. The current which can be supplied economically depends upon the duration of its use. This is shown as follows:

Period of use	Amperes
2 hours per day	0.50
4 to 8 hours per day	0.25
Continuous service	0.10

Dry cells deteriorate even when not in use. For average radio work about 0.25 ampere can be taken from the cell. A curve showing the relation between service and rate of discharge is given in Fig. 65.

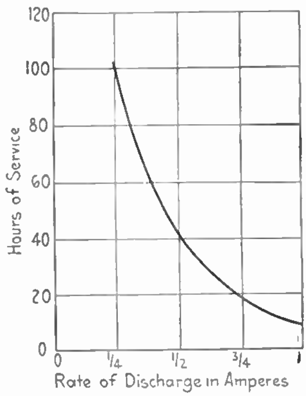

Fig. 65.—Curve of discharge of dry cell.

Testing the "A" Battery.—Lacking a suitable instrument for measuring volts or amperes, the best guide to the condition of the "A" battery is the brilliance of the filament. If that is less than usual and does not increase perceptibly as the rheostat is adjusted, and the sounds in the telephone receivers are noticeably weak, the "A" battery is exhausted. It is best to test dry cells with an ammeter and when the reading of this instrument is less than 5 amperes, new dry cells are needed. A satisfactory ammeter may be purchased for a dollar or two.

Another cause of weak signals is the exhaustion of the tube filaments. The WD-11, WD-12, UV-199, C-299, UV-301A and C-301A vacuum tubes, (see table, page 79) have a special filament which generally becomes dimmed or useless by the exhaustion of certain active material and not by actual burning

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out. If the tubes of a receiving set have been in use for a long period, a weakening in signals may be an indication that new ones are needed.

VACUUM RECEIVING TUBES

Kind	Filament		Rheostat (ohms)	Plate-volts		Filament battery volts	Use
	Volts	Amperes		As detector	As amplifier		
UV-199	3.0	0.06	30	25–40	40–80	D-4.5[1]	Detector
C-299	3.0	0.06	30	25–40	40–80	D-4.5[1]	Amplifier
UV-200 / C-300	5.0	1.0	6	16–25	......	S-6[1]	Detector
UV-201 / C-301	5.0	1.0	6	.....	45–100	S-6[1]	Amplifier
UV-201A	5.0	0.25	6	25	45–120	D-6[1]	Detector
C-301A	5.0	0.25	6	25	45–120	S-6[1]	Amplifier
WD-11	1.2	0.25	6	20–45	45–80	D-1.5[1]	Detector / Amplifier
WD-12	1.2	0.25	6	20–45	45–80	D-1.5[1]	Detector / Amplifier
Myers	3.3	0.8	6	10–20	30–60	S-6[1]	Detector / Amplifier
DeForest	2.0	0.06	30	26–40	40–80	D-3[1]	Detector / Amplifier
Silvertone	3.0	0.15	30	25–40	40–80	D-4.5[1]	
DV-6A	5.0	0.25	6	25–40	40–80	S-6[1]	
	2.7	0.3	6	22–45	45–80	D-3[1]	
Sodion	3.5–4.5	0.2	30	15–25	......	D-6[1]	Detector
VT-I	3.6	1.2	6	20	60	S-6[1]	Detector / Amplifier

[1] D—Dry cells; S—Storage battery.

VACUUM POWER TUBES

Kind	Filament		Plate-volts	Plate-amperes	Watts output
	Volts	Amperes			
VT	7.0	1.35	350	0.04	
UV-202	7.5	2.35	350	0.05	5
UV-203	10.0	6.50	1,000	0.15	50
UV-203A	10.0	3.25	1,000	0.125	50

Size of Rheostat Required for Vacuum Tubes.—In deciding what size of rheostat to use, it is necessary to know the battery

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voltage and the current consumption. Thus in the case of a UV-201A tube which requires 5 volts for the filament, and takes 0.25 ampere, the current is about as high as can be supplied by dry cells. Since each new dry cell has a voltage of 1.5, four cells connected in series will be needed as shown in Fig. 66. In a series connection the total voltage is always the sum of the individual voltages and in this case is 6 volts.

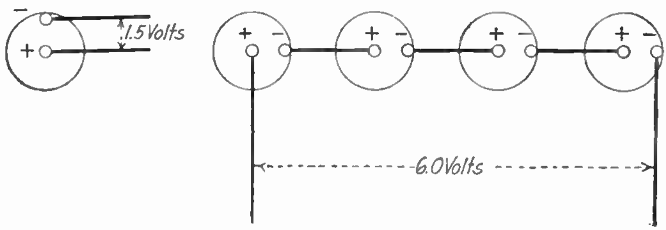

FIG. 66.—Dry cells connected in *series*.

Since only 5 volts are required and the dry-cell battery gives 6 volts, it is necessary to produce a voltage drop (loss of volts) of 6 minus 5, or 1 volt. Remembering that electrical resistance in ohms is equal to voltage drop divided by amperes, then the required resistance of the rheostat is 1 volt divided by 0.25 ampere, or 4 ohms. Rheostats are commonly made in 6 to 30-ohm sizes, so in the case above, the 6-ohm size will be sufficient. Figure 67 shows two cells connected in parallel. This arrangement might be used to light the filament of a WD-11 or WD-12 tube which requires 1.2 volts and 0.25 ampere. The total current would be divided by parallel connections, so that in this case, each cell would give one-half of 0.25 or 0.125 ampere, and the life of the cell would, of course, be increased considerably. Here the size of the resistance required is equal to $\frac{1.5 - 1.2}{0.25}$ or 1.2 ohms, hence a 6-ohm rheostat would be used.

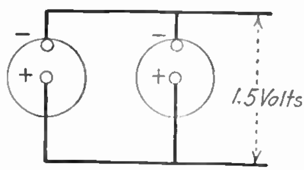

FIG. 67.—Dry cells connected in *parallel*.

When a current of more than 0.25 ampere is required it is neither economical nor convenient to use dry batteries because

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they last but a short time. For such purposes the storage battery is generally used. The essential difference between a dry battery and a storage battery is that in a dry battery the operation depends entirely upon the chemical energy of the materials and when this energy is used up the battery must be replaced by a fresh one, while in a storage battery the chemical energy can be built up by the process of passing an electric current through the battery, which is called *charging*. After a storage battery is charged, a current can be drawn from it, and when it is discharged its chemical energy can be built up again by charging[1] it once more. Storage batteries are now rated in ampere-hours, and sometimes a definite period of discharge is stated. Thus, a battery having a capacity of 60 ampere-hours at 5 hours will deliver 12 amperes for 5 hours. If the discharge is greater or less than this rate, the capacity is decreased or increased somewhat. Thus, a flow of 60 amperes would discharge the battery in less than one hour while a flow of one ampere could continue for somewhat more than 60 hours. A 60-ampere-hour battery would supply for example, four UV-201A vacuum tubes for more than 60 hours.

The size of battery to use depends largely upon the rate at which current is taken out and how often the battery is charged. For currents of 1 to 3 amperes a 60-ampere-hour storage battery is generally used, while for currents as small as about 0.1 ampere, a special low-capacity storage battery can be used which is much smaller and cheaper than the large size; or even dry cells may be economically used.

The two general types of storage batteries are the lead-plate batteries, using an acid as the active liquid and the nickel-iron batteries, using an alkali. Lead batteries consist of lead plates placed in a sulphuric acid solution. The container is usually made of hard rubber. The lead plates are generally of the *pasted* type consisting of a frame into which lead oxide paste is pressed. These plates are then *formed* by charging

[1] The amount of electrical energy required in charging is measured in watt-hours (a watt-hour is equal to the product of voltage in volts, current in amperes and time in hours). Since an ampere represents rate of flow of electricity, the product of amperes and hours, called ampere-hours, gives a measure of the amount of electricity used in charging.

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with direct current. During this process the lead oxide of the plates intended for "positives" changes to lead peroxide which is brown in color, while the oxide of the other plates is changed to sponge lead which is grey. To prevent contact between plates, wood or rubber separators are inserted. The complete

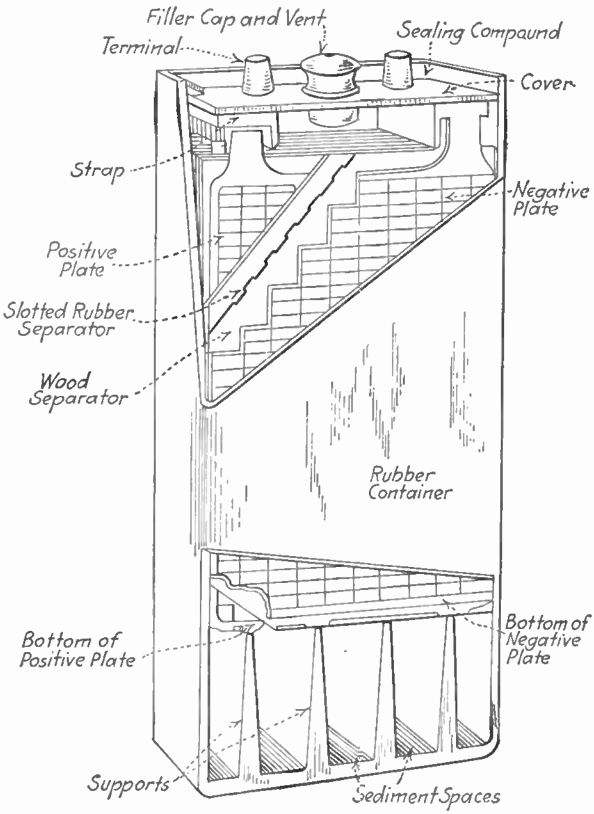

FIG. 68.—Typical lead-plate storage battery.

cells are joined together to form a battery by connectors which are welded to the terminal posts. A lead-plate battery is shown in Fig. 68.

The positive plates of nickel-iron batteries are made of steel and contain nickel oxide while the negative plates contain

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a finely divided iron. The active liquid is a potassium hydroxide solution. The container of this battery is of steel and the cells are joined together to form a battery by means of copper connectors. Since the container is a conductor the cells must be insulated. This is done by a tray which keeps the cells separated by means of suspension bosses on the sides of the cells. This type of battery is shown in Fig. 69.

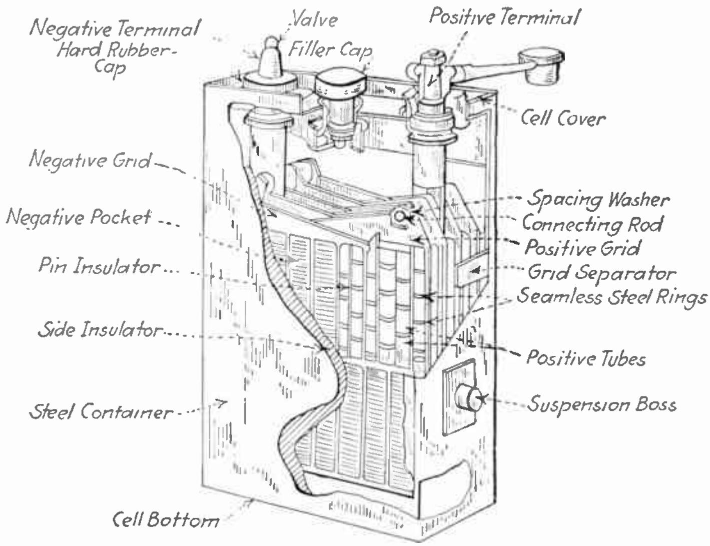

FIG. 69.—Typical nickel-iron storage battery.

The positive terminal of a storage battery is sometimes marked +, or with the letters POS, or by a spot of red paint, or by a red bushing around the positive terminal post. If none of these are to be seen, the polarity can be determined by connecting a voltmeter to the two battery terminals. If the needle of the meter swings to the right, then the battery terminal which is connected to the positive terminal of the voltmeter, is positive. Another method is to attach a copper wire to each of the terminals of the storage battery and then put the free ends of the wires a short distance apart in a glass

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vessel containing water in which a little salt has been dissolved—about a teaspoonful to a pint of water. The electric current will decompose the water and bubbles of hydrogen gas will collect at the wire connected to the negative (−) terminal of the battery. This test must be made with great care that the two wires do not touch each other either when in

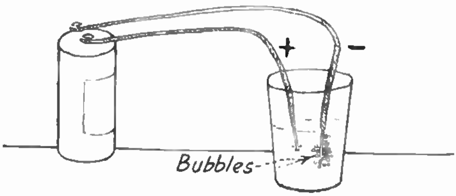

FIG. 69*a*.

salt water solution or outside, as a short-circuited current would heat the wires to redness and might cause painful burns. This method of determining the polarity of electric current is illustrated in Fig. 69*a*. A similar method by the use of a potato from which the top has been cut is shown in Fig. 69*b*.

The open-circuit voltage of *each cell* of a lead-plate battery is 2.0 volts, but when discharge is at a normal rate, the voltage

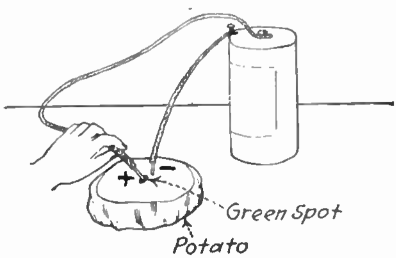

FIG. 69*b*.

gradually falls to about 1.75 at which point the complete capacity has been delivered. The voltage of a nickel-iron battery ranges from an open-circuit value of about 1.45 to 1.52 volts, to about 0.9 volt, at which point the capacity has been delivered. The voltage of the nickel-iron battery falls more rapidly than that of the lead-plate battery. Since this requires frequent adjustment of the filament rheostat, the lead plate

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is better suited then the nickel-iron battery for lighting the vacuum tubes.

The state of charge of the nickel-iron battery cannot be ascertained by the specific gravity of the liquid, as is the case with the lead-plate battery. The specific gravity of a lead-plate battery may be obtained by means of a syringe hydrometer (Fig. 70), which consists of a weighted float with a graduated scale in a glass tube. The tube is open at one end and has a rubber bulb at the other, so that the battery liquid may be sucked up into the tube. When this is done the float will take a certain position and the reading on the graduated scale of the float at the surface of the liquid corresponds to the specific gravity of the liquid. The specific gravity ranges from 1.275 to 1.300 when the battery is fully charged, and is 1.140 at complete discharge. The readings should be taken frequently (once a week) and the battery recharged when the specific gravity falls to 1.200. The supply of liquid should be kept ½ inch above the plates by adding distilled water. Acid should be added *only* when some of the liquid has been spilled. The distilled water and acid can be obtained at drug stores, automobile and battery service stations.

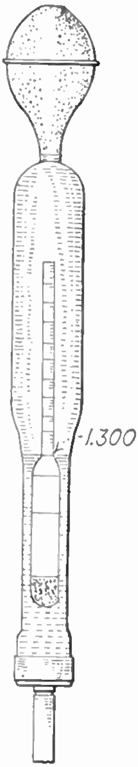

Fig. 70.—Hydrometer for testing storage batteries.

The cost of having a battery charged at a service station is rather high and the inconvenience of moving the battery is considerable. For these reasons many people prefer to do their own charging. The type of charging equipment depends upon the source of power. If the electric service is direct current, the battery may be charged from a lamp socket provided that a suitable rheostat or a number of lamps is placed in the circuit to control the amount of current, as shown in Fig. 71.

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Rectifiers.—For charging storage batteries, an alternating-current supply must first be rectified and its voltage reduced to about 12 to 15 volts by means of a device called a *rectifier*. This kind of apparatus does not change an alternating current to a direct current but it has the effect of cutting in two the alternating-current wave, so that only one-half of the current wave passes through the instrument. The other half of the wave does not get through, and yet is not wasted. This means that the electric current delivered at the terminals of the

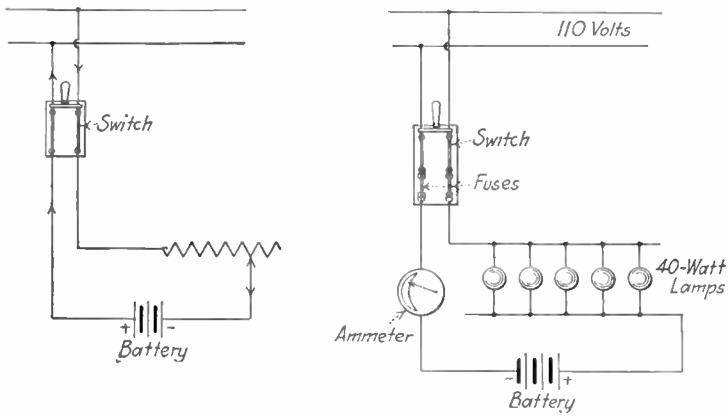

FIG. 71.—Device for charging storage batteries with direct current.

instrument comes along in pulsations which are so rapid, however, as to be effective for charging storage batteries. No current is wasted in this device because no current flows into the battery during the *off* half of the wave, and therefore no energy is taken from the supply circuit.

There are several types of rectifiers, among which are the chemical or electrolytic, the mechanical or magnetic or vibrating, and the vacuum-tube rectifiers. The vibrating type is the most economical but requires some care in adjustment and is somewhat noisy. The chemical type is cheap, easy to make and gives fairly satisfactory operation. It is less efficient than the vibrating type and moreover has the objection that the solution may spill over or leak out. The vacuum-tube type such as the "tungar" and "rectigon" is the least efficient,

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and costs more. In deciding upon the type of rectifier, however, efficiency is not so important a consideration as the ease and constancy of operation and the amount of adjustment required. From this point of view the vacuum-tube rectifier is the most desirable.

The positive terminal of the charging device must be connected to the positive terminal of the battery. Failure to observe this will result in injury to the battery.

The vacuum-tube type of rectifier consists of a bulb, not unlike a bulb of an electric light, which is attached at the

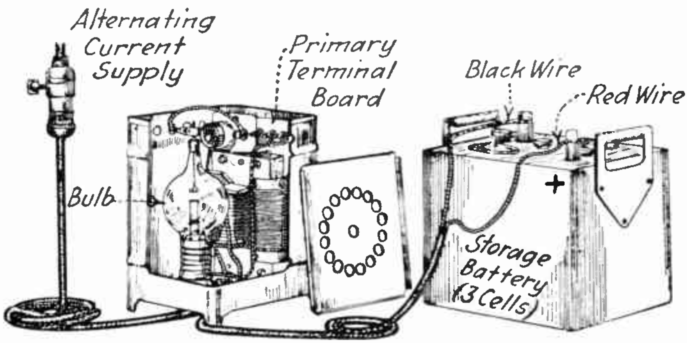

FIG. 71*a*.

bottom to a socket or screw base connected electrically to tungsten wires, separating near the middle of the bulb into a short filament of special Tungsten alloy. A short rod of nickel is fused into the top of the bulb and has on its lower end a small graphite plate inside the bulb already described. A typical vacuum-tube rectifier is shown in Fig. 71*a*, and standard bulbs in Fig. 71*b*. The bulb "rectifies" the alternating current for the reason that on one-half of the alternating-cycle when the incandescent tungsten filament is negative, the electric current is drawn toward the graphite plate; that is, making the gas inside the bulb conductive for electricity in the direction from the graphite plate toward the tungsten filament. On the other half of the alternating cycle when the tungsten filament is positive, the tendency is for the electric current to

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be driven back into the filament, because now the gas in the bulb is non-conductive for electricity.

All bulbs, whatever the material of which they are constructed, are carefully exhausted to the highest possible vacuum and then filled with argon gas in a high state of purity; but as certain impurities, even though present in very small quantities, produce a more or less rapid disintegration of the tungsten filament and also have quite a marked effect on the voltage characteristics of the rectifier, means must be used to insure absolute freedom of the argon gas from these other

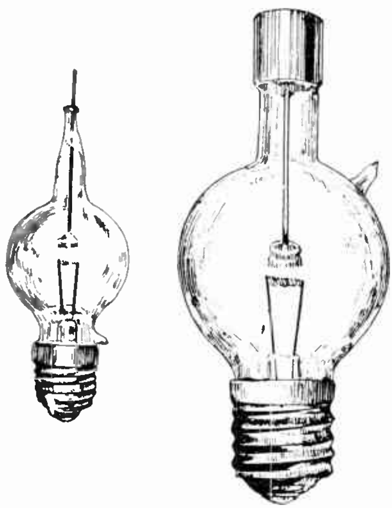

FIG. 71*b*.

gases. To accomplish this, certain substances are introduced into the bulb at the time of manufacture, which chemically react with such impurities as may be present in the bulb. This reaction keeps the gas in a pure state practically throughout the life of the bulb. This purifying agent is shown in Fig. 71*b* in the form of a wire ring on the graphite. As soon as the tube is started, the purifier is volatilized and absorbs any foreign gases and also (unfortunately for the appearance of the bulb) somewhat discolors the interior of the bulb. This

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is particularly true of the lower voltage bulbs in which a larger amount of purifying agent is used.

Figure 71*c* shows the connections of a half-wave rectifier in its simplest form. The equipment in this case consists of the bulb *B*, with a tungsten filament *F* and graphite plate *A*, transformer *T* for exciting the filament, rheostat *R*, and the load which is shown as a storage battery.

Assuming an instant when the side *C* of the alternating-current supply is positive, the current follows the direction of the arrows through the load, rheostat, and bulb, and back to the opposite side of the alternating-current line. A certain amount of the alternating current, of course, goes through the transformer *T* to excite the filament, the amount depending

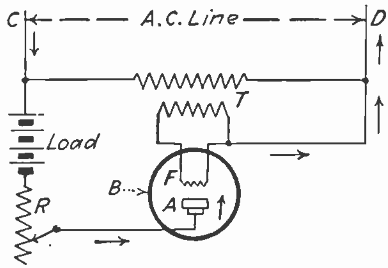

FIG. 71*c*.

on the capacity of the bulb. When the alternating-current supply reverses and the side *D* becomes positive, the current is prevented from flowing for the reason already mentioned. In other words, the current is permitted to flow from the graphite plate to the tungsten filament. The rectifier must include a transformer which serves to reduce the voltage, usually from about 115 volts to 30 volts for small outfits and to 75 volts for larger ones. For a storage battery an impressed voltage of 2½ volts per cell is necessary so that the transformer voltage is reduced from 30 volts or 75 volts as the case may be, to the number of volts necessary for the number of storage cells being charged, by adjusting a suitable resistance which serves to reduce the current, as necessary in order to make the maximum voltage per cell about 2½. The small sizes of these instruments have an equivalent

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direct-current rating of 2 amperes for a three-cell battery, and 1½ amperes for a six-cell battery, and for any number of cells up to 12 in the battery, the cells can be charged in series at proportionately reduced current rates. Although this rating is best on a normal line voltage of 115 volts, satisfactory operation will be obtained on an alternating-current circuit of from 105 to 125 volts. A small 2-ampere outfit is ideal for private use, as a small direct current will not injure the storage battery if the charging outfit is connected longer than the usual period. It is not intended, however, for service where a full charge must be given overnight. It should rather be used as a tank to refresh the battery as occasion demands. By frequent use of 2-ampere outfits in connection with the generator of an automobile, for example, the cells of the storage battery of an automobile can be kept in fully charged condition, thus prolonging the useful life of the battery.

On the other hand, where it is necessary to supply a large amount of current to provide for nearly a full charge overnight, a larger outfit (probably 5-ampere capacity) should be used. However, a 2-ampere size will deliver sufficient electrical energy overnight to revive a rundown battery so that it can be used the next day.

Most automobiles and radio sets have batteries ranging in *rated* capacity from 80 to 150 ampere-hours, which require for a full charge approximately 120 per cent of the *rated* ampere-hours. Since the ampere-hours delivered to the charging circuit are the product of the amperes flowing and the time in hours, it is obvious that the 2-ampere outfit will deliver 2 amperes per hour to a three-cell storage battery. The charging time, therefore, for a 100-ampere-hour battery will be about $(100 \times 1.20) \div 2$, or about 60 hours. The long time required to supply a full charge to the average automobile or radio "A" battery has led some people to believe that a full charge would not be obtained with the small number of amperes available with the smaller outfits. This is not the case as all batteries which are capable of receiving and holding a charge can be successfully brought to a state of full charge if the charging period is sufficiently long.

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Plate or "B" Battery.—The plate circuits of the vacuum tubes of receiving sets use voltages ranging from 20 to 120 volts. This voltage is generally obtained by the use of dry batteries. The standard unit, giving 22½ volts is made of 15 small cells in series. When higher voltages are required, the necessary number of these units are connected in series. The current taken from a plate battery is so small that the life of the battery is determined by natural deterioration rather than by discharge. Some plate batteries are made up of ordinary flash-light cells which are designed for rather heavy current output and not particularly for long life. A battery which is designed to give the long life and low current required in radio work will give better service.

Testing the "B" Battery.—As long as dry cells contain a sufficient amount of electrical energy, the drop in voltage from day to day is so little that it can scarcely be noticed. When, however, the cells in the "B" battery become exhausted beyond their useful life, the voltage begins to fall very rapidly and the effect of reduced voltage will then be observed by the weakness of the currents received. The human ear is very sensitive to large changes in voltage, as indicated by change in strength of the sounds of speech or music in the telephone receivers, and is the best guide in testing to determine whether dry cells are exhausted when no instruments are available. When the operator has increasing difficulty in getting distant stations and when the local stations fail to come in as loudly as they usually do, it may be assumed, provided the vacuum tubes are sufficiently bright, that the "B" battery is exhausted and should be replaced.

An exhausted "B" battery produces very peculiar frying and hissing noises in the phones which are frequently mistaken for *static*. Exhausted "B" batteries are best detected by the voltmeter test. The useful life of the battery is ended when the voltage falls below 17 volts.

A "B" storage battery for use in plate circuits may be obtained. Such batteries are made with a capacity of about 2 ampere-hours and have a voltage of about 24.

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Charging Radio "B" Batteries.—On a line voltage of about 115 volts an eleven- or twelve-cell radio "B" storage battery can be charged at an approximate rate of 0.4 ampere, with the small 2-ampere outfit. Since the voltage of the eleven- or twelve-cell battery approaches quite closely (especially toward the end of its charge) to the standard voltage of the small outfits, that is 30 volts, there is practically no resistance in a transformer circuit during the charging period. It should be noted that in case of exceptionally low line voltage, as for example below 100 volts, an outfit of this kind may fail to start.

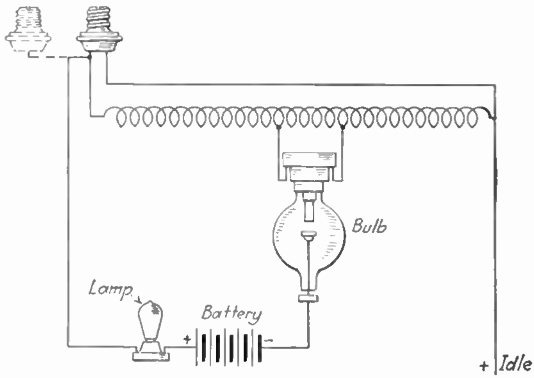

FIG. 72.—Vacuum tube rectifier for charging "B" batteries.

It is always desirable when charging storage batteries to have a rheostat for adjusting the current and an ammeter for reading the current in series with the battery. It is easy to provide for charging "B" batteries up to 45 volts by leaving idle and taping the regular positive lead and running a special wire to the other side of the alternating-current line as shown in Fig. 72. This gives an increased voltage and hence a mazda lamp of suitable rating, as given in the table below, should be connected as a resistance unit to cut down the amount of current flowing. This extra wire may be connected to one side by an extra separable plug shown dotted in Fig. 72, and by using a double socket, in which case the line connections can be changed by simply reversing the prongs of

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the plug. When the connections are correctly made the lamp will light but will not reach full brilliancy as the current will always be less than the rated current of the lamp. If the lamp glows dimly or entirely fails to light, the wire to the lamp is connected to the wrong side of the line circuit.

TABLE I.—CHARGING RATES OF RADIO "B" STORAGE BATTERIES WITH VARIOUS SIZES OF LAMPS

Rating of lamp, watts	Charging current (one 11- or 12- cell battery), amperes	Charging current (two 11- or 12-cell batteries in series), amperes
25	0.075	
40	0.125	0.090
60	0.165	0.125
75	0.250	0.175
100	0.275	0.225
150	0.350	0.275

Usually physicians and other professional men who operate their automobiles daily, draining the battery with numerous starts or by continued burning of the lamps, desire a charging outfit that will put in the largest part of a full charge overnight. For service of this kind, where the charging time is important, the 5-ampere outfit is recommended; also for radio service where the receiving set has a number of high-current tubes that discharge the "A" battery in a comparatively short time.

During the charging period a lead-plate battery gives off gases which may form an explosive mixture. Good ventilation should be provided and care taken that no open flame of any kind is brought into the room.

Storage batteries for both "A" and "B" use are now made which incorporate a rectifier in the container. This adds greatly to the convenience of charging, since it is only necessary to connect it to a light socket. When a larger number of batteries is to be charged it is most economical to use a motor-generator set. This is arranged so that the motor, operating

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on the alternating-current line, runs the generator which delivers direct current.

Direct Current for Filament and Plate.—The voltage of the ordinary direct-current power line is constant in value, for all ordinary purposes. Actually it has small variations or ripples in value which would produce a hum in the telephone receivers of the receiving set. In using a direct-current source of power for the filament and plate circuits it is necessary to insert the proper amount of resistance in order that the voltage may be reduced to the required value, and also, to use some form of filter for the purpose of smoothing out reasonably well the ripples in the current. Suitable forms of filters are mentioned later in this chapter. Very often the expense of a suitable filter system is too high to justify its use. It is often difficult to obtain the high value of direct-current voltage which is required for plate circuits (particularly in transmitting sets). This difficulty is remedied by using a system including a transformer, a rectifier, and a filter intended for alternating current.

Alternating Current for Filament and Plate.—If the filament of a vacuum tube is lighted by means of a proper transformer from an alternating-current circuit (batteries being used for the plate current) radio telephone currents will be received but will be accompanied by a loud humming noise, which is due to the alternations of the current. If, on the other hand, the alternating current is applied, through a transformer, to the plate circuit, the signals will be unintelligible, since the plate is made alternately positive and negative; thus first allowing and then blocking, the flow of current.

In the case of the filament, the difficulty can be overcome by using the arrangement shown in Fig. 73 in which the grid return wire is connected to the movable arm of the potentiometer *P* (which may have a value of about 1,000 ohms). If the grid return wire is connected to the filament, the voltage variations will be transmitted to the grid and will thus cause fluctuations in the plate current which produce the hum mentioned above. But with the arrangement shown, a neutral point may be found, by adjusting the potentiometer, at which

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the voltage variations, due to the drop in the filament, are not introduced into the grid and plate circuits. The same result

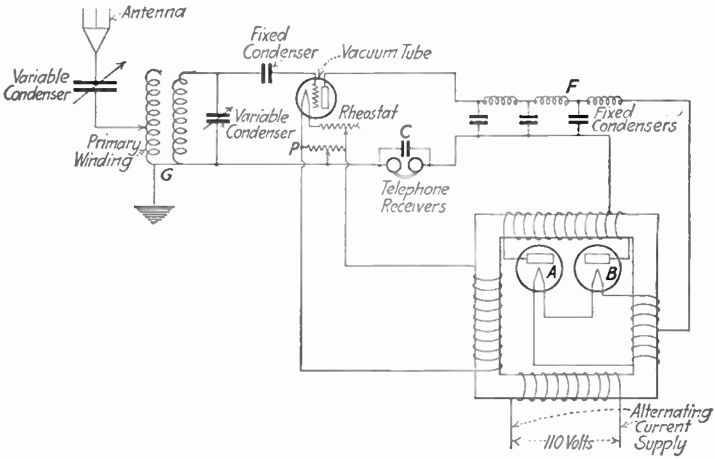

FIG. 73.—Potentiometer connections for alternating current.

can be accomplished by the arrangement shown in Fig. 74 in which the grid and plate connections are made to the mid-

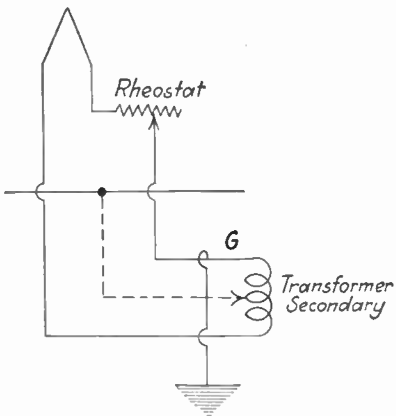

FIG. 74.—Transformer connections for alternating current.

point of the filament transformer (secondary). Note that in each arrangement a ground connection is indicated at *G*.

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In the case of the plate circuit, the difficulty can be overcome by using some device which will change the alternating current into a direct current. Such a result is accomplished approximately by utilizing, first, a rectifier, to change the alternating current to a pulsating direct current, and second, a filter system to change the pulsating direct current into a form approaching that of a "pure" direct current.

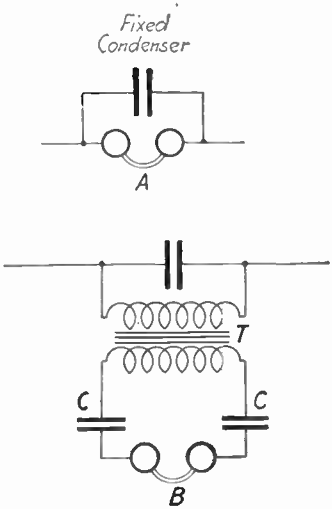

FIG. 75.—Devices for reducing hum.

One arrangement for producing this result is shown in Fig. 73. Here *A* and *B* are rectifier tubes which are connected so that they utilize both halves of the current cycle and which deliver a pulsating direct current. This pulsating direct current is smoothed out by the combination of inductances and capacities in the *filter F*, and is then delivered to the plate circuit.

Sometimes the hum may be further reduced by replacing the phones as shown at *A* (Fig. 75) by the arrangement at *B*, in which *T* is a telephone or output transformer and *C* a condenser of about 0.001 microfarad. This has the effect of blocking any low-frequency variations due to the alternating-current supply which may still be present.

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QUESTIONS

1. How would you test the condition of an "A" battery, and what should be the value of the readings obtained?
2. Show the method by which you can determine the proper size of rheostat to use with a UV-199 tube.
3. What is meant by the ampere-hour capacity of a storage battery?
4. Describe the use of a vacuum-tube rectifier in charging a battery.
5. (*a*) How would you test a "B" battery?
   (*b*) When should this battery be replaced?
6. What precautions are necessary when a direct-current source of supply is to be used for the filament and plate circuits?
7. What precautions are necessary when an alternating-current source of supply is to be used for:
   (*a*) the filament circuit?
   (*b*) the plate circuit?

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CHAPTER VII

AUDIO-FREQUENCY AMPLIFICATION

Stages of Amplification.—It has been shown that feeble voltage variations in the *grid* circuit of a vacuum tube produce comparatively large changes in the *plate* current. In a continuation of this method, it is obvious that the increased or amplified current from one vacuum tube may be passed into a second tube which will still further increase or amplify the radio current and then again the current from the second tube may be passed into a third tube and amplified still more. Each one of these tubes with its related apparatus gives *one stage of amplification*. By means of amplification spoken words and music may be heard in the telephone receivers, which are too weak to be heard without such amplification. Any of the *hard* tubes now sold commercially may be used for amplification. As a rule, a vacuum tube when used for amplification requires a much higher plate voltage than when used in a detector. The plate voltage depends upon the kind of tube and also upon its position in the circuit. Thus the *plate voltage* for a tube in the second stage of amplification may be two or three times as great as that for the first tube. Likewise the voltage on the plate of the third-stage tube may be greater than that on the second tube.

Types of Amplifiers.—There are two general types of amplifiers; first, those which amplify the radio current *before* it has passed through the detector; and second, those which amplify the radio current *after* it has passed through the detector. Those of the first type are called *radio-frequency amplifiers* and those of the second type, *audio-frequency amplifiers*. The position of these amplifiers in a receiving set may be represented as in Fig. 76.

The principle of operation is the same for both types of amplifiers, but the fact that the one deals with a high-fre-

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quency (radio frequency) current and the other with a low-frequency (audio frequency) current, accounts for the difference in the design and use of these two types.

Thus it might be said that the object of amplification is not only to make audible sounds louder, but also to increase inaudible sounds so that they may cause a perceptible effect. Amplification at audio frequency is effective only if the radio current is originally strong enough to produce variations in the plate current of the detector of such magnitude that they are *audible* in the telephone receivers after amplification. If the original radio current is so weak that it produces no perceptible sound in the telephone receivers even after passing through the audio-frequency amplifying tubes, some other

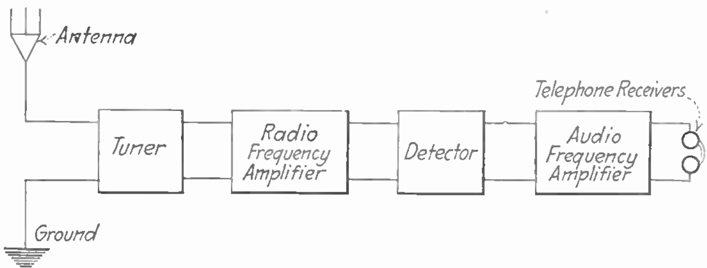

FIG. 76.—Position of amplifiers in radio receiving sets.

method becomes necessary. For this purpose amplification at radio frequency is used so that the variations of the radio current are increased before reaching the detector, by applying the principle that the amplification of the radio current by a vacuum tube when used in a detector, varies as the square of the voltage impressed on the grid. To make this clearer, assume that an amplifying tube is used which is capable of increasing a radio current 5 times, either before or after it has passed through the detector. Also, assume some value of current flowing in the plate circuit of a detector vacuum tube. If now a vacuum tube is used to obtain *audio-frequency amplification*, that is, if it is placed so that it receives the radio current *from* the detector tube, the value of the radio current in

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the plate circuit of the amplifier will be 5 times as large as the current which flows *in* the plate circuit of the detector vacuum tube. If, however, the vacuum tube is used for *radio-frequency amplification*, that is, if the tube is placed so that the radio current coming from it will be passed on to the detector tube, the voltage at the detector tube will be 5 times the value of the voltage at the amplifier tube. Now, since the plate current of a detector varies as the square of the impressed voltage, the current in the plate circuit of the detector tube as used in radio-frequency amplification is now 5 times 5, or 25 times the original value.

But, particularly at the wave lengths required, radio-frequency amplifiers cannot be constructed to operate as well as those for audio frequency, because of the effect of the grid-filament capacity of the vacuum tube upon the degree of amplification. On the other hand, the audio-frequency amplifier increases not only the volume of the spoken words or music in the telphone receivers, but also all the low-frequency noises which may arise in the set whether they come from the outside such as regenerative noises, or from the inside, such as battery and vacuum tube noises. For these reasons, *audio-frequency amplification is used more extensively at present than radio-frequency amplification.*

Types of Audio-frequency Amplifiers.—In actual practice it is not possible to connect the plate terminal of one vacuum tube directly to the grid terminal of the next tube. This will be understood readily when we remember that the plate circuit requires a battery to produce a *current* flow, while the grid is used to introduce *variations in voltage.* Thus it is necessary to use a device which includes a "B" battery in the plate circuit of one vacuum tube and passes on only the voltage variations to the grid of the next vacuum tube. Amplifiers are classified according to the type of device used for connecting or *coupling* one vacuum tube to the next. The three types are:

1. Transformer coupling,
2. Resistance coupling,
3. Inductance coupling.

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Whether an amplifier is made in the form of a separate unit or whether it is built into the receiving set is a matter of construction only and will not affect the discussion here. A set may be

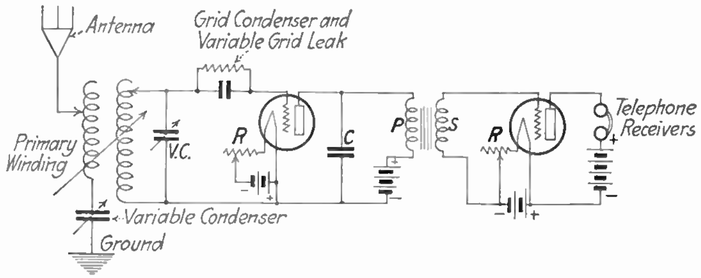

FIG. 77.—Audio-frequency amplification by transformer coupling.

provided with either audio- or radio-frequency amplifiers, or both, either built in or in separate units.

Transformer Coupling.—An arrangement using one stage of audio-frequency amplification is shown in Fig. 77. In order to show the connections and action more clearly, separate batteries are indicated. In the figures to follow, the same "A" and "B" batteries will be used on the detector and the amplifier. The audio-frequency transformer, as shown in Fig. 78, is made up of two coils, a primary and a secondary, placed on an insulated form and having an iron core. The secondary winding has more turns than the primary in order to increase or *step up* the voltage. The usual ratio of the number of turns in the coils is 3 or 4 to 1, but transformers with a ratio of 10 to 1 may be obtained. The best value of this ratio depends upon the design of the set and the kind of tube.

FIG. 78.—Audio-frequency transformer with iron core.

The primary winding *P* is placed in the *plate* circuit of the *detector*, and the secondary winding *S* in the *grid* circuit of the amplifier. The grid circuit of the detector may have any type of *tuner*—the double-circuit variety is shown here. The condenser[1] *C* serves as a by-pass for any radio-frequency current.

In the operation of this set, the current in the primary winding *P* of the transformer induces a voltage in the secondary winding *S* which is impressed on the *grid* of the vacuum tube of the amplifier and produces magnified current variations in the plate circuit. A steady current from the "*B*" battery in passing through the primary winding of the transformer does not induce any current in the secondary winding since only a *varying* current in one winding will induce a current in the other. Because of this, it is not possible to transfer a steady current, but an alternating current will pass readily. The ratio of the secondary to the primary voltage is the same as the ratio of turns of wire in the secondary winding to turns of wire in the primary winding.

If more volume of sound in the telephone receivers is desired, one or two more stages of amplification may be added. This, of course, means correspondingly greater magnification of noises due to induction, static, and physical vibration and unless great care is taken the noises will be louder than speech or music in the telephone receivers.

It is possible also to combine regeneration with audio-frequency amplification. A circuit using a tickler coil for regeneration and two stages of audio-frequency amplification is shown in Fig. 79. Note that the grid return of the detector is connected to the positive side of the filament, while the grid returns of the two vacuum tubes of the amplifier are connected to the negative side of the filament. In the case of the amplifier tubes even this connection may not make the grid *negative* enough for satisfactory operation. This difficulty may be overcome by the use of a *potentiometer* or of a "*C*" *battery.* On pages 151 (table) and 226, will be found the values of "C" voltage to use for various plate voltages on different types of vacuum tubes. One disadvantage of transformer coupling is

[1] In many cases the distributed capacity of the transformer windings is large enough and will serve instead of the condenser.

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that the amplifying power of the ordinary transformer varies at different frequencies, which leads to some distortion. The reason for this variation is that the transformer has a point of resonance at a certain frequency and thus one or a few frequencies come through more easily than others. Some manufacturers claim that they can produce a transformer which amplifies consistently over a wide range of wave lengths. Equal amplifying power over the required range of frequencies may be obtained in several ways, some of which, however, decrease the amplification. In some amplifiers with more than two stages of amplification it is claimed that the transformers may be so chosen that the resonance points occur at

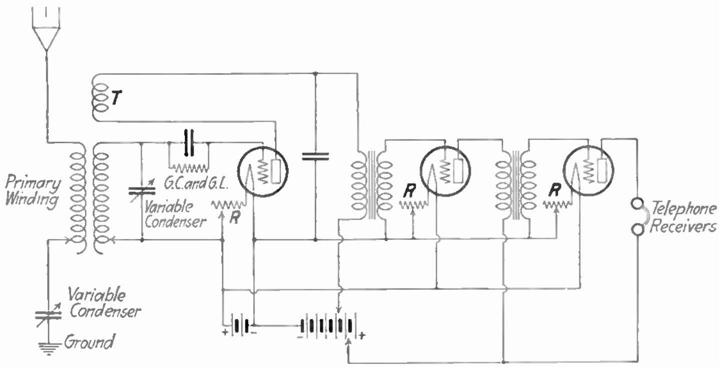

Fig. 79.—Tickler coil for regeneration with audio-frequency amplification.

various frequencies over the entire range. This gives an approximation of the ideal equal amplification.

Resistance Coupling.—The type of coupling for vacuum tubes which uses a simple resistance for this purpose is nearly independent of variations of the frequency of the radio currents and amplifies without appreciable distortion the low-frequency current coming from the detector. At the high frequencies, however, of some of the wave lengths now commonly used, the resistance included in the coupling may be practically short-circuited by the capacity action between the vacuum tube elements. This effect is somewhat less noticeable at high wave lengths, but, as a rule, other methods of coupling give better

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results. The application of the resistance method of coupling vacuum tubes in an amplifier is shown in Fig. 80, for two stages of audio-frequency amplification. Here the variation of the plate current in the resistance R_1 produces across it a varying voltage drop which actuates the grid of the vacuum tube of the amplifier. In order that the plate voltage of the detector tube is not impressed on the grid of the amplifier it is necessary to insert a so-called *blocking condenser C*. The grid is kept negative by means of the resistance *r*, and, if necessary, by the use of a "C" battery. The voltage drop in the plate circuit lowers the normal plate voltage and hence the "B"

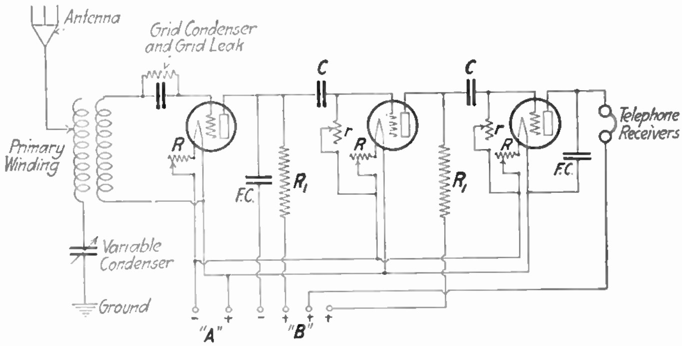

FIG. 80.—Audio-frequency amplification by resistance coupling.

battery voltage must be increased enough to compensate for the loss. One of the most important disadvantages of this method of coupling is the high "B" battery voltage needed. The resistance *r* is of the standard variable grid-leak form and the coupling resistance R_1 may have a value of from 10,000 ohms up. For maximum voltage output the resistance used in the plate circuit may have a value equal to 2 or 3 times the average internal resistance of the vacuum tube between the filament and the plate. With the vacuum tubes ordinarily available, resistance coupling does not give so high a degree of amplification as some of the other methods.

Inductance Coupling.—This method uses an inductance instead of a resistance in the plate circuit. The theory of

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the action is the same as that for the resistance coupled amplifier. Two stages of amplification are shown in Fig. 81.

The inductance L may be of any form. The small *blocking condensers* C_1 and C_2 and the grid-leak resistances, r, perform the same function as in the resistance coupling. The first plate circuit is tuned by means of the *condenser* C and the selectivity is thus increased. In this method of coupling, as in the preceding, the amplification in one stage cannot be greater than that of the vacuum tube itself. It has the advantage that the inductance[1] offers very little resistance to direct-current flow. Therefore, the amount of direct-current energy lost is small and the "B" battery voltage need not be so high.

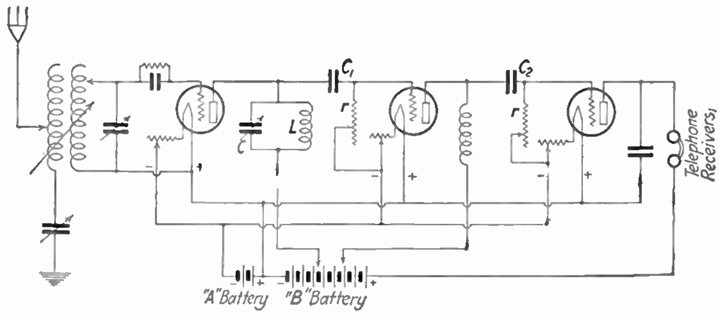

Fig. 81.—Audio-frequency amplification by inductance coupling.

In this type the variation of amplification with changes of frequency is greater than in the transformer coupling.

In general, then, it can be said that if a good transformer is available which amplifies equally well and without much distortion over the required range, the transformer coupling is better suited for use with audio-frequency amplification.

Loud Speakers.—A loud-speaking device may be used in place of the telephone receivers. Such devices may be divided into two classes, first, the *sound distributor*, and second the *sound producer*. The first class utilizes the ordinary telphone receiver as part of the equipment and uses a horn, megaphone,

[1] Inductance coils for this purpose are generally made with an iron core and must have low iron losses and a small capacity effect between the turns of wire.

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or phonograph sound-box to concentrate and direct the sound. The diaphragm of the ordinary telephone receiver is not designed for currents of very great amplitude and distortion results when the telephone receiver is used with any type of loud speaker of the sound-distributor type. This type is illustrated in diagrammatic form in Fig. 82. It is sometimes found that more sound volume is obtained by using only one of the telephone receivers with a sound distributor than when both receivers are used. This may often be overcome by

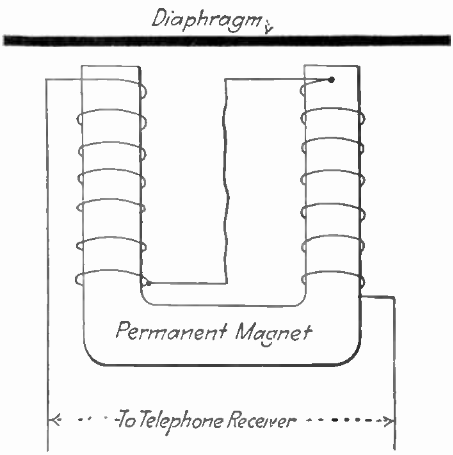

Fig. 82.—Diagram of loud speaker (sound distributor type).

reversing the wires which are connected inside the casing of the distributor. Better results are obtained from instruments which use specially constructed receivers, in connection with the distributor. These receivers allow a wider range of movement of the diaphragm and in some the distance between diaphragm and magnet can be varied to control chattering and noisy operation. The volume of sound may be increased by using a *power tube*[1] of, say, 5 watts of electric power, in

[1] A radio power tube is a vacuum tube designed to operate with considerably more electric power than an ordinary vacuum tube. An ordinary vacuum tube operating at 5 volts and 0.25 ampere uses only 1.25 watts.

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the last stage of amplification, and at the same time, increasing the plate voltage of each vacuum tube.

Where extremely loud signals are desired, the second class or *sound-producer* type of loud speaker shown in Fig. 83 must be used. This type, instead of having a permanent magnet to produce the necessary magnetic field, uses an electromagnet which must be supplied with current. In this type there is no pull on the diaphragm when no energy is received from the plate circuit as may be seen in Fig. 84. When this unit is to replace a telephone receiver a transformer must be used to increase the current and lower the voltage.

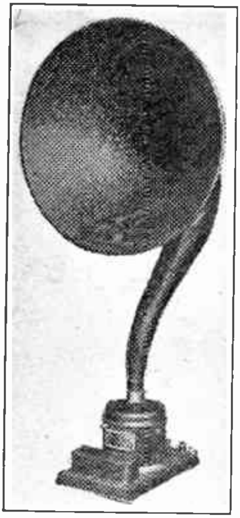

FIG. 83.—Diagram of loud speaker (sound producer type).

The *balanced*-armature type of loud speaker is shown in Fig. 85. It is claimed that this construction gives good response to very weak radio currents and avoids most of the chattering that results when several stages of amplification are used.

The *relay* type of loud speaker (Fig. 85*a*), is somewhat similar to that shown in Fig. 85. The use of a core carrying a number of coils of wire and the more accurate control of the opposing pole-magnets add to its sensitiveness.

Both the horn and the diaphragm have a point at which resonance occurs. If these two points coincide, vibration will result. A horn has a damping effect on the resonance of the diaphragm and hence a long horn gives more uniform operation over the required range. Some types get the effect of length by mounting the diaphragm in the mouth of the horn and placing it so that the sound wave is reflected from the back of the horn chamber.

In the effort to obtain higher plate currents, higher voltages are necessary on the plate circuits of vacuum tubes of the amplifiers. Amplifier and power tubes will take up to 200 or

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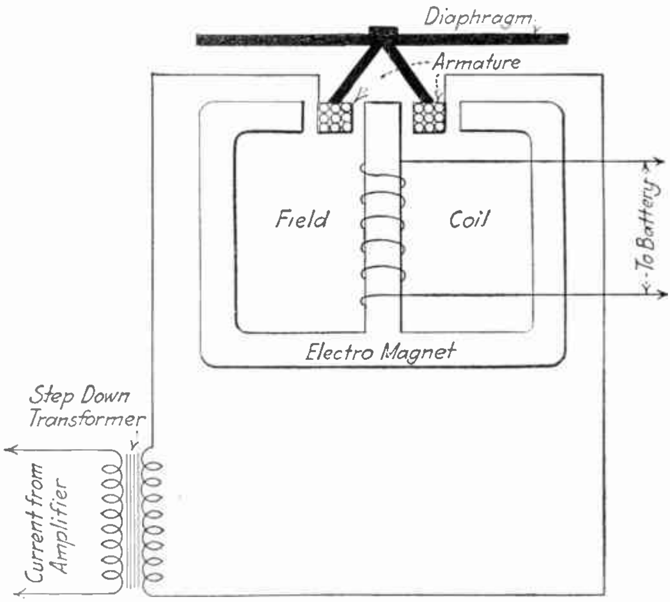

FIG. 84.—Electric circuit of loud speaker (sound producer type).

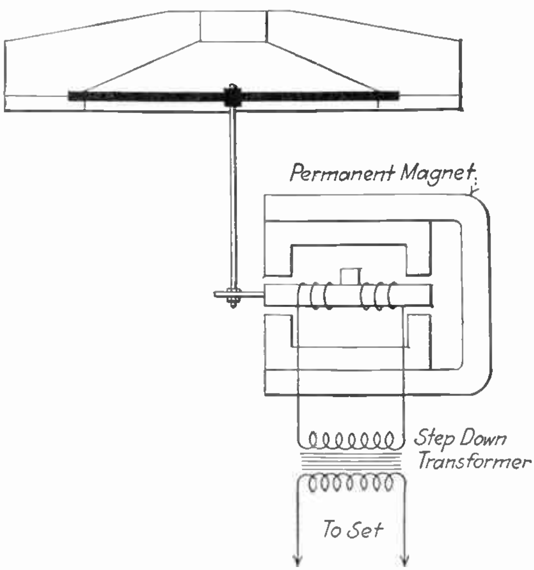

FIG. 85.—Loud speaker (balanced armature type).

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300 volts but the usual amplifying transformers are limited to about 125 volts. Thus the plate voltage in amplification is limited by the allowable current in the transformers.

Figure 86 shows a loud speaker of unusual design. It consists of a 26-inch flat conducting disc, in a magnetic field,

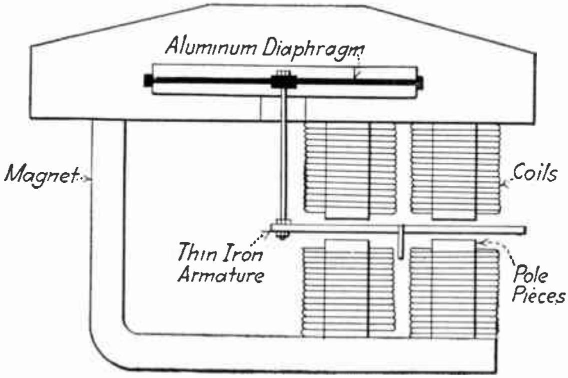

FIG. 85a.—Loud speaker (relay type).

the vibrations of which correspond to the voice currents and reproduce the sound waves without the use of a horn. In the operation of this device, the feeble electric forces of the radio waves are applied to the grid of a vacuum tube in the receiving set and cause relatively large variations in the electric current flowing between the filament and the plate, which in turn are used to secure larger electric forces to be applied to the grid of another vacuum tube. By the use of several amplifying vacuum tubes the original feeble electric currents are multiplied several thousand times and supplied to the loud speaker which reproduces the original sounds with many times the original volume and great faithfulness of quality. To operate this amplifier requires a direct current of several hundred volts. This may be obtained by first transforming power from the ordinary alternating current

FIG. 86.—Loud speaker for which no horn is needed.

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lighting circuit to a relatively high voltage, next "rectifying" this high-voltage alternating current to a direct current by means of a vacuum-tube rectifier, and finally smoothing out this pulsating direct current by means of appropriate electric circuits.

The high degree of faithfulness of reproduction realized in this loud speaker is due partly to the absence of a horn, eliminating horn resonance (one of the usual sources of distortion in a speech reproducer), and partly to the method of vibrating the diaphragm by forces which are distributed fairly uniformly over its surface, instead of acting upon it in a very limited region, as is the case in most other loud speakers. This

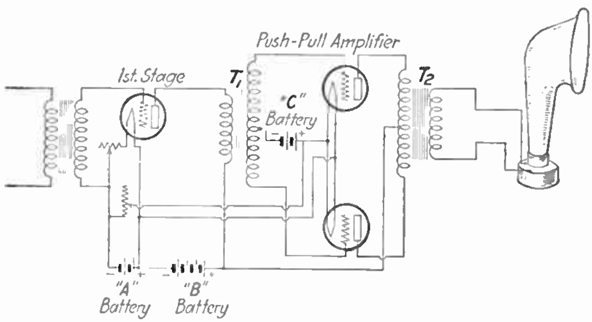

Fig. 87.—Push-pull amplifier.

feature eliminates rattling and ringing of the diaphragm or the production of high overtones by the diaphragm vibrating in its partial nodes.

Push-pull Amplifier.—The current in the last stage of an amplifier may be so large that the vacuum tube in that stage of amplification is overloaded. One way to avoid the resulting distortion is to use a *power tube*, as mentioned above. Another way is to replace the vacuum tube in the last stage of amplification by two tubes in parallel. The most popular method, however, is to use the "push-pull" amplifier which generally replaces the second stage of amplification. The circuit is shown in Fig. 87. The regular vacuum tubes for amplification may be used but even more volume is obtained with power tubes.

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The first transformer shown is of the ordinary audio-frequency type while the other two are special transformers, T_1 having a tap at the center of the secondary winding, and T_2 a tap at the center of the primary winding. In such a construction the voltage across the secondary winding of transformer T_1 is divided equally between the two vacuum tubes, and the resulting plate currents combine in their effect upon the secondary winding of transformer T_2. Therefore, the secondary winding of T_1 can be constructed so that it gives a voltage twice as large as that ordinarily required for one vacuum tube and when the total voltage variation is doubled, the total plate current increases in proportion. The important point to notice is that this increase has been obtained without overloading the vacuum tube and consequently less distortion results. A stage of push-pull amplification will not remove the distortion from previous stages but will give further amplification without distortion.

Jacks for Vacuum Tubes.—Often it is desirable to control the filaments of vacuum tubes automatically by means of *jacks.* The construction of a 5-spring jack and plug for this

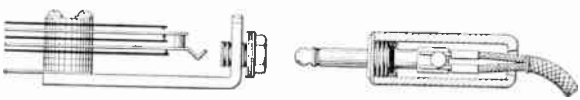

FIG. 88.—Five-spring jack for vacuum tubes.

purpose is shown in Fig. 88. This method adds to the cost and complicates the wiring. The use of 5- and 3-spring jacks is indicated in Fig. 89. The telephone receivers or the loud speaker are connected to the plug of the jack and when this plug is inserted in the detector jack, only the vacuum tube of the detector will be lighted. When it is inserted into amplifier No. 1 jack, the first two vacuum tubes will be lighted, and when inserted into the last jack, all the vacuum tubes will be lighted. There is no need of controlling the plate circuit in Fig. 89 because no plate current flows when the filament is cold. There are many kinds of jacks made for the control of the filament or plate circuits. Another type of jack is shown in

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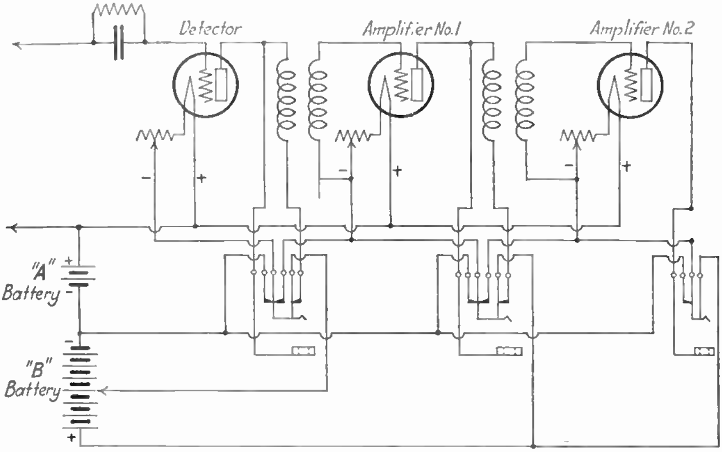

FIG. 89.—Five-and-three spring jacks for vacuum tube filament circuit.

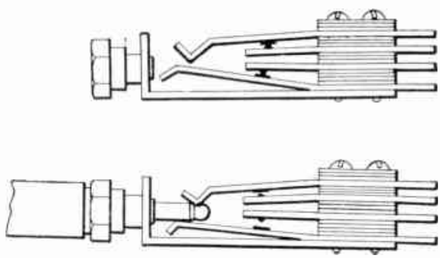

FIG. 90.—Typical jack for vacuum tube plate circuit.

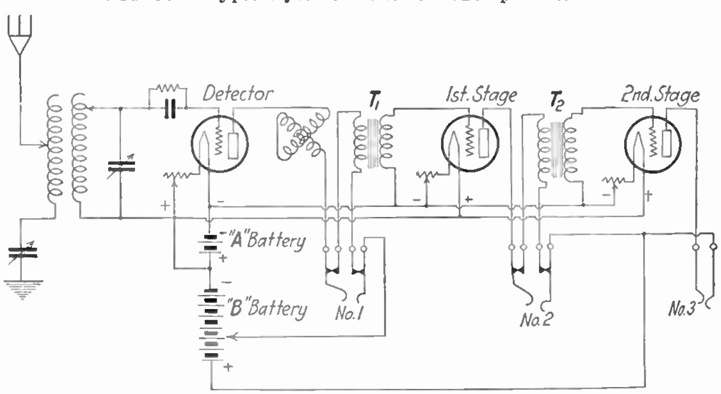

FIG. 91.—Control of vacuum tube plate circuit with jacks.

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Fig. 90 and its use in Fig. 91. All these jacks have no control over the filaments of the tubes. Jack No. 1 completes the plate circuit of the vacuum tube of the detector. Jack No. 2 completes the plate circuit of the vacuum tube of the first stage of amplification. Jack No. 3 opens the plate circuit of the vacuum tube of the second stage of amplification. When the plug is inserted in jack No. 3, all the circuits are complete and the entire receiving set may be operated. When the plug is inserted in jack No. 1, only the vacuum tube of the detector is acting, because as the contact points in the jack are separated the primary winding of transformer T_1 is opened and the vacuum tube in the first stage of amplification becomes inactive. When the plug is inserted in jack No. 2, the vacuum tubes in both the detector and in the first stage of amplification will operate.

Audio-frequency Amplifiers.—But little need be said concerning the operation of audio-frequency amplifiers. The "A" battery voltage is adjusted to suit the vacuum tube. In order to get individual control of the filament current of the vacuum tubes, it is desirable to use a rheostat for each tube. The filament should be operated at the *lowest temperature that will give good results.* In general it may be said that, for a given value of plate voltage there is one value of filament current at which the operation is most satisfactory. The "B" battery voltage depends upon the tube as well as the loudness of the sounds desired from the amplifier. The plate voltage requirement of an amplifying tube depends upon the voltage impressed on its grid. Thus the plate voltage for the second stage is from 2 to 3 times the plate voltage of the first stage. The plate voltage for the third stage is increased similarly.

The strength of signals can be controlled by the filament current to some extent, but it is better to do this by adjusting the "B" battery voltage or by the use of jacks and stages, so that a stage may be added or cut out as desired. The importance of the "C" battery has already been emphasized.

Squealing of Audio-frequency Amplifiers.—The squeals and howls in an amplifier are more the result of design and construction than of operation. At present it is necessary

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only to understand the cause of such disturbances. If energy from any plate or grid circuit of the amplifying tubes is *fed back* into any previous plate or grid circuit, a form of *regeneration* results, meaning that a part of the radio current on its way to the telephones is turned back and re-impressed on the grid of the vacuum tubes. If the amount of regeneration is sufficient, the circuit or parts of it may be caused to oscillate and thus produce a distorting effect. The feed back or regeneration in such cases is due to some form of coupling which may be one of the following types:

a. magnetic (inductive),
b. capacity,
c. resistance.

Magnetic or inductive coupling is that which exists between the wires of the different stages of amplification and between the coils of different stages.

Capacity coupling is largely the result of the capacity effect between the grid and plate of each vacuum tube. This effect is not confined to one tube since the feed back from one may affect all the others.

Resistance coupling occurs when one "B" battery is used for all tubes. Here the battery resistance forms a part of each tube circuit and hence such circuits are coupled directly. Also, if the receiving set includes a potentiometer and only one is used for all the vacuum tubes, there is the same condition of feed back or regeneration due to resistance coupling.

In audio-frequency amplification the disturbance due to feed-back or regeneration is not serious and may be minimized by careful construction. In the next chapter we shall see how high frequencies increase such feed-back or regenerative effects, and how important it is to observe every detail which may bear on the subject.

QUESTIONS

1. Explain briefly how a stage of audio-frequency amplification increases the volume of sound.
2. Compare the relative advantages of audio-frequency and of radio-frequency amplification.

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3. By means of diagrams, show the essential parts of the three methods of coupling audio-frequency amplifier stages which are mentioned in the text.
4. In your opinion which method is the most suitable for this work, and why?
5. Explain the use of the *push-pull* amplifier and draw a diagram of connections.
6. After studying Fig. 89 draw two sketches to show how the jack of the first amplifier tube operates when the plug is out and also when it is in.
7. What precautions should be observed in operating the audio-frequency amplifier?
8. In general, what are the causes of squeals and howls in an audio-frequency amplifier?

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CHAPTER VIII

RADIO-FREQUENCY AMPLIFICATION

Amplification at radio (high) frequency occurs before the radio current from the antenna comes to the detector of a receiving set. This kind of amplification is used when the radio current is too weak to produce good results in the telephone receivers. The advantage of amplification by this method is apparent when it is remembered that a radio current coming from a detector is proportional to the square of the radio current which it receives. Also, amplification at radio frequency amplifies the radio current to which the circuit is tuned without amplifying interfering signals and local noises due to the method of coupling the vacuum tubes. Thus the advantages obtained by amplification at radio frequency instead of audio frequency are greater sensitiveness, freedom from distortion and from interference.

When radio currents of varying frequency are amplified there is always some distortion. In a *radio-frequency* amplification such distortion cannot occur, because the *frequency of the carrier wave from a transmitting station is constant.* But in *audio-frequency* work the range of voice and music frequency may be from about 30 to over 10,000 cycles per second and distortion is almost unavoidable. However, distortion may occur in a radio-frequency amplifier if too much regeneration takes place. In that case, there will be radio currents of different intensities and these will be amplified unequally with consequent distortion.

Amplification of this kind can be carried out very easily at *low frequencies* (high wave lengths) but is difficult at *high frequencies* (500,000 cycles per second corresponds to a wave length of 600 meters). Much progress, however, has been made along this line and very satisfactory results have been obtained.

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The very *high frequencies* involved in radio-frequency amplification present the main obstacle. This is due to the fact that the capacity effects between wires and between the elements of vacuum tubes make a path of easy flow for high-frequency currents. This capacity effect increases directly with increase in the frequency of the radio currents; and, at high frequencies, such capacity effects act almost like short circuits for the currents of radio frequency.

The three types of devices for coupling the vacuum tube of one stage of radio-frequency amplification to the next stage are:

1. resistance coupling,
2. inductance coupling,
3. transformer coupling.

Resistance Coupling.—Radio-frequency amplifiers with resistance coupling have been unsatisfactory on wave lengths

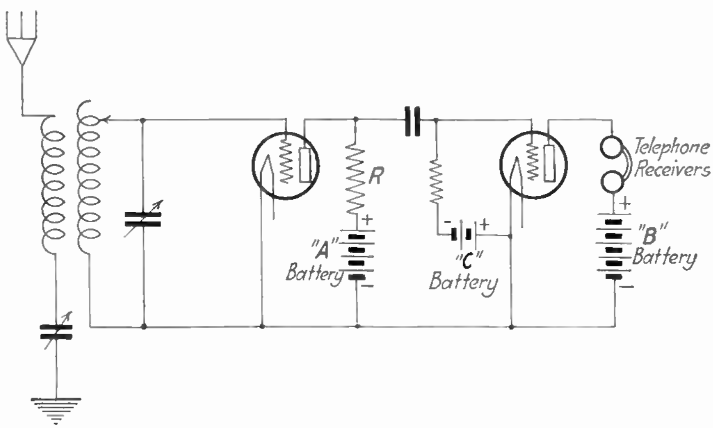

FIG. 92.—Radio-frequency amplification by resistance coupling.

under 500 meters because of the high frequency. A typical device including resistance coupling is shown in Fig. 92, where two other paths for the radio current besides the designed path through the coupling resistance *R* are indicated. The first of these *other* paths is made possible by the plate-filament capacity of the first vacuum tube, and the second path by the grid-filament capacity of the second vacuum tube. At high frequencies (radio frequencies) the low opposition offered by these paths to current flow will cause the resistance coupling to be non-effective. Furthermore, the grid-plate capacity of the second vacuum tube produces a harmful feed-back or regenerative action. *Note that separate batteries are used in this case and some essential parts are omitted in order to simplify the diagram.* Several types of vacuum tubes, such as the Myers, for example, have been designed to minimize the capacity effects between the vacuum tube elements. However, in spite of its advantage in uniform amplification at *moderate frequencies*, resistance coupling is not generally satisfactory, for the reasons already stated, and also because of the small amplification that is possible for each vacuum tube used and the high plate voltages that are required for the vacuum tubes.

In Europe where longer wave lengths (lower frequencies) are more generally used and where vacuum tubes for amplification with low internal capacity may be obtained, radio-frequency amplifiers operating with resistance coupling have been extensively developed.

Inductance Coupling.—A diagram of an amplifier for radio-frequency currents, arranged for inductance coupling is shown in Fig. 93. This circuit contains the capacity C and the inductance L which are tuned to the desired wave length to increase both selectivity and amplification.[1] If the inductance L has a *fixed* value, this circuit will give maximum amplification on one wave length only, or at best, on a very narrow band. Further, when the coupling inductance is varied in tuning, the feed back or regenerative action due to the capacity of the vacuum tube may be quite large and may even start oscillations. In fact, the tendency to oscillate as resonance is approached is one of the serious disadvantages of this method. To avoid this tendency to oscillate some form of *stabilizer* (*potentiometer*) is necessary, which, however, decreases the amplification which is obtainable. Another disadvantage of this type of coupling is that it is necessary to use grid condensers and grid leaks which may cause trouble due to the high frequencies used. With this arrangement regeneration

[1] This cannot be greater than the amplification factor of the tube itself.

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may be obtained by opening the plate circuit of the amplifier and inserting an extra coil of wire, as for example a tickler

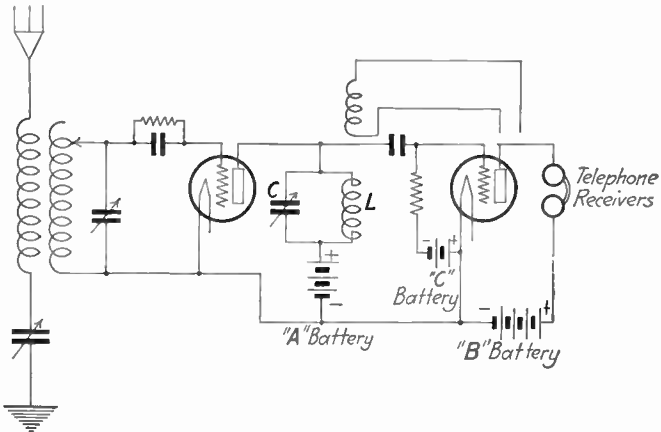

FIG. 93.—Radio-frequency amplification by inductance coupling.

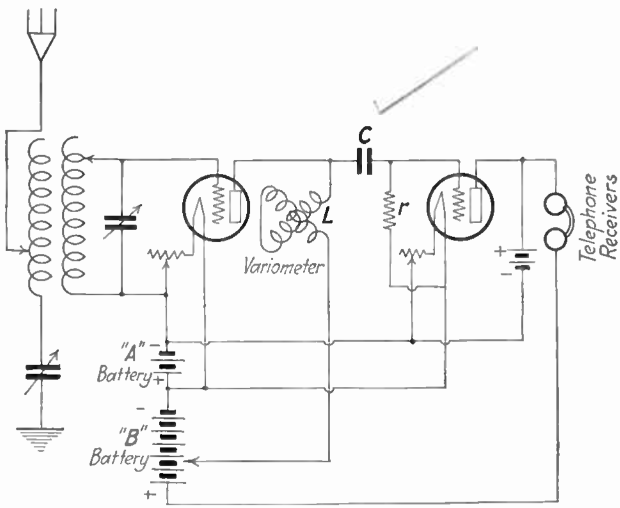

FIG. 94.—Radio-frequency amplification with plate variometer.

coil, to be coupled inductively to the inductance *L*. In some cases regeneration from feed back due to the grid-plate capac-

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ity of the vacuum tube may be obtained by using a variometer in the plate circuit of the vacuum tube in the *detector*.

When a receiving set with a single vacuum tube obtains regeneration by the use of a plate *variometer* (tuned plate), the addition of one stage of radio-frequency amplification becomes very simple and satisfactory. Such a combination is shown in Fig. 94. A single-circuit tuner, as illustrated in Fig. 95, can be used to advantage with this arrangement, although it decreases the selectivity. The condenser C is used to isolate the grid of the vacuum tube of the amplifier. When the inductance L is tuned it is possible to get not only a maximum voltage drop to impress on the grid of the vacuum tube in the amplifier, but also a regenerative or feed-back action due to the grid-plate capacity. The grid leak, r, may be used to control oscillation in the vacuum tubes—that is, to give stability. Several stages of amplification with this variometer coupling can be used with satisfactory results. The disadvantages are the increased number of adjustments required and the use of a *potentiometer*.

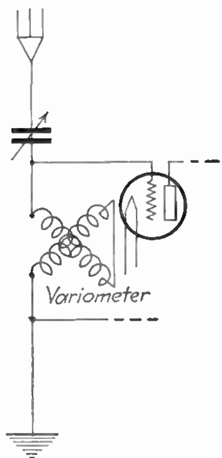

FIG. 95.—Radio-frequency amplification with single circuit tuner.

Another method of controlling oscillation is by means of resistance in the plate circuit which would have but little effect upon amplification. Such a resistance might be introduced by using fine wire for the inductance, or by utilizing an iron core.

In the next paragraphs both tuned and untuned transformer couplings for radio-frequency amplifiers will be explained. In general it may be said that amplifiers with inductance couplings give less amplification, more selectivity, and require more controls than coupled amplifiers with untuned transformer couplings.

Transformer Coupling.—Transformer coupling is coming into general use for several reasons. By using a suitably designed transformer, an overall amplification several times

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the normal amplification of the vacuum tube may be obtained. Unless, however, the transformer is very carefully designed, the capacity effect between the windings will allow only a small stepping up of the voltage. This type of coupling does not require a high "B" battery voltage. In a *good* transformer, the uniformity of amplification may be made as good as that in inductance coupling. Finally, less auxiliary apparatus is required, since the grid condenser and grid leak are not needed.

Transformers of the air-core type when properly made and used, give more amplification than those with an iron core, but the amplification is not uniform. That is, the amplification curve shows a peak occurring usually at a narrow band of frequencies as compared with a more or less flat curve for the iron-core type. While the use of iron gives more *uniform* amplification, the losses introduced by its use *decrease* the amplification. On the other hand, the repeating action of the air-core transformer is poor on wave lengths other than the natural wave length of the transformer. The wave length of an air-core transformer can be decreased by separating the coils or by removing some of the turns of wire.

An air-core transformer may be tuned by using a variable condenser across the secondary winding. In this way a resonance peak may be obtained at each wave-length setting. Then not only is high amplification possible but the selectivity is increased since, at any particular setting, the amplification of wave lengths, other than the one desired, is small. In most of such transformers the primary winding has relatively few turns and this helps in reducing the tendency to oscillate. When the secondary winding is tuned it reacts on the primary winding in such a way that the latter is tuned also to some extent. Just as the tuning of the secondary winding increases the selectivity, so the tuning of the primary winding by reaction increases the selectivity, and this increase is obtained without introducing another control. The tuning of a transformer may be accomplished also by varying the inductance, instead of using a variable condenser with a fixed inductance.

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In a tuned plate regenerative receiver the tuning of the plate circuit produced regeneration through the capacity of the vacuum tube. The tuning of a transformer coupling has the same effect. In addition to the regeneration by means of the grid-plate capacity, there were given, in Chap. VII, various other ways by which regeneration occurs because of interaction among the various parts of a circuit, namely, regeneration from resistance coupling and from magnetic coupling. The regeneration from these several causes must be controlled in order that oscillation will not take place, with the resulting distortion and decrease of amplification.

To minimize the regeneration due to the resistance coupling resulting from the use of a common "B" battery, experimenters recommend that a 1.0 microfarad condenser be connected across the "B" battery terminals. The magnetic coupling between stages may be decreased by using a metal container with metal partitions so that each stage is entirely enclosed. Small holes in the partitions are necessary for the passage of the connecting wires. A more practical but less efficient method is to space the stages quite a distance apart and tilt the coils or place transformers at right angles, so that the induction is reduced. The wiring may be shielded by enclosing it in grounded flexible metallic tubing.

Potentiometer Control of Regeneration.—The regeneration due to grid-plate capacity is an important cause of trouble in amplification, so that the methods devised to control this regeneration should be explained. One method depends upon a *brake* action in that, by limiting amplification it reduces regeneration. This result is secured by the use of grid potentiometers, shunt resistances on transformers, high-resistance transformer windings, and iron-core transformers. The most popular of these is the method of control by a *grid potentiometer* as shown in Fig. 96.

A common stabilizer for all the radio-frequency stages is generally sufficient. The two grid returns of the vacuum tubes for radio-frequency amplifying are connected to the potentiometer *P*. In some cases a better arrangement is that shown in Fig. 97 in which the grid return of the vacuum tube

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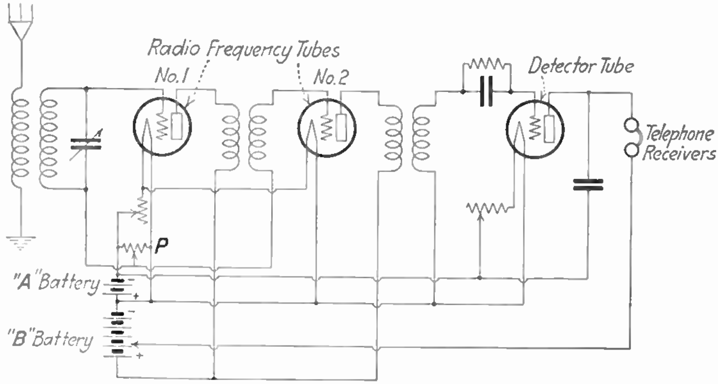

Fig. 96.—Grid-potentiometer for regeneration control.

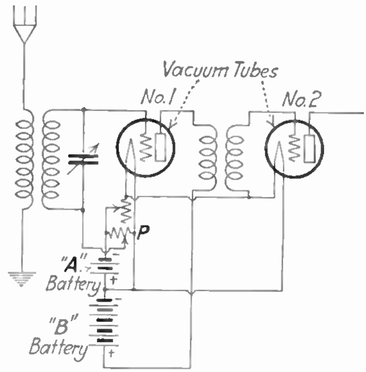

Fig. 97.—Grid-potentiometer for regeneration control.

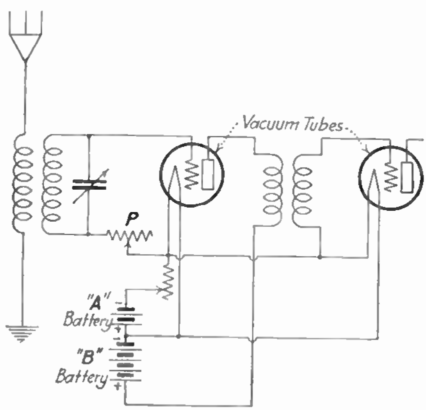

Fig. 98.—Grid-potentiometer for regeneration control.

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marked No. 1 is connected to the potentiometer and that of tube No. 2 to the negative side of the filament. The least harmful use of a potentiometer is that illustrated in Fig. 98 which gives greater selectivity than the other connections. In fact, one great weakness in all the types of this method for controlling regeneration is the lack of sensitivity. The only point in favor of this general method of controlling regeneration by reducing amplification is that it is easily applied.

Tickler Coil Control of Regeneration in "Superdyne" Receiver.—The object of the various types in the second method of controlling regeneration is either to compensate for, or to prevent the feed-back action through the grid-

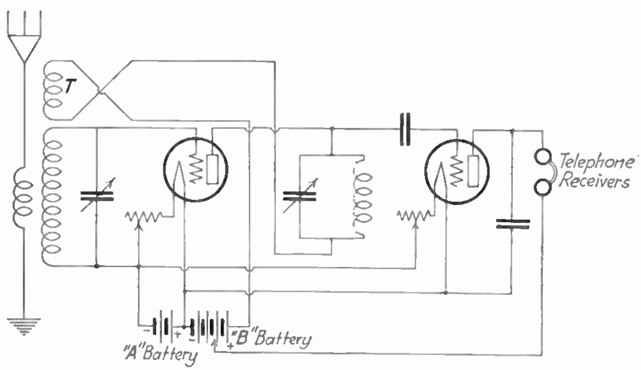

FIG. 99.—Tickler coil for regeneration control.

plate capacity of the vacuum tube. The most easily applied type of this method is the one used in the Tuska *superdyne receiver.* This uses a tickler or feed-back coil *T*, as indicated in Fig. 99, which is *reversed in its action* so as to decrease regeneration. Thus the amount of regeneration produced by the tickler coil *T* may be made just equal to that due to grid-plate capacity. Since the two actions are opposite in their effects, oscillation is prevented and the circuit can be operated at the point of resonance. A disadvantage of this type of control is that the setting of the reversed tickler is not permanent but must be changed for each wave length.

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Operation of "Superdyne" Receiver.—Starting with the plates of the variable condensers nearest together and the tickler coil at an angle of about 75 degrees with the secondary winding of the tuning coil, the position of the plates of the condensers should be varied until the desired transmitting station is obtained. Then the tickler coil should be adjusted for maximum strength. After this it will be necessary to readjust the first condenser. If two stages of radio-frequency amplification are used, the condensers in the two stages should be rotated in tuning, the settings being kept at the same value. If it is found that best results are obtained when one

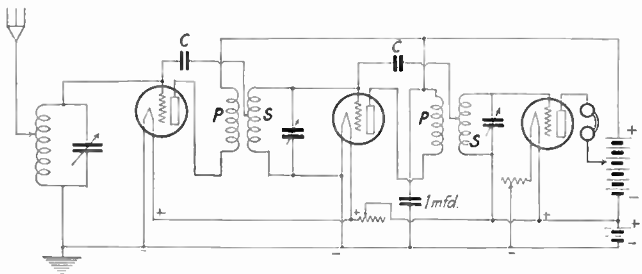

FIG. 100.—Reversed capacity for regeneration control.

condenser setting varies a fixed amount from the other, the dials can be shifted to correspond.

The range of any set is limited by local induction and atmospheric disturbances. The high amplification of sets using radio-frequency stages increases the volume of such interference. This is one of the reasons for the use of a loop with radio-frequency amplifiers.

Reversed Capacity Control of Regeneration. "Neutrodyne" Receiver.—Another popular type of control is the reversed capacity back-coupling as used in Hazeltine's *neutrodyne receiver.* The circuit in Fig. 100 shows two stages of radio-frequency amplification and a detector.

The voltage induced in the secondary winding S is opposite to that in the primary winding P. Hence by choosing a suitable value of the neutralizing condenser C, the effect of a

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current flowing in one direction through the grid-plate capacity of the vacuum tube can be balanced by the effect of the current flowing through the neutralizing circuit. If the voltage in S is always opposite to that in P at all wave lengths, the neutralizing adjustment, once made, would not be effected by tuning at different frequencies. In practice, however, this condition is very difficult to obtain and hence the neutralization when made at one frequency, often does not produce an exact balance at other frequencies.

The neutralizing condensers are of very small capacity, depending upon the tube capacity and the ratio of the number of turns of wire in the secondary and primary windings of the transformer, and are usually made up of an insulated wire inside a metal tube, although a variable plate condenser would be more convenient. The secondary windings of the transformers are generally wound outside the primaries. This lessens the interaction which would otherwise exist between the primary coil of one stage and the secondary circuit of the preceding stage.

The adjustment of each neutralizing capacity is made by tuning to the radio current of some transmitting station, turning out the filament of the vacuum tube to be neutralized (but not removing the tube) and adjusting the capacity until all the sounds in the telephone receivers disappear. If the adjustment is not correct, capacity coupling will exist and the sounds will still be transmitted.

The addition of regeneration in the form of a plate variometer does not increase signal strength for wave lengths which are over 360 meters. The reflex arrangement in which a vacuum tube acts as both radio- and audio-frequency amplifier has not been very successful with the *neutrodyne* receiver. A properly adjusted *neutrodyne* receiver does not radiate energy and hence causes no interference with nearby receivers. In the non-regenerative type there is no oscillation and in the regenerative type oscillation exits in the detector circuit only. Each stage should be thoroughly shielded from the adjacent stages by grounded metal partitions and grounded metal linings in the cabinet.

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Operation of "Neutrodyne" Receiver.—The neutrodyne works best on an antenna but may be used on a loop. The object of tuning is to get each circuit tuned to the wave length desired. The second and third condenser dials may be set so that their readings will be identical. The first condenser dial setting depends somewhat on the type of antenna, and also on the type of tuner, that is, single circuit or double circuit. In calibrating a *neutrodyne* receiver it is advisable to start with a transmitting station at the low end of the wave-length range and also one at the high end. Then a chart can be made as shown in Fig. 101 by connecting the

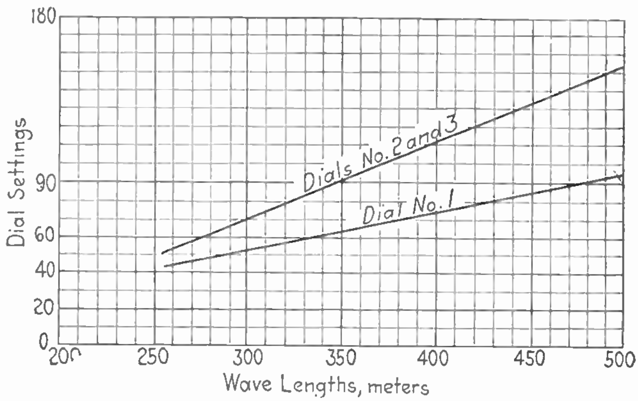

FIG. 101.—Chart for locating radio transmitting stations by wave length.

high and low points with a straight line, in order to make easier the process of locating a desired station. Thus, a station on 400 meters would be obtained by the approximate setting of 73 for dial 1 and 112 for dials 2 and 3.[1] A chart of this kind is desirable for any kind of receiving set.

Other Methods of Control of Regeneration.—It has been suggested that the type of control of regeneration shown in Fig. 102 is more convenient than some others since it allows the use of but one compensated radio-frequency stage, and the coupling *T* may be of any form desired. The inductance

[1] The values used in making this chart are assumed and cannot be applied to a receiver in tuning.

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coils L_1 and L_2 have very close coupling and are wound in opposite directions.

In France, the type shown in Fig. 103 has been quite widely used for controlling regeneration due to vacuum-tube capacity.

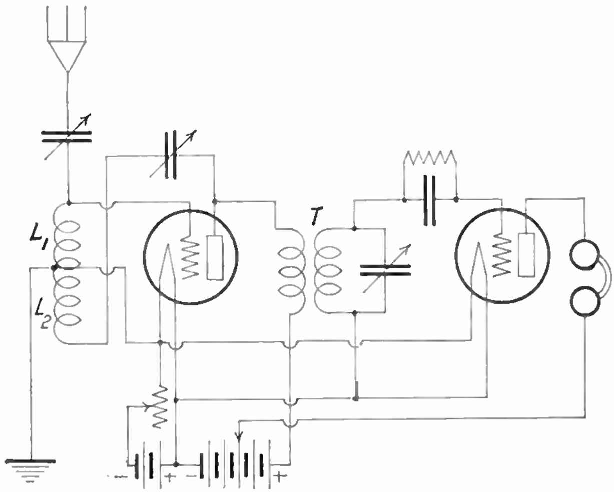

FIG. 102.—Inductance coupling for regeneration control.

The plate of one of the radio-frequency amplifier tubes is coupled by means of a capacity to the grid of the two previous tubes. When M is moved toward S_1 the feed-back due to the

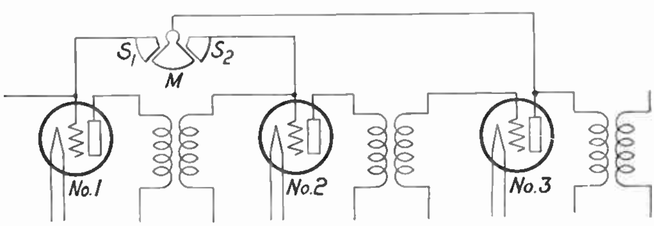

FIG. 103.—Capacity for regeneration control.

capacity between M and S_1 is such that it weakens regeneration and thus oscillation is prevented. Regeneration is increased by moving M toward S_2.

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Another general method of control which depends upon the establishment of a balance between the different parts of the

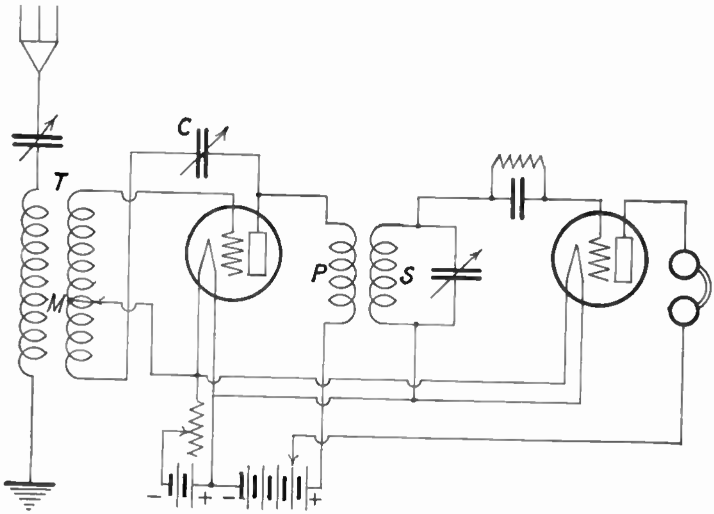

FIG. 104.—Balanced circuit for regeneration control.

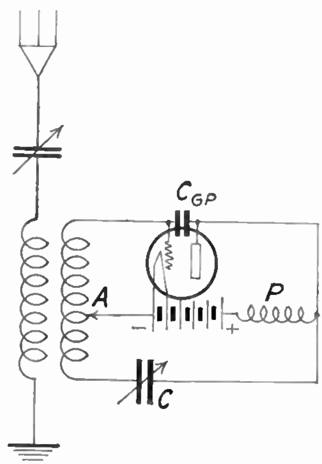

FIG. 105.—Rice (balanced) circuit for regeneration control.

circuit, such that the control of the feed-back current is exact, is illustrated in Fig. 104. Here the coupling in the tuning

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device *T* must be close. A tap *M* must be provided at the center of the secondary winding so that this point may be connected to the negative side of the filament of the vacuum tube. The compensating condenser is adjusted as in previous methods. This arrangement is based on the *Rice circuit* and can be explained with the aid of Fig. 105 which represents a radio-frequency stage adapted from Fig. 104. The parts have been rearranged but no change has been made except to introduce C_{GP} which represents the grid-plate capacity of the amplifier tube. The adjustment may be made by moving the connection at *A* when C_{GP} and *C* are equal, or by varying *C* when the connection *A* is placed at the mid-point of the coil. When a condition of balance is obtained, any feed-back current will be balanced by an equal and opposite current through the circuit containing the condenser *C*. The control is then permanent and independent of the wave length. Thus the tuning of the circuits has no effect upon the control.

Reflex Circuits.—In the amplifier circuits so far considered the vacuum tube of an amplifier had but one duty to perform. If used in an audio-frequency amplifier it amplified the radio current after detection and in a radio-frequency amplifier it amplified the radio current before it came to the detector. Thus if two stages of radio-frequency amplification and two of audio-frequency amplification are desired, four tubes are needed, in addition to the detector tube. In a *reflex circuit with a crystal detector,* all this is accomplished with two vacuum tubes, or, if a tube detector is used, it is accomplished with three vacuum tubes. The advantages claimed for combining radio-frequency and audio-frequency amplifications in this way are (1) economy in the use of vacuum tubes, (2) better efficiency than can be obtained from the equivalent number of separate amplifier stages, (3) fewer controls, and (4) easier construction. On the other hand, in most commercial applications of the reflex arrangement, iron-core radio-frequency transformers are used together with potentiometer control on the vacuum-tube grids. The potentiometer, by putting a positive voltage on the grids, prevents oscillation. When, however, the grid is thus made positive, a condition results

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which is very unfavorable to good *audio amplification.* Hence a potentiometer should not be used on a vacuum tube which is serving for both radio-frequency and audio-frequency amplification.

In receiving sets having a single vacuum tube some other means of control should be used such as the reversed tickler, grid resistance, or plate resistance.

Various arrangements of circuits having one vacuum tube are shown in Figs. 106 to 108. In these cases the vacuum tube

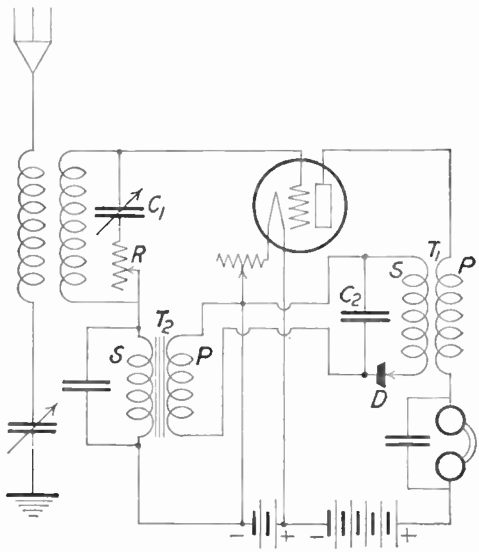

FIG. 106.—Acme reflex circuit.

may be considered to act first as a radio-frequency amplifier. When the radio-frequency plate current passes through the primary winding *P* of the radio-frequency transformer T_1, a current is induced in the secondary winding *S*. This current in passing through the crystal *D* is rectified (making it pulsating direct current) and flows through the primary winding *P* of the audio-frequency transformer T_2. The voltage induced in the secondary winding *S* is, of course, a rectified voltage, which, when impressed on the grid of the vacuum tube pro-

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duces similar variations of the plate current. In this way the strength or amplitude of the plate current is increased considerably thus producing more volume. The *Acme receiving set* shown in Fig. 106, uses a double-circuit tuner. The resistance R is varied to prevent oscillation. C_2 is a by-pass for radio-frequency currents. In the *Harkness receiving set* (Fig. 107), the antenna is untuned, the grid of the vacuum tube is tuned by C_1 and oscillations are prevented by C_2 which serves also as a by-pass.

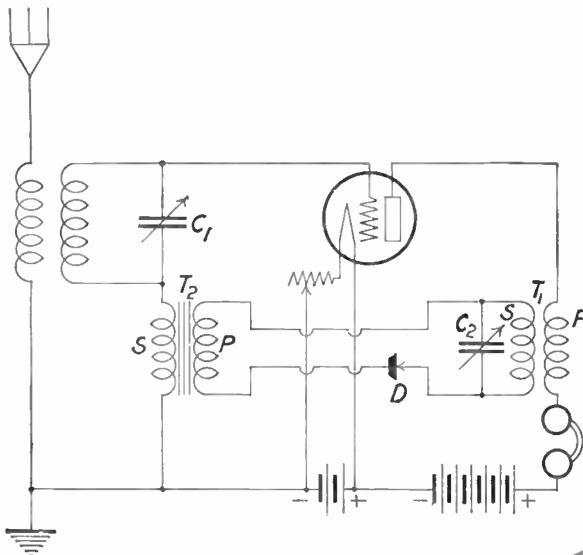

FIG. 107.—Harkness reflex circuit.

In the *Erla receiver* (Fig. 108) the connection from the antenna to the lower end of the secondary winding of the tuner T, makes it possible to control oscillation by means of the coupling.

The four-tube circuit shown in Fig. 109 has three stages of radio-frequency amplification and three stages of audio-frequency amplification. A loop may be used and should be connected to the two points marked X after the tuning unit T has been removed.

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The addition of a stage of tuned radio frequency, using the arrangement shown in Fig. 110 will increase the range and the selectivity.

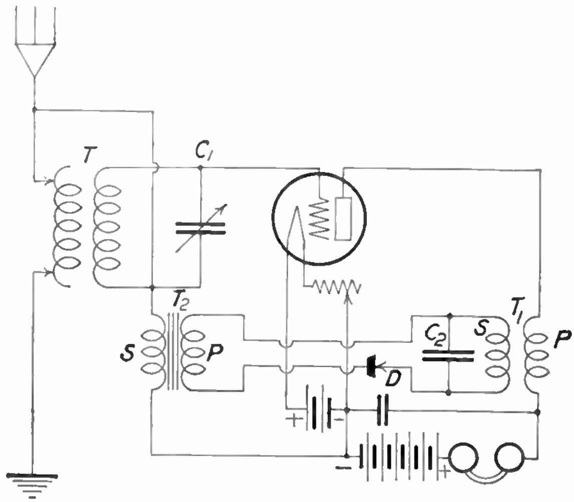

Fig. 108.—Erla reflex circuit.

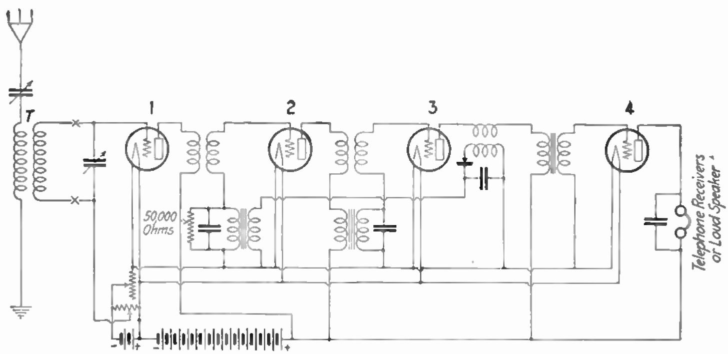

Fig. 109.—Four-tube Acme reflex circuit.

From Fig. 109 it can be seen that in a reflex circuit the tubes are not all loaded alike. Thus tube No. 1 carries a relatively weak radio-frequency current; tube No. 2 carries a stronger

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radio-frequency current and a weak audio-frequency current; tube No. 3 carries a still stronger radio-frequency and a strong audio-frequency current; tube No. 4 carries only a very strong audio-frequency current. As a result, some of the tubes may

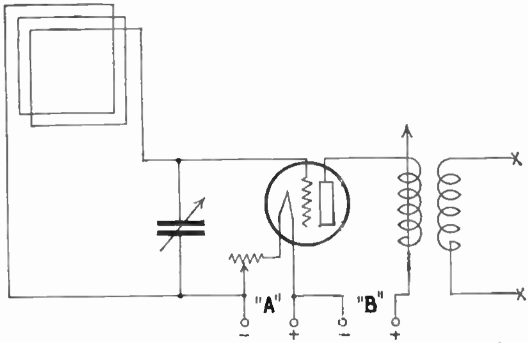

FIG. 110.—Tuned radio-frequency circuit.

be overloaded and others not loaded enough. Furthermore, extreme care must be taken to prevent feed back due to magnetic coupling, and to prevent the amplification in the audio-frequency stages (which precede the detector) of interference

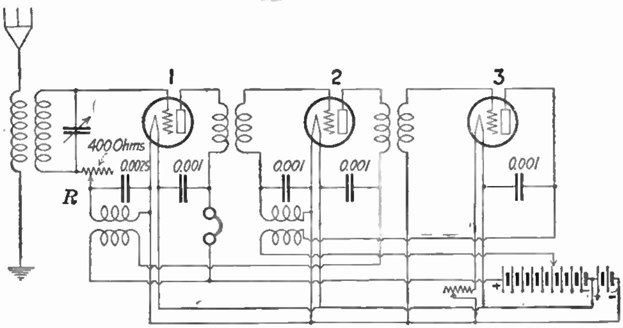

FIG. 111.—Grimes inverse duplex circuit (reflex).

from power lines and machinery. The *Grimes inverse duplex circuit* as shown in Fig. 111 is intended to overcome some of these difficulties. This circuit uses two vacuum tubes for amplification and another vacuum tube in the detector,

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giving two stages of radio-frequency amplification and two of audio-frequency amplification. A crystal may be used in the detector in place of the vacuum tube.

In the arrangement shown in Fig. 111 the radio-frequency current passes through the vacuum tubes in the conventional way, that is, through tubes 1, 2, and 3, in the order given, to the detector. From here, however, the rectified current goes first through tube 2, then through tube 1, and the telephone receivers are in the plate circuit of tube 1. The advantages of this arrangement are that the stability of the circuit is increased, overloading of the tubes is reduced, and audio-frequency noises are decreased. The location of the by-pass condensers allows radio-frequency currents to return directly to the tube without going through the "B" battery or around the audio transformers. The circuit is operated in the same manner as the ordinary reflex, since there is one control for

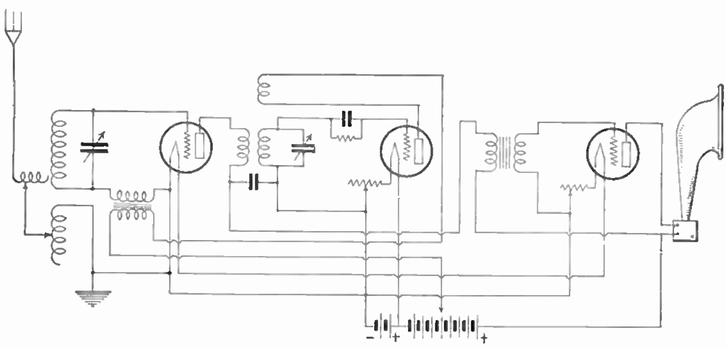

FIG. 112.—Receiving set applying both regeneration and reflex action.

tuning, one for the vacuum tubes, and one for stability. When the radio currents are strong the resistance R should be cut in to prevent overloading the vacuum tubes with radio-frequency currents and thus avoid distortion and howling. In some cases it may be found necessary to use "C" batteries in order to maintain the proper negative grid voltage.

Manufacturers are showing a tendency toward economy in the number of vacuum tubes and toward the use of regeneration and reflexing the radio-frequency and audio-frequency

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stages. A good example of this tendency is shown in Fig. 112. This circuit has three vacuum tubes; the first vacuum tube gives one stage of tuned radio-frequency amplification and one stage of audio-frequency amplification by a *reflex arrangement.* The second vacuum tube is in the detector and gives regeneration by means of the tickler coil in its plate circuit. The third vacuum tube gives the second stage of audio-frequency amplification. Such circuits can be improved greatly by using some method of controlling the undesirable feed-back due to the grid-plate capacity of the first vacuum tube.

"Super-heterodyne" Amplification.—Because of the difficulty of designing and constructing amplifiers for high frequencies, Armstrong produced a method of amplification called the *super-heterodyne.* In this method the high frequency of the radio current from the antenna is changed to a lower frequency more suitable for amplification. This change in frequency is made with but little distortion and without losing any of the original characteristics. The method depends upon the *heterodyne* principle in which a local generator or oscillator is used to add to the original radio current another radio current at a slightly different frequency. These two radio currents will then combine in such a way that the *amplitude* of the resulting third radio current varies at a rate equal to the difference between the other two frequencies. The so-called *beat* current has a wave form indicated by the variations of the amplitudes of the frequency of this third radio current. The difference between the *received* and *local* frequencies should be about 100,000[1] cycles per second. This action is illustrated in Fig. 113, in which it is assumed that the incoming wave has a frequency of 1,000,000 cycles per second (300 meters) and that the heterodyne or local generator is adjusted to give a frequency of 900,000 cycles. Then the difference between these frequencies is a beat current having a frequency of 100,000 cycles per second. At this low frequency the feed-back is so small that it is incapable of causing oscilla-

[1] There is a difference of opinion on this. Some manufacturers are making intermediate transformers for a frequency of 30 kilocycles.

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tion. The local frequency may be either greater or less than the received frequency. The original radio current has, of course, been modulated by the voice or music at the transmitting station. The beat current retains this modulation and thus the radio current from the second detector is a rectified modulated direct current.

The purpose of all this complexity is to make possible the satisfactory use of an amplifier with several stages of amplifica-

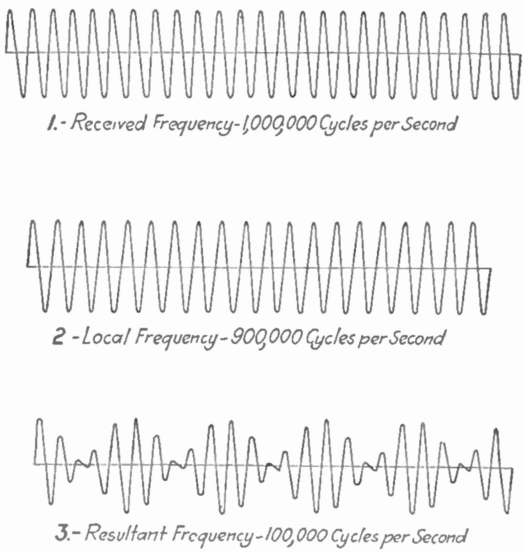

Fig. 113.—Heterodyne action.

tion, designed for a frequency of say 100,000 cycles (3,000 meters), which will not have the limitations of a radio-frequency amplifier (1,000,000 cycles for the received signal) or of an audio-frequency amplifier. In the radio-frequency amplifier, these limitations are due to the capacity effects of a high-frequency current, and, in the audio-frequency amplifier, to the amplification of vacuum tube or battery noises, and external electrical disturbances. After sufficient amplification has been obtained in the long-wave, low-frequency stages the radio current is rectified in the usual way by the vacuum tube

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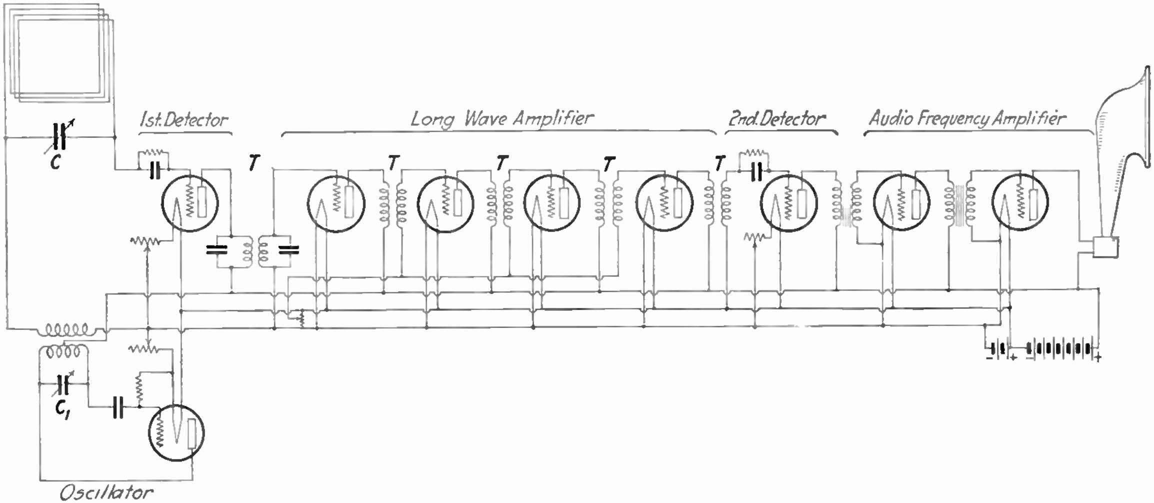

FIG. 114.—Armstrong super-heterodyne circuit.

in the detector. After this the radio current may be amplified at audio frequency as desired.

The original Armstrong super-heterodyne receiver was made with 8 vacuum tubes which were arranged as follows: one vacuum tube in the detector; one tube in the oscillator; three tubes in the three stages of long-wave (6,000 meter) amplification; one tube in the second detector; and two tubes in two stages of audio-frequency amplification. A typical diagram of this circuit is shown in Fig. 114. There are in this case four stages of long-wave amplification. Regeneration in the vacuum tube of the first detector may be used if desired.

Operation of Super-heterodyne Receiving Set.—In the operation of the "super-heterodyne" receiving set, the trans-

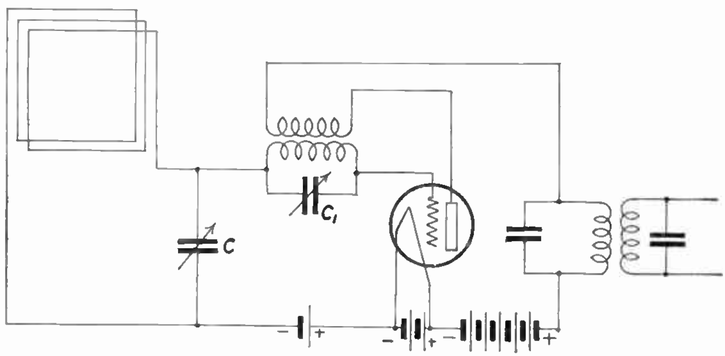

FIG. 114*a*.—Self-heterodyne detector.

formers *T*, must be tuned to the wave length used (which is 3,000 meters in the case assumed above) and then this adjustment may be made permanent. There are but two controls—the condenser *C* which tunes the loop circuit to the radio current of the desired transmitting station—and the condenser C_1, which is used to vary the *heterodyne current*.

The tuning of the transformers must not be too sharp as then they will not transmit effectively the *side-band* oscillations. The modulated wave may be considered to consist of the original carrier wave and two side-bands, one with frequencies less than that of the carrier, and the other with greater frequencies. Each side-band consists of the range of

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frequencies (about 200 to 3,000 cycles) resulting from voice and music modulation.

A self-heterodyning detector could be used if the frequencies of the incoming radio current and of the oscillator circuit are far enough apart so that no interaction exists. If the received radio current is, for example, at 600,000 cycles and if the amplifiers are adjusted for 50,000 cycles, the heterodyne frequency must be 550,000 or 650,000 cycles. Under these conditions

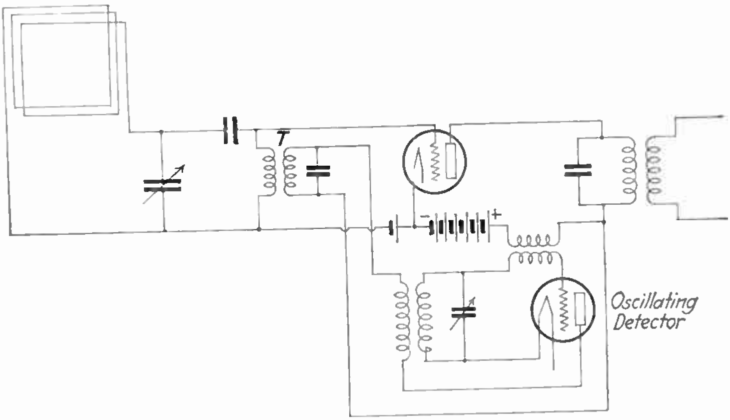

FIG. 114*b*.—Super-heterodyne circuit with reflex arrangement.

it can be seen from Fig. 114*a* that the tuning of the loop condenser C to the desired radio current will affect the setting of the heterodyne control C_1. Likewise the tuning of the condenser C_1 to 550,000 or 650,000 cycles will react on the loop circuit.[1]

[1] To avoid this difficulty the *second harmonic* of the oscillator was used for heterodyning. The vacuum tube generates not only a current of one fundamental frequency, but also produces upper *harmonics*. These are currents at frequencies of 2, 3, 4, etc. times the fundamental frequency, corresponding to the 2d, 3d, 4th, etc., harmonics. When as in the case given, the second harmonic is used, the oscillator should be adjusted for a fundamental frequency of 275,000 or 325,000 cycles, giving a second harmonic of 550,000 or 650,000 cycles. Tuning the grid circuit to 275,000 cycles will not affect the tuning of the loop at 600,000 cycles. Incidentally, this eliminates one tube.

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The next development in the Armstrong super-heterodyne was the *reflex* arrangement and the use of an *oscillator-detector* tube, as indicated in Fig. 114*b*.

The radio current from the oscillator-detector tube is passed by means of transformer *T*, to the first vacuum tube. Thus the first vacuum tube amplifies not only the original current but also the beat current. This eliminates the use of another tube.

One make of super-heterodyne uses 6 vacuum tubes which are arranged to give one stage of radio-frequency amplification, two detectors, two stages of intermediate-frequency (long-wave) amplification and two stages of audio-frequency amplification. Tuning is accomplished by two variable condensers.

QUESTIONS

1. What is the main obstacle to the successful use of radio-frequency amplification?
2. Why is the transformer method of coupling used so generally?
3. What is the principal feature of the neutrodyne receiving set, and what is its purpose?
4. Describe the arrangement used in the superdyne receiving set for the control of undesired regeneration.
5. Describe briefly the action of a single-tube *reflex* circuit, using a crystal detector, and illustrate by means of a diagram.
6. What is the essential difference between the standard *reflex* and the Grimes *inverse duplex* arrangement?
7. Explain the action of the "super-heterodyne" receiving set.
8. Name a few of the other methods used for the control of the uudesired regeneration.

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CHAPTER IX

SELECTION, OPERATION AND CARE OF RADIO RECEIVING APPARATUS

The distance at which a radio transmitting station can be received varies with the season, the period at which transmission is carried on such as day or night, atmospheric conditions, the character and location of the antenna, the power of the transmitter, the sensitiveness and selectiveness of the receivers, and the skill of the operator.

Radio reception in the summer is hindered by electrical disturbances in the atmosphere, called strays or static. The possibility of getting a clear sound in the telephone receiver depends upon the relative strength of the radio currents and the static. Signals received at night are, in general, stronger than those received in the daytime. However, the intensity or strength of night signals is often variable. The nature of the space between the transmitter and receiver also plays an important part in reception.

Atmospheric Conditions. "Fading."—Certain localities seem to be *dead spots* as far as reception is concerned. This might be due to the weakening of the radio waves because of geographical or atmospheric conditions, or geological formations. An antenna placed in such a dead spot would pick up only a very small amount of radio current, if any at all. A long high antenna with the lead-in toward the desired station gives better results than a short low antenna with its lead-in pointing away from a station. It is evident that the power of the transmitter has some bearing on the range, for the more power there is transmitted, the more there will be available at a given point. A study of fading, meaning varying strength of radio currents during short intervals, which was made by the U. S. Bureau of Standards with the assistance of the Ameri-

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can Radio Relay League, shows the principal conclusions in the following table:

	FADING	STRENGTH OF RADIO CURRENT
Wave length	Slightly more fading with short wave lengths.	Slightly stronger radio currents at short wave lengths.
Barometric pressure	More fading along a region in which the barometric pressure is rising or falling.	Stronger radio currents along a region of constant barometric pressure.
Temperature	Slightly more fading along a region in which the temperature is rising or falling.	Stronger radio currents along a region of constant temperature.

Figure 115 is a "Radio Air Map" of the vicinity of New York City. The system of curves on the map indicates the

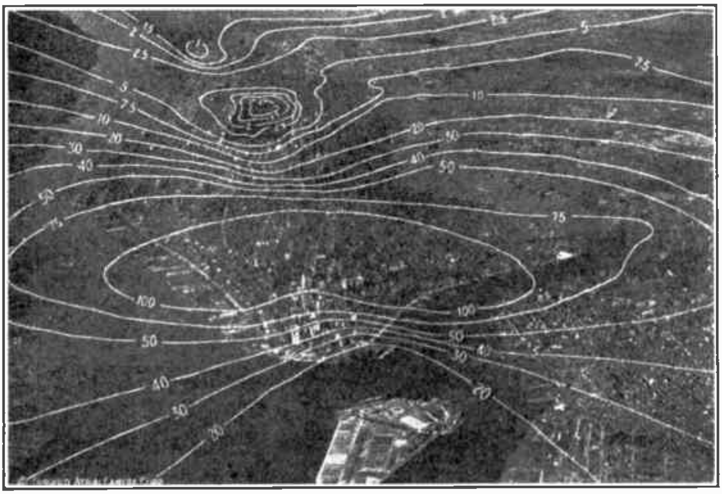

FIG. 115.—Radio air map of New York City and vicinity.

relative strength of radio reception on the basis of 100 as a maximum. The high buildings at the lower end of Manhattan Island (just below the center of the map) obstruct the movement of the radio waves. The fact that the radio waves travel better over water than over land is shown by the elongation

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of the curves over the rivers on each side of Manhattan. The irregularities in the curves gradually correct themselves at considerable distance.

Another radio map is shown in Fig. 116 which is intended to show the variability of radio transmission in the vicinity of Washington, D. C.

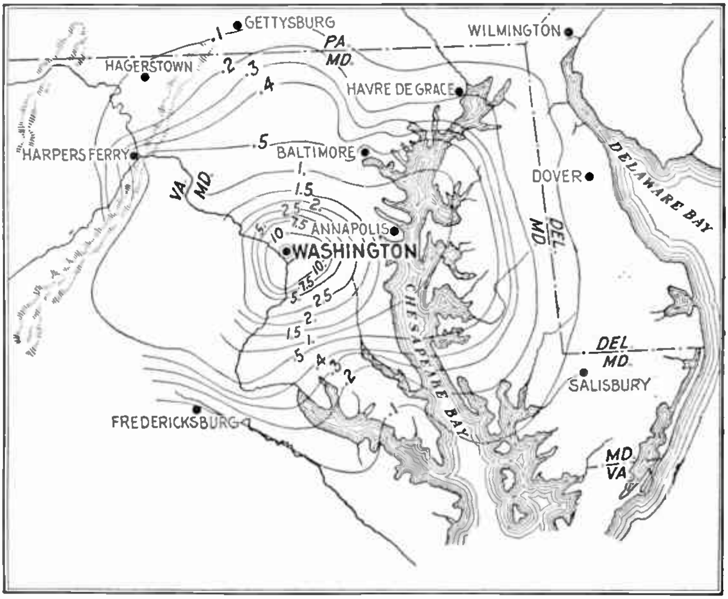

FIG. 116.—Map showing radio transmission in the vicinity of Washington, D. C.

Selecting a Receiving Set.—Three qualities which are desirable in a radio receiving set are (1) selectiveness, (2) sensitiveness and (3) accurate reproduction. The *selectiveness* of a receiving set is its ability to select any particular wave length to the exclusion of others, that is, a fine control of tuning. Thus the selectiveness of a single-circuit receiving set can be increased by using a wave trap, a double circuit arrangement, or a stage of radio-frequency amplification. The sensitiveness of a receiving set may be considered as a measure of the possible range, since it refers to the smallest radio current

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which will reproduce sounds in the telephone receivers in a satisfactory manner.

The sensitiveness depends upon the design of the circuit in the receiving set, the quality of the apparatus used, including the workmanship and the type of the vacuum tubes. Thus, a soft tube is more sensitive than a hard one but requires more care in operation so that other means of increasing sensitiveness have found more favor. Sensitiveness may be increased to some extent by adding one stage of audio-frequency amplification which also, of course, gives more volume of sound. The addition of a second stage of amplification increases volume of sound only. The addition of a single well-constructed and designed stage of radio-frequency amplification will not give much better results than can be secured from a regenerative detector. If, however, such a stage is compensated for feed-back, a considerable increase in sensitiveness is obtained and several stages give an enormous increase in range.

Accurate reproduction is not possible when distortion is present. Such distortion may come from outside the receiving set and may enter at a point along the path of the current through the instrument. The various causes of distortion and their remedies will be considered in Chap. XII. Obviously it would be futile to add any form of amplification to a receiving set which itself produces distortion.

It must be obvious that the practice of specifying a definite range for a receiver is misleading, to say the least. No such specification can take into account the various factors which affect radio reception. The most sensitive and selective instrument yet produced will not give consistent reception at any time of day, in any month of the year, or in any locality. At best it can be said that with a good receiving set radio reception from broadcasting stations within 100 miles is possible at any hour of the day over the entire year, with perhaps the exception of a week or two in mid-summer. Reception from stations within 500 miles is possible during the evening hours for 9 or 10 months of the year. Signals from stations within 2,000 miles may be received with fair

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intensity during a few hours late at night (around midnight) for three or four months in mid-winter. At distances over 2,000 miles, satisfactory reception is possible only during one or two hours very late at night for a few weeks in mid-winter. It must be understood that these are average conditions since, in some places, even a one-tube regenerative receiver will occasionally get signals of fair intensity from stations several thousand miles away.

With all but a few types of instruments the skill of the operator has much to do with the results obtained as to sensitiveness, selectiveness and clearness. The operation of particular types of receiving sets has already been considered and a few general observations, which apply to all receivers, will be taken up later in this chapter.

In selecting a receiving set the price is an important factor. The cost of apparatus varies considerably and is affected, among other things, by the quality of the parts and the cabinet, by patent rights, by quantity production, by service charges, and by performance. The prices quoted usually include only the receiving instrument proper, and, in addition to the set itself, it is necessary to buy the antenna outfit (in some cases), vacuum tubes, batteries, telephones, and loud speaker. At the present time, prices for the complete receiving sets range from about $15 for a crystal set, $25 to $30 for a single-tube set to about $450 for a super-heterodyne in a suitable cabinet.

It is advisable to keep in mind also the operation of the receiving set, that is, the number of adjustments which must be made in receiving, and the character of such adjustments. For equal performance a receiving set with but one or two controls which are not critical in adjustment and can be easily made, is preferable to one which requires a very careful setting of several controls.

If one has decided to buy a receiving set instead of constructing one it is wise to compare the performance of different instruments before making a final choice. The ideal arrangement for such a comparison is to try out the two or three instruments in question under the same conditions in each test.

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The nearest approach to such conditions is to try one of the receiving sets on a given station and then the others in turn, using the same antenna and ground connection. Then in the tests observe the relative selectiveness, sensitiveness, and ease of operation, as well as the quality of speech and music. Finally, the instruments should be compared as to the number and kinds of tubes, battery requirements, initial cost, and probable cost of operation.

In deciding upon the type of circuit to use in constructing a receiving set, one must rely entirely upon his own judgment and the published accounts of performance. Any of the popular receiving sets, if constructed carefully of well-made parts, will give satisfactory results. However, it must be remembered that there are not many people who can pattern a receiving set so closely to the manufactured article that equally good results will be obtained. If the performance of a receiving set depends upon a delicate and accurate balance of electrical constants, the construction is best left to the manufacturer. The amateur constructor who is willing to experiment with different arrangements and has some facilities for testing can duplicate any instrument provided that the necessary parts are available. Some indication of the interest shown in the construction of receiving sets may be inferred from statistics which show that 25 per cent of the receipts of dealers in radio equipment is from the sale of parts, while 75 per cent is from the sale of complete receiving sets.

Selection of Parts for Receiving Sets.—The choice of any part to be used in making a radio receiving set should depend upon a consideration of its electrical properties, mechanical properties, and cost. In the selection of a condenser, for example, the kind of service for which it is to be used is important. In the first place, is a fixed condenser or a variable condenser to be used? A *fixed condenser* is one in which the value of capacity stays constant. For best results, therefore, the construction and materials must be such that this capacity does not change. One very good type uses mica as the insulating material (dielectric) and when completed is put under high pressure which is maintained by means of a metal case, or

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by impregnating with wax so that the shape and characteristics will not vary. Fixed condensers using a paper insulating material have large losses, and are likely to be unstable because they are affected by changes in weather conditions.

In a *variable condenser* the moving plates, when revolved, must not touch the stationary plates and the spacing should not vary throughout the revolution. Large plates of thin metal are less desirable than thicker plates of smaller diameter. A *pig-tail* connection between the shaft and bearing is an advantage, though not essential. End plates, not less than ¼ inch thick of bakelite, hard rubber, or cast aluminum are much preferable to end plates of iron or of an unknown molded insulation. If the construction of the condenser frame is not rigid, sagging and twisting will take place. This together with side play from worn bearings will affect the accuracy of operation in tuning.

The losses in a condenser are due to absorption of electric power in the insulating materials, in the plates of the condenser, and in the contacts. Such losses are least in the condenser with air spaces for insulation, somewhat greater in the mica type and quite considerable in the paper type. To reduce the loss in the plates, a metal of low resistance, such as aluminum or brass, should be used, and the joints between the contact posts and the plates of the condenser should be soldered. The soldered construction has the additional advantage of holding the plates firmly in place. A satisfactory form of *vernier condenser* is the three-plate type mounted on the end of the main condenser.

For the usual commercial sizes of condensers the relation between capacity and number of plates is as follows:

Capacity (Microfarads)	Number of Plates
0.00025	11
0.0005	23
0.001	43
0.0015	65

Construction of Variocouplers and Variometers.—In a coil of wire which is to have low losses it is not advisable to

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use a winding frame of any kind of molded insulation. Even bakelite and similar materials are far from perfect. A thin-wall cardboard tube soaked in paraffin gives good results. A self-supporting coil is best but, of course, offers considerable difficulty in construction. In the construction of *vario-couplers* and *variometers*, in order to keep the resistance low a solid wire of about No. 12 or No. 14 wire gage is used. Of the commercial types of these instruments the most *efficient* has the primary winding on the inside of a hollow rounded stationary form and the secondary on the outside of a ball-shaped rotor. The frame should be rigid and so made that the moving coil will rotate evenly and will not touch the stationary coil at any point during a revolution. Pig-tail connections in place of spring or friction contacts are desirable. The type in which the primary winding is placed on the outside of the stationary part of the frame, and the one in which the primary is wound on a cylinder are in general use but are less efficient than the type first mentioned. There should be as little solid insulating material as possible in the space surrounding the wires of the two windings because the presence of such material causes a loss of power and a reduction in the strength of radio currents. Some insulation, however, is necessary to prevent contact and cotton is the most desirable as well as the cheapest; while shellac or varnish in any form is to be avoided. Even enamel or silk insulation introduces a loss.

Resistance Units: Rheostats and Potentiometers.—In resistance units such as *rheostats* and *potentiometers*, the contact arm should slide easily over the coil of wire used for resistance, but at the same time should make good contact at all points. The turns of wire should be wound tightly enough so that the wire does not move as the slider passes over it and each end of the resistance wire should be fastened firmly to its binding post, not merely wound around it. The wire must be properly exposed and spaced so that it will cool quickly. A vernier rheostat is necessary only with a soft vacuum tube, as used in a detector. A very good type of rheostat operates by variable pressure on a column of graphite disks and thus gives an extremely fine regulation. This type

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of construction has been applied also to *grid leaks, potentiometers* and *high-resistance units.*

Vacuum Tube Sockets.—The best sockets for vacuum tubes are made entirely of bakelite, except for the contact parts which are of bronze. These are preferable to the kind having a metal receptacle. The metal contacts at the bottom of the receptacle should be fairly stiff and springy so that a good, firm connection is made with the wire terminals of the vacuum tube. One form of construction, which has some advantages, places the contact springs in such a position that the pressure is on the side rather than on the bottom of the terminals of the vacuum tube. Sockets mounted on a base of sponge rubber help to reduce noises from jarring of the tube in places where there is much vibration of the receiving set due to persons walking on weak floors, nearby machinery, etc.

Audio Transformers.—An audio transformer must give as much amplification as possible without producing distortion. Moreover, this amplification must be fairly uniform over the voice and musical range of frequency which is from about 50 to 5,000 cycles per second. An important consideration in the selection of audio transformers is the ability to respond to sudden changes in frequency and voltage. While such factors can be determined only by trial, no transformer should be chosen without some information about the shape of its amplification curve and the degree of amplification. When the ratio of the number of turns on the secondary winding to the number of turns on the primary winding is 4 or 5 to 1, the best results are likely to be obtained. Also, the primary winding must be large enough to carry the plate current of the vacuum tube to which it is connected, and the insulation of this winding must be sufficiently good to withstand the plate voltage. It is desirable to enclose the windings of these transformers so that the magnetic field due to them will not affect other parts of the receiving set.

Lightning Arresters.—Insurance regulations state that only devices which have been approved by the Board of Fire Underwriters are acceptable. There are two kinds of arresters, one which can be used indoors and the other outdoors. In

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some places the insurance companies will not pass the indoor kind even though it is approved by the underwriters. The method of construction of a lightning arrester is not important provided it has a stamp stating that it has been approved by the Board of Fire Underwriters.

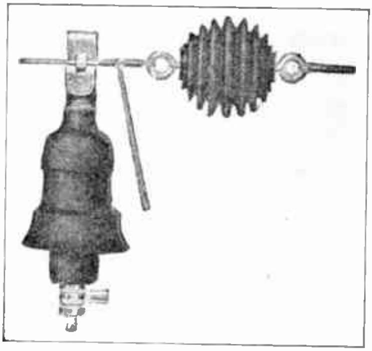

FIG. 117.—Brach lightning arrester (type 223).

Inside the body of the lightning arrester there are two small metal disks separated by an air gap. Through the connecting wires inside the arrester and by means of the outside terminals, the antenna lead-in wire is joined to one of the disks and the

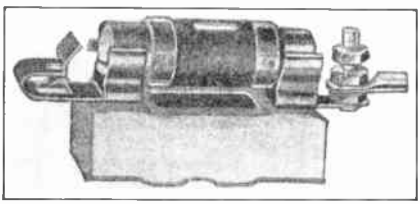

FIG. 118.—Brach lightning arrester (type 200).

ground wire to the other. It is claimed that the type of construction which uses the gap in a vacuum is the most efficient. The ordinary radio current will not flow across an air gap, but if an excessive amount of atmospheric electricity collects on the antenna, it can escape to the ground

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across the gap. Several types of approved arresters are shown in Figs. 117 to 120.

The Brach type 223, shown in Fig. 117, operates on the vacuum principle and is approved for either indoor or outdoor

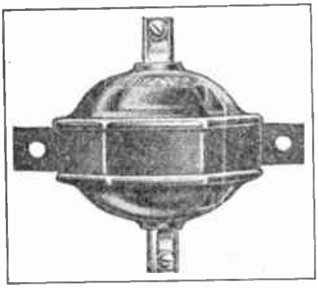

FIG. 119.—Keystone lightning arrester.

mounting. The body containing the gap is removable. The Brach type 200, shown in Fig. 118, operates on the vacuum principle and is approved for indoor mounting. This type also has a removable body. The Keystone arrester

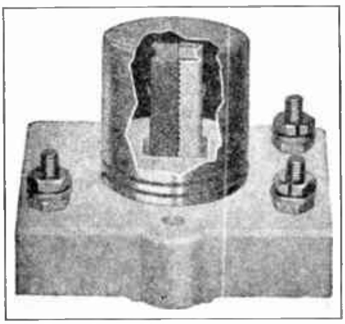

FIG. 120.—Frost lightning arrester.

(Fig. 119) is another well-known type for outdoor use, and the Frost arrester (Fig. 120) is used for indoor mounting.

Panels and Insulating Materials.—Hard rubber and resin compounds are most generally used for insulating purposes. A rubber panel must be fastened to a cabinet or to some

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permanent support to prevent warping. Some of the vulcanized fibre panels are not satisfactory for some purposes because it is difficult to drill holes in them, and are objectionable because they absorb moisture. Molded forms made of insulating material for radio units must have high mechanical strength and the best possible insulating properties—both hard rubber and the resin compounds have these properties.

Selecting Telephone Receivers.—If telephone receivers are to be used with a loud speaker (horn) or one or two stages of audio-frequency amplification, it is preferable to use a type having diaphragms made of mica rather than those made of metal. When the sound volume is large, metal diaphragms will rattle against the magnets in the telephone receivers and cause a chattering noise.[1] They must give high sensitiveness and clearness of tone over the usual range of frequencies rather than exceptional response over a narrow range of frequencies. It is a good precaution to buy telephone receivers or loud speakers on the basis of actual performance and comparsion with other makes. The resistance rating is no measure of the sensitiveness. In some cases an improvement is noted when the two wires connecting the telephone receivers to the receiving set are interchanged at either the points of attachment to the receiving set or to the telephone receiver. Most of the apparatus required for radio receiving sets has been standardized to a considerable extent. If the purchaser can describe the type of receiving set he intends to use, and can give information as to whether he intends to cover very great distances, a reliable dealer is usually able to recommend several makes which will give satisfactory results.

Selecting Vacuum Tubes.—The choice of vacuum tubes depends on the type of receiving set in which they are to be used, and the method of obtaining the electric current for the operation of the tubes. Thus a vacuum tube may be required

[1] In a good headset the two telephone receivers should be matched in tone and should have an impedance about equal to that of the tube or transformer with which they are used. *Impedance* is the resistance of a circuit carrying an alternating-current circuit. It corresponds to the *ohmic* resistance of a circuit carrying direct current.

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Receiving Tube Data

Name	Type	Filament			Plate		Detector			Amplifier		
										Rating		"C" battery volts
		Volts	Amperes	Source of power	Volts	Output impedance, ohms	Rating	Grid condenser	Grid leak ohms	Audio	Radio	
Alpha	....	3.0	0.25	2 dry cells	45–60	....	Fair	0.00025	....	Fair	Poor	
*Audiotron	....	6.0	0.80	6-volt storage	15–40	....	Fair	0.00025	....	Fair	Fair	
Cunningham	C-300	5.0	1.00	6-volt storage	15–24	9,000	Excellent	0.00025–0.0005	0.25–2.50	Fair	Poor	
Cunningham	C-301	5.0	1.00	6-volt storage	45–100	14,000–24,000	Fair	0.0005	2–5	Very good	Good	1.5–4.5
Cunningham	C-301A	5.0	0.25	Storage or dry	40–120	12,000–16,500	Good	0.00025	2–6	Excellent	Fair	1.0–6.0
*Cunningham	C-299	3.0	0.06	3 dry cells	40–80	16,000–18,500	Good	0.00025	2–6	Fair	Good	1.0–4.5
Cunningham	C-12	1.1	0.25	1 dry cell	20–90	17,000–19,000	Very good	0.00025	2–3	Good	Good	1.5–4.5
DeForest	DV-1	3.0	0.06	3 dry cells	20–80	20,000	Fair	0.00025	2–3	Fair	Fair	
DeForest	DV-2	5.0	0.25	Storage or dry	40–150	9,000	Fair	0.00025	....	Very good	Fair	
DeForest	DV-6A	4.0	0.25	Storage or dry	20–100	20,000	Fair	0.00025	....	Good	Good	
*French Tube	....	4.0–6.0	0.6	6-volt storage	20–200	....	Good	0.00025	....	Good	Good	
Melotron	DC-12A	1.25	0.25	1 dry cell	20–80	....	Fair	0.00025	2.00	Poor	Poor	
Melotron	DC-12D	1.25	0.25	1 dry cell	15–25	....	Fair	0.00025	2.00	Poor	Poor	
Melotron	SB-200	6.00	....	6-volt storage	15–25	....	Good	0.00025	2.00	Poor	Poor	
Melotron	SB-201	6.00	....	6-volt storage	40–100	....	Good	0.00025	2.00	Good	Good	
Melotron	SB-201A	5.00	....	6-volt storage	40–120	....	Fair	0.00025	2.00	Good	Fair	
Moorhead A.P.	....	4.0–5.0	0.6–0.7	6-volt storage	20–100	15,000	Very good	0.00025	2.0–4.0	Good	Good	
*Mullard	....	4.0–6.0	....	6-volt storage	....	....	Good	0.00025	....	Good	Very good	
Murdon	....	1.0–3.0	0.75	4-volt storage	16–60	....	Fair	0.00025	....	Fair	Poor	
*Myers	RAC-3	4.0	0.8	6-volt storage	20–300	30,000	Good	0.00025	1–5	Good	Good	
*Myers	....	2.5	0.25	2 dry cells	20–150	....	Good	0.00025	1–5	Good	Good	
Radiotron	UV-200	5.0	1.00	6-volt storage	15–24	9,000	Excellent	0.00025–0.0005	0.25–2.5	Fair	Poor	
Radiotron	UV-201	5.0	1.00	6-volt storage	45–100	14,000–24,000	Fair	0.0005	2–5	Very good	Good	1.5–4.5
Radiotron	UV-201A	5.0	0.25	Storage or dry	40–120	12,000–16,500	Good	0.00025	2–6	Excellent	Fair	1.0–6.0
*Radiotron	UV-199	3.0	0.06	3 dry cells	40–80	16,000–18,500	Good	0.00025	2–6	Fair	Good	1.0–4.5
Radiotron	WD-12	1.1	0.25	1 dry cell	20–90	17,000–19,000	Excellent	0.00025	2–3	Good	Good	1.5–4.5
*Radiotron	WD-11	1.1	0.25	1 dry cell	20–90	17,000–19,000	Excellent	0.00025	2–3	Good	Good	1.5–4.5
*Welsch	WT-501	4.0–6.0	0.5–0.8	6-volt storage	16–25	....	Fair	0.00025–0.0005	1–5	Poor	Poor	1.0
*†W. E.	215A	1.1	0.25	1 dry cell	40–60	25,000	Good	0.00025	2–5	Fair	Fair	1.5
†W. E.	203B	2.5	1.10	Storage	20–45	10,000–20,000	Excellent	0.00025–0.0005	0.5–3.0	Good	Fair	1.5
†W. E.	V-T1	2.5	1.10	Storage	20–45	10,000–20,000	Excellent	0.00025–0.0005	0.5–3.0	Good	Fair	1.5
†W. E.	J	2.5	1.10	Storage	20–45	10,000–20,000	Excellent	0.00025–0.0005	0.5–3.0	Good	Fair	1.5
W. E.	216A	6.0	1.00	6-volt storage	120	5,000–6,000	Fair	0.00025	1–5	Excellent	Good	9.0

* These tubes have a special base. † Western Electric.

for use in a detector or in an amplifier or in an oscillator (for transmission); and any of these requirements may be for radio sets used for either portable or stationary services. Whether the tubes are to receive current from a storage battery or from dry cells is also very important. Soft tubes are suitable only for use in a detector, and are not recommended for portable work since they need a storage battery to deliver the amount of current they require. They are very sensitive, sometimes noisy and demand critical adjustment. Hard vacuum tubes are more quiet, less critical, and are made for various battery requirements. Hard tubes are used for amplification[1] and also as power tubes and oscillators in transmitting apparatus. The following table gives all the necessary data for a number of *power* tubes.

POWER TUBE DATA

Name	Type	Filament		Plate		Watts output
		Volts	Amperes	Volts	Amperes	
Radiotron......	UV-202	7.5	2.35	350	0.050	5
Radiotron......	UV-203	10.0	6.50	1,000	0.150	50
Radiotron......	UV-203A	10.0	3.25	1,000	0.125	50
Radiotron......	UV-204	11.0	14.75	2,000	0.250	250
Radiotron......	UV-204A	11.0	3.85	2,000	0.200	250
Radiotron......	UV-206	11.0	14.75	10,000	0.125	1,000
Radiotron......	UV-207	22.0	52.00	15,000	1.800	20,000
Radiotron......	UV-208	22.0	24.50	15,000	0.450	5,000

Grid Condensers and Grid Resistances.—The condenser used in the grid circuit of a receiving set is of the fixed type (not variable) and has already been considered. The grid resistance *may* be of the fixed type and if of this type, it should be constant in value and preferably enclosed so that it is protected from weather changes. If a variable grid resistance

[1] For radio-frequency work they should have a low-capacity effect between elements while for audio-frequency work a high amplification-factor is necessary.

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is used, it should have fine regulation over a range of from ¼ to 10 megohms and must stay constant in value when adjusted.

Batteries.—When purchasing batteries be sure to get those which are designed expressly for radio service. Radio storage batteries for both filament and plate circuits can be obtained. The table on page 151 shows under what conditions it is advisable to use a storage battery rather than dry cells for the "A" batteries used for the filaments of vacuum tubes. In portable sets, and when space and weight must be considered, the small sizes of "B" batteries are allowable, but on a basis of hours of service per dollar of price, the large sizes of "B" batteries are the most economical. A large size of "B" batteries of good make will give from 1,000 to 1,500 hours of service before the voltage reaches the minimum of 17 volts. This drop in voltage is gradual and continues at a nearly constant rate during the life of the battery (at certain specified rates of discharge). For use in "A" batteries dry cells have the advantage of light weight, portability, low initial cost, no care, no danger from acids, and a fairly low maintenance cost on low-current tubes. However, the combination of a storage battery and a charging apparatus (current rectifier) ensures at all times a constant value of voltage.

Radio-frequency Transformers.—The tendency is toward the use of the air-core type of radio-frequency transformers in which the primary and secondary windings are on cardboard or bakelite tubes with comparatively close coupling. The secondary winding is tuned by means of a variable condenser. When tuned[1] transformers are selected the same type of transformer may be used in each stage. The requirements as to current-carrying capacity and insulation strength as stated for audio-frequency transformers apply here also.

[1] The untuned type of radio-frequency transformers must be so chosen that the interaction of the individual sharp amplification curves gives a resultant which is more or less flat in shape. In most circuits in which there is no compensation for vacuum tube capacity a turn ratio of about 1 to 1 is used. This gives no step-up action and serves merely as a coupling. When the tube capacity effect is compensated a higher turn ratio may be used. Thus a 4 to 1 ratio for the neutrodyne transformers is recommended.

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General Instructions for Operation of Receiving Sets.—Specific directions for *tuning* various types of radio apparatus have been given so that the following information is in the nature of general instructions which are intended to apply to all receiving sets. Before starting to locate a transmitting station it is best to check all the external connections, noting especially whether the lead-in wire from the antenna and the ground wire are connected on to the proper terminals. Make certain that all the wires from the batteries to the parts of the receiving set are connected firmly and that the nuts on the battery terminals are tight since some of them are likely to get loose. Review the directions and description prepared by the manufacturer or the designer of your receiver.

The first step in the operation of a receiving set having vacuum tubes, is to light these tubes and increase the brilliancy of the filaments until a slight hiss is heard in the telephone receivers. The rheostat controlling the filament current in the vacuum tubes should then be turned back (increasing resistance) until the hiss disappears. In general it may be said that a filament should be burned at the voltage recommended by the manufacturer of the vacuum tube. This can be checked by the use of a voltmeter connected across the filament terminals. In tuning it is absolutely impossible to locate any transmitting station when the control dials are moved rapidly. Turn the dials slowly, only a few *degrees* at a time. The operator is urged again to make a chart or table showing the dial settings for various wave lengths. If one has trouble in locating some distant station, and finds after tuning in to the carrier wave, that he is receiving squeals and whistles from other receivers which are also having difficulty, it is best to give up the effort and turn to some other station which offers less interference. If a regenerative receiving set is being used, one should avoid increasing the tickler coupling or plate variometer feed back to a point at which the vacuum tube begins to oscillate and interfere with other receivers. As the feed-back is increased the regeneration increases until a hissing noise is heard which is a sign of oscillation. A further increase of feed-back will produce a very loud squeal in the

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telephone receivers. The correct operating position is at a point just below the appearance of the hissing noise. Sometimes this does not appear and oscillation must then be detected in some other way. In that case, a good test is to place the thumb on a filament terminal and a finger on some part of the grid circuit (preferably the grid terminal). This acts to stop the oscillations and will produce a click in the telephone receivers. When the finger is removed from the grid a second click is heard. If the vacuum tube is oscillating the two clicks will be of practically equal strength. If the tube is not oscillating the first click will be stronger than the second, the difference being most marked when large grid condensers are used.

Avoid jarring the receiving set since this may not only produce noise but may also change your adjustments. Finally, try to learn the peculiarities of the receiving set, so that it may get a real trial before necessary changes are made.

Care of Batteries.—The use of the hydrometer in testing the storage battery, and the use of a charging outfit have already been considered. For testing "B" batteries a voltmeter may be used. It is best to test each block separately. A 22½-volt battery should be discarded when its voltage drops to 17 volts. An exact value of "B" battery voltage is not necessary since the strength of the sounds in the telephone receivers will not vary much with a small voltage decrease (except with soft tubes). But a marked decrease in the strength of the sounds of speech and music in the telephone receivers is to be expected when the battery is nearly discharged since then the voltage drops rapidly. There is no gain in a series connection of a number of rundown batteries because of the large resistance thus introduced into the battery circuit. When one portion of a series of "B" batteries must supply more current than the others, it is advisable to interchange the batteries occasionally so that the demand for current is more equally distributed. Voltmeters may be obtained with various ranges, of voltage such as 0 to 3, 0 to 10, 0 to 16, 0 to 30, 0 to 50 volts and so on. Some types combine in one casing the connections for a small and also a large range and be used for testing "A," "B,"

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and "C" batteries. Another type combines in one casing, a voltmeter and an ammeter.

When dry cells are used to supply current to the filaments of vacuum tubes, it is best to test the cells by means of a low-range voltmeter. In doing this, light the filaments of all the vacuum tubes so that they are burning at the normal rate. Then the voltmeter, connected in turn across each cell, should read but slightly less than 1.5 volts, and the voltage across the group of cells should be greater than the voltage requirement of one of the vacuum tubes. The usual short-circuit test with an ammeter in series gives an approximate indication of the condition of a battery; but the voltage test is more important. Try to avoid accidental short circuits on the batteries since such a sudden and large flow of current may cause much harm. All dry batteries will depreciate when stored away for long periods, even though they are idle, and this depreciation is more marked in small than in large cells.

Care of Vacuum Tubes.—Successful operation requires a *constant voltage* across the filament of a vacuum tube. *Constant current* is not good practice since after a tube has been in use for some time the condition of the filament varies in such a way that *less and less current is required* for best results. When a decided increase in filament voltage becomes suddenly necessary, the usefulness of the tube is nearly gone. If an excessive voltage is applied to a tungsten filament (without burning it out,) the vacuum tube may refuse to respond. In most cases it may be restored to service by burning the filament at the standard voltage for the vacuum tube for about 20 minutes with the plate circuit open.

Until better facilities are at hand, it is a risky matter to have a vacuum tube repaired by anyone but the manufacturer. Without sensitive instruments the amateur is not able to check the performance of a repaired tube with its specifications. Usually the current consumption of a repaired tube is considerably greater than the original requirement.

Care of Telephone Receivers and Loud Speakers.—Sooner or later abuse will affect the sensitiveness of telephone receivers and loud speakers. They should not be allowed to fall on

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floors, and should not be handled roughly, because sudden shocks may demagnetize the magnets, distort the diaphragm, or otherwise disturb the adjustments made at the factory. The cap of the casings of these instruments should be removed only by an experienced person when it is necessary to examine the interior. The diaphragm of a telephone receiver should not be pulled away forcibly from the attraction of the magnets, but should be pushed sideways so that it will slide off the case. This simple precaution will prevent bending the diaphragm.

Care of Receiving Sets.—The most important precaution to observe in handling a receiving set is to avoid jarring. Occasional jarring and handling may not only loosen some of the connections but may even change the value of the electrical constants. Trouble introduced in this way is very hard to locate. The receiving set should be protected from moisture, the presence of which in some parts of the set will lead to electrical leakage losses. Dust may cause such leakage losses also and, in a condenser, may short-circuit some of the plates, or, in a coil, it may short-circuit some of the turns of wire.

KEEP YOUR RECEIVING SET IN CONDITION[1]

Clean	Adjust	Inspect	Test
Antenna insulators	Condenser bearings	Antenna masts	Dry cell "A" batteries
Antenna joints	Vario coupler bearings	Antenna lead-in	Dry cell "B" batteries
Ground connection	Variometer bearings	All wiring in set	Dry cell "C" batteries
Wires to batteries	Switch arms	All joints	Storage "A" battery
Condenser plates	Rheostat arms	Connections to binding posts	Storage "B" battery
Condenser end bearing	Potentiometer arms	Operation of jacks	Flexible connections on variometers and variocouplers
Socket contacts	Socket springs	Operation of rheostats	Sensitivity of tubes
Socket bases	Jack springs		
Jack contacts	Tighten all nuts and binding posts		
Storage battery terminals			

[1] From an article by Goldsmith in *Boston Globe*, June, 1924.

Reactivation of Vacuum Tubes.—Vacuum tubes in radio receiving sets eventually lose their sensitivity. This sometimes progresses to the point where the receiving set operates

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very poorly or not at all, even though the tube filament is not burned out. The user of the set frequently confuses this condition with that due to an exhausted "B" battery. If the tubes are of the thoriated tungsten filament type, they can usually be rejuvenated by a simple process, and made to serve as well as new tubes in the receiving set.

It happens that most of the tubes now used are of the thoriated tungsten type, and it therefore becomes of quite general interest to know how to secure the full life of these vacuum tubes. The WD-11 and WD-12 type of vacuum tubes are the only ones extensively used which cannot be reactivated. In these tubes the source of the electrons is a coating of certain oxides on the *surface* of the filament, and when this has been used up, no process can renew it. However, the thoriated tungsten filaments, used in most of the various other types of tubes contain the oxide of thorium throughout the whole mass of the tungsten filament, this oxide being used to keep the filaments from being too fragile. In the process of manufacture these filaments are given a treatment which produces a layer of atoms of thorium on the surface of the tungsten, and this thorium, which is radioactive, emits electrons much more copiously than the tungsten would. After long use, or after burning the filament too brightly, the layer of thorium atoms is evaporated off, and so few electrons are then emitted that the tube does not function properly. Reactivation is a process which boils additional thorium atoms out of the interior of the tungsten filament and forms a new layer of thorium atoms on the surface.

The thoriated filament was developed by the General Electric Co., which has also developed the methods of reactivating tubes of this type. The Bureau of Standards has found that the reactivation process is quite successful, and frequently makes a wonderful difference in the results obtained with a receiving set. The process is essentially the operation of the filament for a very brief interval at a specified high voltage (called "flashing"), followed by a lower voltage for a longer time (called "aging"), all of this *with no grid or plate voltage.* The "flashing" reduces some of the thorium oxide in the

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wire to thorium, and the aging forms the required surface layer. The following schedule of these operations is the result of extensive experimentation by the Radio Corporation of America, and is published here by courtesy of that company and the U. S. Bureau of Standards.

FLASHING

Radiotron	Filament voltage	Time
UX and UV-199	10	30 seconds
UX and UV-201-A	15	1 minute
UX-120	10	1 minute

AGING

Radiotron	Filament voltage	Time
UX and UV-199	4.5	10 minutes
UX and UV-201-A	7.5	10 minutes
UX-120	4.5	10 minutes

Exactly the same procedures apply for C and CX tubes as for the UX tubes of corresponding number; thus, C and CX-299 correspond to U and UX-199; C and CX-301-A to U and UX-201-A; and CX-220 to UX-120.

In carrying out this schedule it is absolutely essential to have a voltmeter of a good degree of accuracy and to use a watch. No grid or plate voltages are used. Either alternating or direct current may be used for heating the filaments.

It is important that reactivation should not be attempted *until the tube user has assured himself that the tubes actually need this treatment;* that is, he should make certain that his batteries are not run down, and that other parts of the receiving set are in proper order. The schedule above should be followed with great care. The process is useful only for the thoriated tungsten filament type of tubes.

The apparatus necessary for carrying out the process is simple. The filament is connected to the necessary source of voltage, *nothing being connected to the grid and plate.* A

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COMPARATIVE CHARACTERISTICS OF TYPES OF RADIO RECEIVING SETS

Cost of set	Type	Battery, phone and vacuum tube equipment	Selectivity	Quality	Distance
1	Crystal set	No batteries; no tubes; ear phones	Very poor	Very good	Poor
2	One-tube set (regenerative)	Dry cells and 22½ volt "B" battery; one tube; ear phones	Fair	Good	Good
3	Two-tube set (one radio-frequency stage)	Dry cells; 90-volt "B" battery; 2 tubes; ear phones; "C" battery	Fair	Good	Good
4	Reflexed two-tube set with two-stage amplifier	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 90-volts "B" battery; 4 tubes; loud speaker or ear phones; "C" battery	Fair	Good	Good
5	Five-tube "tuned radio-frequency set"	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 90-volts "B" battery; "C" battery; 5 tubes; loud speaker or ear phones	Good	Good	Very good
6	Five-tube "Acme" reflex	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 90-volts "B" battery; "C" battery; 5 tubes; loud speaker or ear phones	Good	Fair	Very good
7	Five-tube Browning-Drake (Regeneformer (resistance-coupled audio stages)	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 5 tubes 67½–90 volts "B" battery; "C" battery	Good	Very good	Very good
8	Five-tube neutrodyne	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 5 tubes; 90 volts "B" battery; "C" battery	Good	Good	Very good
9	Eight-tube superheterodyne	Dry cells if low-current tubes used; storage batteries if high-current (0.25 to 1 ampere) tubes used; 8 tubes; 90 to 135 "B" battery· "C" battery.	Excellent	Good	Excellent

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voltmeter is connected across the filament terminals. *If alternating current is available the source of voltage can be a small transformer, such as those for running doorbells or electric toys.* The voltage tap nearest the voltage specified should be selected and a rheostat in series with the filaments used to adjust to the exact voltage. *The voltmeter must be one for alternating current.*

If alternating current and a transformer are not available, dry batteries or storage batteries may be used as a source of voltage. A single dry cell when new will furnish approximately 1.5 volts. A rheostat should be connected in series to give the exact filament terminal voltage as indicated on a direct-current voltmeter.

QUESTIONS

1. Describe the effect of some of the factors which must be considered in determining the range of a receiving set.
2. Explain the meaning of three qualities which a receiving set should possess.
3. How would you select a pair of good telephone receivers?
4. What are a few of the precautions to be observed in connection with the care of a receiving set?
5. What care do the vacuum tubes require?
6. Name some of the general instructions which apply to the operation of receiving sets.
7. If you were asked to compare the performance of two receivers, what items would receive your attention?

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CHAPTER X

RADIO TELEPHONE AND TELEGRAPH TRANSMISSION

The purpose of a transmitting station is to vary an electric current in such a way that it bears the characteristics of a message and then to utilize this current for the propagation of radio waves. The essentials of a transmitting station are, first, a source of electrical energy; second, a means of converting this energy into a form having high voltage and high frequency; third, some device for interrupting, or modulating this energy; and finally an aerial[1] or antenna to act as a distributor of the energy.

Systems of transmission may be classified according to the type of wave transmitted. *Spark* transmitting stations produce *damped waves* of *radio frequency* which consist of *series or trains* of waves *repeated* at regular intervals at an *audible rate of frequency.* The succeeding waves in each series are of decreasing amplitude. *Undamped* waves, also known as *continuous waves* (C.W.) are produced by transmitting stations using a high-frequency alternator, an electric arc, or a vacuum tube designed for high-frequency currents. *Undamped waves* are not broken up into series or trains, but are *continuous,* that is, one cycle follows the other at *constant frequency,* except when interrupted by the key in telegraphy, or when varied in amplitude by the interrupter in I.C.W. (interrupted-continuous-wave) telegraphy, or by the device used in radio telephony for modulating the continuous waves by spoken words or music in a telephone transmitter called a *microphone.*

"Spark" or Damped-wave System.—The spark transmitting station is a survival of the early days of radio when the spark

[1] Some authors make the distinction in the use of the words *aerial* and *antenna* that aerial should be the name for the wire or system of wires *transmitting* radio waves and antenna should be used for the wire at the *receiving* end of a radio system.

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method of producing high-frequency currents was the only satisfactory one. Although this system is convenient and economical in operation and construction, the fact that it causes considerable interference, and that devices for the production of high-frequency *continuous* waves have been developed to a high degree of perfection, is leading to a gradual replacement by the continuous-wave system. Any of the usual types of crystal or vacuum-tube receiving sets may be used to receive damped-wave signals.

Continuous-wave Systems.—The use by a radio transmitting station of a continuous carrier wave having a constant frequency permits the very sharp tuning of the receiving set, and also reduces the interference at other transmitting stations. Since the oscillations of the radio waves in this system are continuous and not intermittent as in the case of damped or spark waves, the value of current need not be so great and smaller voltages may be used. In other words, a continuous-wave (C.W.) transmitter has a greater range with a given amount of power than a damped-wave or spark transmitter. In radio telegraphy, the receiving operator can control the tone of the signals so that they may be distinguished from others and from atmospheric interference. Finally, the whole development of radio telephony rests on the use of the continuous-wave system.

The high-frequency currents used in the continuous-wave system are usually produced by a high-frequency alternator, by an oscillating electric arc, or by a vacuum tube oscillator. The alternator is used in long-wave transmitting stations of high power, and electric arcs, or vacuum-tube oscillators are used in the short-wave transmitting stations of smaller power. The expense of the electric arc method practically limits the amateur transmitter to the use of the vacuum tubes for the production of high-frequency currents; hence, the vacuum-tube method only will be considered here.

Vacuum-tube Oscillator.—In its use for producing high-frequency currents, the vacuum tube operates on its *feed-back* action, which is obtained by coupling the grid and plate of the vacuum tube. In this respect it is like the using

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of the vacuum tube in a regenerative receiving set in which some of the current in the plate circuit is fed back to reinforce the incoming radio current. In a transmitter using this method, however, the original disturbance may be due to the small amount of current flow caused by the closing of a battery circuit, or to a slight variation of capacity, and so on. Once this has started the feed-back action will begin and the values

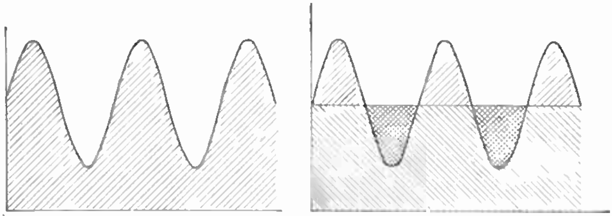

Fig. 121.—Alternating current super-imposed upon direct current.

of the currents flowing will increase. If a correct portion of the current in the plate circuit is fed back to the grid, the pulsating current wave in the plate circuit will be continuous. This pulsating current may be considered as made up of an alternating current superimposed upon a direct current, as

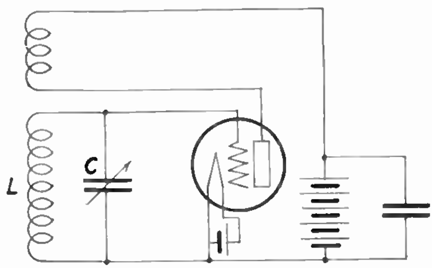

Fig. 122.—Control of tube oscillator.

shown in Fig. 121. In this way the action of a vacuum tube converts part of the energy of a battery supplying current to it into an alternating current. The frequency of this alternating current is determined by the adjustment of the inductance L and the capacity C, in Fig. 122. In a transmission system the plate circuit of the vacuum tube is coupled to the antenna

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circuit so that the plate energy is transferred to the antenna for the purpose of sending out the continuous radio wave. The power vacuum tubes used in transmission are similar to receiving vacuum tubes, but, for large outputs, require some provision for carrying away the heat such as air blast or water cooling. The apparatus used in transmitting sets must carry much larger currents than that used in receiving and hence the construction of the parts is somewhat different.

The difference between circuits for the transmission of *radio telegraphy* and those for *radio telephony* is mainly in the arrangement by which the continuous current is modulated to follow the variations of the telegraph code or those of the voice. The sources of power are similar to those used in radio receiving instruments. As has already been shown, alternating current may be used for lighting the filament of the vacuum tubes by means of suitable transformers, and, in transmitting work, is preferable to direct current for this purpose. Direct current for the plate circuit is sometimes obtained from batteries but usually from the 60-cycle alternating-current distribution lines. This is converted into direct current by means of a motor-generator set, or by the use of an arrangement including a transformer, a rectifier, and a filter. Alternating current may be applied directly to the plate in continuous wave telegraphy (not telephony), but is not advisable because it produces an audible note in a receiving set and causes considerable interference. In the circuit diagrams in this chapter the source of electric current will be indicated but not specified.

Radio Telegraphy.—In radio telegraphy the dots and dashes of the Morse code are impressed upon the grid circuit as shown in Fig. 123, but continuous waves, even when rectified will produce clicks and not musical tones in the telephones unless they are broken up at an audio-frequency rate. This is accomplished by a rapid interruption of the current at either the transmitting or the receiving end. At the transmitting end the interruption may be produced by placing a circuit breaker or *chopper* in the antenna wire. The chopper may be used also to short-circuit some of the turns of the antenna inductance, which causes a change in frequency.

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In the *buzzer* method which is sometimes employed the radio-frequency oscillations are modified at an audio-frequency rate.

Thus if transmission by radio telephone is effective over a certain range, then, transmission by radio telegraph using interrupted continuous waves (C.W.) may double that range, while by radio telegraph transmission using continuous waves without interruption may triple the range.

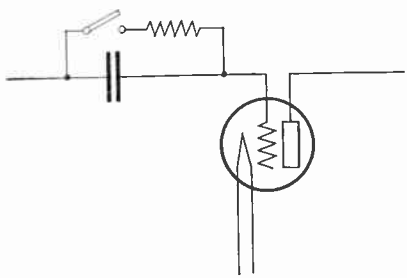

FIG. 123.—Telegraph key in grid circuit.

At the receiving end the continuous wave may be broken up by:

1. A *chopper* in series with the detector and telephone receivers.

2. A variable, rotating (by mechanical means) *plate condenser* in the secondary circuit.

3. A *tikker* instead of a detector.

4. The use of a separate *heterodyne* (see page 133).

When the key at the transmitter is pressed down, the resulting series of waves produces one click in the phones. When the key is released another click is heard. A short interval between clicks corresponds to a *dot* at the transmitter while a longer interval corresponds to a *dash*. When any of the methods mentioned above are employed the signal appears as long and short musical tones of constant pitch. In the first three devices the interruption is produced mechanically and at an audible rate, so that a group of waves intercepted at the receiver will be broken up at the same rate. The pitch of the tone produced in the telephone receivers depends, then,

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upon the frequency of the rate of interruption. Heterodyne action has been described and need not be considered again.

The relation between the type of receiving set, the character of the received signal, and the kind of message is indicated in the following table:

Message	Type of receiver	Received signal
Continuous wave telegraphy	Crystal set	Series of clicks
	Vacuum-tube set, non-oscillating	Series of clicks
	Crystal set, using an interrupting device, as a *chopper* or *tikker*	Musical tone
	Vacuum-tube set, oscillating (separate or self-heterodyne)	Musical tone
Interrupted continuous-wave telegraphy.	Crystal or non-oscillating vacuum-tube set	Musical tone
Telephony..............	Ordinary crystal or vacuum-tube set	Message as delivered to microphone

When an alternating-current plate current is used with a transmitter in continuous-wave (C.W.) telegraphy the received signal, in a crystal or non-oscillating vacuum-tube set, will consist of clicks together with a muscial tone.

A good arrangement of radio telegraph apparatus for general purposes is the *Meissner circuit*, shown in Fig. 124. It is important that each of the inductance coils, L_1 and L_2, should be coupled to the antenna coil L and not to one another. If L_1 and L_2 are placed inside the antenna coil, they should be arranged to allow rotation so that the amount of coupling may be controlled.

Up to a certain point it is possible to obtain increased output by adding vacuum tubes in parallel to the original number of

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tubes; but when the resistance of the plate circuit becomes very low it is best to use a larger tube. Some data on power vacuum tubes are given in the table on page 152. When a vacuum tube is to be connected in parallel to another tube,

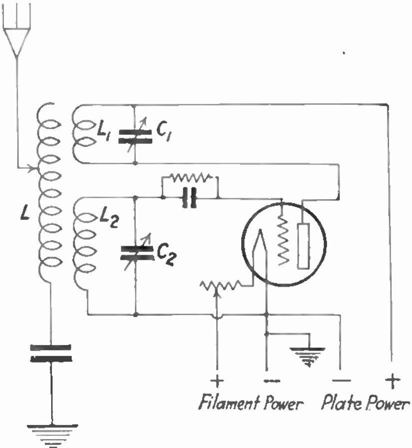

FIG. 124.—Meissner circuit for radio telegraphy.

its grid is joined to the grid of the other, its plate to the other plate, and its filament terminals to the corresponding filament terminals of the other tube. Figure 125 shows two vacuum tubes in parallel, using one grid leak and grid-condenser.

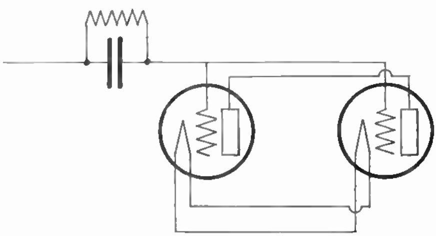

FIG. 125.—Parallel connections of vacuum tubes.

Operation of Radio Telegraph Apparatus.—For the most satisfactory results the adjustments of the transmitting apparatus for radio telegraphy must be such that, at the required wave length, the radio current in the antenna is as

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large as possible. Under these conditions the current passing through the vacuum tube has its highest value. In making the adjustments it is necessary, first, to set the circuit for the desired wave length and then to vary the coupling between the plate and antenna circuits for maximum current and to maintain the feed back at a proper value. The several controls are not independent so that the original setting for wave length may have to be readjusted.

In detail, the process is carried out in the following order: First disconnect the antenna and ground. Then put the radio telegraph set into operation by lighting the tubes and adjusting the condenser C_2 in the secondary circuit until the desired wave length is obtained. Then connect the antenna and ground wires to the instrument and set the coupling between the antenna and the secondary at some preliminary value while the antenna is being tuned to the proper wave length by adjustment of its inductance coil. This condition will be indicated when an ammeter in the antenna circuit shows a maximum reading.

The coupling is then made closer until two points of resonance appear. Now the coupling must be loosened until the wave is pure, or, in other words, until there is but one point of resonance. Finally it is necessary to re-check the wave-length readings.

To assist the operator in making the adjustments and in operating the instrument it is advisable to use the following instruments:

1. Filament ammeter, as a check on filament current.
2. Plate ammeter, in order not to exceed the rated output (watts) of the tube.
3. Plate voltmeter, as a check on the source of current.
4. Ammeter to measure antenna current, as a measure of the radiation (losses).

Radio Telephony.—In order to produce speech-modulated waves of radio frequency, there must be a means of causing variations in the current of the radio-frequency generator supplying the electric current, which will follow accurately the low-frequency variations of the sounds to be transmitted.

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Methods of Modulation.—The simplest method of modulation, which may be used only on small powers, utilizes a *microphone* coupled either directly or inductively to the antenna circuit, as in Fig. 126. The coupling has the effect of decreasing the effective resistance of the microphone which should be equal to that of the antenna circuit. Here the radio-frequency current is divided between the antenna and microphone resistances. In order to use this method for larger powers the power absorbing effect of the microphone must be increased. This has been done in the so-called *audion amplifier* and in the *magnetic modulator.*

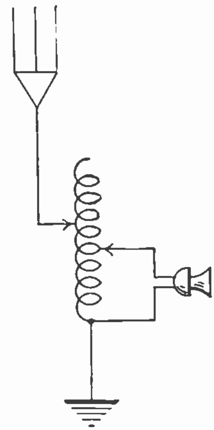

FIG. 126.—Microphone in antenna circuit.

Modulation is also accomplished by attaching the secondary of the transformer in a microphone circuit to the grid connection of the vacuum tube. Figure 127 illustrates an application of this method to the Meissner circuit. The secondary S of the modulation transformer T takes the place of a grid resistance across the condenser C. *A Ford spark coil* may be used instead of a transformer, since this method of modulation is suitable only for a small current. This system, while simple and economical, is not very effective since the current delivered is not appreciably affected by changes in grid voltage. Better modulation is obtained if the vacuum tube is operated at reduced current. If the grid voltage is reduced below the range of stable operation, however, the vacuum tube may cease to oscillate, and the antenna current will fall to zero. Fairly satisfactory operation may be secured by careful settings of the circuit and of the modulating voltage limits.

The most efficient method of tube modulation is by variation of the current delivered to the plate of the vacuum tube. Here there is a nearly direct relation between the variation in microphone current and the antenna current over a wide range. The microphone in itself is not capable of controlling

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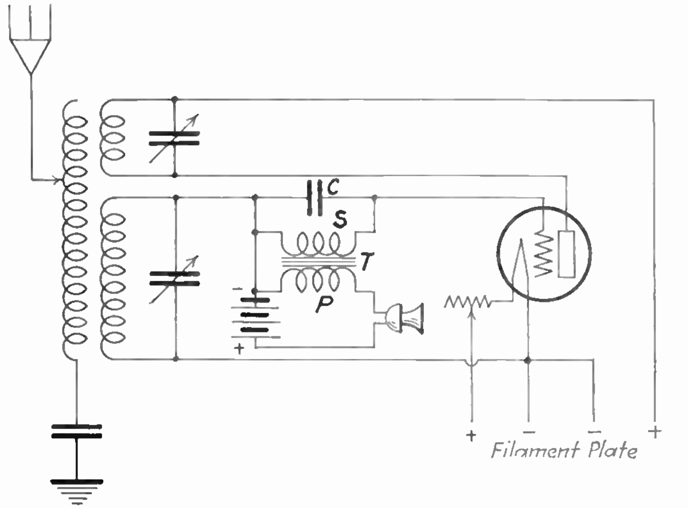

Fig. 127.—Microphone in grid circuit.

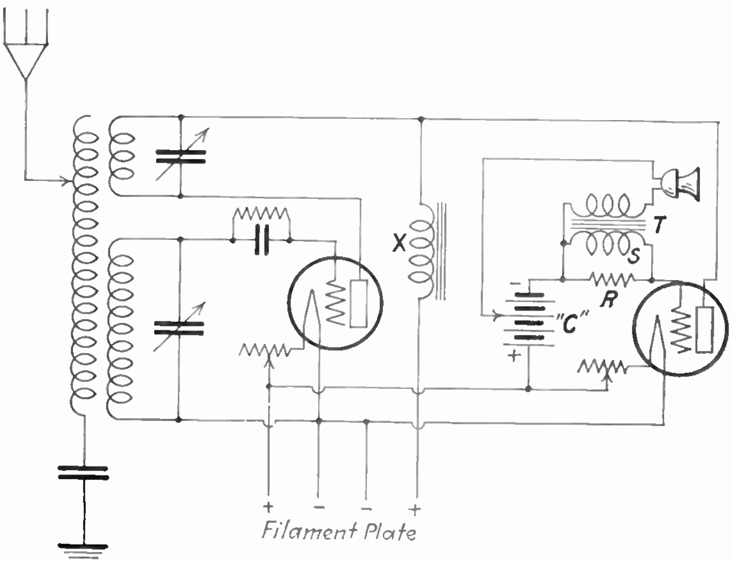

Fig. 128.—Heising system (modulator tube).

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the current supplied by the oscillating tube, and hence its effect must be increased by the use of another vacuum tube called a *modulator tube.* Such an arrangement, known as the *Heising system,* is shown in Fig. 128. In this system, the two vacuum tubes should be the same type and as nearly electri-

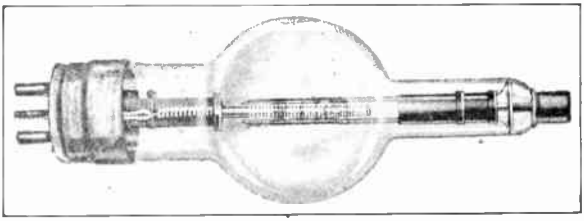

FIG. 129.—UV-204 vacuum tube for radio transmission.

cally identical as is possible. The choke coil X should have an *impedance* which is equal to the resistance of one of the tubes. The resistance, R (1 to 2 megohms), decreases distortion by reason of its control of secondary voltage. It serves also as a

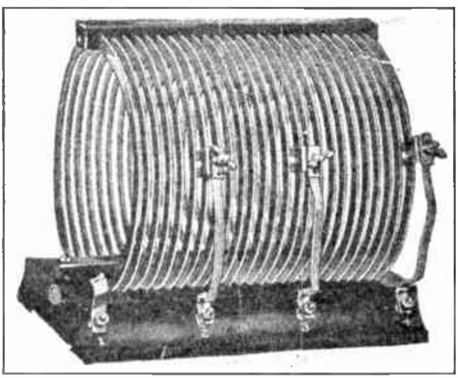

FIG. 130.—Oscillation transformer.

grid leak. The "C" battery furnishes current for the microphone circuit, and is used to maintain the proper negative voltage of the grid. The "C" voltage necessary to accomplish this varies from about 25 volts for 5-watt power tubes to 60 volts for 50-watt tubes.

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The choke coil X and the modulation transformer T may be constructed by the amateur, but generally more satisfactory results are obtained with commercial types.

The difference in design and construction between transmitting apparatus and receiving apparatus may be seen from the

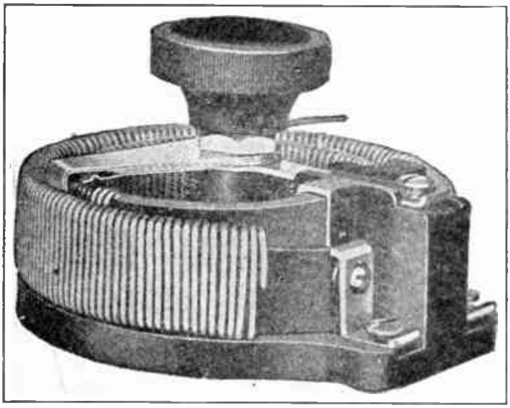

Fig. 131.—Transmission rheostat.

illustrations in the following figures. In most cases the size of the unit depends upon the rating of the vacuum tube which is used. Figure 129 shows a UV-204 tube, whose characteristics have been described in Chap. IX. Figure 130 is an oscillation

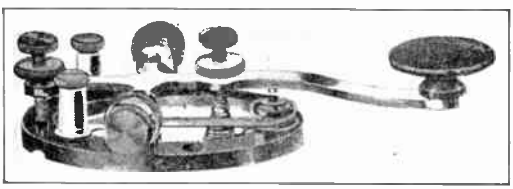

Fig. 132.—Sending key.

transformer with 25 turns of 0.060- by 3/8-inch nickel-plated copper strip, having rounded edges and mounted on a wooden base. The dimensions are about 8 by 6 by 10 inches. The transmitting rheostat in Fig. 131 is designed for use with UV-203 and UV-204 vacuum tubes and gives four dif-

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ferent values of resistance depending upon the connections. Figure 132 shows a sending key made of brass with sterling silver removable contacts. The overall dimensions are 5 by 2¾ inches.

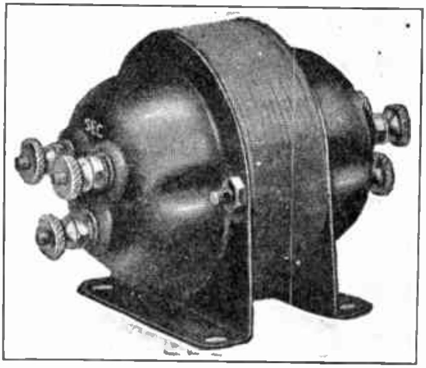

FIG. 133.—Microphone transformer.

The microphone transformer which was mentioned in connection with the *Heising method* of modulation is illustrated in Fig. 133. This is of about the same size as the transformers used in receiving sets. The choke coil used in the plate circuit with modulator tubes is similar in construction to a microphone transformer.

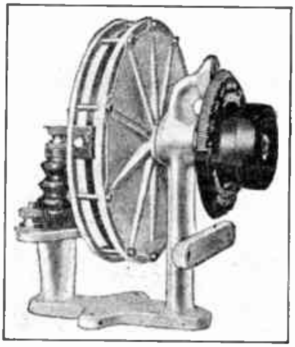

FIG. 134.—Variable condenser for transmission antenna circuit.

Figure 134 shows a variable condenser designed for use in series with the antenna. It is rated at 4,000 volts, 0.0012 microfarads (maximum), 0.0001 microfarad (minimum), and will stand 5 amperes at maximum capacity. The overall dimensions are about 5 by 5 by 4 inches. These condensers may be used in receiving sets as well as in transmitting apparatus.

A grid leak for use with 50- and 250-watt Radiotron tubes is shown in Fig. 135. This has a resistance of 5,000 ohms

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with a connection at the center to give 2,500 ohms. The size of this unit is 8½ by 1½ inches. Transformers for filament heating and plate supply, and for use on an alternating-source of electric current, are shown in Fig. 136.

Figure 137 shows the construction of the ordinary low-capacity microphone or transmitter for radio telephone work.

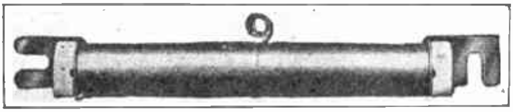

FIG. 135.—Grid-leak for transmission circuit.

This does not differ essentially from the transmitter used in telephone work and, in fact, the latter can be used in radio. The diaphragm *D*, is connected to the carbon block *C*. At the back of the casing is another carbon block C_1, and the

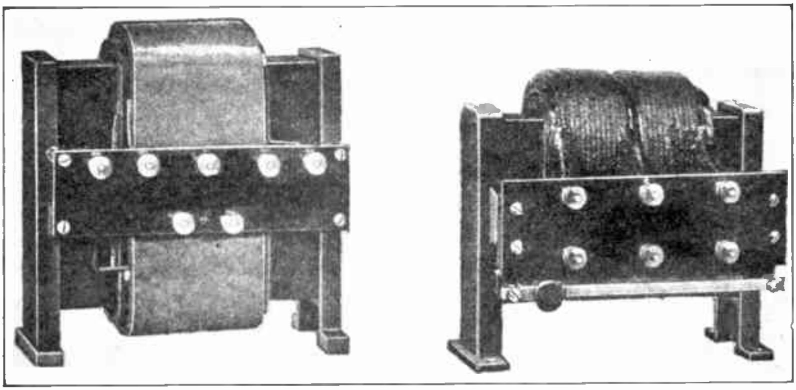

FIG. 136.—Transformers for filament heating and plate supply.

space between the two blocks is filled with small grains of carbon *G*. Now if a source of power is connected to the block *C* and the block C_1, a current will flow through the carbon grains. On speaking into the transmitter, the diaphragm vibrates and the vibration is transferred to the carbon block *C*. This vibration of the block *C* varies the pressure on the carbon grains and hence changes the resistance and the

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current. The fluctuations of the current follow the vibrations produced by the voice and the current is said to be *modulated* by the voice.

High-capacity transmitters may consist of several ordinary microphones connected in series-parallel, or may use the carbon grain construction with some mechanical device for cooling the grains of carbon. Other types of high-capacity transmitters have been developed, the action of which depends

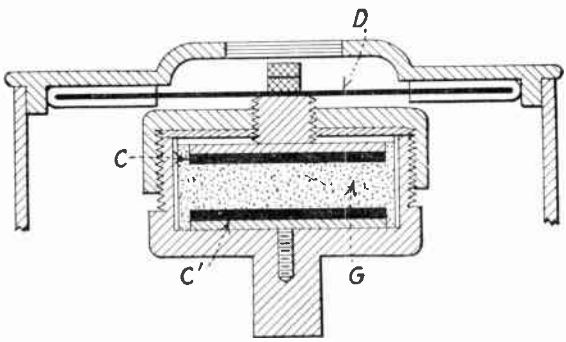

FIG. 137.—Low-capacity microphone for transmitter.

upon the change in area of a current path in a conducting liquid.

Government regulations state that every radio transmitting station must be inspected and licensed. Aside from the station license, a person who desires to operate a radio transmitting set must have an operator's license. Requests for information and applications for operating or station licenses should be addressed to the inspector of the district in which the applicant or station is located, thus:

Radio Inspector
Custom House
..................(City)
....(State)

The region covered by the inspector of each district is given in the following list:

1. *Boston, Mass.*—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.

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2. *New York, N. Y.*—New York (Counties of New York, Staten Island, Long Island and those on Hudson River to and including Schenectady, Albany and Rensselaer), New Jersey (Counties of Berger, Passaic, Essex, Union, Middlesex, Monmouth, Hudson and Ocean).

3. *Baltimore, Md.*—New Jersey (Counties not in district 2), Pennsylvania (Counties of Philadelphia, Delaware, Franklin, and those south of the Blue Mountains), Delaware, Maryland.

4. *Savannah, Ga.*—North Carolina, South Carolina, Georgia, Florida, Porto Rico.

5. *New Orleans, La.*—Alabama, Mississippi, Louisianna, Texas, Tennessee, Arkansas, Oklahoma, New Mexico.

6. *San Francisco, Cal.*—California, Hawaii, Nevada, Utah, Arizona.

7. *Seattle, Wash.*—Oregon, Washington, Alaska, Idaho, Montana, Wyoming.

8. *Detroit, Mich.*—New York (Counties not in district 2), Pennsylvania (Counties not in district 3), West Virginia, Ohio, Michigan (lower peninsula).

9. *Chicago, Ill.*—Indiana, Illinois, Wisconsin, Michigan (upper peninsula), Minnesota, Kentucky, Missouri, Kansas, Colorado, Iowa, Nebraska, South Dakota, North Dakota.

The pamphlet entitled *Radio Communication Laws of the United States* may obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. Call letters are assigned to stations at the time the license is granted. A list of such stations together with their call letters is given in the pamphlets *Amateur Radio Stations of the United States*, and *Commercial and Government Radio Stations of the United States* which may also be obtained from the Superintendent of Documents. Supplements to these lists are issued monthly in a pamphlet called *Radio Service Bulletin* which gives also information about changes in radio regulations.[1]

The tables on page 175 give the international Morse Code with signals and abbreviations used in radio communication:

[1] A price list of all radio publications issued by the Government may be obtained without charge from the Superintendent of Public Documents.

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DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

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

A · —
B — · · ·
C — · — ·
D — · ·
E ·
F · · — ·
G — — ·
H · · · ·
I · ·
J · — — —
K — · —
L · — · ·
M — —
N — ·
O — — —
P · — — ·
Q — — · —
R · — ·
S · · ·
T —
U · · —
V · · · —
W · — —
X — · · —
Y — · — —
Z — — · ·

Ä (German) · — · —
Á or Å (Spanish-Scandinavian) · — — · —
CH (German-Spanish) — — — —
É (French) · · — · ·
Ñ (Spanish) — — · — —
Ö (German) — — — ·
Ü (German) · · — —

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

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

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DEPARTMENT OF COMMERCE
BUREAU OF NAVIGATION
RADIO SERVICE

INTERNATIONAL RADIOTELEGRAPHIC CONVENTION
LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

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

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

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

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QUESTIONS

1. What are the essentials of a transmitting station?
2. Name some of the advantages of the continuous-wave system of communication as compared with the damped-wave system.
3. Describe the action of a vacuum-tube oscillator as used for the production of high-frequency currents.
4. In radio telegraphy how are the variations of the Morse code impressed upon the current which causes the radio wave.
5. Explain why a continuous wave does not produce a musical tone in the telephone receiver.
6. What methods are used at the receiving station to interrupt a continuous-wave signal at an audio-frequency rate?
7. Draw a diagram of a circuit which may be used for the transmission of radio telegraph signals.
8. Describe and illustrate one method of modulation for radio telephony.
9. What are the principal points which must be observed in the operation of a transmitting set?

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CHAPTER XI

CONSTRUCTION AND TESTING OF RECEIVING INSTRUMENTS

The proper tools for making a radio receiving set are almost as necessary as the apparatus itself. To those who are not familiar with the kind of work required, a short description of the tools will be of interest.

Drills and Screws.—Drills for boring holes in wood, metal and rubber are nearly always needed. Those used for boring metal may be used also for boring wood and rubber. Drills are classed according to size (diameter) of the *boring* end and the form of the shank which is gripped in the drill holder.

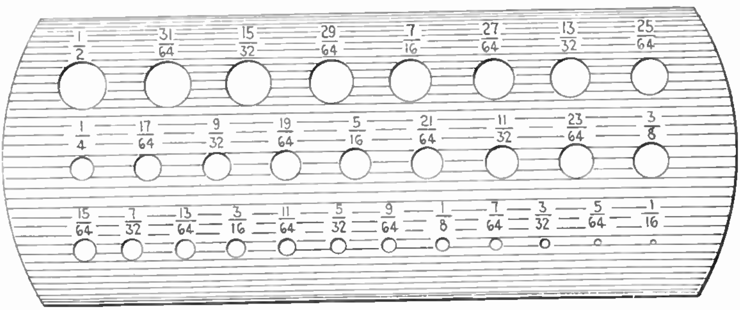

FIG. 138.—Machinist's (drill) gage.

The small sizes of drills are designated by number—from No. 80 having a diameter of 0.0135 inch, to No. 1 with a diameter of 0.2280 inch. Larger sizes are designated by letters, beginning with *A* having a diameter of 0.234 inch up to *Z* with a diameter of 0.413 inch. Regular twist drills listed in fractional sizes begin at 1/16 inch and advance by 1/64 inch to 3 inches in diameter for both straight and taper shanks.

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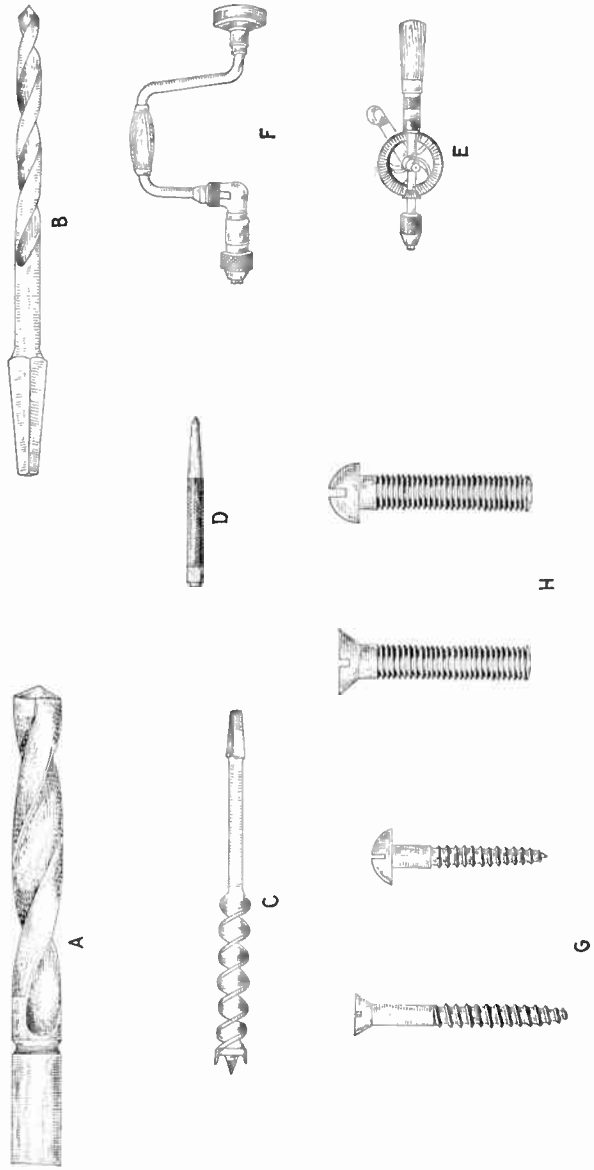

FIG. 139.—Drills for metal and wood.

Usually the size of a drill is stamped on the shank, except in small sizes. If the size is not marked on the shank, it can be determined by the use of the gage shown in Fig. 138.

A *straight shank drill* and a *bit stock drill* are shown at *A* and *B* in Fig. 139. A bit such as shown at *C* in Fig. 139 is used on soft materials such as wood, but never on metal.

A *center punch* which can be obtained in various sizes is shown at *D* in Fig. 139.

It is not necessary to buy a full assortment of drill and bit sizes, but only those which are actually needed, and usually these are mentioned somewhere in the directions for building a receiving set. The holder for a drill is called a *hand drill* and that for a bit is a *brace;* both of these are shown at *E* and *F* in Fig. 139.

Screws are classified as *wood* screws and as *machine* screws. A wood screw is used in wood; a machine screw principally in metal. Two kinds of each of these screws are shown at *G* and *H* in Fig. 139.

A small wood screw can be screwed into the material directly but in the case of large screws, a small hole should be bored first to prevent splitting.

Ordinarily metal does not have to be bored in making a radio-receiving set, but the following information is given to help in meeting such emergencies as may arise. The hole for a brass machine screw must be drilled, and then tapped in order to take the threads on the screw.

The table below gives the sizes (number) of tap drills and clearance drills which are necessary for certain standard machine screws. The first column indicates the number and threads per inch of the screw and also of the tap to be used in cutting the threads for the screw. Thus "2–56" means a No. 2 size with 56 threads per inch. The second column gives the size (number) of the drill which is used to bore a hole for the use of the tap. The third column (clearance drill) gives the size (number) of the drill for boring a hole which is large enough to take or pass the machine screw when it is unnecessary to have a thread in the hole.

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Screw V thread	Tap drill	Clearance drill	Screw V thread	Tap drill	Clearance drill
0—80	56	52	8—32	28	18
1—72	53	47	10—32	19	9
2—56	48	42	¼—20	12	F
3—48	44	37	5⁄16—18	¼	P
4—36	41	31	5⁄16—24	F	P
6—32	32	26	⅜—16	5⁄16	W

The hole for a flat-head machine screw must be set in with a special tool called a countersink, in order that the top of the head may be flush with the surface. In ordering screws it is necessary to state the size, length, type of head, material, the kind of screw, and, in the case of machine screws, also the number of threads per inch.

The size of both flat- and round-head machine screws which is used most commonly is the ¾ inch, 32 thread, while flat- and round-head wood screws are used in No. 4, No. 6, No. 8 and No. 10 sizes, usually in ½, ¾ or 1 inch lengths. Brass hexagon nuts and brass washers are of course, required with the machine screws. It is advisable to have on hand all the necessary screws, nuts and washers, since the lack of one may delay construction and lead to makeshift devices.

Tools.—A small *hacksaw C* (Fig. 140) for cutting metal, a small and large *screwdriver D*, a small "*dead smooth*" flat file *E*, some medium fine sandpaper, solder, flux, and a soldering iron complete the list. Most of these articles are illustrated in Fig. 140.

An electric soldering iron is a great convenience and allows the inexperienced worker to turn out a much more efficient piece of work. Unless the maker of a radio set has considerable skill in soldering wire he should practice a little on pieces of scrap copper or tin before actually soldering his set. In soldering, it is necessary first to heat the iron until it is hot enough to melt the solder readily. Then clean the faces of the iron with a file or sandpaper until a clean surface is obtained.

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Solder in the form of wire with a flux core may be obtained and will save much time on the job; otherwise the flux (rosin, not acid) must be applied before beginning to solder. Now melt some solder on the tip of the iron and spread it so that a thin coating covers the tip; this is called *tinning* the iron. When you are ready to make the joint, place the hot iron against the wires to be soldered and keep it there until the wires get so hot that the solder will melt on them and not *freeze* or harden without sticking. Then when a drop of solder is applied it will flow readily to form the required joint which should be held firmly with a pair of pliers until the

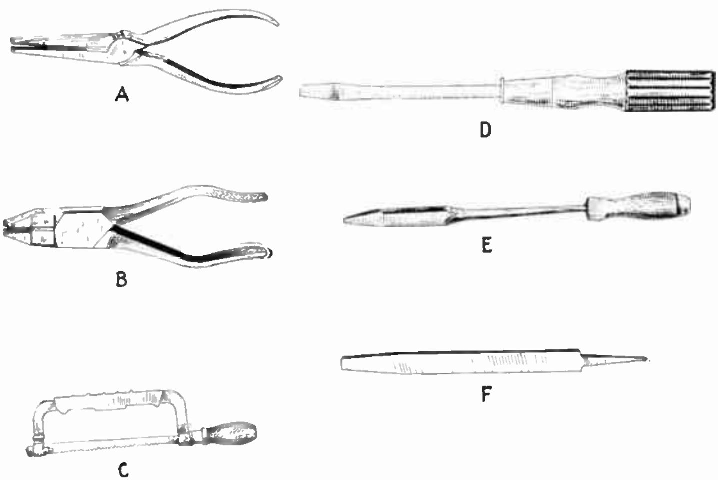

FIG. 140.—Tools for radio construction.

solder is cool. Do not use any more solder than is necessary since the amount of solder on a joint is no indication of its efficiency.

In making a joint with solder be sure that the solder actually unites with both the pieces of metal which are to be joined. Sometimes the two pieces of metal appear to be united when in fact they are only temporarily stuck together by the rosin in the flux. Such a joint ordinarily soon pulls apart, but even if it holds together, no radio current can pass through it.

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Pliers are necessary for work which requires any cutting, shaping or gripping. A pair of long-nose pliers and a pair of combination cutting pliers as shown at *A* and *B* in Fig. 140, will cover all the usual requirements. The 6-inch size is ordinarily most convenient, but this, of course, is a matter of preference.

With the aid of a wiring diagram and a guide for the drilling of the panel, it is possible for even a very inexperienced person to build a receiving set which will function in a satisfactory manner. The general precautions to be observed are not many and can readily be applied.

Panels.—Many radio dealers will drill panels to order and can supply cabinets in a variety of sizes. Also, it is possible to obtain panels already drilled for many of the popular circuits. If this procedure is to be followed it is necessary to get a wiring diagram for the type of receiver in question. In the construction data which follows the panels are all of standard size, but the spacing of holes is special and hence the drilling must be done either at home or as a special job. Use a center punch for laying out the holes. Holes should be drilled from the front of the panel with metal twist drills, and should be countersunk with a reamer or larger-sized drill.

Arrangement of Parts.—The arrangement of parts should be such that the connecting wires are as short as possible. Inductance units, such as grid and plate variometers, and transformers, should not be placed too close together because the magnetic fields which they create may conflict, and produce distortion of signals, that is, inaccurate reproduction of sound. Inductance switches should be close to the coil taps.

A rheostat is mounted on the panel in front of the socket it serves in order that the leads may be short. Battery wires can be run along the panel and will not give any trouble from capacity because there is not much voltage difference between them and the ground.

Recent designs put the "A" and "B" battery connections at the back of the receiver, leaving only the phone connections on the panel.

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Grid and plate leads *must* be short and should be run along the back of the cabinet, and not parallel to each other.

The variable grid leak and condenser can be placed close to the grid terminal of the socket.

When the wiring is done with heavy bus wire of about No. 14 size and is self-supporting, there is no need for insulation, otherwise a small tubing called *spaghetti* should be used to avoid contacts.

If it is seen, after the receiver is completed, that a different arrangement of parts would allow the use of shorter wiring, it is advisable to make the change, rather than to take a chance.

The antenna condenser in a single-circuit receiver should be in the antenna lead and should have the movable plates connected to the antenna. In a double-circuit receiver the antenna condenser may be put in the ground lead with the movable plates grounded. A condenser used in the grid circuit should have its movable plates connected to the "A" battery, while a condenser used in the plate circuit should have the movable plates connected to the "B" battery. These arrangements are necessary to reduce the effect of body capacity.

Shielding.—If you have had much to do with receiving sets while they were in operation you have doubtless noticed that in some instances when you place your hand upon or near the instrument, the signals are made louder or weaker. This effect is due to what is technically known as body capacity. Shielding is a term usually applied to the use of a sheet of tin foil or of copper foil placed on the back of the panel for the purpose of reducing the effects of body capacity. The same result can be accomplished if those parts of the receiver which must be touched are kept at a low voltage. In the case of the condenser this is done by the proper connections of the fixed and movable plates as explained in the preceding paragraph.

Wave Trap.—The utility of a wave trap in reducing interference from local broadcasting stations has been mentioned on page 141. A suitable form of wave trap may be made by connecting a condenser and a coil in parallel. The method of connection is shown in Fig. 141 in which C is a condenser of

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0.0005 microfarad capacity, L_1 is a coil having about 45 turns of No. 28 double cotton covered wire on a 4-inch tube. L_2 is a coil of 8 to 12 turns of No. 22 wire wound over a piece of paraffin paper which has been wrapped around the coil L_1.

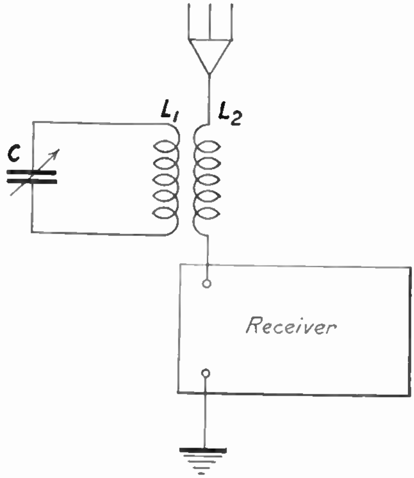

FIG. 141.—Radio wave trap.

In using a wave trap, the first step is to tune in on the station which causes interference until the signals are strongest. Then adjust the condenser C until the signals are weakest. The trap is now adjusted to absorb energy on this particular wave length. Then when another station is tuned in, very little interference is experienced.

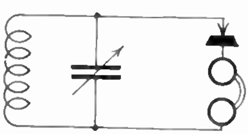

FIG. 142.—Radio wave meter.

After a number of trials with several stations a chart can be made for this apparatus showing the wave length corresponding to any setting of the condenser.

Wave Meter.—The wave trap described above may be used to tune a transmitter. To do this a crystal detector and a pair of telephone receivers are added as shown in Fig. 142. This apparatus is called a *wave meter*.

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The antenna and ground of the transmitter are then disconnected and the wave meter placed near the secondary of the oscillation transformer. The wave meter is then set to the desired wave length and the inductance of the oscillation transformer is varied until a maximum response in the telephone receivers is obtained.

The wave-length range of any circuit, such as coil and condenser, or transformer and condenser may be ascertained by making the wave meter into a transmitter. This is done by adding an interrupter or buzzer and a battery as indicated in Fig. 143.

The circuit whose wave-length range is to be measured is arranged as in Fig. 144 with a crystal detector and phones.

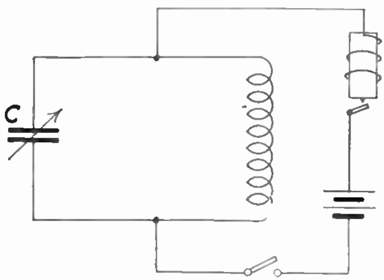

FIG. 143.—Radio wave meter with interrupter and battery.

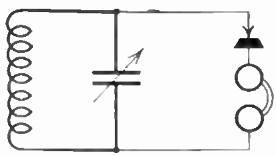

FIG. 144.—Measuring range of wave length.

When the wave-meter switch is closed, the instrument acts as a transmitter using a wave length determined by the setting of the wave-meter condenser *C*. By working over the required range and noting the response in the phones, the wave-length range of the circuit in question can be determined and the design changed, if necessary.

Loop.—A loop is a special form of the antenna. It is merely an enlarged coil, consisting of several turns of wire on a wooden frame about 2 feet square. Detail directions for building a set are given later in this chapter.

The method of connecting a loop to a receiving set depends upon the wiring inside the set. If the set has a coil and condenser connected in series, then the loop is attached as shown in

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Fig. 145. If the receiving set has a coil only, then a condenser must be placed so that one of its terminals is attached to the loop and the other to the ground connection of the set. Then the other end of the loop is connected as shown in Fig. 146. A loop and condenser may be used also to replace the tuning

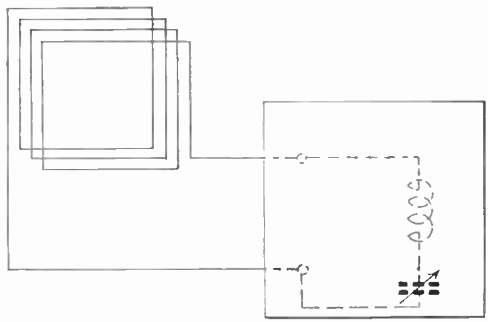

FIG. 145.—Typical method of connecting radio loop to receiving set.

arrangement of a set by the connection shown in Fig. 147. In this case the condenser is connected across the terminals of the coil which are then attached to the grid and filament terminals of the set.

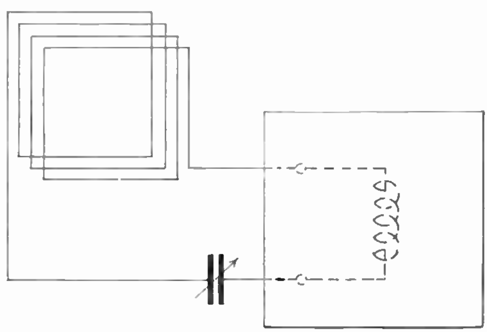

FIG. 146.—Radio loop and condenser for single coil receiving set.

For all ordinary purposes the wire used for a loop may be No. 20 or 22 ordinary insulated solid copper wire, spaced from ¼ to ½ inch apart. A loop made on a 4-foot square with 6 or 8 turns and using a condenser capacity of 0.001 microfarad

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can be used over the entire broadcasting range. If the size of the square is made less, the number of turns must be increased.

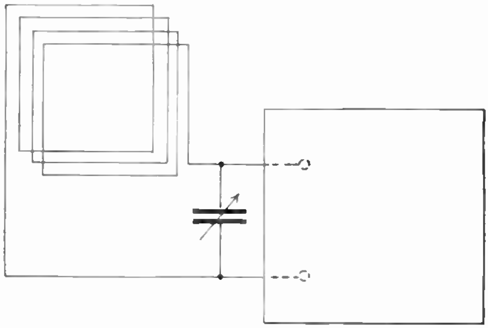

FIG. 147.—Radio loop and condenser to replace tuner.

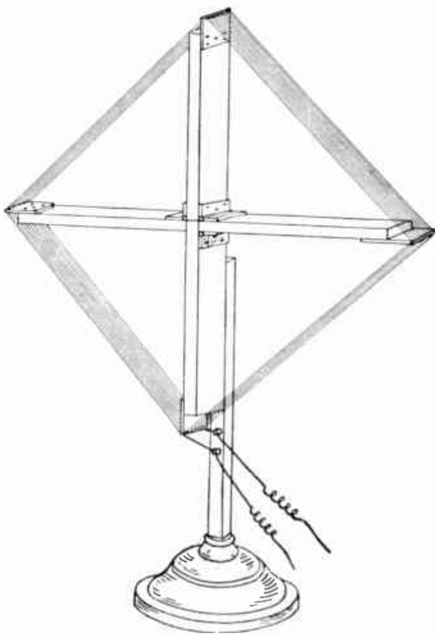

FIG. 148.—Small radio loop.

Thus for a 20-inch square there should be about 20 turns. One form of small loop is shown in Fig. 148. In general about 100

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feet of wire may be wound on a loop irrespective of the size. If a clip is used on one of the wires leading from the set to the loop, the number of turns may be selected as desired.

If this is done it will be noticed that the dead or unused turns do affect the others since the results are not the same when, for example, a loop of 6 turns is compared with one of 10 having 4 turns cut out. It is evident that as the size of the loop is decreased, it approaches the conventional tuning coil.

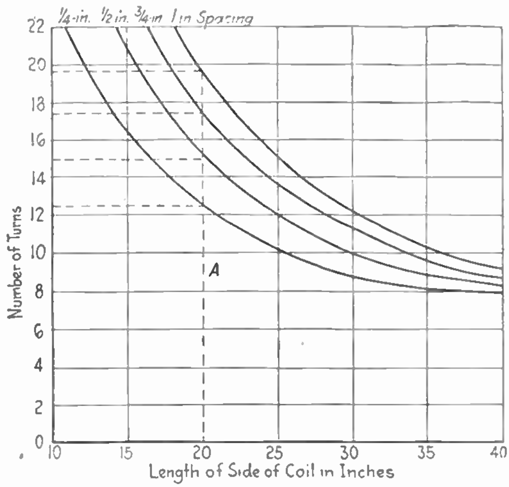

FIG. 149.—Drawing for construction of radio loop.

With the aid of Fig. 149 it is a simple matter to build a loop which has the proper wave-length range of 222 to 545 meters. The chart is based on the use of a 0.0005-microfarad condenser connected across the terminals of the coil and assumes that the minimum capacity of the condenser is 0.00005-microfarad. The capacity of the coil itself is relatively negligible and has been omitted. A No. 14 wire is used but the difference for other sizes of wire is very small.

In order to build a loop one must first decide upon the size of the square. Then the number of turns and the spacing of the wire are obtained from the chart. Thus, assume the coil is to be 20 inches square. On the chart follow up the line through

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20 inches to the 1-inch spacing curve and from there to the left. This shows about 20 turns; 18 turns are needed for ¾-inch spacing; 15 for ½-inch spacing and 12 for ¼-inch spacing. It will be noticed that for a large coil the number of turns is not affected much by the spacing.

Construction of Receiving Sets.—In the following pages complete constructional data for several typical receiving sets are given. The list includes the following:

1. Crystal receiver.
2. Single-tube regenerative receiver.
3. Two-stage audio-frequency amplifier.
4. Two-stage radio-frequency amplifier.
5. Single-tube reflex receiver with crystal detector.
6. Four-tube reflex receiver with crystal detector
7. Three-tube neutrodyne receiver.
8. Six-tube super-heterodyne.

The first four receiving sets are designed in such a way that the experimenter can begin with a simple crystal set and add to it, as opportunity allows, until he has a 5-tube receiving set in which almost all of the apparatus from the previous receivers can be utilized. This is a factor of considerable importance and should be considered carefully by the amateur before he makes the decision to build any type of receiving set.

This flexibility in design applies also to the two reflex receivers. The neutrodyne receiver uses two stages of radio-frequency amplification with air-core transformer coupling and a detector tube. The two-stage audio-frequency amplifier can be used with it to increase both the range and volume. The transformers used in the neutrodyne can be rewound for the proper wave-length and are then suitable for the super-heterodyne.

Crystal Detector Receiving Set.—This is a single-circuit arrangement, using a variometer for tuning. By noting the size of the panel (as given in the list of materials) and measuring the drilling templet as shown in Fig. 151 it is a simple matter to locate the holes which must be drilled. The drills required are, No. 25, No. 18, and $\frac{5}{16}$ inch.

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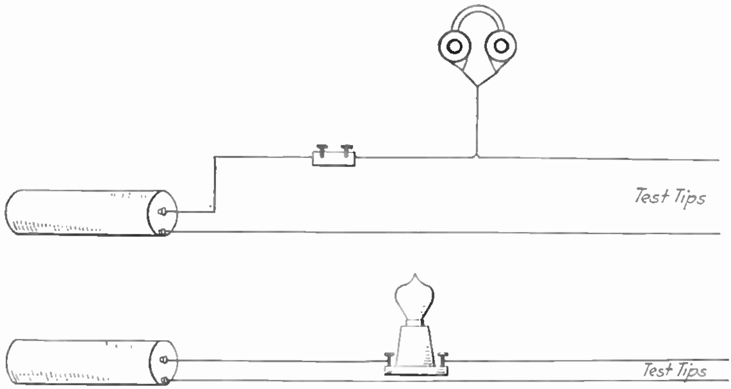

FIG. 150.—Practical radio testing outfit.

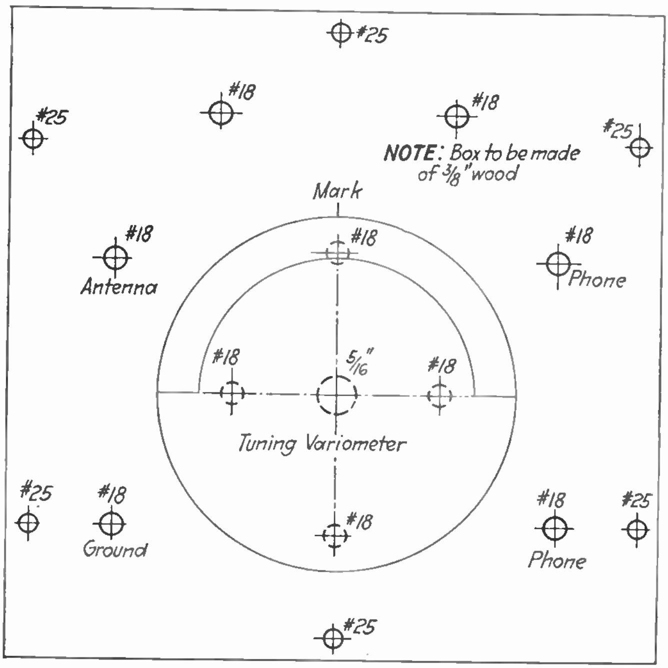

FIG. 151.—Drilling templet for crystal detector receiving set.

The diagram in Fig. 152 shows the wiring as it would appear if the panel was removed.

List of Materials for Crystal Detector Receiving Set

- 1 5½- by 5½-inch panel.
- 1 Variometer.
- 1 Crystal detector.
- 1 Series fixed condenser, 0.00015–0.00025 microfarad.
- 1 Phone condenser, 0.002 microfarad.
- 1 Dial (3 inch).
- 4 Binding posts.
- 3 Feet of bus wire.

It will be noticed that the material lists do not call for batteries, cabinets, lugs, screws, tools, telephone receivers, loud speaker and the antenna system. These items are classed as accessories and are not included as parts of a receiving set.

Testing the Crystal Receiver.—After the various units of the receiving set have been connected, it is a worth while precaution to test the assembly for faults. A simple testing outfit which is sometimes necessary in locating short or open circuits may be made conveniently with a dry cell and the telephone receivers of a headset, or a flash-light bulb, as shown in Fig. 150. The bulb-testing outfit is not, however, as sensitive as the telephone receivers, since the latter will indicate the presence of very small currents. It is advisable to use insulated wire to prevent contacts with other wiring than that which is being tested. When the tips of the test outfit are touched to the ends of a circuit which has no breaks in it, a click will be heard in the phones, or the bulb will light. On an open circuit no click will be heard, or the bulb will not light. In testing any unit it may be necessary to disconnect its terminals from the receiver in order to be sure that no other path for the current is provided. In some poorly constructed rheostats, an open, or a loose connection is due to the fact that the end of the resistance wire is merely wrapped around its binding post, instead of being fastened firmly to it.

When the test tips are touched to the points 1 and 2, as indicated in Fig. 152, no click should be noticed. If a click does occur the fixed condenser has a short circuit, meaning

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that some current finds its way through the condenser. If this is the case a new condenser must be obtained.

It is necessary to bear in mind that even a perfect condenser will produce a very faint click in the test telephone. This, however, is due to the momentary "charging" current of the condenser and cannot be mistaken for the sharp, loud click which occurs with a short circuit.

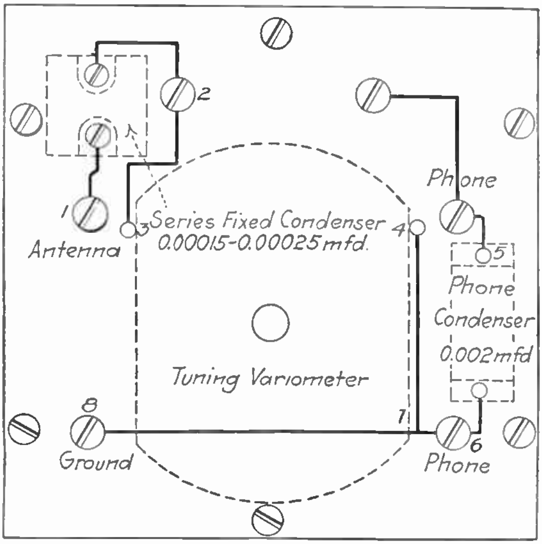

FIG. 152.—Wiring diagram for crystal receiving set.

If no clicks are heard when the tips are touched to 3 and 4 there is an open circuit or a break in the wiring of the variometer which must be repaired.

It is not advisable to test the crystal in this way because the comparatively large current which would pass through might injure the crystal. The crystal is best adjusted by trial while the receiving set is in operation.

The testing of the "phone" condenser brings out a point which must be observed very carefully. In testing any part of a circuit make certain that there is no other path for the test current than the one which you are testing. If the test tips are touched to points 5 and 6 a click will be heard, even

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though the condenser is perfect, because the current can flow through the path between points 5 and 6 by way of the crystal and the variometer. Hence it is necessary to disconnect the condenser at one side, say at point 5, and then touch the test tips to point 6 and to the disconnected condenser terminal. A click indicates the presence of a short circuit in the condenser.

In the same manner tests may be made for an open circuit in the various parts of the connecting wires, such as between points 6 and 7, 7 and 8, and so on.

As far as concerns the operation of the crystal itself there is no choice in the matter of placing it in a circuit. That is,

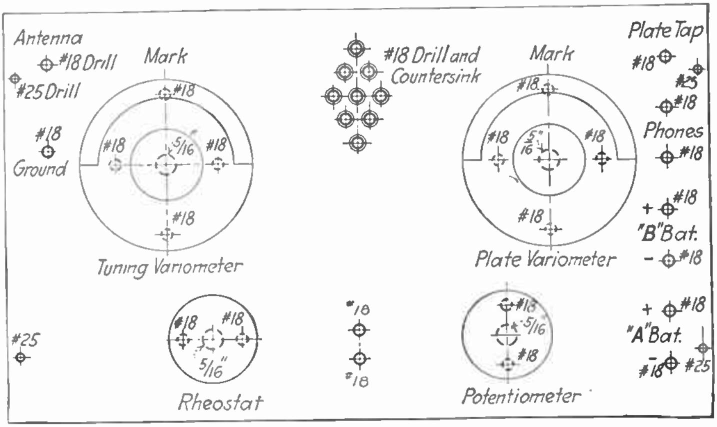

FIG. 153.—Drilling templet for single-tube receiving set.

the crystal may be placed before the flexible wire (or cat-whisker) or the flexible wire may be placed before the crystal. However, it may be found that the effect of body capacity does produce a difference in results. Thus in radio-frequency circuits, the unit is placed so that the crystal is toward the radio-frequency side.

Single-tube Receiving Set Using Regeneration.—The drilling templet for this arrangement is shown in Fig. 153. The drills required are No. 25, No. 18, $\frac{5}{16}$-inch, and a countersink. A variometer is used for tuning, and regeneration is controlled by another variometer in the plate circuit.

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The diagram in Fig. 154 shows the wiring as it would appear if the panel was removed. The socket for the tube is shown tipped up, instead of being in its normal position, in order that the wiring may be visible. The *plate-tap connection* as shown in the upper right corner of the wiring diagram plays no part in the action of *this* receiving set but is needed if radio-frequency amplification is to be added.

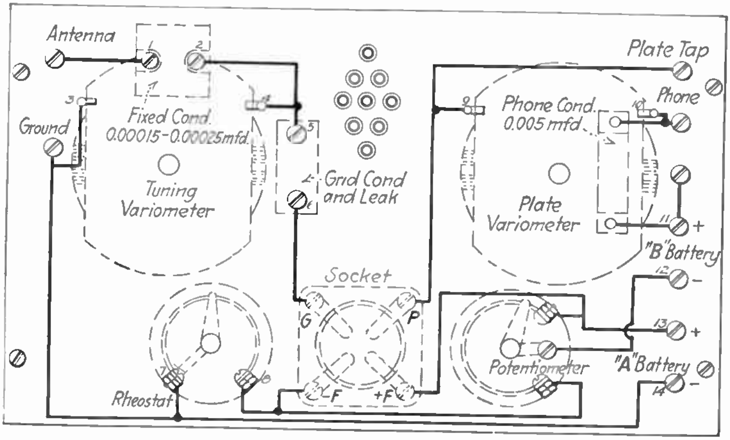

Fig. 154.—Wiring diagram for single-tube receiving set.

LIST OF MATERIALS FOR THE SINGLE-TUBE RECEIVING SET

1 7- by 12-inch panel.
2 Variometers.
1 Potentiometer.
1 Rheostat to suit vacuum tube.[1]
1 Socket for vacuum tube.
1 Grid condenser and grid leak.
1 Fixed condenser, 0.00015–0.00025 microfarad.
1 Phone condenser, 0.005 microfarad.
2 Dials (3-inch).
1 Socket bracket.
9 Binding posts.
10 Feet of bus wire.
1 Vacuum tube.

[1] See table on page 79.

Testing the Single-tube Regenerative Receiver.—At the time the vacuum tube for this receiver is purchased the buyer should be shown that the filament lights when the tube is put into the test socket at the store. No other test than that of actual performance in the receiving set can be made on the tube.

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To prepare the receiving set for testing, remove the antenna and ground connections, take the tube out of its socket and disconnect all battery wires at the binding posts on the set. The battery wires should be turned back out of the way and placed in such a position that no short circuit on the batteries can occur. An accidental contact of this kind, even though it may last for but a few minutes, will cause considerable harm to the battery.

The fixed antenna condenser is tested by touching the test tips of the simple testing outfit (page 193) to the points 1 and 2. No click should be noticed. A click shows that there is a short circuit in the condenser. Such a defective condenser should be replaced.

An open circuit in the tuning variometer is indicated by the absence of a click when the test tips are touched to points 3 and 4. An open circuit in a variometer is found most frequently at the flexible connections between the rotating and stationary windings. The plate variometer may be examined in a similar manner by using the test tips between points 9 and 10.

If the grid condenser and grid leak cannot be separated, that is, if they have been made in one unit, the use of the test tips between points 5 and 6 will produce a click if there is no open circuit in the grid leak. This test, however, is of no value as regards the grid condenser. If the two parts can be separated from each other then the usual test for open circuit can be applied to each.

The rheostat may be tested by touching the test tips to points 7 and 8. No click should be heard while the moving arm is in the "off" position.

When the test tips are touched to points 10 and 11 for testing the phone condenser no click should result. If there is a sound there is a short circuit in this condenser and it must be replaced.

Finally, a click should be obtained at any position of the movable arm of the potentiometer when the test tips are touched to points 12 and 13, and 12 and 14. In the latter test the rheostat must be turned "on" in order to complete the circuit.

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Two-stage Audio-frequency Amplifier.—The drilling templet for the panel is drawn in Fig. 155. The drills required are No. 25, No. 18, $\frac{5}{16}$-inch, and a countersink.

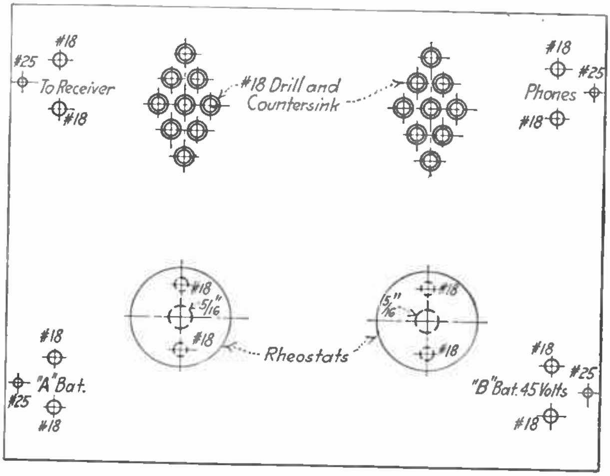

Fig. 155.—Drilling templet for two-stage audio-frequency amplifier.

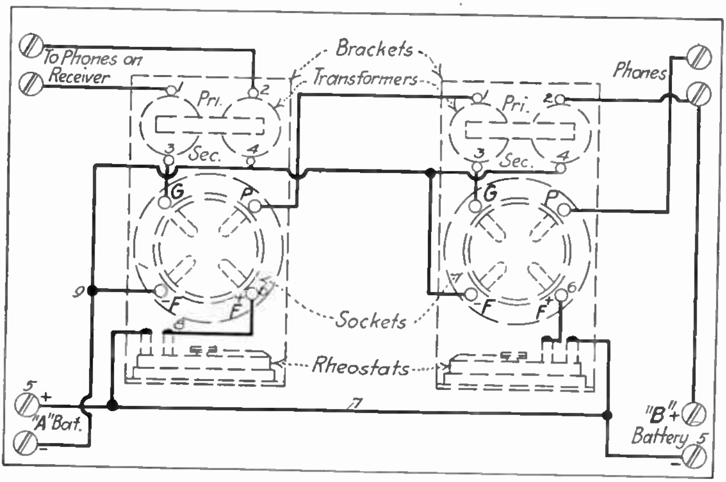

Fig. 156.—Wiring diagram for two-stage audio-frequency amplifier.

The diagram in Fig. 156 shows the wiring as it would appear to anyone looking down into the inside of the receiver. The telephone receiver and battery connections may be as shown or may be placed on the front of the panel.

LIST OF MATERIALS FOR TWO-STAGE AUDIO-FREQUENCY AMPLIFIER

1 7- by 9-inch panel.
2 Brackets.
2 Audio-frequency transformers.
2 Rheostats for vacuum tubes.[1]
2 Sockets for vacuum tubes.
8 Binding posts.
8 Feet of bus wire.
2 Vacuum tubes.

[1] See table on page 79.

Testing the Two-stage Audio-frequency Amplifier.—Remove the connections between the amplifier and receiving set, and disconnect the battery wires.

It is not possible to detect a short circuit in either winding of a transformer by means of the simple testing outfit (page 193) but an open circuit in either the primary winding or the secondary winding is readily observed. If no click is noticed when the test tips are touched to points 1 and 2 of each transformer there is an open circuit in the primary winding of the transformer for which the testing outfit gives no sound. A break in the secondary winding of a transformer is indicated by the absence of a click when the test tips are touched to points 3 and 4. It is not advisable to attempt to repair transformer windings. A new transformer should be obtained.

The rheostats are tested by touching the test tips to points 5 and 6; first on one rheostat and then on the other. No click should be heard while the arm of the rheostat is in the "off" position.

When the same "B" batteries are used for both the receiving set and the amplifier, a short circuit may result in the battery wiring if the connections do not follow the diagram. It will be noticed that the point 5 of the "B" battery binding post on the amplifier is connected through wire 7 to point 5 which is the positive (+) binding post for the "A" battery. This binding post is, in turn, connected to the positive (+) binding post for the "A" battery on the receiving set, and from this point there is, as a rule, a connecting wire going to the negative (−) terminal of the "B" battery. Hence it is essential to make certain that point 5, which is the "B" battery positive (+) binding post on the amplifier, is connected

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to the terminal of the "B" battery which is joined to the negative (−) binding post for the "B" battery on the receiving set.

If the rheostat is in proper condition and if there is no break in the wiring between the filament terminals on the socket and the "A" battery binding posts on the receiving set, the vacuum tube should light when it is inserted in the socket and the "A" battery connected to the proper binding posts. If it does not light, examine the spring contacts at the bottom of the socket and see that they press firmly on the tube contacts. If all other parts of the filament circuit have been tested, and the tube does not light, the trouble is in the tube filament. The tube filament may be tested by touching the test tips to the filament contacts at the bottom of the base of the tube. If no click is observed the filament is burned out and a new tube is required. If a click *is* noticed, the tube probably is paralyzed. Ordinarily the activity of the filament may be regained by lighting it at the proper voltage for about half an hour with the plate voltage off.

There is no simple test for detecting a poor connection between the spring and the tube grid contact, or between the spring and the tube plate contact. In order to avoid trouble from this source, it is advisable to remove the tubes occasionally and bend the springs in the socket by pushing them up with the fingers from below the socket base, or by pulling them up with a device like a buttonhook. If it is suspected that there is something wrong with the grid or the plate of the tube, the most satisfactory test is to try out the tube in another receiving set.

The wiring leading to the terminals on the tube socket may be checked with our test outfit. To test the connection at "P" of the socket for the first tube remove the tube and the batteries, then touch the test tips to the *plate* wire and the spring which is attached to "P." If no click is heard there is a break somewhere between the two points. The connection at "G" of the socket is tested between the point 3 and the spring which is attached to "G". The connections at "F+" and "F−" are correct if the tube lights. It is possible also

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to check these connections with the test outfit. The connections at "F+" may be tested between the points 8 and the spring attached to "F+". Likewise the connection at "F−" may be tested between the point 9 and the spring attached to "F−".

Two-stage Radio-frequency Amplifier.—The drilling templet for the panel is drawn in Fig. 157. The drills required are No. 25, No. 18, 5⁄16-inch, and a countersink.

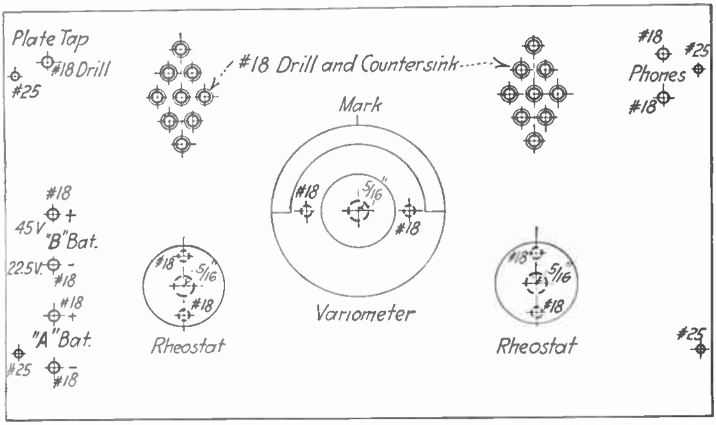

FIG. 157.—Drilling templet for two-stage radio-frequency amplifier.

This radio-frequency amplifier is designed to be added to the single-tube receiving set using regeneration. When this is done the telephone binding posts on the single-tube set must be joined together and a connection must be made between the binding post labelled "plate tap" on the amplifier and the "plate tap" on the single-tube set. Then the single-tube set becomes the first radio-frequency stage and the first tube of the amplifier acts as the second radio-frequency stage. The second tube of the amplifier unit then acts as the detector.

The diagram in Fig. 158 shows the wiring as it would appear to anyone looking down into the receiver. The various binding posts may be brought out to the front of the panel.

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List of Materials for Two-stage Radio-frequency Amplifier

1 7- by 12-inch panel.
2 Rheostats to suit vacuum tubes. (See table on page 97.)
1 Variometer.
2 Sockets for vacuum tubes.
7 Binding posts.
10 Feet of bus wire.
2 Brackets.
1 Dial (3-inch).
1 Variable condenser, 0.0001 microfarad.
1 Variable condenser, 0.0005 microfarad.
1 Resistance, ½ to 2 megohms.
1 Variable resistance 10,000 ohms.
2 Vacuum tubes.

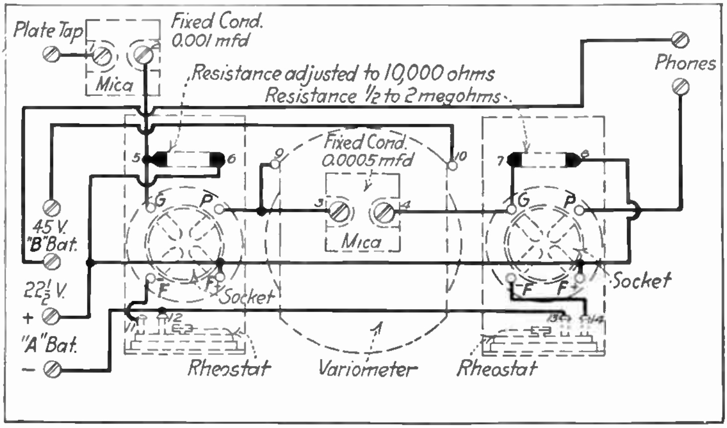

Fig. 158.—Wiring diagram for two-stage radio-frequency amplifier.

Testing the Radio-frequency Amplifier.—Remove the tubes from the set and disconnect all the battery wires.

The grid condenser of the first tube may be tested by touching the test tips to points 1 and 2. Similarly the grid condenser of the second tube is tested by using points 3 and 4.

The grid resistance of the first tube may be tested between points 5 and 6, and that of the second tube between 7 and 8. An open circuit is shown by the absence of a click. It must be kept in mind that a test of this nature does not serve as a check on the amount of resistance. In fact a short-circuited resistance unit would give practically the same indication with this test outfit as a resistance of the proper value.

The variometer is tested by touching the test tips to points 9 and 10. The absence of a click denotes an open circuit

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which occurs most commonly at the flexible connections between the rotating and stationary windings. A short circuit in the windings can not be detected with this test outfit. In most types of variometers the turns of wire are spaced so that it is possible to follow the wire from one terminal to the other. If there is a short circuit in the wiring of the variometer, an examination of this kind will disclose it.

The rheostat for the first tube is checked by touching the test tips to points 11 and 12. The rheostat for the second tube is tested between points 13 and 14. In each case the arm of the rheostat should be moved over its entire range. The absence of a click denotes an open circuit. An open circuit in a rheostat may be caused by poor contact between the wire and the movable arm, by a break in the resistance wire, and by a loose or broken connection between the end of

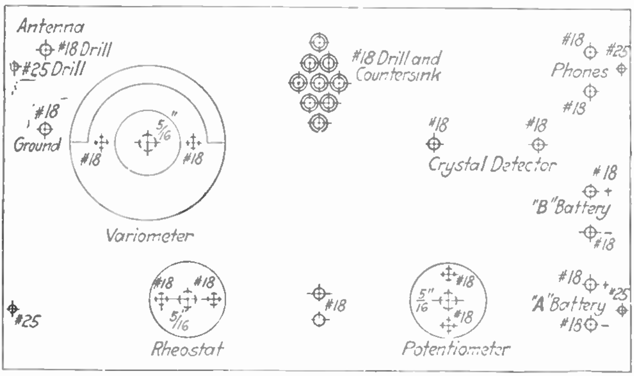

FIG. 159.—Drilling templet for single-tube reflex receiving set.

the resistance wire and the terminal on the rheostat. A short circuit between points 11 and 12, or 13 and 14 would be indicated by the fact that the tube remains lighted even when the arm of the rheostat is in the "off" position.

It will be noticed that the grid leak connections are not made in the conventional way. In this circuit it is necessary to insure a sufficient positive voltage on the grid. For this reason one end of the grid leak is led to the wire connecting with the positive binding post for the "A" battery on the receiving set.

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Single-tube Reflex Receiving Set with Crystal Detector.—In this arrangement the crystal serves as the detector and the tube acts as an amplifier of both radio-frequency and audio-frequency currents. A variometer is used for tuning. The drilling templet is drawn in Fig. 159. The drills required are, No. 25, No. 18, 5/16-inch and a countersink.

The diagram in Fig. 160 shows the wiring as it would appear if the panel was removed. Notice that in order to make the connections plain, the various condensers and transformers have been swung up toward the panel.

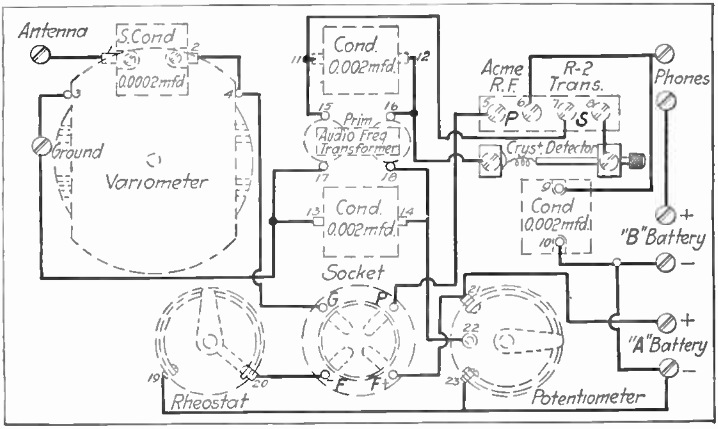

FIG. 160.—Wiring diagram for single-tube reflex receving set.

LIST OF MATERIALS FOR SINGLE-TUBE REFLEX RECEIVING SET WITH CRYSTAL DETECTOR

1 7- by 12-inch Panel.
1 Rheostat to suit vacuum tube.[1]
1 Potentiometer.
1 Variometer.
1 Acme R-2 radio-frequency transformer.[2]
1 Audio-frequency transformer.
2 Variable condensers, 0.002 microfarad.
8 Binding posts.
1 Dial (3-inch).
1 Socket bracket.
1 Socket for vacuum tube.
1 Crystal detector.
1 Series condenser 0.0002 microfarad.
1 Vacuum tube.
10 Feet bus wire.

[1] See table on page 79.
[2] Or a radio-frequency transformer with equivalent properties.

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Testing the Single-tube Reflex Receiver.—Remove the tube, the antenna and ground connections, and the battery wires.

A short circuit in the antenna condenser is indicated by a click when the test tips are touched to points 1 and 2.

If there is a break in the variometer no click will be heard when the test tips are touched to points 3 and 4.

When the test tips are touched to points 5 and 6 no click will be observed if there is an open circuit in the radio-frequency transformer winding. This simple test however will not indicate a short circuit in a transformer winding. In order to test the secondary winding of this transformer for a break it is necessary to open the circuit somewhere, say at point 8, so that the only path for the testing current is through the transformer. The test tips may then be touched to point 7 and the disconnected transformer terminal 8. The absence of a click denotes an open circuit.

The telephone by-pass condenser may be tested by using the outfit between points 9 and 10. In testing the two by-pass condensers on the audio-frequency transformer it is necessary to disconnect one terminal of the condenser from the circuit. Thus, disconnect the wiring at point 12 and touch the test tips to point 11 and the free condenser terminal. Similarly, for the other condenser, disconnect at point 14 and test between point 13 and the free condenser terminal. In each case no click should be obtained if the condenser is in good condition.

Before beginning a test on the audio-frequency transformer it is best to disconnect the wiring at one terminal of each winding, say at point 16 and at point 18. Then the primary winding can be tested between point 15 and the free terminal 16. The secondary winding can be tested between the point 17 and the free terminal 18.

In testing the rheostat the test tips can be touched to points 19 and 20. Likewise the potentiometer is tested between points 21 and 22 and also between 22 and 23. During these tests the arm should be moved over the entire range.

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As in the tests of other receiving sets, it is advisable to try out each portion of the connecting wires in order to make certain that there is no break or loose contact.

Four-tube Reflex Receiving Set with Crystal Detector.—The drilling templet for this arrangement is drawn in Fig. 161. Note that the receiver is designed for use with a loop which

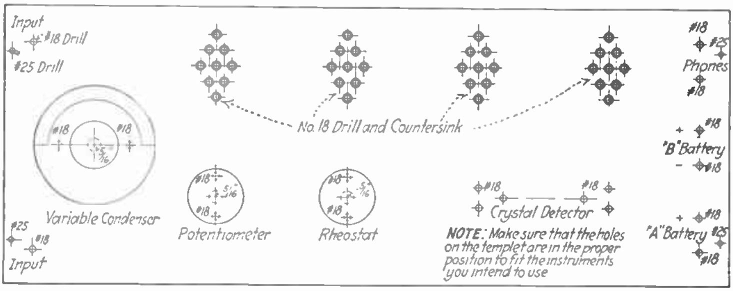

Fig. 161.—Drilling templet for four-tube reflex receiving set.

should be connected across the binding posts marked "Input." If it is desired to try an antenna with the receiver, a tuning device of some kind, such as a vario-coupler, must be added.

The diagram in Fig. 162 shows the wiring as it would appear to anyone looking down into the inside of the receiver. The various binding posts may be brought out to the front of the panel.

List of Materials for Four-tube Receiving Set with a Crystal Detector

1 23-plate variable condenser.
8 Binding posts.
1 Dial (3-inch).
1 Rheostat, 6-ohms.
1 Potentiometer.
4 Socket brackets.
3 Acme A-2 audio-frequency transformers.[1]
1 Acme R-2 radio-frequency transformer.[1]
1 Acme R-3 radio-frequency transformer.[1]
1 Acme R-4 radio-frequency transformer.
4 Sockets for Vacuum tubes.
4 UV-201A Radiotron vacuum tubes.
1 7- by 18-inch panel.
1 Crystal detector.
2 Condensers, 0.00025 microfarad.
1 Condenser, 0.002 microfarad.
1 Condenser, 0.005 microfarad.
25 Feet bus wire.

[1] Or transformers of equivalent properties.

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Testing the Four-tube Reflex Receiving Set.—Remove the tubes from their sockets, disconnect the input wires, and the battery wires.

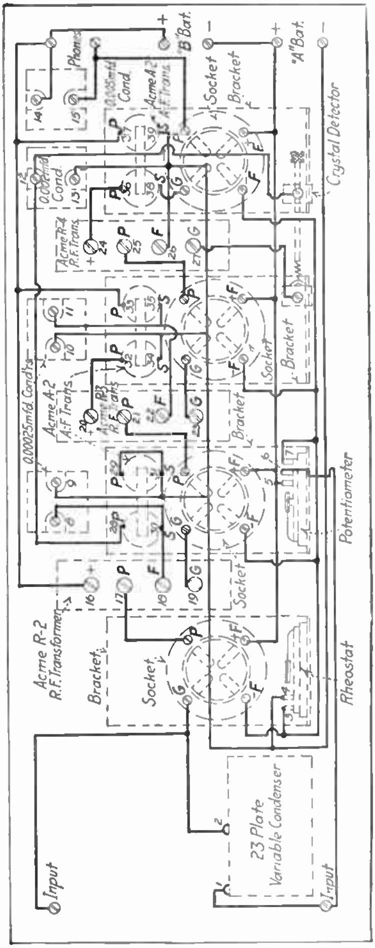

FIG. 162.—Wiring diagram for four-tube reflex receiving set.

The input variable condenser is tested by touching the test tips to points 1 and 2. During this test the plates of the condenser should be turned throughout their range in order to detect a possible short circuit due to contact between stationary and movable plates. If this does occur the bent

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plate can be pushed back into place by inserting a screw driver between it and a stationary plate. The connection between the movable plates and their terminal on the condenser frame should be tested for loose contact while the plates are turned.

A poor contact of this kind results in an interrupted current flow and produces a series of clicks in the test phones.

The rheostat is tested in the usual way between points 3 and 4. During the test the arm should be moved over its range.

The potentiometer may be checked by testing between points 5 and 6, and also between 6 and 7. In each test the arm is to be moved over its entire range.

The fixed by-pass condenser across the secondary of the first audio-frequency transformer must be disconnected at one end, say at point 9, before it can be tested. After this is done the test tips are touched to point 8 and the free terminal of the condenser at 9. A short circuit is indicated by a click in the test phones. The condenser across the secondary of the second audio transformer must be disconnected at, say, point 11 and then tested between point 10 and the free terminal of the condenser. Likewise, the third by-pass condenser is disconnected at point 12 and tested between point 13 and the free terminal of the condenser. The phone condenser may be tested directly by touching the test tips to points 14 and 15. If a condenser of this type shows a short circuit, it is best to replace it with a good one instead of attempting to make repairs.

The primary winding of the first radio-frequency transformer is tested between points 16 and 17. An open circuit is denoted by the absence of a click, but a short circuit cannot be detected with this outfit. The secondary winding is tested between points 18 and 19. In the same manner the primary winding of the second radio transformer is tested between points 20 and 21, and the secondary winding between 22 and 23. The primary winding of the third radio transformer is tested between points 24 and 25. Before the secondary of this transformer can be tested it is necessary to remove one of the connecting wires, say at point 27. Then the test

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tips can be touched to point 26 and the free terminal of the transformer at 27. Most transformers are wound with a small wire which is not very strong. Rough handling may result in a broken wire which will make the transformer useless.

The primary of the first audio-frequency transformer must be disconnected at one side, say at point 29, before it can be tested. After this is done, the test tips are touched to point 28 and the free terminal of the transformer. If no click is heard there is a break somewhere in the primary winding. Since the condenser across the secondary of this transformer was disconnected at one side for a previous test, the secondary winding of the transformer may be tested directly. To do this touch the test tip to points 30 and 31. The absence of a click indicates an open circuit in the winding.

The primary winding of the second transformer is tested between points 32 and 33. The secondary winding of this transformer may be tested between points 34 and 35, provided that the condenser which is placed across this winding has been left disconnected at point 11. Here again the absence of a click means an open circuit in the winding.

The primary winding of the third transformer is tested between points 36 and 37, and the secondary winding between points 38 and 39. The tests on these windings may be made directly as there is no other path over which the test current can flow.

The various connecting wires between the parts may now be tested. In order to avoid omitting some of the wires it is a good plan to trace over a wire on the diagram with a pencil or crayon as soon as it has been tested. In this way it is a simple matter to see which circuits have been tested and also those which have not been checked.

Three-tube Neutrodyne Receiver.—This arrangement gives two stages of neutralized radio-frequency amplification and a detector. If a large volume of sound is desired, it is necessary to add the two-stage amplifier which has been described earlier in this chapter. The drilling templet is drawn in Fig. 163.

The diagram in Fig. 164 shows the wiring as it would appear to anyone looking down into the receiver. The various bind-

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ing posts must be brought out to the front of the panel. For the sake of clearness the two rheostats have been swung up out of their normal position.

The tuner is a single-circuit arrangement with no provision for adjustment. Although it would appear that the primary turns of wire are untuned, as a matter of fact, the effect of the secondary turns upon the primary turns serves the purpose

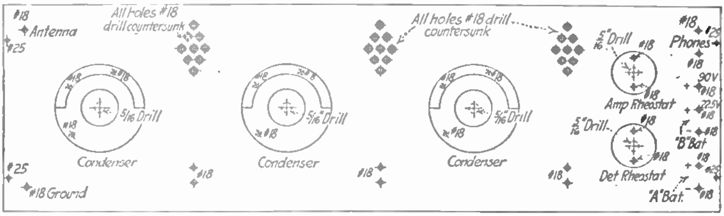

FIG. 163.—Drilling templet for three-tube neutrodyne receiver.

of tuning. Perhaps this can be understood more clearly by considering a double-circuit tuner with an untuned primary. It is then simple to see that when the secondary is tuned, its reaction upon the primary serves to tune the primary. It has been shown that an untuned primary gives greater signal strength. But since close coupling is necessary under these conditions, we obtain greater signal strength at a sacrifice of selectiveness.

LIST OF MATERIALS FOR THREE-TUBE NEUTRODYNE RECEIVER

1 7- by 24-inch panel.
3 Neutroformers (tuned secondary radio-frequency transformers).
3 Variable condensers (11 plates).
3 Sockets for vacuum tubes.
3 Dials (3-inch).
2 Rheostats suitable for vacuum tubes. (See table on page 79.)
2 Neutrodons (neutralizing condensers).
9 Binding posts.
3 UV-201A or UV-199 vacuum tubes.
3 Socket brackets.
3 Condenser shields.
1 Fixed condenser, 0.001 microfarad.
1 Fixed condenser, 0.006 microfarad.
1 Fixed condenser, 1.0 microfarad.
1 Condenser, 0.00025 microfarad.
1 Grid leak (suitable for detector tube).
25 Feet of bus wire.
1 Shield for panel.

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Testing the Neutrodyne Receiving Set.—Remove the tubes from their sockets and disconnect the antenna, ground, and battery wires.

The testing of this instrument is much simplified by making the necessary breaks, in the connections to the parts, all at one time, and before the actual testing is begun.

The secondary of the first transformer is to be disconnected at point 3. The secondary of the second transformer is to be disconnected at point 12. The secondary of the third transformer is to be disconnected at point 21. The first neutralizing condenser is to be disconnected at point 7, and the second neutralizing condenser at point 16. This completes the arrangement for testing.

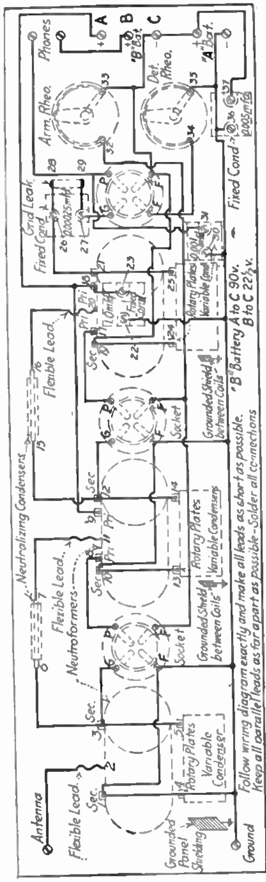

FIG. 164.—Wiring diagram for three-tube neutrodyne receiver.

In testing the secondary of the first transformer, touch the test tips between points 1 and 2. If no click is obtained there is a break in the winding between the connections at 1 and 2. Then test between point 2 and the free terminal of the secondary winding. If there is no break in the circuit a click will be noted in the test phones.

The first variable condenser is tested between the points 4 and 5. If a click is obtained, it is due to a short circuit which may be caused by two adjacent plates touching, or by a piece of metal caught between adjacent plates. These faults can be located and remedied very easily. During the test the dial should be turned in order to detect

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a possible poor connection between the movable plates and their terminal on the frame.

The first neutralizing condenser is tested between point 6 and the free terminal of the condenser. A short circuit would result if the two inside ends of the wires were in contact either with each other or with a piece of metal, or if the two wires were touching the hollow metal tube which slides over them. The setting should not be disturbed as otherwise the process of neutralization must be repeated. It is best to solder the neutralizing tube in place to prevent accidental shifting.

The primary winding of the second transformer is tested between points 8 and 9. If no click is noticed the turns of wire should be examined for a break. The secondary winding is tested first between points 10 and 11 and then between point 11 and the free terminal of the secondary winding. The absence of a click in either test denotes a break in the winding which can be discovered readily by examining the turns of wire.

The second variable condenser is tested between points 13 and 14. A short circuit is indicated by a click in the test phones. While dust on the plates does not ordinarily produce a short circuit, it may cause noises, interfering with reception, which are hard to trace. To avoid this trouble the condenser plates should be wiped occasionally.

The second neutralizing condenser is tested between point 15 and the free terminal of the condenser. As before, the presence of a click indicates a short circuit.

In like manner the primary winding of the third transformer is tested between points 17 and 18. The secondary winding is tested between points 19 and 20, and also between point 20 and the free end of the winding.

The large fixed condenser is tested between points 22 and 23. If a short circuit is found, as shown by a click in the test phones, it is better to get a new unit than to attempt repairs.

The third variable condenser is tested between points 24 and 25. No new feature is met with here, so that the preceding remarks on the variable condenser apply equally well.

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The small fixed condenser in this stage is tested between points 30 and 31 and should not show any click in the phones. Sometimes a short circuit is due to a piece of solder running over and connecting one side with the other. A fixed condenser which has absorbed considerable moisture also may indicate a short circuit.

The condenser across the "A" battery binding posts is tested by touching the test tips to points 36 and 37.

If possible the grid leak and condenser should be disconnected from each other so that each may be tested separately. If the wiring at point 28 is disconnected, the grid condenser may be tested between points 26 and 27. A click in the test phones is an indication of a short circuit which means that the condenser must be replaced. The only test which can be made on the grid leak is for an open circuit. This is indicated by the absence of a click when the test tips are touched to points 28 and 29.

The two rheostats are tested between the points 32 and 33, and 34 and 35. As the arm is moved from the "off" to the "on" position, a click should be observed. If there is a break in the winding another click will be heard when the circuit is interrupted.

The success of the neutrodyne circuit depends upon the care with which the feed-back capacity of the tubes is reduced or neutralized. To adjust the neutralizing condenser, tune in on a strong signal. Then disconnect the filament of the tube which is being neutralized by placing a piece of heavy paper between each filament spring contact in the socket and the corresponding filament terminal of the tube. Now adjust the neutralizing condenser of this tube until the signal disappears entirely. Then remove the paper from the tube socket, replace the tube and test the next tube in the same manner. If any change is made in the setting of the neutralizing condensers it may be necessary to relocate the positions of the operating dials for various wave lengths.

Six-tube Super-heterodyne.—This arrangement consists of an oscillator tube, three stages of intermediate-frequency amplification and a second detector tube. The two-stage

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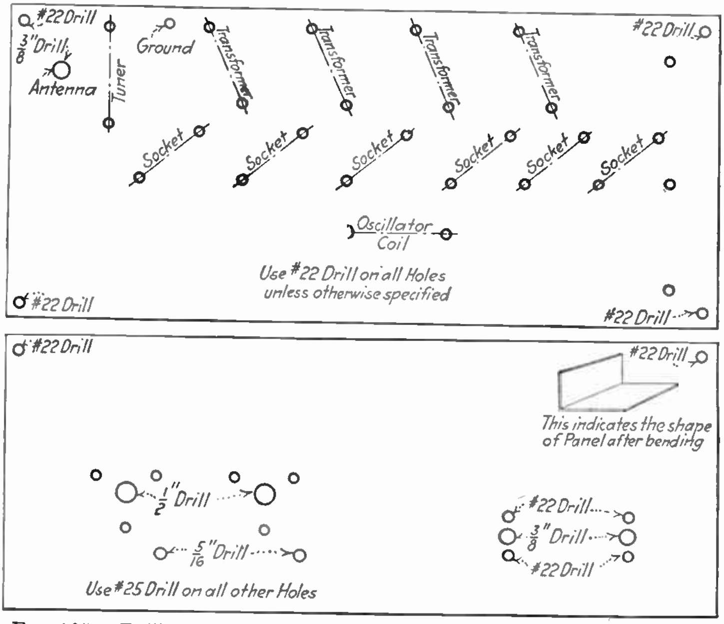

FIG. 165.—Drilling templet for six-tube super-heterodyne receiving set.

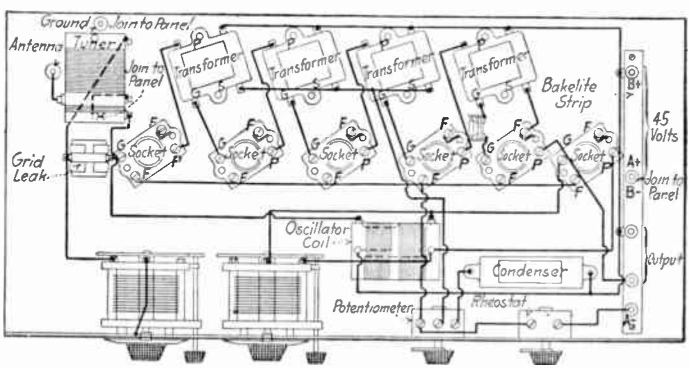

FIG. 166.—Wiring diagram for six-tube super-heterodyne receiving set.

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audio-frequency amplifier, which has already been described, must be added in order to get volume of sound. The drilling templet is drawn in Fig. 165.

The diagram in Fig. 166 shows the wiring as it would appear to anyone looking down into the receiver.

LIST OF MATERIALS FOR SIX-TUBE SUPER-HETERODYNE

6 Vacuum tubes.
3 Transformers-type No. 271 and 1-type No. 331. When installed the case should be grounded to shield or to the metal panel if that is used.
2 Variable condensers[1] type No. 247-H, .0005 microfarad.
1 Fixed coil 15 turns No. 26 SCC on 2¾-inch tube.
1 Fixed coil 60 turns No. 26 SCC on 2¾-inch tube.
1 Fixed coil 2 turns No. 26 SCC on 2¾-inch tube.
2 Fixed coils 30 turns each No. 26 SCC on 2¾-inch tube.
2 Grid leaks, 1 megohm.
2 Fixed condensers, .00025 microfarad.
1 Paper condenser, type No. 236, 0.4 microfarad.
1 Rheostat, type No. 301, 10 ohms.
1 Potentiometer, type No. 301, 200 ohms.
1 Shield for panel.
7 Binding posts.
7- by 18-inch panel (baseboard is 8 inches deep).
6 Sockets for vacuum tubes.

The lower drawing in Fig. 165 shows the front of the panel. The panel and baseboard made in one piece of 1/16 inch sheet brass can be bought, cut, and drilled.

Recent improvements in design have resulted in transformers in which the amplification has been so increased that one stage will give nearly the same volume as two stages using ordinary transformers. The addition of one stage of audio-frequency amplification to the super-heterodyne receiver described above is shown in the following diagrams.

Figure 167 gives the circuit diagram for a super-heterodyne receiving set using 7 vacuum tubes, 3 for the intermediate frequency amplifying stages, 1 for the oscillator, 2 for the detectors, and 1 for the audio-frequency amplifying stage. A one-piece metal panel and baseboard is used as a container for

[1] The transformers, panel, coils and condensers listed are made by the General Radio Company, Cambridge, Mass.

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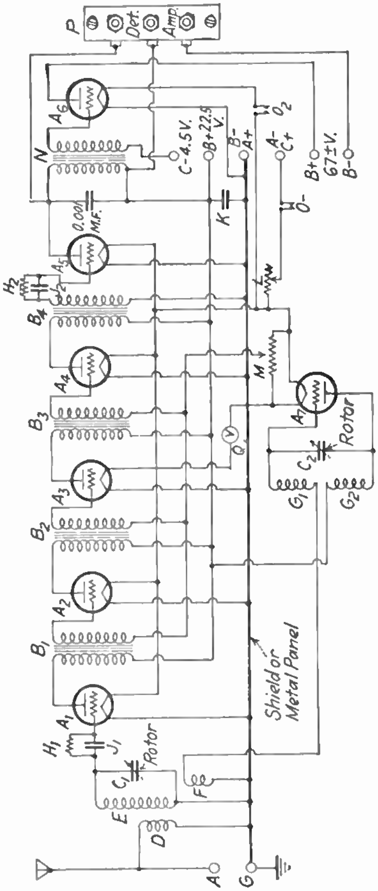

FIG. 167.

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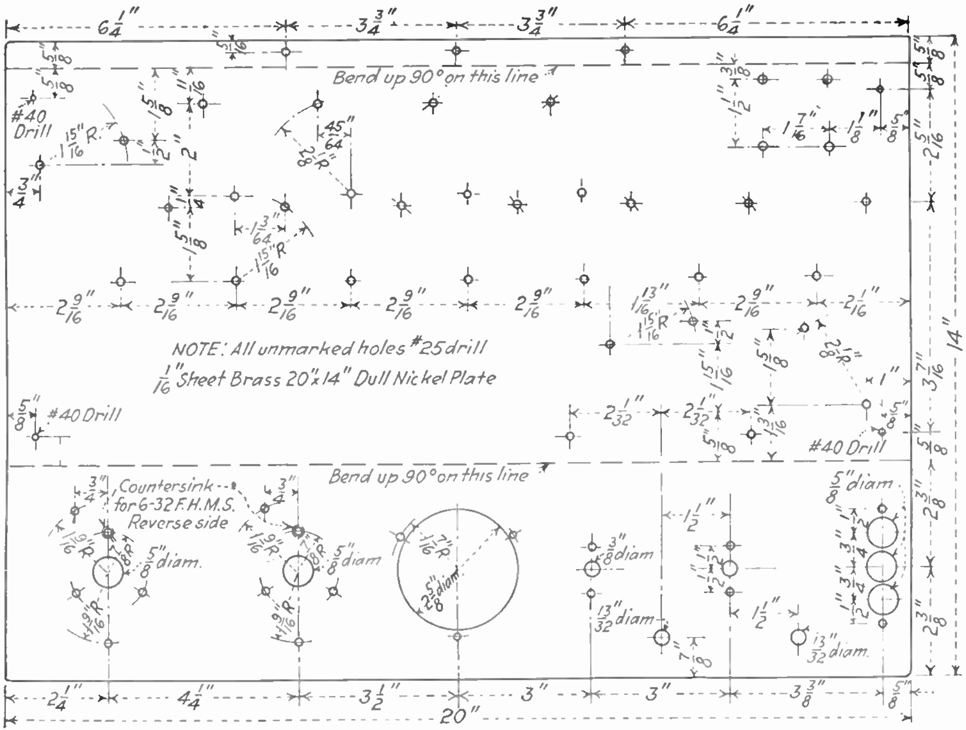
Bend up 90° on this line
#40 Drill
NOTE: All unmarked holes #25 drill
1/16" Sheet Brass 20"x14" Dull Nickel Plate
#40 Drill
#40 Drill
Bend up 90° on this line
Countersink for 6-32 F.H.M.S. Reverse side
5/8" diam.
5/8" diam
2 5/8" diam
3/8" diam
13/32" diam
13/32" diam
5/8" diam
20"
14"

Fig. 168.

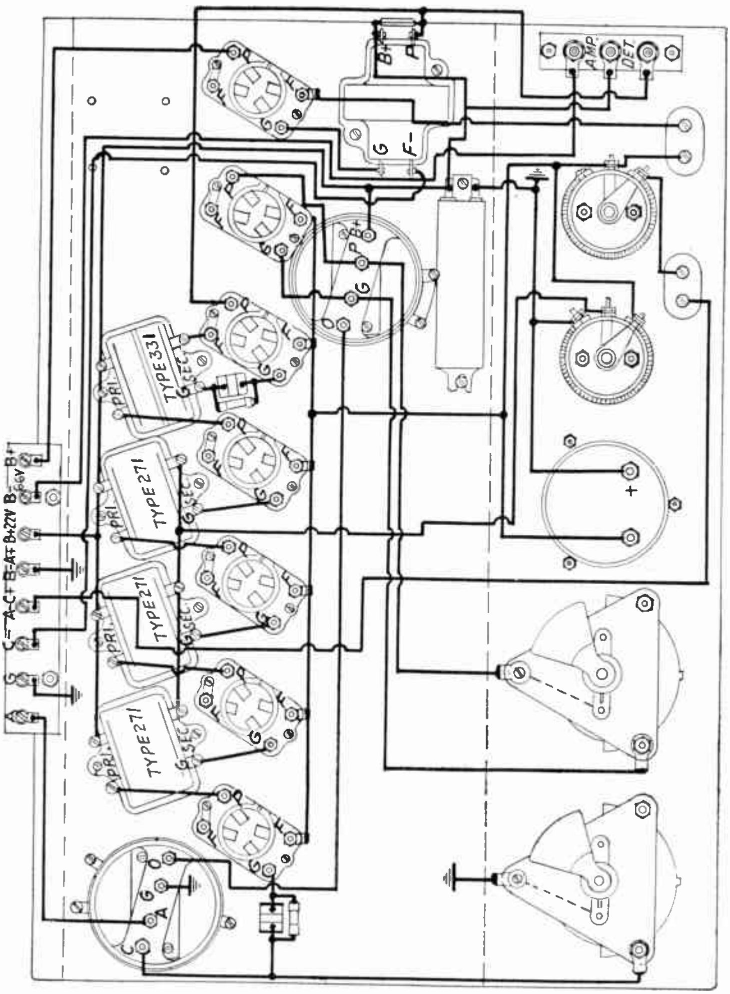

Fig. 169.

the apparatus. This acts both as a shield and as a return wire since some of the connections are made directly to the container.

The drilling templet is drawn in Fig. 168 which is one-quarter actual size. It is, of course, possible to use the ordinary wood baseboard and bakelite panel with a one-piece tin-foil or copperfoil shield. The metal container, however, gives a rigid construction and, furthermore, may be obtained, cut, and drilled to size.

The diagram in Fig. 169 shows the wiring as it would appear to anyone looking down into the receiver if the panel is imagined to be bent over until it is flat with the baseboard. Note that the case of each transformer is to be grounded, that is, connected to the shield, or to the metal container.

A separate "B" battery is used for the audio-frequency stage. This drawing indicates clearly the simplicity of the layout and the ease with which it may be constructed.

Those who wish to wind the coils will find the drawing in Fig. 170 of considerable assistance. The scale of the picture is one-half actual size.

The oscillator coil consists of two adjacent windings on the same tube spaced about ⅛ inch apart. All the coils are wound in the same direction.

The cabinet in Fig. 171 is designed for the seven-tube superheterodyne which has been described in Figs. 167 to 171.

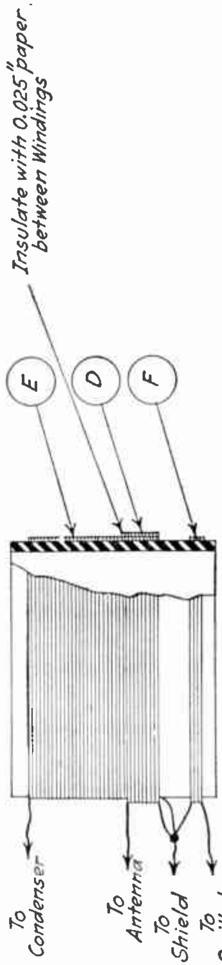

Fig. 170.

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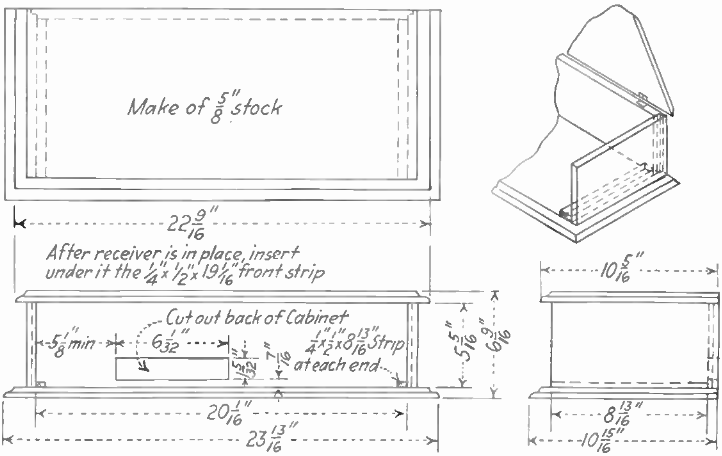

FIG. 171.

LIST OF MATERIALS FOR SEVEN-TUBE SUPER-HETERODYNE

A-7 Vacuum tubes, 199 type.
B-4 Transformers, 3 of type No. 271 and 1 of type No. 331.
C-2 Variable condensers[1] type No. 247-H, 0.0005 microfarad.
D-1 Fixed coil 15 turns No. 26 SCC on 2¾ inch tube } type No. 255-V.
E-1 Fixed coil 60 turns No. 26 SCC on 2¾ inch tube } type No. 255-V.
F-1 Fixed coil 2 turns No. 26 SCC on 2¾ inch tube } type No. 255-V.
G-2 Fixed coils 30 turns each No. 26 on 2¾ inch tube, type No. 277-C.
H-2 Grid leaks, 1 megohm.
J-2 Fixed condensers, 0.00025 microfarad.
K-1 Paper condenser, type No. 236, 0.4 microfarad.
L-1 Rheostat, type No. 301, 10 ohms.
M-1 Potentiometer, type No. 301, 200 ohms.
N-1 Audio transformer, type No. 285.
O-2 Switches, Cutler-Hammer type No. 7160.
P-1 Triple contact plate, type No. 274-A.
1 Telephone plug, type No. 274.
Q-1 Voltmeter (4 or 5 volt), Weston type No. 301.
7 Sockets suitable for vacuum tubes used.

[1] The transformers, panel, coils and condensers are made by the General Radio Company, Cambridge, Mass.

The letters in front of the quantities above correspond to those used in the circuit diagram, Fig. 167.

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The Browning-Drake Receiver.—Recent improvements in radio equipment have been in the line of scientific designing to secure as much efficiency as possible for each vacuum tube used. The Browning-Drake circuit has been laid out with an efficient tuned radio-frequency transformer as an essential part. This transformer has been designed to obtain 90 per cent of the amplification theoretically possible. A brief history of the development of this radio receiver is interesting. In August, 1924, F. H. Drake of Harvard University conceived the idea of designing a tuned radio-frequency transformer from

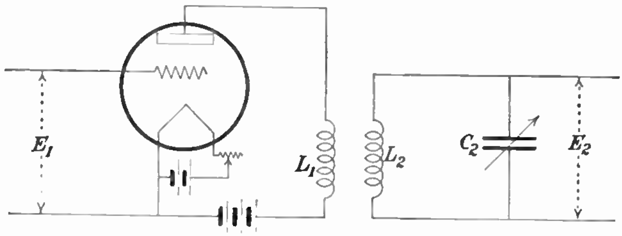

FIG. 172.—Radio-frequency transformer circuit.

a theoretical standpoint. At that time, G. H. Browning, who was also a research expert at Harvard, became interested in this investigation.

The designing problems which these men attacked really consisted in solving mathematically the circuit shown in Fig. 172. Here L_1 and L_2 represent the primary and the secondary windings of a radio-frequency transformer with an air core. The secondary of the transformer is tuned by means of the variable condenser C_2. The primary is connected to the plate circuit of a vacuum tube, which acts as a radio-frequency amplifier. The total voltage amplification of the system, that is, the ratio of E_2 to E_1 (Fig. 172), was then calculated.

Solving for the necessary designing constants in this circuit in all its parts took considerable time and labor, but the solution gave relations between all the constants which must be satisfied for maximum efficiency. With these constants determined, the next step was to build a transformer and subject

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it to laboratory tests, which gave the best results when a slot-wound primary was used. As shown in Fig. 173, the primary is wound in a slot ⅛ by ⅛ inch cut in the disc. The disc should be placed so that the turns of wire are centered under the first turn of the secondary winding. As this type of transformer is made commercially, however, the primary is wound

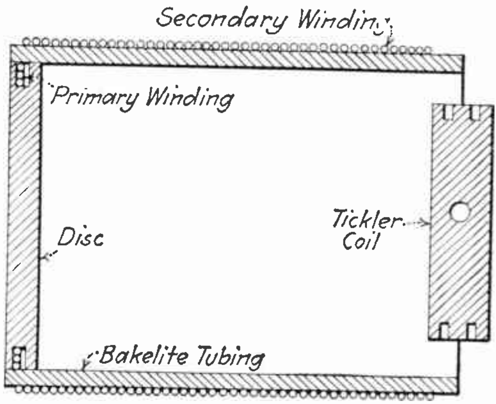

Fig. 173.—Simple "slot" transformer winding.

in a slot which is cut in the tubing itself and the secondary is wound over it. Figure 174 shows the results obtained by mathematical analysis and laboratory measurements of the effect of this type of winding on radio amplification. Curve *A* in this figure gives the theoretical amplification of a standard UV-199 vacuum tube and the usual type of radio-frequency transformer, while curve *B* gives the actual laboratory test values after the "slot" winding of the primary had been adopted. For comparison, curve *C* gives the amplification of one of the best radio-frequency transformers of the standard type now commercially available.

Mathematical analysis indicates that a coil placed in the plate circuit of a detector vacuum tube and coupled magnetically to the secondary of the radio transformer increases the amplification ten to twenty times. This arrangement is employed in the circuit diagram of the Browning-Drake set

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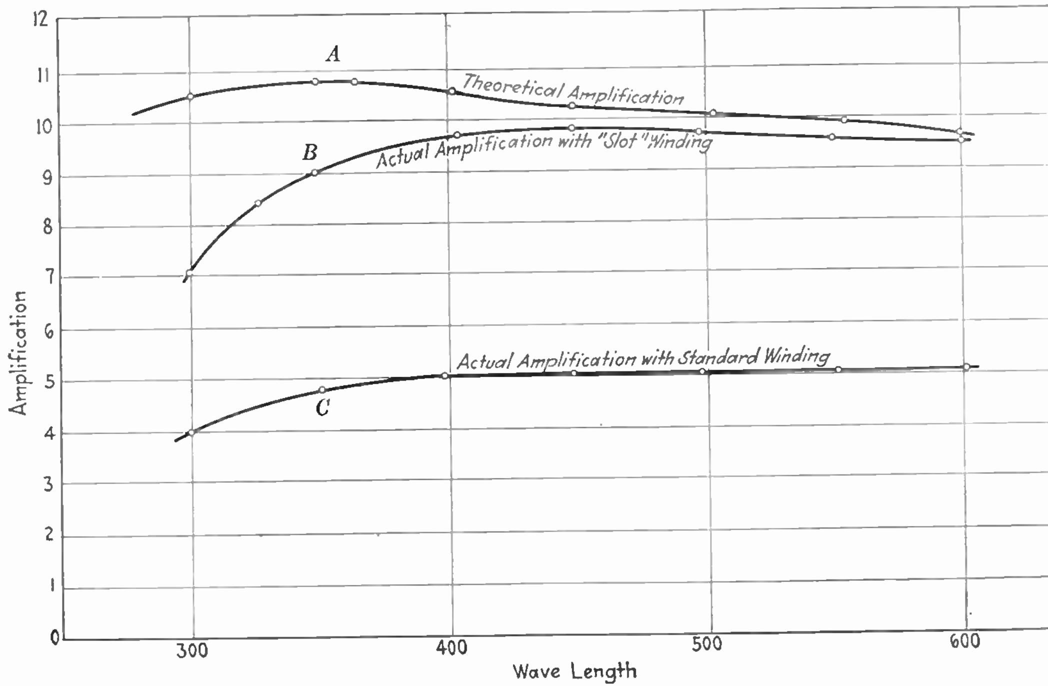

FIG. 174.—Theoretical and actual transformer amplification.

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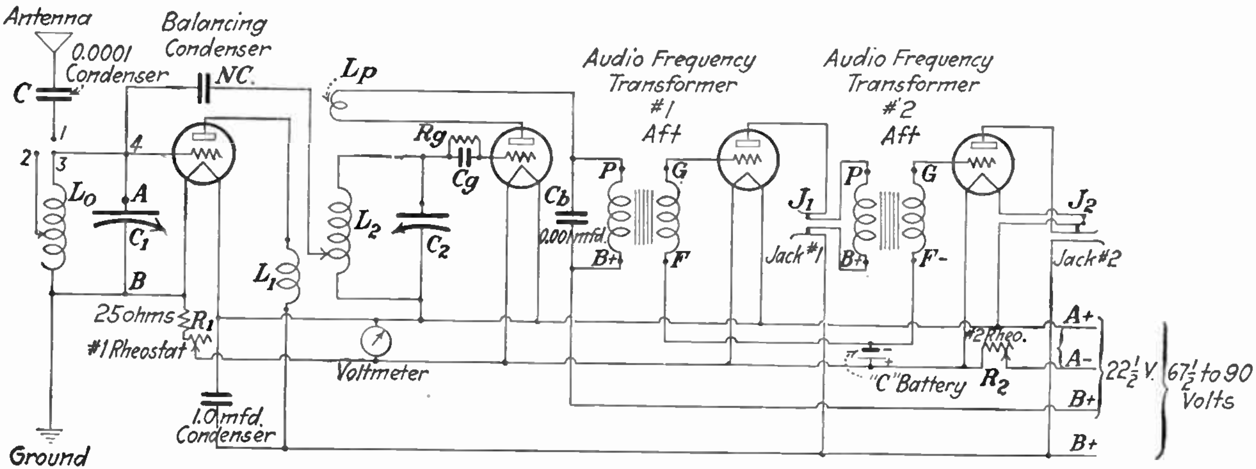

FIG. 175.—Browning-Drake circuit diagram.

shown in Fig. 175 and gives very good sensitivity and selectiveness. This receiving set consists of one stage of tuned radio-frequency amplification, a detector vacuum tube arranged for regeneration, and two stages of audio-frequency amplification. Thus this receiver is essentially a two-tube set with two more tubes added for loud-speaker volume on distant stations. The regeneration is in the radio-frequency transformer, not in the antenna circuit, so that no "whistles" are sent out to disturb the radio community at large. Thus the first vacuum tube, besides amplifying the incoming signals, acts as a "blocking" tube, preventing the radiation nuisance. C is a 0.0001-microfarad fixed mica condenser in series with the antenna. Its purpose is to enable long or short antennas to be used, and to increase selectivity. A flexible lead should be attached to one side of this condenser so that it may be connected either to the middle or to the grid end of the coil L_0.

The symbols shown in Fig. 175 represent the essential parts, which are described below:

L_0 is a single-layered coil wound with No. 20 DSC wire on a 3-inch tube. It has an inductance of 0.16 microhenrys. C_1 is a 0.0005-microfarad low-loss variable air condenser with vernier dial. L_1, L_2, and L_p are coils constructed in one unit called a "regenaformer." L_1 is wound in a "slot" under L_2 at its low-voltage end. It consists of 24 turns of No. 30 DCC wire and has an inductance of 0.094 microhenrys. L_2 is wound over L_1 and consists of 77 turns of No.20 DSC wire on a 3-inch cylinder. L_p is a rotating tickler coil mounted in one end of L_2. It may be constructed from a piece of 2-inch tubing with thirty turns of No. 28 DSC wire. C_2 is a 0.00035-microfarad low-loss variable air condenser with vernier dial. Coils L_0 and L_2 must be mounted at right angles to each other and in such a manner that an imaginary line drawn through the axis of one passes through the center of the winding of the other. R_g is a variable grid leak. C_g is a 0.00025-microfarad fixed-grid condenser. C_b is a 0.001-microfarad fixed-by-pass condenser. NC is a small variable balancing or neutralizing

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condenser. *AFT* are audio-frequency transformers. J_1 and J_2 are jacks. R_1 and R_2 are rheostats.

Figure 176 gives a suggested panel layout for the receiver, while Fig. 177 shows the placing of the apparatus on the baseboard behind the panel. In laying out the panel, the centers of the two condensers should be 8 inches apart, making the "balancing" easier than with a smaller spacing. The grid leads should be made as short as possible, and should not be near the plate leads. Be sure that one side of the coil L_0 goes to the *negative* side of the filament of the first tube, while one side of L_2 goes to the *positive* side of the filament of the second tube. This arrangement is important for maximum strength.

The condensers C_1 and C_2 (Fig. 176) should be placed so that the rotor plates face one another. The fixed plates should run to the grids of the vacuum tubes, as this will eliminate body capacity when tuning. A new arrangement of rheostats is shown in the wiring diagram in Fig. 178. This plan facilitates the use of a voltmeter as indicated—an extremely handy device—and enables the operator to keep the tubes at their proper brilliancy. Rheostat No. 2 is for general voltage control and should be adjusted so that 3 volts will be used with UV-199 tubes or 5 volts with UV-201A tubes. Rheostat No. 1 controls only the voltage on the filament of the first tube.

Many people believe that a separate rheostat for the detector tube will help to bring in distant stations. With DV-2, DV-3, UV-201A, UV-199, WD-12, and WD-11 tubes it seems to make no difference in volume whether the detector has a separate control or not. In fact, it is better to run the detector tube at rated voltage on the filament, as cutting down this voltage tends to distort signals. This is why the detector and two audio tubes are connected in this set to the same rheostat.

A 1-microfarad fixed condenser is shown in Fig. 178 connected across the terminals of the "B" battery. This arrangement is useful if the "B" battery leads are long, but is not essential. In using this receiving set, if the antenna is long, point 1 should be connected to point 2, and, for a short

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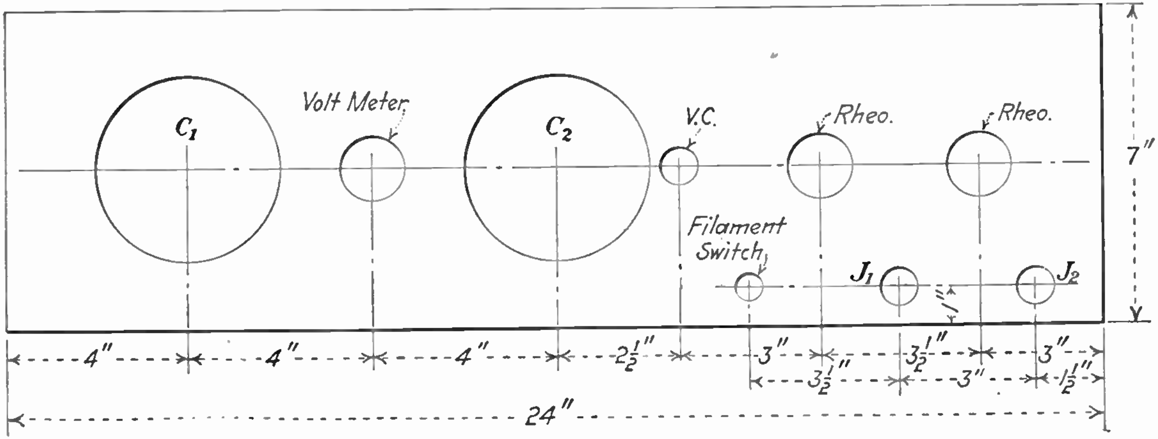

Fig. 176.—Panel lay-out for Browning-Drake receiver.

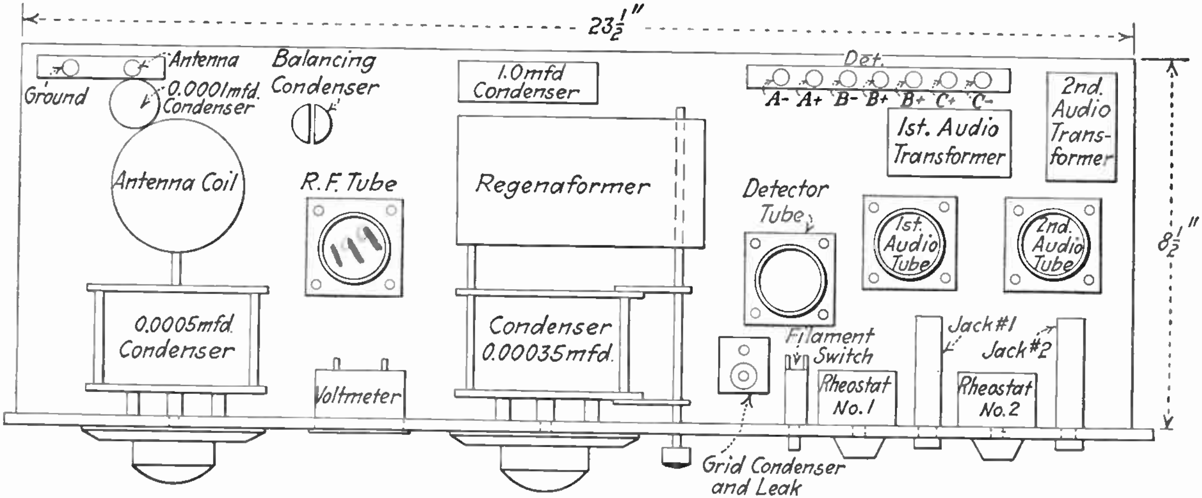

FIG. 177.—Base-board lay-out for Browning-Drake receiver.

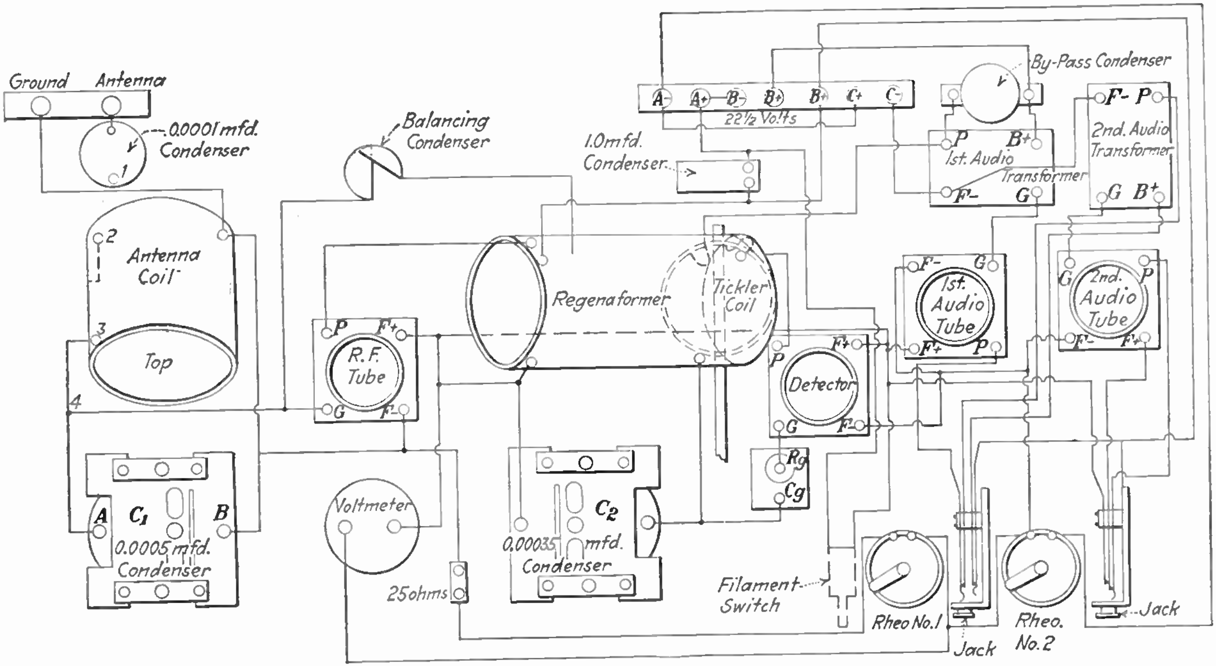

FIG. 178.—Wiring diagram for Browning-Drake receiver.

antenna, point 1 should be connected to point 3. If a loop is to be used instead of an antenna, it should be connected across points *A* and *B*, after the wire from point 3 to point 4 is disconnected.

The ideal arrangement would be to have a DV-3 or a UV-199 tube in the socket for the R. F. tube with UV-201A tubes in the other three. The 25-ohm fixed resistance shown takes care of the filament voltage, on the R. F. tube, so that if rheostat No. 1 is never turned on more than half way there is no danger of burning it out. The picture diagram shows a standard socket for the radio-frequency tube. If a UV-199 tube is used, a small socket should be substituted. DV-3 or UV-199 tubes may be used in all sockets satisfactorily, though not quite so much volume will be obtained. Then the 25-ohm resistance should be omitted.

After the set is constructed according to the directions given, the next point is to balance it so that maximum amplification may be obtained and radiation eliminated. Turn the tickler coil of the regenaformer to a point where placing a moistened finger on the grid side of the condenser C_2 will give a click. (Of course, the antenna and ground as well as the batteries have been connected, the tubes lighted to their proper brilliancy, and the phones plugged in.) Turn back the tickler coil until this click just disappears. Then rotate condenser C_1 and if, at any setting of this condenser, touching the grid side of C_2 produces a click, the set is not "balanced" or neutralized. The capacity of the balancing condenser *NC* should then be adjusted until the test proves satisfactory. Another method of "balancing" is to tune in a loud signal, turn out the filament of the first tube with rheostat No. 1, retune for the station, and then set the balancing condenser *NC* so that the volume of the signal is reduced to a minimum.

It is possible to use UV-201A tubes throughout, although some difficulty will be experienced in balancing. UV-199 tubes are recommended, especially for the first R. F. tube. If UV-201A tubes are used throughout, the rheostats should have a resistance of 6 ohms, while with UV-199 tubes (for

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operation with dry cells of 4.5 volts), the rheostats should have a resistance of 10 ohms.

Tuning In.—A few suggestions may be helpful in tuning in stations. Set the tickler coil where placing a finger on the grid side of the condenser C_2 produces a click in the phones. This

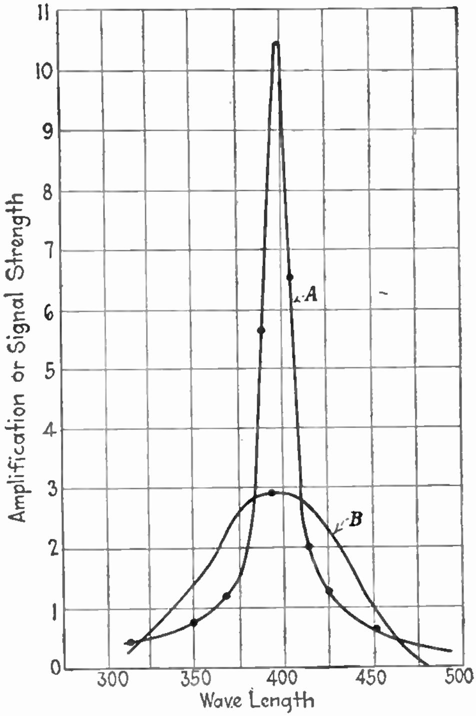

FIG. 179.—Comparative amplification and selectivity.

means that the grid circuit of the detector tube is oscillating. Then turn C_2 slowly until a whistle is heard This is the carrier wave of a station beating with the oscillations being produced in the circuit of the detector tube. However, the set will not cause any interference with other receiving sets because of radiation if it is neutralized. Now turn C_1 until the whistle is loudest, turn back the tickler coil until the whistle

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disappears, and then adjust C_1 and C_2 *slightly* until loud and clear signals are obtained. The volume of the signals may be controlled readily by adjusting the tickler coil and rheostat No. 1.

The dials of condensers C_1 and C_2 may be "logged" so that a station once located may be found readily when it is operating, and if the conditions are such that the receiver can pick up the signal.

The comparative amplification and selectivity of the circuit is shown clearly by the curves in Fig. 179 in which curve *A* gives the amplification of this type of radio-frequency transformer, and curve *B* the amplification of a typical neutrodyne transformer.

List of Materials For Browning-Drake Receiver

1 7-by 24-inch panel.
1 8½- by 23½-inch baseboard.
1 Regenaformer kit (includes coils L_0, L_1, L_2, and L_p(Fig. 175) and variable condensers C_1 and C_2 with 4-inch vernier dials).
1 Balancing condenser.
3 Standard sockets and 1 UV-199 socket, or 4 standard sockets, depending upon the tubes used.
2 Transformers,[1] one with 6-to-1 ratio, the other with 3-to-1 ratio.
2 Rheostats, one (R_2) of 10 and one (R_1) of 30 ohms. These are to be used with one 3-volt and three 5-volt vacuum tubes.
1 Fixed resistance, 25 ohms.
1 Fixed condenser, 0.001 microfarad.
1 Combined variable grid leak, and 0.00025-microfarad fixed grid condenser.
1 Double circuit jack.
1 Single open-circuit filament control jack.
1 Filament switch.
9 Binding posts.
1 By-pass condenser (optional), 1.0 microfarad.
20 Feet of bus wire.
A "B" battery of at least 67½ volts is needed and the "C" battery should have 4½ volts.

[1] A general radio transformer type 285 for the first stage of audio amplification and a Sampson 3-to-1 or an Amertran 3½-to-1 transformer for the second stage are recommended.

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QUESTIONS

1. What are some of the tools required for the construction of receiving sets?
2. Describe the procedure to follow in making a soldered joint.
3. What is the purpose of *shielding* and how is this result obtained?
4. (*a*) Explain the construction of a wave trap.
   (*b*) How is this type of wave trap used?
5. As determined from the chart in this chapter, how many turns of wire and what spacing would be used on a 24-inch loop?
6. If you constructed one of the receiving sets described in this chapter what difficulties did you have?

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CHAPTER XII

COMMON TROUBLES AND THEIR REMEDIES

The owner of a receiving set soon finds that it does not perform its duty unless all the parts are in working order. The troubles to which the instrument is susceptible have certain very definite and characteristic symptoms which will be described in detail. Moreover, at the present stage of development a receiving set will detect not only the desired broadcasting, but also any extraneous electrical disturbance which comes within its range.

Kinds of Radio Interference.—A classification of the different kinds of interference will help in determining what a receiving set can do under certain conditions, and also in locating the source of trouble in the instrument itself. Improper reception may be due to interference from outside, or from inside the receiving set.

External interference comes from *faulty tuning* at either the transmitter or receiver and can be remedied by providing means for sharper adjustments. *Spark transmitting stations* and *power transmission lines* are another source of interference. The interference of spark transmitting stations may be diminished by loose coupling between the primary and secondary circuits of the receiving set, by reducing the regeneration, or by a *wave trap*[1] in the ground wire of the receiving set. The interference of power transmission lines will usually disappear when the antenna is placed at right angles to the power transmission line. If this is not possible, good results are obtained, in some cases, by connecting in series with the antenna, a loop which can be adjusted both vertically and horizontally to a position at which the interference is a minimum.

Interference from continuous-wave (C.W.) transmitting stations or from radiating receiving sets produces a whistling

[1] See page 185.

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sound or a continuous musical tone. If the pitch of the tone changes as the receiving set is tuned, the receiving set itself is in a state of oscillation. *Fading* if due to conditions which do not exist in the receiving set, cannot be remedied.

Atmospheric Conditions: Static.—Another kind of interference is caused by *atmospheric conditions* and the faulty operation of electrical apparatus such as arc lights, industrial motors, motors in vacuum cleaners, electric fans, violet-ray machines, elevators and trolley wheels on electric cars. The noises from electrical apparatus vary considerably but are similar to those from atmospheric conditions. A discharge of lightning produces a loud and sudden click, while charged clouds give a continuous hissing noise like that of a rain storm, or a flow of water. Another characteristic noise due to static is a continuous, rattling one like the sound of pebbles thrown against a wall. The irregular noises coming from atmospheric conditions are more common in summer than in winter, and, in the tropics, are more frequent as well as more active, than in places farther north. The most satisfactory methods for reducing the effects of static are the use of very loosely coupled circuits, small antennas, or loops, together with sensitive amplifiers. Much has been said and more written about devices for the elimination of static. So far, however, such devices have proved successful under conditions of operation, but they are so elaborate that the cost is prohibitive.

Testing Receiving Sets.—To determine whether the source of trouble is in the receiving set or whether it is external, light the vacuum tubes and use the telephone receivers in order to find out, first, whether noises of interference are present. If the filament fails to light or flickers, there is an open circuit or a loose connection in the filament circuit. In the order of common occurrence the fault may be at the "A" battery terminals, the spring contacts in the tube socket, the rheostat, or the tube terminals. If a tube burns dimly, the "A" battery voltage is low. It must not be inferred that an open circuit can occur only at the places mentioned, because a break may be found at any point around the complete circuit.

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If the reception is clear it is advisable to postpone the testing until poor results are again experienced. If interference is present, disconnect the lead-in wire from the antenna and the ground wire when the vacuum tubes are lighted with no change in the settings. If the noise then disappears, the trouble is either in the antenna to ground circuit, or is due to some form of external interference which has already been described. Antenna trouble may be located by inspection. Look over the system to make sure that there is no contact anywhere between the antenna or lead-in and any nearby object such as a tree, building, guy wire, or telephone line, and that the lead-in is insulated from the building at the place of entry. Leaky insulators, or a break in an insulated (covered) lead-in wire will also prove troublesome.

To test the effectiveness of the *ground connection*, tune in the "whistle" of some station and then tap the ground binding post several times with a finger. If the ground is poor, a decided variation in the pitch of the "whistle" will be noticed as the binding post is tapped. It is well to examine occasionally the clamp which is used to attach the ground wire to the ground connection and to scrape it clean if it gets corroded.

Noises resulting from trouble in the receiving set would be rather difficult to locate were it not for the fact that certain faults produce characteristic sounds. This narrows the search from a complete test to an examination of but a few circuits.

To the amateur the most baffling type of trouble is the one in which no response whatever is perceived in the telephone receivers. The most common cause is an *open* or break in any one of the circuits such as the antenna, ground, grid, plate, telephone and filament circuits. It may be due also to a crystal which is out of adjustment, a short circuit in the telephone receivers, or to exhausted batteries. A tuner which is not designed to respond to either the upper or lower range of wave lengths obviously will not be able satisfactorily to receive radio waves which are out of its range.

An open circuit is caused by broken wires, wrong connections and poor or loose contacts. A short circuit is the result of contact between wires, wrong connections, contact between a

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fixed and a movable plate in a condenser, particles of dust or other material between condenser plates, and a leakage path due to the effects of corrosive flux. Sometimes a piece of wire, or a screw driver, screw, washer or even a piece of tin foil will fall across two wires and short-circuit them very effectively.

After the antenna, ground, and filament circuits have been found in working order, the tester may often save much time by going over all the terminals and binding posts to make certain that there are no loose connections. Poor or loose connections may be detected by tapping the wiring with a pencil and listening in on the telephone receivers. An increase in noise when a wire is tapped shows the presence of a faulty connection in that wire. A condenser which is short-circuited from any way whatever will show a flow of current when tested. Soldering flux between the sheets of a fixed mica condenser is a common source of trouble. When a short circuit occurs between two wires which should not have any part in common, a testing current will find a path through the *short*. To test the plate circuit, first check the plate battery voltage, then light the tubes and disconnect one of the "B" battery wires, touching its several times to its terminal. If a series of clicks is heard in the telephone receivers, the plate circuit is complete, but if no clicks are heard, there is an *open* somewhere in the circuit. Telephone receivers may be tested by touching the tips of the cord to the terminals of a dry cell. If no clicks are heard the circuit is open.

Before a home-made receiving set is tried out it is best to check each branch circuit in the set with the wiring diagram. When one branch is verified, mark the corresponding circuit on the diagram with colored ink or crayon so that the tracing process may be simplified. At the time the checking is being done, see that all connections are firm and clean; that contact is not prevented by insulation of a wire caught under a terminal or binding post; that no wires are touching; that there is no extra wiring which does not appear on the diagram and that no part of any insulated wire has any concealed breaks. Take each vacuum tube out of its socket and make certain that the tube terminals and the spring contacts in the socket

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are clean; if the springs are not making contact, bend them in the proper direction to increase the pressure against the tube terminals.

When imperfect reception is experienced, the imperfections may be listed as follows:

1. Weak reception,
   (*a*) accompanied by a rasping, scratchy, *fuzzy* noise.
   (*b*) very dull and muffled in tone.
   (*c*) accompanied by a humming sound of low pitch.
   (*d*) accompanied by a loud whistling tone.
2. Reception of normal strength, accompanied by intermittent sounds which may be described as hissing, frying, rasping, scratching and cracking.
3. Reception of normal strength, breaking off periodically with a popping sound followed by a few seconds of silence.
4. Reception of normal strength, accompanied by squealing, howling, roaring sounds.

Weak reception, accompanied by a rasping, scratchy, fuzzy noise may be caused by a telephone condenser, or by a grid condenser, which does not have enough capacity. The connection of the grid return of the detector vacuum tube to the positive terminal of its filament is a remedy in some cases. An oscillating receiving set acts in this manner and the remedy here is simple, being merely a reduction of regeneration. If too much feed-back is still present, even after the control dial is in its minimum position, it is necessary to try one or more of the following expedients—less "B" battery voltage on the detector tube, a lower filament current, fewer turns on the tickler coil, or a grid leak having less resistance. Curiously enough, the same trouble is caused when the amount of feed back is too small. The feed-back can be increased by adding more turns to the tickler coil, or by using a larger plate variometer or a coupling condenser. If the volume decreases as the tickler coupling is increased, the feed-back is reversed and acts in the wrong direction. Interchanging the tickler connections is the solution for this trouble. In general, the failure to obtain oscillation may be caused by too loose coupling between the tickler and secondary coils, reversed tickler connections, reversed "B" or "A" battery leads, low "B"

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battery voltage (which in turn may be due to a defective cell), a by-pass condenser whose capacity is too small, a grid condenser which is not suited to the vacuum tube used, and a defective tube. Poor telephone receivers give very ragged reproduction, especially if the diaphragm is distorted in any way.

In applying the above remedies care must be taken not to introduce too great a change in value, otherwise the only difference will be the appearance of another kind of noise. Thus, weak signals which are dull and muffled in tone are the result of a telephone or grid condenser with too much capacity, or a grid leak having too little resistance. Certain defects in the telephone receivers and in the grid condenser also will destroy the quality of reception. An open or poor connection in the ground circuit will make the reception very faint regardless of the tuning.

Weak radio currents (or none at all) with a humming sound of low pitch are usually traced to an open in the grid circuit. This may occur at the grid terminal of the vacuum tube, the grid-leak resistance, the secondary tuning coil, the grid-return connection, the spring contacts in the tube socket and at the flexible lead of a grid variometer.

A sound like that of water flowing through the receiver may be due to an excessive flow of current in the tube. This will disappear when the filament current and plate voltage are reduced, or when a "C" battery is used.

Reception of normal strength accompanied by intermittent noises like the sound of hissing, frying, rasping, scratching and cracking probably occur more frequently than any other. This peculiar type of interference may come from without the receiver and also from within it. External sources of interference have been enumerated at the beginning of this chapter. Interference from this source may also cause a sound like that of an electric motor when running, or just a plain hum, and sometimes a series of clicks.

In the receiving set a common cause of this trouble is a run down or defective "B" battery. A new battery which is in good condition will produce only a click in a receiving headset

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connected across its terminals. If the battery is defective, a series of scratchy noises will be heard in addition to the clicks. Some detector vacuum tubes (especially soft tubes) are noisy in operation, no matter what precautions are taken, and such tubes had best be discarded. Above a certain value of filament current, even a good soft detector tube produces a hissing sound, while a further increase in current will result in a frying noise. If a vacuum tube is noisy because of vibration of its elements, a base of sponge rubber under the socket and the use of short, heavy, rigid wires will minimize the vibration. The tube noise has a *ringing* sound which appears when the receiver is jarred or knocked in any way. Poor contact between the vacuum-tube terminals and the spring contacts in the socket often causes noise. Indeed, loose connections in any part of the receiver such as the grid, filament or plate circuits are responsible for much of the intermittent irregular interference. And again, at other times, no bad effect is noticed, or else the signal is merely weak. Loose connections in the filament circuit result in changes of intensity rather than in noise. A flexible lead from the proper terminal of the rheostat to the shaft will overcome poor contact between shaft and bushing. Loose connections in the plate generally are much noisier than those in the grid circuit.

Some forms of grid-leak resistance are constructed so that the slightest jar disturbs the setting very slightly. Such a grid leak, as well as a defective grid condenser should be replaced by reliable apparatus which is not affected by weather conditions or by shaking. Few amateurs think of suspecting the phone cord. If any increase in noise is observed when the cord is shaken it should be taken apart and examined for partial breaks.

Normal radio currents which break off with a popping sound and disappear entirely for a few seconds, then come back and again stop with a pop are found when there is an open in the grid circuit, or when the grid-leak resistance is too high. The action of the vacuum tube may be blocked entirely if the grid-condenser capacity and the grid-leak resistance are not properly proportioned. The correct values to use with a tube

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are stated by the tube manufacturers. There is no need for experimenting because all this has been done very thoroughly by the commercial laboratories.

Radio reception of normal strength, accompanied by roaring, howling, whistling, and squealing noises, indicates an oscillating circuit somewhere in the receiver, or heterodyne action on a wave length near the one being received. When the vacuum tube itself is oscillating a clear musical whistling tone is noticed the pitch of which changes as the set is tuned. The whistle is the result of beats formed by the interaction of the incoming and locally generated frequencies, and the remedy is to reduce the feed-back. When regeneration is increased a gentle hiss is first heard, and, as the increase continues, a loud squeal results. The correct point of operation is just below the place at which the hiss occurs. A receiver, in which the proper operating position lies very near the squealing position, is hard to adjust. This is due to much regeneration which may be reduced by using fewer turns on the tickler, or a grid leak having a lower resistance. If the pitch of the tone does not change with tuning the interference is from a continuous-wave (C.W.) transmitting station, or from nearby radiating receiving sets. In this case the beats are due to interaction between the two incoming frequencies. Interference from a C.W. station can usually be reduced by the use of loose coupling, and by a wave-trap. Interference from radiating receivers is difficult to handle, because, as such a radiating receiver is tuned over the range of wave lengths, the frequency of the radiated wave varies also. In some cases such interference produces a continuous whistle, while in others the whistle is momentary. The only remedy is correct operation which means that the feed-back must be kept below the value at which oscillation begins. Interference between two stations, each of which is producing signals of about the same strength and nearly the same wave length, cannot be overcome. Squealing due to body-capacity effects on grid condensers may be remedied by connecting the condenser so that the stationary plates are attached to the grid and the movable plates to the grid return.

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In an audio-frequency amplifier, squealing may be due to an open in the grid circuit, or to magnetic coupling between the transformers. This can be overcome by spacing the transformers 4 or 5 inches apart and placing them in such a position that their cores are at right angles. When both the telephones and the loud speaker are connected into a receiver, howling may take place from the effect of the diaphragm of the one upon the diaphragm of the other. This action is similar to that in the ordinary telephone system in which a roaring sound is heard when the transmitter and receiver are placed close together.

In home-made receiving sets the constructor discovers very frequently, upon the first trial, that the audio-frequency amplifier does not function properly, or, in other words, it does not amplify. The most common cause of this is an open circuit in the secondary winding of one of the transformers. Such a fault cannot be repaired by the amateur, so that if the manufacturer does not have any repair service, it is necessary to get a new transformer. A cheap transformer may not give any voltage amplification at all, being merely a form of coupler. It has been found that a poor unit may even *step down* the voltage so that the amplifier acts as a very efficient reducer. There is no standard method of marking transformer terminals so the experimenter is often in doubt as to the proper connections. The outside lead of the secondary winding should be connected to the grid of the amplifier tube, and the inside lead of the secondary to the negative terminal of the "A" battery. The grid leads should be as short as possible and should not be run near the plate leads. Howling is often due to long and carelessly arranged leads. If the amplifier oscillates at a frequency above audibility, no noise is heard, but the amplification is poor. A 0.001 microfarad fixed condenser connected between the grid and filament of the second audio-frequency stage will prevent this action and often will improve reception even when there is no howling. It is best to try the primary winding connections both ways, that is, connect them one way and note the results, and then notice if any improvement is gained when the connections are reversed. Grounding the cores of transformers will reduce capacity effects. Loose connections or an open in any of the circuits, or poor contact in the jacks will cause improper performance. Sometimes poor signals are the result of a short circuit in the transformer due to leakage paths made by the effects of corrosive flux used in soldering. Exhausted batteries will give very poor amplification. Although an exact value of "B" voltage is not essential, the amplifier is very sensitive to changes in voltage after the voltage has dropped considerably. Proper values of "C" batteries have been given on page 151, but a variation in both directions from the value given should be tried in order to take care of possible differences in the tubes. A negative voltage having a maximum value of about 1.0 volt may be applied to the grid by connecting the grid-return wire to the negative terminal of the "A" battery. Up to about 40 volts in the plate circuit this method is satisfactory, but beyond that a greater value of negative voltage is needed. This may be obtained by means of a "C" battery which is connected in the grid-return wire with the negative terminal toward the grid. Approximately one volt of "C" battery may be used for each 10 to 15 volts of "B" battery above the value of 40 volts. Ordinarily not more than 6 volts of "C" battery or 100 volts of "B" battery should be used.

To get the best results from vacuum tubes, they should be placed in such an order that the best one is in the first stage, while the poorest one is in the last stage. The testing of the tubes can be done by trying them out, one after another, in the first stage of amplification, with the other stages cut out. The vacuum tube giving best results should be left in the first stage, and then the remaining tubes should be tested in the second stage, with the first stage working, and so on. With slight modifications this procedure can be followed also in the case of tubes used in radio-frequency work.

Trouble with the radio-frequency amplifying stages, in the receiving set of an amateur, usually is the result of faulty arrangement, and improper design. Under this heading may be included the use of condensers having high losses, not enough inductance in the primary and secondary of the vario

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coupler, tubes not suitable for radio-frequency amplification, high-resistance leads, grid leads too long and placed too near the plate leads, jacks in the radio-frequency circuits, the use of regeneration (either tickler coil or plate variometer) in the radio-frequency stages, and the choice of unsuitable transformers. Other causes, which are common to any kind of receiving apparatus, are, a short-circuited lightning arrester, loose connections in the antenna, a poor ground or high-resistance connections, loose connections or short circuits in the secondary of the detector, dirty or weak tube contacts, an open in the stabilizing circuit, leakage due to the use of corrosive flux in soldering, poorly soldered joints, and exhausted batteries.

An oscillating circuit in a receiver may often be located by the howl which is apparent when the hand is brought near that circuit. Such oscillations may be prevented by the use of proper by-pass condensers and by arranging the apparatus so that feed-back is decreased.

Super-power Broadcasting and Fading.—The effect of the high-power broadcasting stations is to increase the loudness of the transmitted sounds and to extend the radius of the small zone around the broadcasting station in which there is freedom from atmospheric disturbances ("static") and other interference. This gain is not proportional to the increase of power. The operation of a broadcasting station at high power does not materially increase the interference produced by the stations.

The signal fluctuation (fading) at a distance is not reduced by high power and it is this phenomenon that limits the zone of satisfactory reception. One of the greatest obstacles to good radio reception is fading. The Bureau of Standards in Washington, D. C., in cooperation with about 40 other laboratories, has been making graphical records of fading on prearranged schedules to study the changes in fading during the sunset period. Accurate knowledge of the sunset-fading phenomena should throw light on the nature and causes of fading.

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Electrical Interference with Radio Reception.—In some localities radio reception is seriously disturbed by interference arising from electrical apparatus in the vicinity. Part of the disturbance from electrical devices is practically inevitable and, like atmospheric disturbances, must be regarded as one of the inherent limitations of radio reception. Some electrical devices when in perfect working order cause disturbances of this kind, while others cause interference because of their faulty operation.[1] The only general remedy for electrical interference is cooperative effort on the part of users of radio, users and owners of the electrical sources of disturbance, and distributors of electrical power, to reduce or eliminate the causes of the trouble. In many cases it is possible to provide filters, shields, chokes, etc., either at the source of disturbance or at the receiving set, which do much to relieve the difficulties.

As a rule, troublesome noises in a radio receiving set are caused by troubles in the set itself, such as loose or corroded battery connections, defective vacuum tubes, loose contacts, damaged audio transformers, etc. The next most likely cause of noise trouble is likely to come from the use of electrical household appliances at the same time the radio receiving set is operated. The household appliances causing the most interference with radio reception are, in the order of severity, (1) "violet ray" instruments, which will cause trouble in all the area within a half-mile radius and, therefore, should never be operated at night; (2) electric motors *with brushes and commutator* such as are used for operating vacuum cleaners, electric fans, washing machines, and automatic oil burners which cause interference with radio waves within a radius of thirty feet or more; (3) defective electric light sockets when the bulb in the socket is lighted; (4) battery charger; (5) defective plug connections on a flatiron. The investigation of noise troubles should begin by "pulling" the main switch or removing the fuses where the electric current enters the house.

[1] A brief outline of the sources of such interference and the methods usually used in mitigation is given in *Letter Circular* 182, copies of which may be obtained upon application to the Bureau of Standards, Washington, D. C.

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If the noise continues, the trouble is most likely in the set itself or outside the house, and the next steps are to get some-one who can read radio telegraphy to find out whether a radio station is causing the trouble, and also communicate with the electric light company (and also electric railway, if near) to have them test their lines for defective joints or "swinging" joints between two wires. The usual method of finding the place where the trouble is caused is by touring the suspected region with a portable radio receiving set of simple design carried in an automobile, and listening to the sounds from the radio set, the place causing the trouble being near the loudest sounds. By carefully cushioning the sockets of the vacuum tubes in the receiving set, it is possible for the investigator to listen when traveling. It is convenient to use a loop type of antenna to pick up the radio waves. In scarcely any cases is the directional action of the loop of any assistance in discovering the place where the trouble is caused. Occasionally, however, the directional action of the loop is helpful and is then a timesaver.

What Is Most Wanted.—The replies of a number of owners of radio receiving sets of good quality in regard to the qualities they most appreciate when again purchasing equipment of this kind show the trend of future developments in radio receiving sets. The percentages given show the proportion of votes for each item in the table below:

	Per Cent of Dealers
Good tone quality	24
Selectivity	21
Ease of tuning	16
Great volume	10
Sensitivity	8
Dealer's franchise sales plan	6
Beautiful appearance	5
Entirely self-contained	3
Use dry cells. No wet battery	3
Fully equipped	2
Non-radiating	2

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RADIO TROUBLE CHART

NO SIGNALS	EXHAUSTED DRY CELLS OR DISCHARGED STORAGE CELLS IF "A" BATTERY	LOOSE, BROKEN OR OPEN CONNECTIONS	BATTERIES "A" OR "B" IF TOO SMALL OR TOO LARGE VOLTAGE	DEFECTIVE TUBE	POOR GROUND OR ANTENNA WIRES AND CONNECTIONS	BROKEN WIRE OR LOOSE CONNECTION IN TELEPHONE CORD	DEFECTIVE CONDENSER, RHEOSTAT, OR LIGHTING	BROKEN WIRE IN PRIMARY OR SECONDARY OF A TRANSFORMER	WRONG SIZE GRID LEAK						
WEAK SIGNALS	DITTO	DITTO	DITTO	DITTO	DITTO	DITTO	DITTO	DITTO				"C" BATTERY IF WRONG VOLTAGE OR ONE MAY BE NEEDED			
SIGNALS GRADUALLY BECOMING FAINTER	WEAK "A" OR "B" BATTERIES														
HOWLING NOISES			TOO HIGH "B" BATTERY VOLTAGE	OSCILLATING TUBE					WRONG SIZE GRID LEAK	BY-PASS CONDENSER ACROSS PHONES AND "B" BATTERY MAY BE NEEDED					TRANSFORMER MAY BE IN TOO CLOSE ELECTRICAL PROXIMITY
HISSING NOISES	WEAK BATTERY														
CRASHING OR CRACKLING	DITTO	BROKEN OR OPEN CONNECTIONS		OSCILLATING TUBE			DITTO		DITTO	DITTO				DISTURBANCE DUE TO EXTERNAL ELECTRICAL* APPARATUS. WAVE TRAP MAY BE NEEDED	
BROAD TUNING	DITTO	LOOSE, BROKEN OR OPEN CONNECTIONS		DEFECTIVE TUBE	DITTO		DITTO							WAVE TRAP MAY BE NEEDED	
POOR RECEPTION ON DISTANT STATION	WEAK "A" OR "B" BATTERIES	DITTO						DITTO	DITTO	DITTO					
SOUND DISTORTION	DITTO	DITTO	"A" OR "B" BATTERIES OF TOO HIGH OR TOO LOW VOLTAGE									DITTO			
LOUD RINGING AND HUMMING NOISES		OPEN CONNECTION IN GRID CIRCUIT													
PERIODIC NOISES		LOOSE OR POOR CONNECTIONS							DITTO					DISTURBANCE DUE TO EXTERNAL ELECTRICAL* APPARATUS. WAVE TRAP MAY BE NEEDED	
FADING DUE TO RECEIVING EQUIPMENT		DITTO			LOOSE OR SWAYING ANTENNA										

* DIRECT-CURRENT MOTORS, COMMUTATOR ALTERNATING-CURRENT MOTORS, TRANSMISSION-LINE POWER LEAKS, DOORBELLS, BUZZERS, IGNITION SYSTEM, VACUUM CLEANERS, X-RAY MACHINES, TROLLEY COLLECTOR WHEELS, HOUSE-HEATING OIL BURNERS WITH MOTOR DRIVE, BATTERY-CHARGING APPARATUS, ETC.

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QUESTIONS

1. What external conditions may cause interference in reception?
2. Describe one form of testing outfit and show how it may be used in detecting
   (*a*) an open circuit,
   (*b*) a short circuit.
3. Suppose that your receiving set shows a complete lack of response. Make a list of the places at which the trouble might occur and state how you would proceed to locate the fault.
4. (*a*) What are the causes of squealing and howling in audio-frequency amplifiers?
   (*b*) How may these causes be removed?

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CHAPTER XIII

THE FUTURE OF RADIO

The first important application of radio was its use at sea. This work covers regular messages between ships and land, reports of positions, weather and general news, and is considered so valuable that the use of radio on board ships is compulsory.

On commercial aircraft, radio is used almost universally and, in bad weather, is just as necessary as on a ship at sea. Due to recent developments a conversation can be carried on from a telephone in a house with an airplane or ship.

By means of radio telephony in transoceanic communication, persons on different continents can converse directly instead of by code as is necessary with the ocean cables. It must be admitted, however, that, for the present at least, messages sent in this way can be picked up at any place in all directions by anyone with the necessary apparatus.

On land, radio is used for communication only where the regular means are impracticable, or have failed in an emergency. An extensive communication system has been formed in the United States by amateurs in the relaying of messages across the country.

Radio is used also in automatic signaling beacons for ships and aircraft and for signaling devices at aircraft landings. It makes possible the distant control of machinery since radio signals can be employed to operate local relays which in turn control a set of machines. This method of absent control has been used on aircraft, armored cars ("tanks"), and ships with complete success. Considerable progress has already been made in the transmission of photographs, thumb prints and handwritings by radio.

An interesting and recently developed apparatus including vacuum tubes as essential parts, is used for transmitting photo-

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graphs over telephone wires on a commercial scale. The principles involved in its construction are not new and have been known for some time. The perfection of the apparatus is due largely to the development and perfection of certain devices, such as vacuum-tube amplifiers, photo-electric cells, and synchronizing equipment which heretofore have not been available. These devices, which have been used widely in the telegraph, telephone and radio fields, have merely been readapted to this new use.

A diagram illustrating the principles of the process is shown in Fig. 181. The heart of the system is the photo-electric cell. This is a small vacuum tube which has the property of

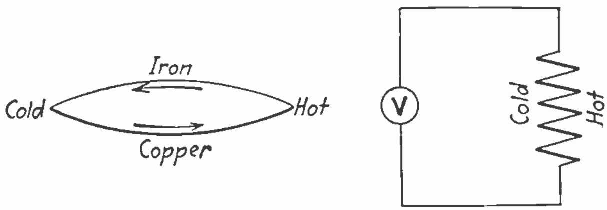

Fig. 180.—Thermo-electric battery.

varying the electric current through it in direct proportion to the intensity of light falling upon it.

This cell is placed inside of a revolving glass cylinder similar to the cylinder on a dictaphone machine, around which the photographic film (negative) to be transmitted is wrapped. The cylinder advances in the same manner as the cylinder on a dictaphone or old style phonograph. A small but intense beam of light is focused through the film on the photo-electric cell within the cylinder so that as the cylinder rotates and advances, each minute portion of the picture in turn affects the intensity of the beam of light reaching the cell. It is apparent, therefore, that the current through the cell will vary in exact accordance with the light and dark portions of the film.

This current is amplified by means of an ordinary audio-frequency amplifier, such as is used in radio work and is then passed through a modulator, where a 1,000 cycle current is

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modulated in accordance with the variations of the picture current.

At the receiving end, the 1,000-cycle modulated current passes through what may be termed a light valve. This is an electromagnetic device which causes a beam of light passing through it to vary in exact proportion to the wave shape of

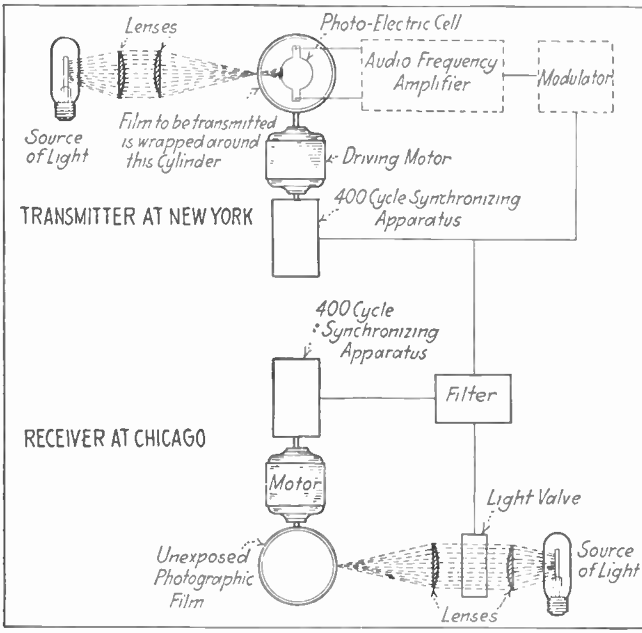

FIG. 181.—Photographic apparatus for radio transmission.

the modulated current. This beam of light is focused upon a photographic film wrapped around a rotating cylinder similar to the one used at the transmitting end.

The cylinder at the receiving end rotates in synchronism with the transmitting cylinder and as each portion of the photographic film passes before the varying spot of light emitted by the light valve, a picture is recorded (Fig. 182) which is a copy of the film wrapped around the cylinder at the transmitting end.

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The future of radio is more difficult to deal with. Aside from expansion and improvement in broadcasting, we can be certain that its use as a means of entertainment and a source of news for passengers on ships and long-run trains, will be greatly extended. In the field of education, radio has already won a place for itself because of the ease with which oral instruction can be given by our most gifted teachers and lecturers to large numbers of people scattered over a vast territory. The development of remote control by radio shows increasing possibilities. This method has, however, the serious disadvantage that the receiving apparatus must be in continuous operation with the consequent consumption of power. For certain purposes this expense is not large enough to be prohibitive.

Some of the problems of radio, namely the lack of secrecy and the disadvantage of the fact that radio waves spread out in all directions, can be solved by the use of "guided-wave telephony" also called "wired wireless," "carrier-frequency telephony" and "wire-radio telephony." These names are given to the process of guiding radio waves along wires between the transmitting and receiving stations. Such wires can be used at the same time for telegraph and telephone work and for the transmission of electric power. In the process a transmitting set is connected to one end of a wire just as it ordinarily is connected to an antenna, and the receiving set is connected to the other end of the wire. In this way the range for a given power is increased from 10 to 20 times. By proper tuning arrangements at each end, a number of messages may be carried simultaneously by a pair of wires. It seems unquestionable that this method will be used considerably as a supplement to the regular telephone system. An installation of this kind should be made only by an expert because of the danger of interrupting the normal service and of making wrong connections which might cause serious injury or damage.

At the present time a radio message may be picked up by anyone who has the proper apparatus. In order to provide secrecy in radio communications, methods are being developed whereby the only persons who can receive certain kinds

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of messages will be those who are provided with a special receiving apparatus which is designed to work with the transmitting apparatus. It is likely that these developments may be carried far enough so that secret communication will be possible between any two individuals who may desire to talk with one another.

Improvements in radio apparatus, naturally, will obtain the best attention of radio engineers. One of the most important of these is the replacement of storage batteries or dry cells by a device which uses alternating current as a source of power. As amplifiers become more sensitive the form of antenna is not so essential. In fact many sets operate effectively with a loop at the present time. The tendency along this line will be to decrease the size of the loop. It will never be possible to eliminate the antenna, or some form of it, entirely, since some device will always be necessary to receive the radio wave. Good results have been obtained in some cases by the use of a special connecting plug which fits into the electric light socket, utilizing the electric wiring for an antenna.

A device intended to eliminate the use of batteries for receiving sets utilizes the action of a *thermocouple*, which consists of two unlike metals (as for example iron and copper) connected as shown in Fig. 180. When one of the junctions is heated, there is set up at the junction point a feeble voltage which produces the flow of a small electric current in the direction shown by the arrows. A larger value of voltage can be obtained by connecting a number of such units as illustrated. The junctions in this device intended to be heated are placed near a resistance coil which is kept hot by alternating or direct current passing through the coil.

In the design of amplifiers, more progress will be made on those which are intended for radio-frequency currents, than on those for audio-frequency currents. The audio-frequency currents are those which alternate at frequencies which can be detected by the human ear. Radio currents of audible frequencies ranging between 16 to 10,000 cycles per second correspond to the sound wave frequencies which are produced by musical instruments and by the human voice. Radio-fre-

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quency currents are all those above 10,000 cycles per second. The design of audio-frequency amplifiers is well standardized

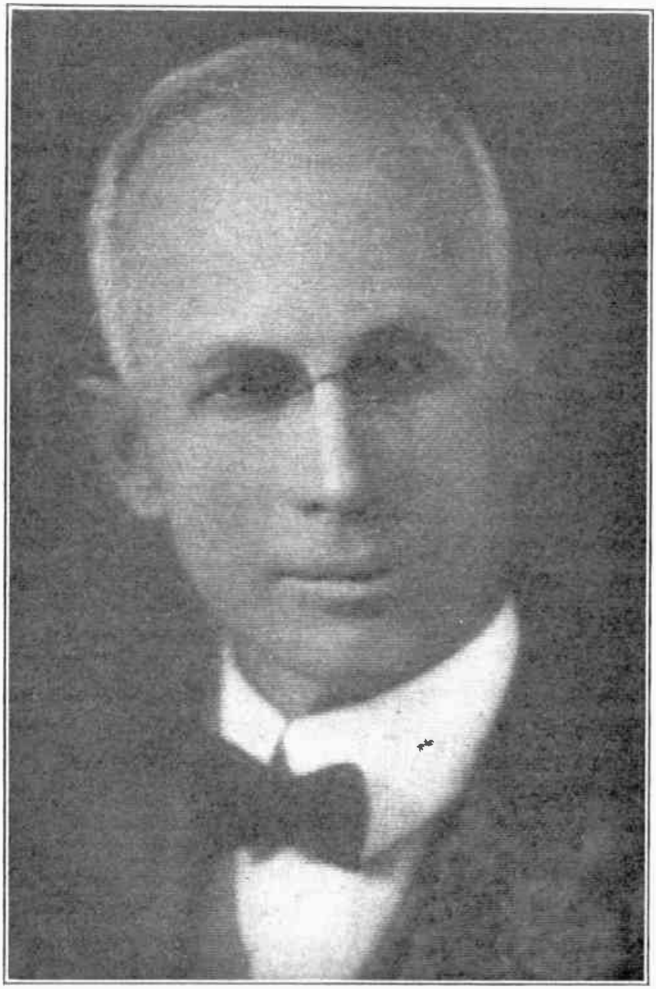

FIG. 182.—Radio photograph.

because amplification at low frequencies presents no special technical difficulties. At high frequencies, however, it has

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been difficult to design apparatus which works effectively over the entire range.

Much attention and study has been given to the prevention of the occurrence of noises in the receiving set which are caused by electrical disturbances in the atmosphere, usually called "static," "strays," and "atmospherics," which form the most serious limitations on radio at the present time, and also the peculiar phenomenon called "fading."

Many methods have been produced to decrease the effect of static, or to increase signal strength without at the same tim-increasing the strength of the static disturbance. The interference from spark sets is being reduced in proportion to the number of such sets which are replaced by continuous-wave transmitters.

Recent experiments have shown that short wave, high frequency transmission is effective over greater distances for a given amount of power than long wave transmission. Moreover, daylight has but little effect on the carrying power of short waves. The Westinghouse station KDKA is broadcasting its regular program on 326 meters, while a 94 meter wave is broadcast for re-transmission at higher wave lengths from other distant stations. This short wave program has been picked up at London with complete success. Even more encouraging results have been obtained with short wave transmission in *radio telegraphy* by methods giving complete *directional* effects.[1]

With directive reception, in which a receiver is so constructed that it is sensitive to waves coming from only one direction, the effects of atmospheric disturbance, so-called "static," have been eliminated almost entirely.

Supervision of Radio Broadcasting.—As the usefulness of radio broadcasting increases, it will become necessary to put this service under careful supervision. Careful consideration of this subject leads many to believe that such supervision should be in the hands of the Federal Government. One of the

[1] Interesting discussions of this subject will be found in *Journal of Royal Society of Arts* (article by Marconi), July 25, 1924; and *General Electric Review* (article by Alexanderson), June, 1924.

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suggestions which has been offered is that authority should be granted to provide for the establishment, in a given center, of a certain number of broadcasting stations. These stations would all operate at the same time, but on different wave lengths and each would furnish a different type of service.

At present, broadcasting stations are classified as A, B, or C. Class A stations use up to 500 watts of power on a wave-length range of 222 to 300 meters. Class B stations use from 500 to 1,000 watts on a range of 300 to 345 and 375 to 545 meters. Class C stations cover all those originally licensed for 360 meters and, in this class, no new licenses will be issued on 360 meters.

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APPENDIX

IMPORTANT EVENTS IN RADIO—PEAKS IN THE WAVES OF WIRELESS PROGRESS

1831.—Farady discovered electromagnetic induction between two entirely separate circuits.

1838.—Steinheil discovered the use of the earth return.

1840.—Henry first produced high-frequency electric oscillations and pointed out that the discharge of a condenser is oscillatory.

1842.—Morse made wireless experiments by electric conduction through water.

1845.—Lindsay made experiments in transmitting messages across the River Tay by means of electricity without submerging wires, using the water as a conductor.

1862.—Heyworth patented a method of conveying electric signals without the intervention of any continuous artificial conductor.

1867.—Maxwell read a paper before the Royal Society in which he laid down the theory of electromagnetism, which he developed more fully in 1873 in his great treatise on electricity and magnetism. He predicted the existence of the electric waves that are now used in wireless telegraphy.

1879.—Hughes discovered the phenomena on which depend the action of the coherer. The coherer was later used practically by Marconi.

1880.—Professor John Trowbridge (Harvard University) found that signaling might be carried on over considerable distances by electric conduction through the earth or water between places not metallically connected.

1882.—Experiments with Trowbridge's method carried out by Alexander Graham Bell on the Potomac River resulted in the detection of signals at a distance of 1½ miles.

Professor Dolbear (Tufts College) was awarded a United States patent in March, 1882, for wireless apparatus in connection with which he made the statement that "electrical communication, using this apparatus, might be established between points certainly more than one-half mile apart, but how much farther I cannot say." It appeared that Professor Dolbear made an approach to the method that was, subsequently, in the hands of Marconi, to be crowned with success.

1885.—Edison, assisted by Gillilaud, Phelps and Smith worked out a system of communication between railway stations and moving trains by means of induction and without the use of conducting wires. Edison

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took out only one patent on long-distance telegraphy without wires. The application was filed May 23, 1885, at the time he was working on induction telegraphy, but the patent (No. 465971) was not issued until Dec. 29, 1891. In 1903 it was purchased from him by the Marconi Wireless Telegraph Co.

1887.—Hertz showed that electromagnetic waves are in complete accordance with the waves of light and heat, and founded the theory upon which all modern radio signaling devices are based.

1891.—Trowbridge suggested that by means of magnetic induction between two separate and completely insulated circuits communication could be effected between points a considerable distance apart.

1892.—Preece adopted a method which united both conduction and induction as the means of affecting one circuit by the current in another. In this way he established communication between two points on the Bristol Channel and at Lochness in Scotland.

Branly devised an appliance for detecting electromagnetic waves, which was known as a coherer.

1895.—Marconi's investigation led him to the conclusion that Hertzian waves could be used for telegraphing without wires.

1896.—Marconi lodged his application for the first British patent for wireless telegraphy. He conducted experiments in communicating over a distance of 1¾ miles successfully.

1897.—March: Marconi demonstrated communication being established over a distance of 4 miles.

March 17: Ballons were first used for the suspension of wireless aerials.

July 10–18: Marconi maintained communication between the shore and a ship at sea at distances up to 10 miles.

September and October: Apparatus was erected at Bath, England, and signals received from Salisbury, 34 miles distant.

November 1: First Marconi station erected at the Needles, Alum Bay, Isle of Wight. Experiments were conducted covering a range of 14½ miles.

December 6: Signals transmitted from shore to a ship at sea, 18 miles distant.

December 7: First floating wireless station was completed.

1898.—July 20–22: Events of the Kingstown regatta in Dublin reported by wireless for Dublin newspaper from steamer *Flying Huntress*.

1899.—April 22: The first French gunboat was fitted with wireless telegraph apparatus at Boulogne.

July: During the naval manoeuvres three British warships equipped with Marconi apparatus interchanged messages at distances up to 74 nautical miles (about 85 land miles).

1900.—February 18: The first German commercial wireless station was opened on Borkum Island.

February 28: The first German liner fitted with wireless apparatus communicated with Borkum Island over a range of 60 miles.

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November 2: The first wireless land station in Belgium was finished at Lapanne.

Between 1900 and 1905 Dr. DeForest was granted numerous patents in the United States and other countries for inventions connected with wireless telegraphy.

1901.—January 1: The bark *Medora* was reported by wireless as water-logged on Ratel Bank. Assistance was immediately sent.

January 19: The *Princesse Clementine* ran ashore, and news of the accident was telegraphed to Ostend by wireless.

February 11: Communication was established between Niton Station, Isle of Wight, and the Lizard station, a distance of 196 miles.

March 1: A public wireless telegraph service was inaugurated between the five principal islands of the Hawaiian group, *viz.*, Oahu, Kauai, Molaki, Maui, and Hawaii.

October 15: The first fan aerials were erected for experiments between Poldhu and Newfoundland.

December 12: The letter *S* was received by Marconi from Poldhu, England, at St. Johns, Newfoundland, a distance of 1,800 miles.

September 28: Professor R. A. Fessenden (formerly of University of Pittsburgh, now of Newton Centre, Mass.) applied for a United States patent for "Improvements in apparatus for the wirelesss transmission of electromagnetic waves, said improvements relating more especially to the transmission and reproduction of words or other audible signals." It appears that in connection with this apparatus there was contemplated the use of an alternating-current generator having a frequency of 50,000 cycles per second. Professor Fessenden was granted a number of U. S. patents between 1899 and 1905 covering devices used in connection with radio telegraphy.

1902.—February: Steamship *Philadelphia*, American Line, received messages a distance of 1,551½ statute miles and received Morse signals up to a distance of 2,099 statute miles from Poldhu station, Cornwall, England.

July 14–16: Marconi received messages from Poldhu on the Italian cruiser *Carlo Alberto*, lying at Cape Skagen, a distance of 800 miles; and at Kronstadt, 1,600 miles.

December 17: The first wireless message was transmitted across the Atlantic. On the eighteenth wireless messages were despatched from Cape Breton station to King Edward VII.

1903.—January 19: President Roosevelt sent a transatlantic radiogram to King Edward via Cape Cod and Poldhu stations.

March 30: First transoceanic radiogram was published in the *London Times*.

August 4: First International Radiotelegraphic Conference was held at Berlin.

Poulsen patented the improved arc oscillation generator, using a hydrocarbon atmosphere and a magnetic field.

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1904.—January 20: The first press message was transmitted across the Atlantic.

August 15: The Wireless Telegraph Act of Great Britain was passed.

November 16: Professor J. Ambrose Fleming took out his original patent No. 24850 for thermionic valves.

1906.—January 18: De Forest was granted a patent for a vacuum rectifier, commercially known as the audion.

Second International Radio Telegraphic Convention was held at Berlin, and a convention was signed by a majority of the principal countries of the world.

General Dunwoody (U. S. A.) discovered the rectifying properties of carborundum crystals and Pickard discovered the similar properties of silicon crystals. These discoveries formed the basis of the widely used crystal detectors.

1907.—October 17: Transatlantic stations at Clifden and Glace Bay were opened for limited public service.

1908.—February 3: Transatlantic radio stations were opened to the general public for the transmission of messages between the United Kingdom and the principal towns of Canada.

In carrying out his invention Professor Fessenden constructed a high-frequency alternator with an output of 2.5 kilowatts and 225 volts and with a frequency of 70,000 cycles per second. Later Professor Fessenden reported successful wireless telephonic communication between his station located at Brant Rock, Mass., and Washington, D. C., a distance of about 600 miles.

1909.—The steamship *Republic*, after colliding with the steamship *Florida* off the coast of the United States on Jan. 23, succeeded in calling assistance by wireless, with the result that all her passengers and crew were saved before the vessel sank.

1910.—The steamship *Principessa Mafalda* received messages from Clifden at a distance of 4,000 miles by day and 6,735 miles by night. On Apr. 23 the Marconi Transatlantic (Europe-America) service was opened.

June 24: Act approved by the United States Government requiring radio equipment and operators on certain passenger-carrying vessels.

1911.—July 1: Radio service organized in Department of Commerce and Labor to enforce the act of June 24, 1910.

1912.—F. A. Kolster (Bureau of Standards) invented and developed the Kolster decremeter, which is used to make direct measurements of wave length and logarithmic decrement. This instrument has been used by the radio service of the Department of Commerce since it was invented.

Early in the year the American Marconi Co. absorbed the United Wireless Co., of the United States.

In February the Marconi Co., procured the patents of Bellini and Tosi, including those for the wireless direction finder.

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On Feb. 9 the Australian Commonwealth station was opened.

On Apr. 15 the steamship *Titanic*, on her maiden voyage, struck an iceberg and sank, but, owing to the prompt wireless call for assistance, the lives of more than 700 of her passengers were saved.

The International Radiotelegraphic Conference opened in London on June 4 and approved important regulations to have uniformity of practice in wireless telegraph services. On July 5 the International Radiotelegraphic Convention was signed at London.

July 23: Act approved by the United States Government extending act of June 24, 1910, to cover cargo vessels and requiring auxiliary source of power, efficient communication between the radio room and the bridge, and two or more skilled radio operators in charge of the apparatus on certain passenger-carrying vessels.

August 13: Act approved by the United States Government licensing radio operators and transmitting stations.

1913.—F. A. Kolster submitted to the Government a paper pointing out the advantages of certain applications of radio signaling for use at lighthouse, lightships, and life-saving stations, especially in time of fog.

In June a wireless telegraph bill was presented to the Ottawa Parliament and passed under the title "Radiotelegraph act of Canada."

On Oct. 11 the *Volturno* was burned in mid-atlantic, and in response to the wireless appeal 10 vessels came to the rescue, 521 lives being saved.

On Nov. 24 the first practical trials with wireless apparatus on trains were made on a train belonging to the Delaware, Lackawanna & Western Railroad.

The station at Macquerie Island was the means of keeping Doctor Mauson the Australian explorer, in touch with the outer world. Radio despatches were published in a small journal which was established, called the *Adelle Blizzard*.

1914.—Experiments in wireless telephony were carried out between several vessels lying at anchor five-eighths of a mile apart, ordinary receivers being used with success. The wireless telephone experiments were continued between two warships on the high seas, and the reception was consistently good over a distance of 18½ miles. Successful wireless telephone communications were effected later, using only very limited energy between vessels on the high seas 44 miles apart.

High-powered transoceanic stations were completed at Carnarvon, Wales, Belmar, Honolulu, and San Francisco during the autumn of 1914. The Honolulu-San Francisco stations were opened to public service Sept. 24. The Tuckerton-Eilvese and Sayville-Nauen stations were in operation about this time.

Most of these stations made use of the latest developments in the art, using undamped and long waves as produced by the Poulsen arc and the radio-frequency alternator.

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On Oct. 6, E. H. Armstrong was issued a patent covering the regenerative circuit also known as the feed-back and the self-heterodyne circuit.

1916.—During the course of a severe blizzard in the United States during February wireless telegraphy was extensively used for train dispatching as the telegraph wires were down.

The determination of the difference in longitude between Paris and Washington with the aid of radio which had been in progress since Oct., 1913, was completed during May, the result, expressed in terms of time, being 5 hours 17 minutes 35.67 seconds, and has a probable accuracy of the order of 0.01 second.

The initiation of the newly established trans pacific wireless service between the United States and Japan was celebrated on Nov. 5, by an interchange of messages between the Mikado and President Wilson.

1917.—June 2 marked the "coming of age" of wireless telegraphy in England, that is, that 21 years had elapsed since the registration of patent 12039 in 1896.

1918.—The trend of progress toward continuous-wave communication as distinct from that by damped waves was very marked during this year, a particular impetus being given by the continued development of the electron tube as an efficient receiver and generator of undamped oscillations. Steady improvement was also evident in the arc form of generator which was installed in many new high-power stations.

Wireless telephony also progressed to a marked extent, particularly in the direction of reliability and increase of range, due mainly to the development of valve generator and receivers.

At the end of the year a high-power station, erected by the United States Government, was opened at Croix d'Hins, near Bordeaux.

In the Argentine the erection of a station destined for direct communication with the North American continent was commenced in the vicinity of Buenos Aires.

On July 31 the United States Government took over all wireless land stations in the United States, with the exception of certain high-power stations, which remained under the control of commercial companies.

On Sept. 22 messages transmitted from Carnarvon were received in Sydney, 12,000 miles away. Cable confirmations of these messages were sent forward at the same time but were received some hours later than the corresponding radio telegrams.

In April a high-power station was opened at Stavanger, Norway, for the use of the Norwegian Government. The station communicates with the United States.

1919.—During the year the Radio Corporation took over the radio interests of the American Marconi Co.

The war-time ban on private and experimental wireless stations was removed.

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1920.—The steady development of continuous-wave wireless stations was continued during the year and some further progress made in the commercial application of tube apparatus.

On Jan. 25 a new high-power stations was opened at Monte Grande, Argentine, call letters LPZ.

Bordeaux, France, high-power station opened.

1921.—The Nobel Prize for physics was awarded this year to Professor Edouard Branly (Paris) for his researches in Radio.

The progress made in amateur and experimental wireless is exemplified by the attempts made in February and December of this year to effect communication on short wave lengths between the wireless amateurs of the United States and Great Britain. The first attempt was unsuccessful, but during the second test signals from many American amateur stations were heard both by British radio amateurs and by the representative of the American Radio Relay League who was sent over for the tests. The signals were also heard in Holland.

The American Radio Relay League held its first annual convention in Chicago, Aug. 30–Sept. 3, at which many thousands of amateurs of the United States were present.

The first licenses for broadcasting stations were issued in September of this year.

New York radio central station opened on Long Island.

1922.—During this year broadcasting stations increased rapidly in keeping with the great interest taken in the art.

On June 7, E. H. Armstrong read a paper before the Institute of Radio Engineers on some recent developments by him of regenerative circuits. Professor Armstrong was granted a patent for the super-regenerative circuit.

Experiments in radio telephoning from ship to shore were conducted during this year. In tests from the steamship *America* it was proved possible to communicate with land telephone stations more than 400 miles distant from the ship.

1923.—On Mar. 2, L. A. Hazeltine (Stevens Institute of Technology) presented a paper before the Radio Club of America on tuned radio-frequency amplification with neutralization of capacity coupling. Professor Hazeltine was granted a patent for the non-radiating neutrodyne receiver.

Great progress was made during the year in the development of vacuum tubes.

Short wave lengths were used to greater advantage than heretofore.

The McMillan expedition to the polar regions had radio for their only means of direct communication. Using low power and short wave lengths their vessel, *Bowdoin*, communicated with several stations in the United States while they were frozen in thousands of miles away. Broadcasting concerts from United States stations were heard during the long dark nights of the arctic zone.

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During the year foreign countries became interested in radio-telephone broadcasting.

Broadcasting in United States heard in England, and *vice versa*.

1924.—In January radio was used in the region of the Great Lakes during a blizzard for dispatching trains.

An expedition from the United States, under the leadership of Hamilton Rice, which will explore the Amazon and Orinoco Rivers in Brazil and Venezuela in the interest of geographical science in general, will have radio as their only means of communication.

On Feb. 5 a radio program broadcast in the United States from Pittsburgh station of Westinghouse Electric Manufacturing Co. was received and re-broadcast in England for the benefit of English stations.

On Feb. 23 a concert broadcast by the same station and relayed from London was heard clearly in Calcutta, India.

Roger Babson, economist, estimates that during this year the American people will spend approximately $350,000,000 for radio equipment. Sales of radio equipment are running nearly twice as large as all kinds of sporting goods.

A wireless lighthouse has been set up on an island in the Firth of Forth, Scotland. Wireless waves are concentrated by reflectors into a beam which can be sent 100 miles, giving ships their position in a fog.

1925.—On Mar. 5, the inaugural message of President Coolidge was transmitted by a series of radio broadcasting stations from the Capitol Building in Washington, D. C., so that it was heard by twenty-five million people.

The MacMillan Polar expedition which was equipped with short-wave radio transmitting apparatus was able to communicate almost constantly by day and night with stations in the United States.

Vacuum tubes for use with alternating currents were developed for use in commercial types of radio receiving sets.

Daily reports of probable radio receiving conditions were published in newspapers.

1926.—International broadcasting of music between New York and London, Paris, and Berlin.

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