RADIO SIMPLIFIED

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KENDALL AND KOEHLER

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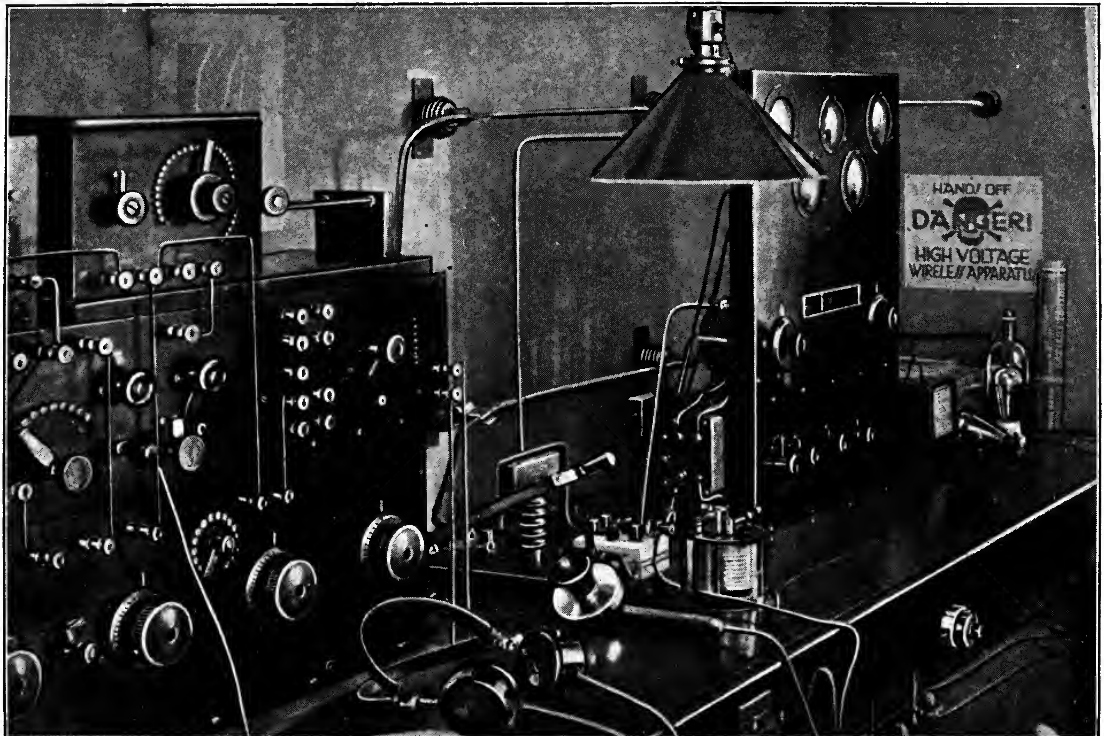

Courtesy of Mr. George P. Hamilton.

AMATEUR HOME-MADE VACUUM TUBE TRANSMITTER.

RADIO SIMPLIFIED

WHAT IT IS—HOW TO BUILD AND OPERATE THE APPARATUS

BY

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FOREWORD

It has been the purpose of the authors in the preparation of *Radio Simplified* to provide in non-technical language an explanation of radio with emphasis upon how it works, and to furnish simple and definite directions and suggestions for assembling and installing home radio equipment at small cost. They have endeavored to answer clearly and simply those questions which first arise in the mind of the novice and which they have found to be most frequently asked by students in radio classes.

Radio itself is introduced in a manner which removes the necessity for a preliminary course in electrical engineering. Technicalities are omitted unless they are to be put to some practical use by the amateur. Equipment which is suggested is that which is most easily obtainable and in many cases can be made at home. In every instance, definite and specific directions are given for hooking it up. Numerous picture diagrams accompany the circuits suggested, so that the novice may have no difficulty in fitting his equipment into the hook-up. A great number of good practical hook-ups are shown, especially for regenerative sets, in which the experimenter may use to advantage the apparatus he already owns, without purchasing additional equipment.

Considerable space has been given to the proper erection of aerials, to the end that they may give the best results and that they may be a protection against lightning rather than a fire hazard.

The advantages and the limitations of various hook-ups and types of sets are frankly discussed. Suggestions are made as to what equipment to select in order to receive what the operator desires to hear. In the operation of receiving sets, particularly in regenerative receivers, novices are given specific directions to follow in tuning.

Many novices, and amateurs as well, have spent good money for equally good equipment, but have been unable to get the best results from the set after it has been assembled. Many others want to own radio sets, but are not clear about what apparatus to buy or how to hook it up after having purchased it. Still other amateurs have been operating sets for years without having become familiar with many of the "kinks" in hook-ups and in operation that add to the efficiency of any set. For these three groups, this book has been written.

The authors desire to express deep appreciation to Mr. Logan Howard-Smith and to Mr. George P. Hamilton, who have unsparingly given time and thought to the preparation of material, and to constructive criticism of manuscript from the viewpoint of the experienced radio amateur.

Foreword to the Revised Edition

The very large sale of this book in the original edition and the great number of enthusiastic letters received from users have prompted the Authors and Publishers to prepare a thoroughly revised edition to cover all new developments in the radio art which have proved practical in the hands of amateurs. This edition includes a number of new Radio Frequency Circuits, the De Forest Reflex, the Grimes Inverse Duplex, the Hazeltine Neutrodyne Receiver, the Reinartz circuit, and many other new hook-ups.

Thanks are due to Professor L. A. Hazeltine, Mr. David Grimes, Mr. Boyd Phelps, the Radio Club of America, "Q. S. T." and the American Radio Relay League for assistance in preparing this revised edition.

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Chapter I

WHAT IS RADIO?

Many theories about radio.—Few scientists, engineers or radio enthusiasts are willing to admit that they know what radio really is. Many theories and hypotheses have been advanced to explain its varied behavior. It is not within the scope of this book, however, to enter into any technical discussion of the theory of radio. There are, on the other hand, a few simple facts concerning "how it works" which even a child can understand. A knowledge of these facts is useful to every radio enthusiast.

Vibrations and waves.—Radio is essentially the control of a type of electrical vibrations and the waves resulting from them.

Everyone is familiar with vibrations and waves of one sort or another. Grasp the loose end of a rope; shake it rapidly up and down, *and waves visible to the human eye* will travel the length of the rope as a result of the vibration. Strike a bell, and the vibration which is set up sends forth in all directions, *sound waves audible to the human ear*. Draw a bow across a violin string, or strike the key of a piano, and audible sound waves are the result. Kindle a fire in a stove, and the energy released from the fuel will cause even the particles of iron in the stove to vibrate and send off *waves of heat* to which human bodies are sensible *through feeling*.

Our vocal cords vibrate when we speak, and the sound waves which result, carry our speech to all people within hearing distance.

How radio works.—In transmitting the voice or music by radio, the sound waves are directed into a sending device which converts them into electrical vibrations far too rapid for the human ear to hear. At the same time, the sending set transfers these vibrations to the wires of

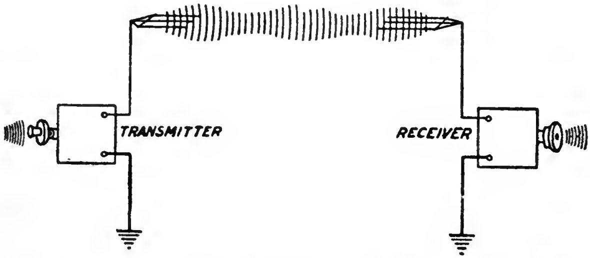

Fig. 1.—Elements of a Radio Telephone System.

the sending aerial. The vibrations in the aerial cause electromagnetic waves to radiate in all directions, instantaneously circling the globe. When these electromagnetic waves come in contact with the wires of another aerial, they set up in these wires, electrical vibrations precisely similar to the vibrations in the aerial which sent the waves on their way around the earth. The electrical vibrations in the receiving aerial are then carried by a lead-in or drop wire, to a receiving set, where they are re-converted into sound vibrations, audible to the human ear. These sound vibrations exactly reproduce the voice or music which is being directed into the sending set. This, in a nutshell, is the principle of radio.

Sound waves and electrical vibrations.—The modern radio telephone sending outfit is essentially a collection of apparatus for converting audible sound waves into electrical vibrations and transferring these very rapid or high frequency electrical vibrations to an aerial.

The modern receiving outfit is essentially an assembly of apparatus for re-converting the high frequency radio waves picked up by an aerial, into the corresponding sound waves, which are of lower frequency and are audible to the human ear.

The manner in which electrical vibrations are controlled or molded by sound waves will be considered more in detail in Chapter V and Chapter X.

Audio frequency and radio frequency.—The word *frequency* in radio language is used to denote rate of vibration.

Sound vibrations in order to be heard by most people must have a frequency lower than 10,000 per second. Sound vibrations having a frequency lower than 10,000 per second are said to be of *audio frequency* because they are *audible* to the human ear.

Electrical vibrations which are utilized to propagate radio waves have a much higher frequency. Electrical vibrations above 20,000 per second are arbitrarily said to be of *radio frequency*. Radio vibrations in the aerial wires may have a frequency of several million per second.

It may be interesting to note, in passing, that the audio frequency range begins at about 40 vibrations per second—the lowest vibration rate at which the human ear is capable of sensing sound. Light and heat vibrations are of extremely high frequency. Heat waves, to which the nerves of the body are sensitive, are the result of 20 trillions to

300 trillions of vibrations per second; light waves, of 430 trillions to 740 trillions per second; and ultra violet and X-rays, 870 trillions to 1500 trillions per second.

Necessity for tuning.—To this point, we have seemed to assume that every radio receiving station is at all times picking up messages from every other station which happens to be sending. Strictly speaking, this is not possible, nor would it be at all desirable. If such a condition were to exist, the confusion of sounds which would come from the receiving apparatus would effectually preclude any possibility of the reception of intelligible messages.

In order to receive messages by radio, the receiving operator must *tune* his station to the station from which he desires to receive. We may more readily understand how this *tuning* is accomplished by considering the action of two violin strings exactly alike in key, length and tension, and strung side by side. If a bow is drawn across one of the strings, causing it to vibrate, the string which was not touched by the bow also begins to vibrate and send out sound waves. In like manner, if two pianos in the same room are tuned to the same pitch, and a note is struck on either instrument, the corresponding string on the other piano will give out the same tone. All the other strings will remain silent. In both of these illustrations, the second string was "in tune" with the first, and so vibrated in sympathy.

Similarly in radio, a receiving station must be in tune with the sending station from which one wishes to receive. That is to say, the wave length, or vibration period—both of which are governed, for the most part, by the effective length of the aerial—must be identical for both stations. Sending stations may transmit on a variety of wave lengths. Tuning to the wave length upon which a station is transmitting, is accomplished at the receiving station.

Wave length.—Everyone who reads the newspapers has noticed that when a program is announced for broadcasting, the wave length of the transmitting station is always given. The question therefore arises as to what is meant by wave length, and how the length of an invisible wave can be measured.

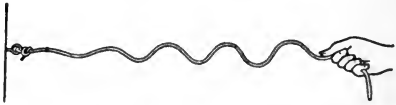

FIG. 2.—WAVES IN A VIBRATING ROPE.

In answering these questions, let us consider for a moment, waves we can really see—water waves, for example, or better still, the waves of the vibrating rope.

The wave length in the case of the rope is plainly the distance from the crest of one wave to the crest of the next; and every vibration of the arm produces a wave of this length. If we measure this distance and count the number of vibrations of the arm per minute, we can calculate, by simple multiplication, the speed at which the wave travels along the rope. Or if we measure the distance which one of these waves travels in one minute, we can divide this distance by the number of vibrations per minute (or the number of waves which follow the first one during the minute) and thereby determine the length cf a single wave.

Radio waves are, of course, invisible. Their length, however, may be calculated as exactly as that of the wave in the rope, and in the same manner.

In the first place, waves sent out by a wireless station are known to travel at the same speed as light—186,000 miles per second, or, in the metric system, 300,000,000 meters per second. In the second place, the rate of electrical vibration in a sending aerial can be determined at the sending station. Therefore, dividing 300,000,000 by the number of vibrations per second will give in meters the wave length upon which the station is sending. For example, if a station is sending out waves at the rate of 1,000,000 per second, the length of each wave must be $\frac{300,000,000}{1,000,000}$ or 300 meters. Likewise, if it is desired to send on a 360-meter wave length, the sending station should be tuned to a frequency of $\frac{300,000,000}{360}$ or 833,333 vibrations per second.*

Varying the wave length, or tuning.—Finally, any given station may be so constructed as to permit both receiving and sending on a considerable range of wave lengths, in order to allow freedom in tuning to the wave lengths of different stations. Such tuning may be accomplished in two ways:

(1) Increasing the effective length of the aerial circuit by adding wire from a tuning coil (commonly termed "adding inductance");

(2) Increasing or decreasing the capacity of the aerial circuit by means of condensers.

Both of these methods we shall consider later in connection with receiving and with sending.

* The shortest electromagnetic wave yet measured is a fraction of an inch in length; the longest, more than 1,000,000 miles.

Chapter II

THE ANTENNA OR AERIAL

Variations in form and size.—The antenna or aerial is a part of the radio equipment used both in sending and in receiving. Aerials may vary in size from miniature aerials used with portable receiving sets, to commercial station types, hundreds of feet long. In form there is also wide variation, as indicated by the illustrations on the following page. As a matter of fact, amateurs often have been able to receive messages more or less satisfactorily, using a bed spring or even a window screen as an aerial.

The receiving aerial.—For receiving only, a single wire, *if of sufficient height and length*, furnishes the most satisfactory aerial. In picking up a given message, one wire, strange as it may seem, will collect nearly as much energy as several parallel or radial wires of equal length. To compensate for any slight loss in the collection of energy, a single wire also collects much less atmospheric electricity (commonly called *static*); *induction* (electric or magnetic influence from local current carrying wires, without direct contact) occurs to a lesser degree; and humming and crackling is reduced to a minimum.

The loop aerial, in which the wire is wound on a frame usually from two feet to eight feet square, is somewhat widely used as an indoor receiving aerial. But owing

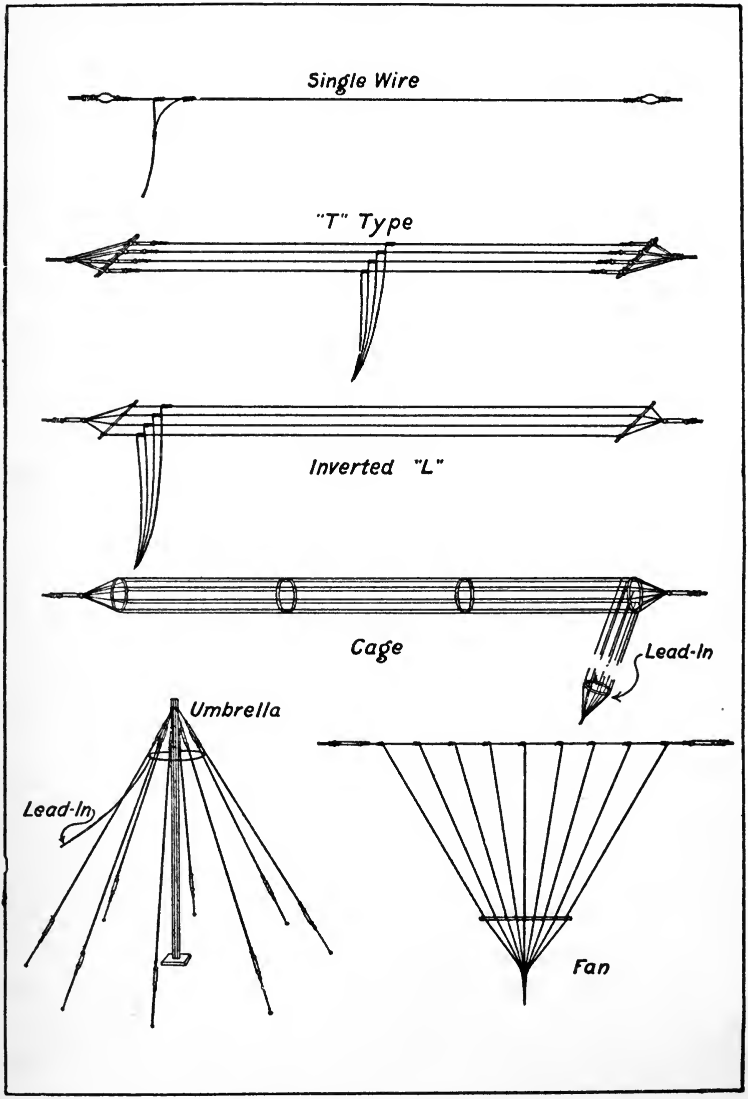

FIG. 3.—TYPES OF AERIALS.

to its small size and its limited capability for collecting energy, sensitive receiving apparatus must be used with it. We shall therefore postpone to a later chapter the discussion of its operation and its peculiar qualities in tuning and in direction finding.

The transmitting aerial.—In sending, best results are to be obtained from a multiple wire aerial. Increasing the number of wires has the effect of lowering the resistance of the aerial to the electrical vibrations impressed upon it and provides a greater amount of surface for purposes of radiation. More energy may, therefore, be transferred from the sending set to the wires and radiated from them.

The counterpoise aerial, which is used chiefly in sending, will be considered in Chapter IX.

If one aerial is to be used both for sending and for receiving, a flat top multiple wire (T or inverted L) type is the most frequent compromise. It is evident from the illustration that the only difference between the T type and the inverted L is in the location of the drop wire connection. In the former, the lead-in is taken from the middle of the flat top; in the latter it is taken from one end. A usual advantage in either of these aerials is ease of erection.

In the preceding chapter, we have seen that a sending set may be used to transfer electrical vibrations to the aerial. We have found that the electromagnetic waves caused by such vibration, spread in all directions over and through the earth. We have learned that when these electromagnetic waves come in contact with the wires of another aerial, they set up in these wires, electrical vibrations precisely similar to those in the aerial which sent the waves on their way through space. We have seen that the receiving aerial must be tuned to the wave length of the sending aerial, in order that it may most efficiently pick up the vibrations which are to be converted by the receiving set into audible sounds. We are now ready to plan and to build an aerial.

MAKING THE CALCULATIONS

The aerial circuit.—Generally speaking, the natural wave length of an aerial depends upon the *total length* of the aerial circuit, which is measured from the farthest end of the longest aerial wire to the point where the grounding device or grounding system enters the earth. It is a fact, however, that height, material of the masts or other supporting structures and other conditions affect the natural wave length of an aerial. But since there are no fixed rules as to the effect of shape, length, number of wires, and the factors mentioned above, the precise dimensions for an aerial which will exactly produce a desired wave length cannot be determined before the aerial is erected. The best procedure is to estimate the circuit as closely as possible, and make allowance for a natural wave length somewhat under the desired sending wave length. A similar procedure should be gone through in the case of a receiving aerial. This will permit including in the aerial circuit a tuning device necessary for sharp tuning, which will be discussed in later chapters.

An aerial constructed from the following specifications should have a natural wave length well under 200 meters, which is the maximum wave length, with certain exceptions,* allocated by the U. S. Department of Commerce to amateur *sending* stations. The introduction of tuning devices, as indicated in Chapter I, will, of course, permit the reception of messages upon much longer as well as upon much shorter wave lengths.

Size of the sending aerial.—To begin with, the total physical length of the aerial circuit for an amateur sending station should not exceed 150 feet. For best results in

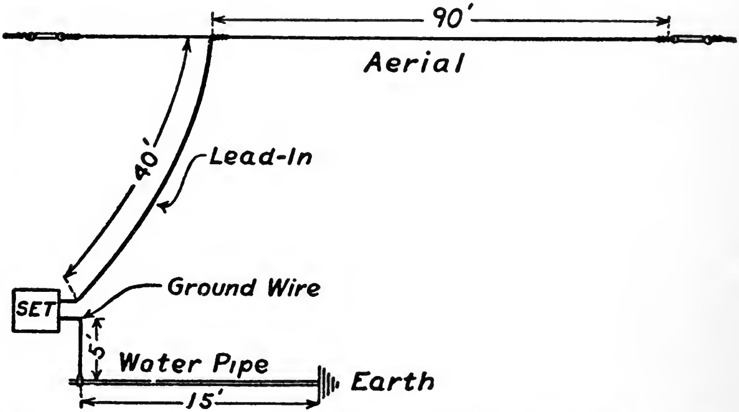

FIG. 4.—METHOD OF CALCULATING THE PHYSICAL LENGTH OF AN AERIAL CIRCUIT.

receiving those stations which broadcast on a wave length of 360 meters, the receiving aerial circuit length should be approximately 200 feet. Purely local conditions, such as parallel wires—telephone or electric service—guy wires, proximity to a tin roof, steel masts, or other metal structures, may have a slight effect upon the natural wave length of the circuit. As indicated above, neces-

* See Government Regulations, Chapter XII.

sary corrections for such variations may be made with a tuning device in the circuit after the aerial has been installed and tried out. The *total length* of the aerial circuit, as outlined in Fig. 4, includes the *length of the longest aerial wire* (if the wires are of different lengths), plus the length of the lead-in or drop wire to the receiving or the sending set, plus the length of the ground wire from the set to the water pipe, radiator or other grounding device, *plus the length of pipe line or grounding device to the point where it actually enters the earth.* Not until this point is reached, is the aerial circuit complete.

The length of the longest aerial wire should be taken as the distance from the point where the drop wire leaves the aerial to the farthest end of the longest wire in the aerial. The fact that there are more wires than one in the flat top T, or the inverted L type aerial, does not affect the above calculation. The *length* is taken as of the *longest* wire.

It should also be noted that zig-zagging the wires in an aerial, that is, carrying the same wire backward and forward between spreaders or other supports, will not increase the effective length of the aerial circuit to any great extent.

T type versus L type.—From the above directions for computing the length of the aerial circuit may arise the questions: What is the function of the extra side in the flat top of the T type aerial? Why not always use an inverted L type? In answer it may be said that the additional wire in the T type makes possible the radiation of a greater amount of energy in sending.

Since best results are obtained from an aerial which extends as high above the earth as possible, and with a lead-in as short and as direct as possible, it might follow that the ideal aerial would extend in a vertical direction from the set itself. This may be true in the case of a receiving aerial, but does not hold for a sending aerial. However, such an erection is seldom practicable, and a compromise which will take existing conditions into account, is usually made.*

Size of the receiving aerial.—The size and the wave length of an aerial to be used for reception only, may be computed in the same manner as that suggested for the transmitting aerial on the preceding pages. It should be said, however, that in case a receiving aerial is to be erected under limited space conditions (as for example, on the roof of a house 25 or 30 feet long) the advantages to be derived from using two to four wires in parallel outweigh the disadvantages noted on page 17. The capacity effect in such an aerial will operate to increase the natural wave length of the aerial circuit which might be somewhat limited if a single wire were erected.

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* It should be noted at this point that the sending aerial described in the following chapter is an elaborate erection. A much simpler aerial of the same type may be erected for receiving, and should give satisfactory results.

Chapter III

ERECTING THE AERIAL

Materials required.—The materials necessary for the sending aerial suggested in the preceding chapter are:

(1) copper wire, either bare or insulated,
(2) two spreaders,
(3) aerial insulators,
(4) two pulleys,
(5) aerial rope,
(6) two poles, or other supports,
(7) guy wire,
(8) guy wire insulators,
(9) supports for guy wires,
(10) lightning arrester or lightning switch, or both,
(11) lightning ground and ground wire.

Almost any form of copper wire will do for use in the aerial. The only requirement is that it be of sufficient size to offer low resistance to the electrical currents and to withstand strains imposed by high winds. Since radio waves can penetrate all substances, insulation on the wire has no deterrent effect whatever. As a matter of fact, there is a slight advantage to be obtained from the use of insulated wire since it protects the surface of the wire from corrosion. No. 14 solid copper wire, or seven strands of No. 22, are prescribed by the National Board of Fire Underwriters as the minimum size. The latter is most commonly used.

Phosphor-bronze wire is not so efficient on account of its higher resistance to electrical currents. It is used, as for example, on ships, on account of its greater mechanical strength. Aluminum wire should not be used in any case because it is not strong enough and because the wire quickly becomes oxidized in the atmosphere, causing a loss of energy owing to resistance at any splices which have been made.

If a single wire type is to be erected, which, as has been stated, is the most satisfactory aerial for receiving, the spreaders are unnecessary. Tall trees, or other supports, if conveniently located, may be utilized instead of masts.

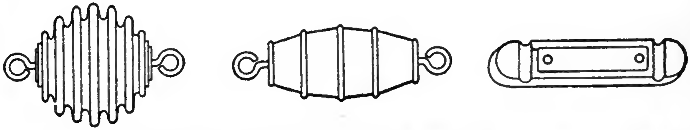


FIG. 5.—TYPES OF INSULATORS SUITABLE FOR A RECEIVING AERIAL.

Owing to the high voltage employed in transmitting, an aerial which is to be used for sending must be particularly well insulated. For transmitting sets using from ¼ to one kilowatt of current per hour, the 10-inch "Electrose" strain insulator such as that shown in Fig. 8, or a similar type, will serve the purpose. With sets which use vacuum tubes for transmitting, glazed porcelain insulators are preferable.

In the case of a receiving aerial, or of a transmitting aerial employed with a set using less than ¼ kilowatt of current, such as a spark coil transmitter, the ball type of insulator may be used. This insulator and other types suitable for an aerial used only for receiving, are shown in Fig. 5. The glazed porcelain cleat is inexpensive and is usually obtainable at any electrical supply store.

The rope should be sufficiently strong to carry the weight of the aerial in a high wind. Sash cord and hemp rope are both satisfactory. The pulleys should be large enough to allow the rope to slip through them easily. Guy wire of seven strands of No. 20 or No. 22 heavily galvanized steel wire is usually obtainable at any hardware store; the latter is strong enough to guy a 40-foot pole. Seven strands of No. 20 should be used for a 60-foot pole.

Choosing a site.—In choosing a site for an aerial, bear these points in mind: (1) The aerial wires should be kept from possible contact with trees or buildings. (2) The aerial should be kept away from tin roofs. If it is found necessary to erect an aerial over a tin roof, raise it as high above the roof as possible—*at least several feet.* Close proximity of aerial wires to trees, buildings, and especially to a tin roof, will result in re-radiation and loss of energy in sending. It will also interfere with receiving, in that these objects will absorb, to some extent, energy which might otherwise be collected by the aerial. (3) The aerial should be elevated as high as possible above all surrounding buildings, especially any which are of steel framework. Such structures will lower the receiving range from their direction, by what is known as a shielding effect. (4) Avoid close proximity to current-carrying wires. Where it is necessary to erect an aerial near high tension wires, it should be run in a direction at right angles to such wires. If this cannot be done, run the aerial as nearly at a right angle as possible. This procedure will reduce induction from the current-carrying wires to the aerial and will largely eliminate the loud humming which is sometimes heard in the receivers. (5) Aerial wires should never be strung over or under other wires carrying electric current. If the higher wires should break or sag, and make contact with the lower wires, danger to apparatus as well as to other property and to life might result. (See page 39.)

Bearing these points in mind, we may cast about for a location for the aerial.

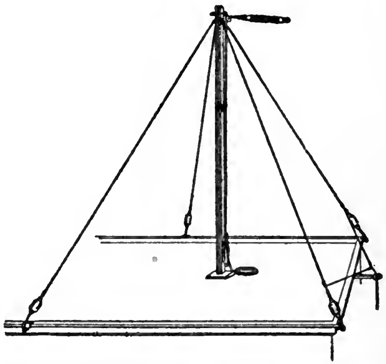


FIG. 6.—METHOD OF INSULATING AND GROUNDING GUY WIRES OF A POLE ERECTED ON THE ROOF OF A BUILDING.

Supports for the aerial.—The aerial may be supported between two house tops. It may be strung from the peak of the house to a tree, a flagpole, or a mast in the yard. It may be suspended from a short pole eight or ten feet long, placed on the roof. A pole of this size may be placed against a chimney and fastened to it, and would not require guy wires for support. This method will eliminate the necessity for nailing and the attendant possibility of a leaky roof. Iron poles or pipes should not be used on a roof unless the pole and its guy wires are thoroughly insulated from all parts of the building and then properly grounded to a lightning rod or other lightning ground. Insulation of the pole may be accomplished by resting its base in a glass or porcelain insulator. If it is not thoroughly insulated and grounded, and lightning should strike the pipe, considerable damage to the building might result. Guy wires may be insulated and grounded after the method shown in Fig. 6.

Since the aerial should be well above the roof, the method of stringing it between low chimneys or other parts of the building is not advisable. If the far end of the aerial is to be supported by a telephone pole or by another building, or if the aerial is to be stretched over other properties, the permission of the owners must first be secured.

If the aerial is to be suspended from a tree, at either end, the pulley should be tied to the tree and sufficient rope allowance made to meet the wire at a point beyond reach of the limbs as shown in Fig. 11. A weight sufficiently heavy to keep the aerial taut should be attached to the other end of the rope as shown. This arrangement will permit the tree to sway without snapping the aerial wire.

Making a mast.—If sufficient height cannot be obtained between the house and a tree, a flagpole, or another building, a tall pole such as is used for a flagpole may be erected. Such a pole should be guyed, even though it is placed several feet in the ground. This kind of pole, however, is hard to obtain, especially in cities. Another good type which has been constructed and successfully used for several years by the authors, is the laminated mast shown in Fig. 7.

For a 40-foot pole, three thicknesses of white pine strips of 1-inch by 4-inch material should be used. These strips should be put together as shown in the drawing.

Five 16-foot pieces, two 12-foot pieces and two 8-foot pieces would be required to make this mast.

For a 30-foot pole, three thicknesses of 1-inch by 3-inch material, making the cross section of this mast 3 inches by 3 inches, should be sufficient. For a 60-foot pole, four thicknesses of 1-inch by 4-inch stock should be used. The 30-foot pole and the 60-foot pole should be laid out on the same plan as the 40-foot pole, care being taken

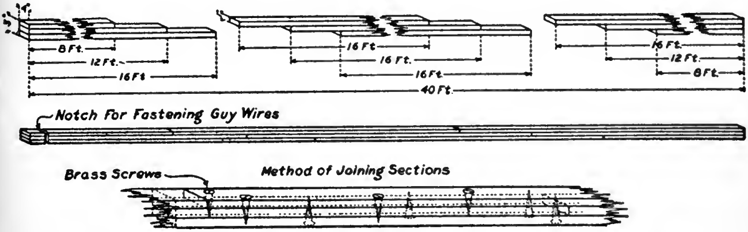


Fig. 7.—Method of constructing a 40-foot laminated mast.

that the joints of the strips in any one layer do not come too close to the joints of the strips in another layer.

Sections may be nailed together as shown in the case of the 40-foot pole. Then these sections which are nailed, should be joined together by means of brass screws, which will not rust. This form of construction will permit the pole to be taken apart for transportation, which otherwise would hardly be feasible in the case of a 40-foot or a 60-foot pole. In joining sections, bolts should not be used on account of their weight and the possibility of rusting. Besides, holes for the bolts would weaken the mast. The laminated pole is more easily constructed and is stronger than masts made by bolting together joists or short poles; it is also much more satisfactory than any iron pole made from pipes of reduced sizes fastened together by reducer couplings. A good coat of paint will add to the life, as well as to the appearance of the laminated mast.

Guy wires and aerial rope.—One set of four guy wires would be sufficient in the case of the 30-foot pole; two sets of four each—one at the top and one at the middle—

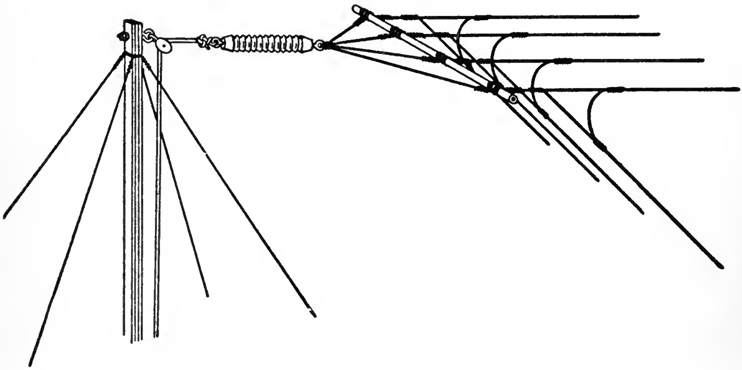


FIG. 8.—AERIAL WITH METAL SPREADERS REQUIRING ONLY A SINGLE INSULATOR AT EACH END. NOTE METHOD OF CONNECTING THE LEAD-IN TO THE FLAT TOP. NOTE ALSO EASED OFF BENDS TO REDUCE BRUSH DISCHARGE IN TRANSMITTING.

should be used for either a 40-foot or a 60-foot pole. All of the guy wires should, of course, be attached to the pole before it is raised. A pulley should also be attached, and the rope for hoisting the aerial should be passed through it and both ends fastened near the base of the pole. The pulley should be fastened to the pole by means of a bolt bent into the shape of a hook at one end and threaded at the other end to take two nuts, as shown in Fig. 8. Or, the pulley might simply be wired to a groove sawed around the pole about two inches from the top, as indicated in Fig. 7.

As previously suggested, the guy wire used for the largest pole should consist of seven strands of No. 20 galvanized steel wire. Insulators should be inserted at about every twenty feet to prevent dissipation and re-radiation of energy in transmitting, which would result if the guy wires were similar in length to the aerial wires. Guy wires may be attached to any convenient supports or to posts driven into the ground. Guy wires should, if possible, be fastened at a distance from the foot of the pole, equal to the height of the pole.

Making up the aerial.—The flat top of the aerial should be made up in a clear space, large enough to permit the wires to be laid out alongside of one another. The wires should be cut in even lengths and then fastened about two or three feet apart to the spreaders. *Aerial wires must be exactly alike in length between the spreaders.* If they are uneven, the longer wires will sag when the aerial is in place. The ideal method of construction would be to attach the wires to metal spreaders so that the spreaders form part of the circuit, as shown in Fig. 8. Brass rods ¾ inch square, or brass tubing of a ¾-inch outside diameter make excellent spreaders for an aerial of this design. Brass spreaders eliminate the necessity for insulating each wire from the spreader. Insulating each wire separately places a number of insulators in parallel in the circuit and thereby reduces the total insulation of the aerial to a fraction of that afforded by a single insulator. In other words, the chance of the high voltage current leaking to the pole or other support would be multiplied by the number of insulators used. If the wires are bolted or soldered to a metal rod or tube of good conducting material, only one insulator is required between the rope and the spreader.

The efficiency of this type of aerial may not be evident to the novice, but by experienced radio amateurs it is believed that "fading signals" and other undesirable phenomena, particularly with vacuum tube transmitters,

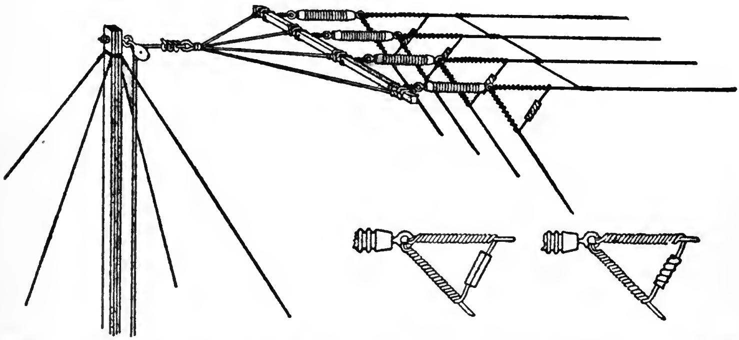


Fig. 9.—Aerial with wooden spreaders requiring insulators for each wire. Small drawings show approved sleeves for splicing.

are partly due to the insulation factor in the aerial, which may vary in moist atmosphere or during rainstorms. If, because of inability to secure material for an aerial of this type, or for some other reason, the reader does not desire to use this kind of spreader, a wooden spreader may be used, with an insulator inserted between each wire and the spreading device, as shown in Fig. 9. In this case the aerial wires should be connected to one another, at each end of the aerial, by a wire soldered across all of them.

The lead-in.—Keeping in mind that the circuit of a transmitting aerial should not exceed 150 feet in order to enable tuning to as low as 200 meters in wave length, we can decide where the lead-in should be connected. For example, if the lead-in is to be 50 feet in length and if the ground circuit is 20 feet in length, we should then be limited to a length of 65 feet in the flat top of an inverted L aerial. If plenty of space is available and the flat top can be extended for as much as 130 feet, we could obtain a circuit of approximately the same length as in the case above by connecting the lead-in at the center of the 130-foot flat top, forming a T type aerial. The lead-in, particularly for sending, should be of the same current-carrying capacity as that of the total number of wires in the flat top. That is to say, if the aerial is made up of four No. 14 wires, the lead-in should contain the same number of wires of the same size.

Splices in aerial wires.—All connections in the aerial and lead-in wires should be scraped bright, tightly twisted, and soldered, as shown in Fig. 8. The National Board of Fire Underwriters requires that these wires, if not soldered, must be connected by approved clamping devices or wire sleeves, as shown in Fig. 9. Necessity for soldering the lead-in wire to the aerial may be eliminated in an inverted L type aerial by passing the aerial wire through the insulator, giving it a number of twists and then continuing the same wire as a drop wire to the lightning arrester or switch.

Making sure of pulleys and guy wires.—Before raising the pole, make doubly sure that the pulley and all guy wires are securely attached to it; also that the rope which is to support the aerial is run through the pulley. This last suggestion may seem to be an unnecessary caution, but amateurs have been known to forget this point, and as a result have had either to climb the pole after it was in place or to lower it again to put the rope through the pulley. The rope should be long enough to reach from the bottom of the pole to the top and down again, so that after the pole has been erected, the aerial may be raised and lowered. (See Fig. 10.) The ends of the rope should be tied together so that an end cannot slip through the pulley while the pole is being raised. Another method is to have the rope long enough to reach from the aerial in the raised position, through the pulley and down to the base of the pole. Then in raising the pole, and again when it is desired to lower the aerial, another piece of rope is tied to the rope used for supporting the aerial and enough of the new piece is let out to allow the aerial to drop to the ground. Of course the aerial should not be attached to the rope before the pole is raised. The aerial should be raised only after the pole is in position with the guy wires securely fastened. *Be sure to have the aerial rope in place before raising the pole.*

How to erect a mast.—In raising the pole, any one of a number of methods may be used. In the case of a 40-foot pole, the base may be rested in a small hollow dug in the ground and while one or two men keep the base in this hollow by placing their feet on it, two or three others may raise the top of the pole from the ground and walk toward the base, elevating the pole as they go. After the pole has been raised to an angle of about 45 degrees, two people pulling on guy wires attached to the top of the pole can raise it the rest of the way. Of course, two other people should have hold of guy wires on the opposite side of the pole, so that when the mast reaches the vertical position, it can be kept from falling over.

In raising a mast, the use of pike poles, which are long, slender poles with spikes in one end, commonly used by

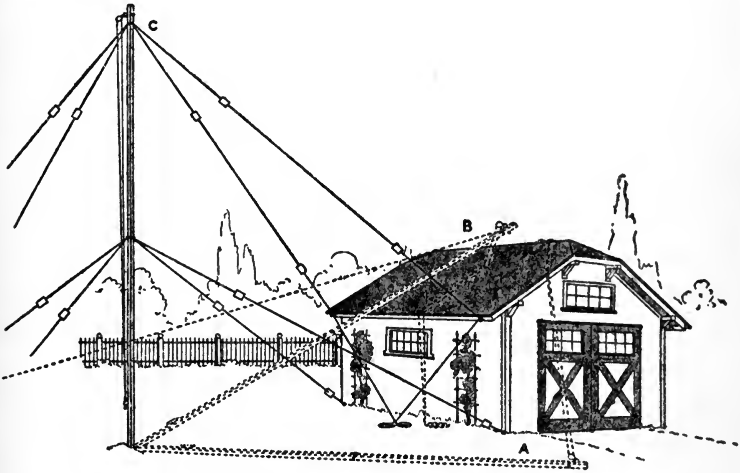


Fig. 10.—A simple method of erecting a mast.

telephone companies and others in erecting poles, is not advised for amateurs, as considerable experience is required to manipulate these poles. Sufficient leverage for a 40-foot pole can be obtained, as has been suggested, by simply pushing it upward with the hands and walking toward the base. A 60-foot pole would no doubt require the use of pike poles or some other device.

A more simple way of raising the mast, if conditions will permit, is to pull up one end of the pole to the roof of a house or other building and rest it against the eaves, as shown in Fig. 10.

The pole should be placed on the ground near the building, as indicated in the drawing. The end of the pole that is to be raised to the eaves may be pulled to that position by the aerial rope lowered from the roof. It may be seen from the diagram how the pole can be raised from this last position to a vertical position: Two people should stand off at a distance, each holding a guy wire attached to the top of the pole. The two guy wires on the other side of the pole may be run through screw hooks temporarily fastened at the corners of the house. One man standing on the ground may hold the two guy wires which are run through these hooks. As the two men pull the pole forward to an upright position, the other man slacks up on his two wires sufficiently to allow the pole to be righted. If it is not feasible to insert the two hooks in the edge of the roof so that one man can hold the two wires, one wire may be carried around each end of the house; two people would then be required to pay out the two wires as the pole is being righted.

As soon as the pole has been raised to an upright position, each man fastens his guy wire. One man can then sight the pole, and, by loosening up one guy wire for a few inches and taking in the slack of the guy wire on the opposite side, may true up the pole and fasten it securely in the vertical position.

This latter method of erection can be successfully employed only where the pole is to be placed near a building. In other words, if the pole were forty feet long, resting one end on the eaves at a height of, let us say, twenty-five feet, would bring the base at the most, only about thirty feet from the house. It is suggested that the amateur does not try to move the pole for any distance after it has been placed in a vertical position.

Raising the aerial.—After the masts have been erected, or if masts are not used, after the pulleys have been attached to other supports, all connections for the aerial should be gone over for the last time. See that the aerial wires are securely fastened to the spreaders or to the aerial rope. Go over the lead-in connections carefully and make sure that strong joints have been made. See that the lead-in wires—one for each wire in the aerial—are made up of sufficient length to reach to the point where they are to connect with the lightning switch.

In raising the aerial, it is necessary to guide it so that it does not become entangled in the guy wires. All kinks or sharp bends should be removed from the wire just as it is being raised. A kink allowed to remain will cause a sharp bend and possibly a fracturing of the wire when the aerial is tightened; and even if the wire is later straightened out, it will be very much weakened at that point. Drop wires should be allowed to swing free while the aerial is being raised.

After the aerial is in place, the lead-in wires may be allowed to hang loose or in a spread out effect to the point where they are to be fastened to insulators on the house or building. From this point, it is necessary to keep them together. This may be accomplished by twisting them together and continuing the lead-in in this form from the point where it first is fastened to the building to the point where it makes connection with the lightning arresting device prescribed by the National Board of Fire Underwriters. As noted below, lead-in wires must be supported in such manner that they are at least four inches away from the building or the supports on which the insulators are mounted in the case of a receiving aerial, and five inches in the case of a sending aerial. These insulating supports may be purchased from any electrical dealer.

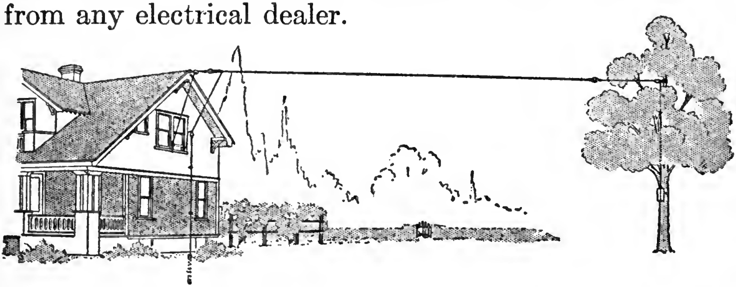


FIG. 11.—COMPLETE INSTALLATION OF AN INVERTED L SINGLE WIRE RECEIVING AERIAL. NOTE CONNECTIONS OF THE LIGHTNING ARRESTER AND THE LEAD-IN. NOTE ALSO METHOD OF SUSPENDING AERIAL WITH PULLEY, ROPE AND WEIGHT, TO AVOID POSSIBILITY OF AERIAL BREAKING IN A WIND.

FIRE UNDERWRITERS' REQUIREMENTS

The aerial as a protection against lightning.—The importance of erecting the aerial in such manner that it will be a protection from lightning instead of a hazard cannot be overestimated. If properly installed, it will collect and carry to earth any lightning discharge which might otherwise strike the building. If improperly installed, it is a source of danger in any locality where lightning discharges occur. In view of the foregoing, regulations have been drawn up by a special committee of the National Fire Protective Association, which is the authority for the National Electrical Code, in co-operation with engineers acting for the American Radio Relay League, the American Telephone and Telegraph Company, the Radio Corporation of America, and the Independent Telephone Association. The findings of this committee are considered standards of good practice in the installation of aerials and should be strictly complied with.

In the following paragraphs, the recommendations of the committee are summarized. In some cases, cautions already given in this chapter are repeated.

No protection for indoor aerial.—In the first place, a receiving set having an indoor aerial is considered devoid of hazard, except when storage batteries or other initial energy is used either for amplification or as a source of energy for vacuum tubes or other apparatus which the art may later develop. Proper installation of such apparatus will be given consideration in later chapters. With any receiving set, the principal danger is from lightning brought in over the aerial to the equipment or to some part of the building. Where there is no outside aerial, this hazard is removed.

Protecting the outdoor aerial.—The regulations prescribe that aerials outside of buildings shall not cross over or under electric light or power wires or any circuit carrying current of more than 600 volts, or of railway, trolley or feeder wires; nor shall they be so located that a breaking of either the aerial wires or the above mentioned electric light or power wires will result in a contact between the aerial and such wires. The amateur, however, should take even further precautions than these and should not attempt to string aerial wires over any electric wires which carry as much as 110 volts. The aerial might be strung under wires which do not carry more than 110 volts with a fair degree of safety, but even then the breaking of the electric light wires above might cause a contact with the aerial wires and destroy the receiving set.

The Underwriters further require that the aerial shall be constructed and installed in a strong and durable manner and shall be so located as to prevent accidental contact with light and power wires by sagging or swinging.

The Underwriters also require that the aerial and lead-in be of solid or stranded copper wire, not smaller than No. 14, excepting that as small as No. 17 copper-clad steel wire may be used. It might be said that it is common practice to use No. 14 stranded copper wire because of its strength as well as its conducting qualities, and not No. 14 solid, as the latter will kink and break very easily.

All splices in the aerial and lead-in wires must be soldered or else be made with an improved connector, as previously noted.

Bear in mind that a single wire is more satisfactory for a receiving aerial than a number of wires; but when more than one wire is used in an aerial employed for both transmitting and receiving, the lead-in should be made up of the same number of wires of the same size, or else of one wire having a current carrying capacity equal to the total number of wires in the aerial.

The lead-in wires, if attached to the outside of the building before reaching the point of entrance, must be mounted upon insulating supports so that they will not come nearer than four inches from the wall, as previously noted. Furthermore, they must be kept at least four inches from electric light and power wires, unless separated from them by a continuous and firmly fixed weatherproof non-conducting material which will maintain permanent separation, regardless of whether or not the lead-in wires have insulation on them. However, it is not good practice in any case to run the lead-in wires parallel to or near electric light or power wires, as induction which will "drown out" the received signals may take place.

The lead-in wires must enter the building through a bushing or tube which is non-combustible, non-absorptive, and insulating—of porcelain, for example, or fibre.

All of the foregoing regulations and suggestions apply to transmitting as well as to receiving aerials, except that transmitting aerials should be even better insulated. The lead-in wires of an aerial used for transmitting must be supported five inches from the walls instead of four inches; and where they pass through the building, they must be so insulated by a long moisture-proof tube or lead-in device that there will be not less than five inches creepage distance between the lead-in wires at the ends of the tube, and the building or any other conducting material.

Lightning arresters and lightning switches.—The lead-in for the receiving aerial must be provided with at least an approved lightning arrester, located either inside or outside the building, but as near as possible to the point of entrance of the wires to the building. The lead-in wires of a transmitting aerial must be provided with a single pole, double-throw switch having a current carrying capacity of at least 50 amperes and having four inches clearance between the contact points of the switch. This switch may also be used for the receiving aerial, in addition to the lightning arrester, and is desirable for additicnal protection; but the switch alone is not sufficient to conform to the Underwriters' requirements for the receiving aerial. Its metal parts must be mounted on a waterproof insulating base. A switch having a slate base should not be used, as slate very often has metallic veins.

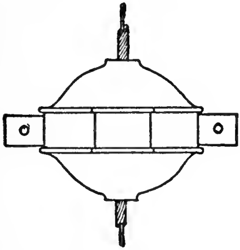


FIG. 12.—AN APPROVED WEATHERPROOF LIGHTNING ARRESTER.

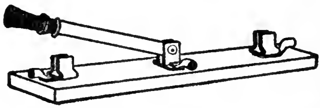


FIG. 13.—AN APPROVED SINGLE POLE DOUBLE THROW LIGHTNING SWITCH.

The switch for a transmitting aerial must be so mounted that its current carrying parts are five inches from the building wall. It may be located either inside or outside the building, but it must be at the immediate point of entrance of the lead-in wires to the building and preferably in the most direct line between the aerial and the lightning ground. The set should be connected to one end of the switch, the lightning ground to the other end, and the lead-in wires to the middle point.

The lightning ground.—In the opinion of the authors, the lightning ground wire for the receiving aerial as well as for the transmitting aerial, should have a current carrying capacity as large as that of the total number of lead-in wires from the aerial, although this specification is made for only the transmitting aerial. According to the regulations, however, in no case shall the lightning ground wire be smaller than No. 10. It must be of copper or other metal which will not corrode to any extent under existing conditions. The wire may be either insulated or bare and it does not have to be mounted on insulated supports, although again it is better practice to have it supported from the building by means of insulators. A good arrangement is to mount the lightning ground wire on porcelain knob insulators such as are commonly used in electrical work. Sharp turns or bends in the lead-in wire and in the lightning ground wire should be avoided and both of these wires should be run in as direct a line as possible between the aerial and the lightning ground.

The lightning ground to which the lightning ground wire is conneoted should be a good, permanent, earth connection such as the water pipe system. **Gas pipe systems must not be used for such grounds.**

Where the water system is used for the lightning ground, the ground wire should be connected to the pipe on the street side of the meter. In other words, the connection to the water pipe should be made at a point between the water meter and the place of entrance of the water pipe into the earth, so that if the water meter were removed, the lightning ground circuit would still be intact to the pipe running into the earth.

Other lightning grounds which are permitted are grounded steel frames of buildings, or approved artificial grounding devices such as pieces of iron pipe driven into the ground, or metal plates buried several feet in the earth. If pipe is used for the lightning ground, it must be of galvanized iron or other metal which will not corrode or rust, and it must be at least one inch in diameter. Furthermore, it must be driven down into the earth for a distance of at least six feet; if a plate is used, it must be buried at

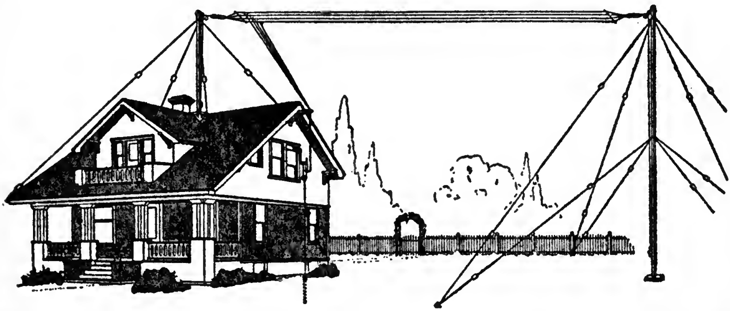


FIG. 14.—A COMPLETE INVERTED L TRANSMITTING AERIAL INSTALLATION, SHOWING MASTS, GUY WIRES AND INSULATORS, FLAT TOP, LEAD-IN, LIGHTNING SWITCH, GROUND WIRE, AND LIGHTNING GROUND.

a similar depth. It would be much better to use two or three such pipes or plates than to use only one, especially if the earth is not very moist at the spot.

An approved device known as a ground clamp must be used wherever the lightning ground wire is connected to driven pipes or to water piping. When the connection is exposed to the weather, an approved device designed specifically for that purpose must be used.

According to the regulations, antenna and counterpoise conductors must be effectively and permanently grounded (that is, with the arrester in place or the switch thrown, as the case may be, or both) when the station is not in actual operation (unattended).

Chapter IV

ESSENTIALS OF A RECEIVING STATION

A radio receiving set, as we learned in Chapter I, is an assembly of apparatus for re-converting into sound waves, audible to the human ear, the high frequency radio waves which have been radiated from a sending station and picked up in the form of electrical vibrations in the receiving aerial circuit.

The simplest receiving set.—The simplest receiving outfit includes (1) an aerial, (2) a lead-in or drop wire, (3) a detector, or rectifier as it is sometimes called, (4) a pair of head telephones, or receivers, and (5) a connection to the earth, commonly called *the ground.* This simple receiving circuit is shown in Fig. 15.

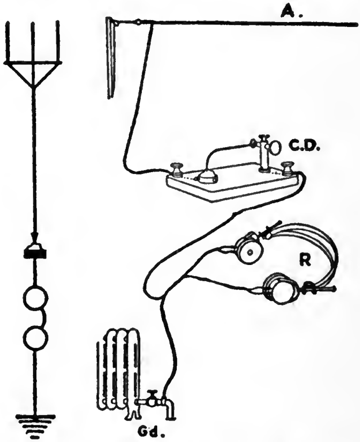


Fig. 15.—The simplest receiving set.

Such an assembly of apparatus can receive signals from points within its range if such signals are transmitted on a wave length corresponding to the natural wave length of its own aerial circuit. The chief disadvantage in this circuit grows out of the impossibility of tuning it to receive signals from stations transmitting on different wave lengths. In other words, no provision has been made for lengthening or shortening the aerial circuit to place it in tune with the aerial circuits of different transmitting stations. This disadvantage may be overcome by introducing a tuning coil into the circuit, as shown in Fig. 16.

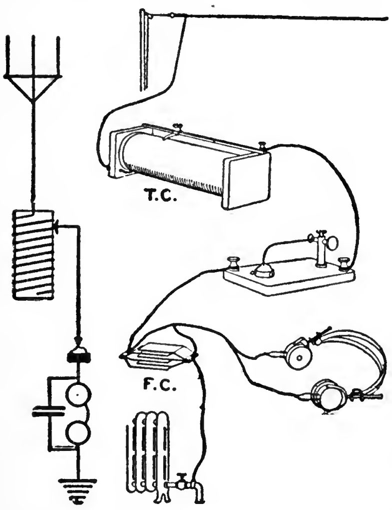


FIG. 16.—THE SIMPLE RECEIVING SET WITH A TUNING COIL AND A FIXED CONDENSER ADDED TO THE CIRCUIT.

The addition of a tuning coil.—A tuning coil is simply a coil of copper wire, usually No. 18 to No. 26, wound on a cylindrical form made of insulating material as, for example, a cardboard tube, and having a contact which may be made to slide across the turns of wire. In this hook-up, the drop wire or lead-in is connected directly to one terminal or end of the coil of wire. The other terminal of the coil remains unconnected. The sliding contact, or slider, is connected to one side of the detector. The other side of the detector is connected to one terminal of the cord attached to the receivers. The other terminal of the receiver cord is connected to the ground wire. In the operation of the set, the currents from the aerial will travel through the coil only to the turn of wire on which the slider rests. As the sliding contact is moved in the direction away from the lead-in connection, the electrical vibrations or currents induced in the aerial circuit must travel around the turns of wire in the coil which have thus been added to that circuit, before they pass to the detector through the sliding contact connection. Adding turns of wire in a coil is commonly called adding *inductance* in the circuit. Adding inductance in this circuit has the effect of lengthening the aerial, as suggested in Chapter I. That is to say, adding wire from a coil eliminates the necessity of climbing to the roof to add additional wire to the aerial, which might otherwise be necessary in tuning.

A tuning having only one sliding contact, as shown in Fig. 16, is called a *single slide* tuning coil.

The purpose of the detector.—The function of the detector in the receiving circuit is only partially indicated by its name. Its real purpose is to rectify or filter the radio frequent vibrations induced in the aerial circuit so that they may be converted by the receivers into sounds which may be detected by human ears.

To this point in our discussion of radio vibrations and waves, we have seemed to assume that the electromagnetic waves caused by the sending set are radiated only from the sending aerial. In order to better understand the action of the receiving set, it will be necessary for us at this point to examine more closely the nature of radio vibrations and waves.

Current oscillations and radio waves.—The electric current which is sent into the sending aerial circuit to produce radio waves is always alternating current. That is to say, when the first surge of current is sent into the sending aerial circuit, the flow in the circuit is in one direction; the second surge of current travels in the opposite direction. In the case of a sending set connected to an aerial and to the ground, if the first surge of current travels up into the aerial, the second surge will travel to the ground, the third to the aerial, the fourth to the ground, and so on. Two successive surges, one in each direction, make up one complete cycle or oscillation. As the current surges up into the aerial, a magnetic influence or pressure or disturbance—commonly called a magnetic field—is set up around the wires and the earth connection, and the first half of an electromagnetic or radio wave is projected from the aerial circuit into space; as this surge dies out the magnetic field surrounding the aerial circuit collapses. The magnetic disturbance, however, continues to move on through space in all directions at the speed of light. The next surge of current flows in the direction of the earth. This alternate surge of current, which goes to the ground, likewise exerts a magnetic influence and a similar field is set up around the aerial circuit and is radiated as the second half of the wave. The next surge in the direction of the aerial starts another electromagnetic wave, and the foregoing process continues as long as the station is sending, with a wave projected from the wires of the aerial circuit and the earth surrounding the ground connection, for every complete oscillation.

What we have heretofore termed vibrations in the aerial are therefore, more properly, oscillations of current in the aerial circuit, up into the aerial and down into the ground.

The distance that the first wave has traveled through space when the second wave starts on its way, is the length of the wave. Bear in mind that the surges or oscillations which we have been calling vibrations, often occur at the rate of many millions per second, and that every complete oscillation projects a wave from the aerial circuit, through the air and through the earth. Remember also that when these waves come in contact with a receiving aerial circuit, they induce in it oscillations of alternating current, exactly similar to the oscillations in the aerial circuit from which the waves have been radiated, although of lower intensity.

With these facts and theories in mind, let us return to our consideration of the simple detector.

The crystal detector.—Certain minerals—among them are galena, silicon, carborundum, and iron pyrites—have the peculiar property of allowing currents of electricity to pass through them much more readily in one direction than in another. If one of these minerals is introduced into the receiving circuit, we have a means of eliminating half of each of the electrical vibrations or, more properly, oscillations which are induced in the receiving aerial circuit, and which we desire to convert into sound waves, by stopping either the currents which enter the aerial circuit and flow to the ground, or the currents which enter the aerial circuit and flow toward the aerial.

In the simple receiving set under discussion, we may utilize one of these materials—usually a galena crystal—mounted in a small cup. As described in connection with Fig. 16, one terminal from the receiver cord is attached to the cup, which makes contact with the crystal. The tuning coil, which as we have seen is an extension of the aerial, has its sliding contact connected to the other side

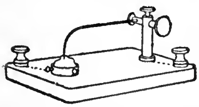


FIG. 17.—A CRYSTAL DETECTOR.

of the detector and makes contact with the crystal through a fine wire, so mounted that it rests lightly on the crystal, as shown in Fig. 17. The connections are indicated in the picture diagram in Fig. 16.

In the reception of signals, the currents flowing in the circuit in the one direction, are prevented from passing. The alternate surges of current, which come from the other direction, are passed through the crystal and into a condenser and then to the head telephones for conversion into audible sounds. In this manner, the galena crystal filters or rectifies the oscillations of the alternating current and passes on to the receivers a *pulsating direct current;* that is, a pulsating current which flows in only one direction. But even though half of each oscillation of current has thus been stopped, those impulses which are allowed to pass are still too numerous and appear in too rapid succession to operate the telephone receiver diaphragm slowly enough so that we can hear its vibration. So we introduce a device called a *condenser* which will store up a great number of these electrical impulses and then discharge them through the receiver circuit in a single pulse, causing an audible sound in the telephone receivers.

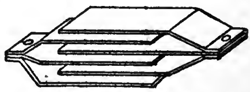


FIG. 18.—ELEMENTS OF A FIXED CONDENSER.

The fixed condenser.—The condenser which we have placed in the circuit in Fig. 16 is a device usually made up of two or more small metal plates or sheets of tin foil, separated by an insulating medium, such as paper or mica, so that no electrical contact between adjacent plates is possible. If there are more plates than two in the condenser, the first, third, fifth, etc., are connected to one another; the second, fourth, sixth, etc., are similarly connected. Fig. 18 shows this *fixed condenser* in its simplest form.

The purpose of the fixed condenser in the circuit is to help to reduce the radio or high frequency pulsations of current to audio frequency pulsations which can register in the telephone receivers and be heard by human ears. It acts as a storehouse for radio vibrations, as suggested above, and then discharges its store or accumulation of vibrations back into the circuit and through the telephone receivers in a single surge or pulse.

The effect of a condenser is called a *capacity* effect, since the condenser may be used to increase, or in some cases to decrease the capacity of a circuit for storing up electrical energy.

In Fig. 16 this piece of apparatus is shown connected "across" the telephone receiver circuit. That is, one set of plates is connected to that part of the circuit between the detector and the phones, and the other set to that part of the circuit between the phones and the ground connection. The condenser may also be said to be "in parallel" with or "in shunt" to the receivers. *Shunt* and *parallel* are two terms having the same meaning and will be used interchangeably hereafter in this book.

The wires in the receivers, as we shall see, are so fine in size that they offer high resistance to the more or less feeble currents coming through the detector. On the other hand, the relatively large surfaces of the plates in the condenser afford an easy path for the pulses of current to enter. So long as they are unable to pass through the insulation in the condenser, these pulses of current store themselves up in the manner previously discussed.

The head telephones.—The radio head telephones, or phones, or receivers as they are usually called, are somewhat similar in appearance and in principle to the ordinary telephone receiver. Their function is to convert the *pulses of electrical current* into *sound vibrations*. In other words their purpose is that of reproducing the voice or music or other signals which are being transmitted from the sending station. The receivers, as we have just seen, are actuated by pulsations of the rectified oscillating current which, in the case of radio telephony, has been moulded by the sound waves of the voice or music at the sending station.

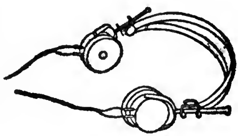


Fig. 19.—The head telephones or receivers.

Each receiver consists of a small hard rubber case enclosing a U-shaped permanent steel magnet, with a coil of fine insulated copper wire wound around each pole, as shown in Fig. 20. A disc of thin sheet iron is supported so that its face does not quite touch the poles of the magnet. A hard rubber cap or earpiece with an opening at its center, is screwed on the case so that it holds the iron disc in place. As the pulsating direct current coming from the condenser flows around the coils on the poles of the permanent magnet, it sets up a magnetic field or influence which either strengthens the fields of the permanent magnet, drawing the steel disc a little closer to the poles, or weakens the fields, allowing the disc, which is always under strain of attraction, to spring away from the poles.

Between pulses, the magnetic field returns to its normal strength and the disc instantly returns to its original position. Thus the disc of the receiver vibrates with the pulses of current, and accurately reproduces the sounds that are being directed into the transmitter at the station which is sending. That is, the current carried to the receiver causes the diaphragm or disc to vibrate exactly

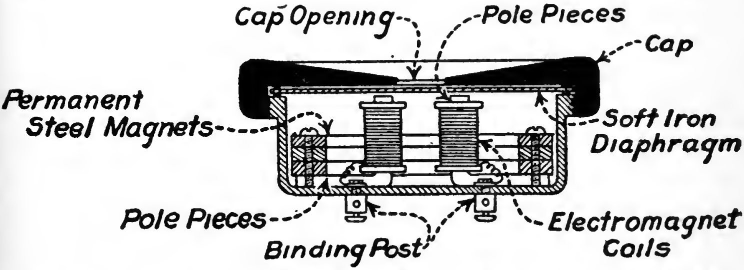


FIG. 20.—CROSS SECTION VIEW SHOWING THE PARTS OF A RECEIVER.

as the recording device of the transmitter is vibrating at the sending station; and these vibrations of the receiver diaphragm create the sound waves which strike the ear.

The ground connection.—The connection to the ground completes the aerial circuit. This connection may be a copper wire connected to a water pipe, radiator, or other continuous metallic system which enters the earth.

Refinements necessary in the simple receiver hook-up.—Although either of the two "hook-ups" or circuits which we have described will accomplish the reception of radio signals, the novice should not proceed to wire up his crystal detector set after the plan of either circuit, unless for the sake of experimenting. Further refinements are necessary in order to get best results from the crystal detector set. These refinements include (1) the removal of the detector and the receivers to what we shall call a *local circuit*, and (2) some slight modification of the tuning device, such as that found in the *tapped coil*, the *double slide* or *triple slide tuner;* or even a greater modification such as that found in the *loose coupler* and the *vario-coupler*. The *variable condenser* as a device for reducing or increasing wave length is a desirable addition; it becomes a necessity, however, only if it is desired to receive signals on a wave length *shorter than that of the receiving aerial.*

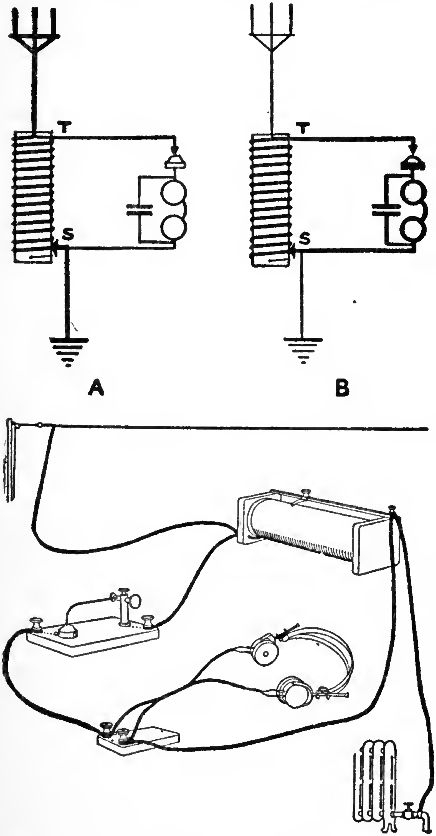


FIG. 21.—CIRCUITS OF THE CRYSTAL DETECTOR HOOK-UP. A. PRIMARY IN HEAVY LINES. B. SECONDARY IN HEAVY LINES.

The local or secondary circuit.—Because of the very high resistance in the detector crystal and in the telephone receivers, best results cannot be obtained if they are left in the aerial circuit or in the direct path of the currents flowing in the aerial, lead-in, and ground wire. The crystal is of such material that it offers very high resistance to the surges of the weak current picked up by the aerial. The receivers also impede or hold back the currents on account of the many turns of fine wire in the coils through which the surges of current have to pass. It is desirable, therefore, to remove these two instruments from the direct path of the currents flowing in the aerial circuit.

These two instruments, therefore, are usually placed in what is known as a local or detector circuit as shown in Fig. 21. The electric current flowing in the aerial circuit now has a less obstructed path from the aerial to the ground, or *vice versa*. The aerial and ground wires and those turns of wire on the coil included between T and S in Fig. 21A, now become what we shall call the *primary circuit*. The *local* or *secondary circuit*, as shown in Fig. 21B, includes the detector and the telephones and the same turns of wire on the coil included between T and S. As in the circuit previously considered, the aerial-and-ground or primary circuit is tuned by moving the slider S up and down the turns of wire. This operation tunes the secondary circuit at the same time.

As the electric current oscillates in the aerial circuit, part of each pulsation is transferred to the secondary circuit by conduction or direct contact. The currents thus diverted or *shunted* through the local circuit are rectified by the detector and then made audible by the receivers, as has been previously explained.

Setting the detector.—Maximum response in the head telephones is obtained when the crystal rectifier or detector is adjusted for the greatest degree of rectification. There is very little to the operation or adjustment of crystal detectors; in the "cat whisker" type, the free end of the fine wire (called the "cat whisker") extending from the upright binding post, is merely raised from and lowered on the crystal at various spots until the spot which gives the greatest degree of rectification, as indicated by strength of signals, is found. In the type of crystal detector which employs two crystals making contact with each other, the two crystals are adjusted by pressing them together lightly until similar results are obtained.

The only difficulty arises from inability, under certain conditions, to tell when the point of the fine wire is resting on the most sensitive spot of the crystal, in the case of the former type; and in the case of the latter type, when the two crystals are touching each other at sensitive spots. In this discussion we shall consider only the "cat whisker" type of crystal detector, as it is the type most commonly used by the amateur.

If signals are being received at the time the adjustment of the "cat whisker" is made, it is very simple to raise and lower the wire until the incoming signals are heard at maximum strength; but signals are not always available as a means for assisting the operator to adjust the detector.

An electric door bell with its clapper removed, or a buzzer of some sort, may be employed to overcome this difficulty. Any buzzer used for this purpose is commonly called a test buzzer.

The test buzzer.—If the ordinary electric bell or house buzzer is set into operation by a battery, pulses of current caused by the making and breaking of the circuit at the vibrator arm, will flow around the buzzer and battery circuit. Each pulsation of current flowing through the wire in this circuit sets up magnetic lines of force which are radiated in the form of electromagnetic waves; and if any part of this circuit is placed near the receiving set, feeble currents will be picked up by the receiving set in

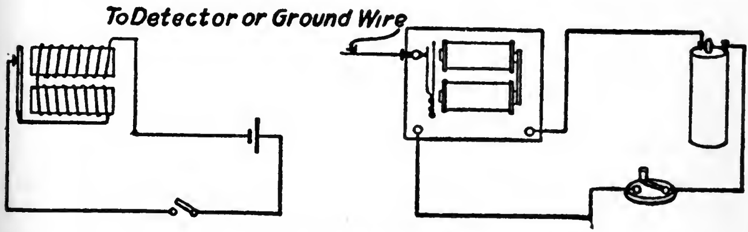


FIG. 22.—HOOK-UP FOR THE TEST BUZZER.

somewhat the same manner as electromagnetic waves from the transmitting aerial are picked up by a receiving aerial. If the crystal detector is then adjusted, as previously explained, it will rectify these feeble currents and produce sounds in the telephone receivers, similar to the tone of the buzzer. In a device of this kind we have a miniature transmitting station, which can be switched on and off whenever we desire, to provide signals with which to set the crystal detector.

In practice, however, the electromagnetic waves produced by the buzzer are usually very weak. Better results may be obtained, therefore, by connecting a wire direct from the contact screw or point of the buzzer to one side of the detector, or else to the ground wire of the receiving set, as indicated in Fig. 22. This enables some of the magnetic waves of the buzzer circuit to travel into either the secondary circuit or the primary circuit of the receiving set by actual contact or conduction.

The loading coil.—If the coil of the tuning device is not large enough to build up the wave length of the aerial to that of the station from which it is desired to receive, additional wire may be inserted in the aerial circuit by the use of what is known as a *loading coil.* Its hook-up is shown in Fig. 23. In tuning the set, all of the wire in the tuning coil is first utilized and then the wire in the loading coil is added until the wave length of the receiving set has been built up to the extent desired.

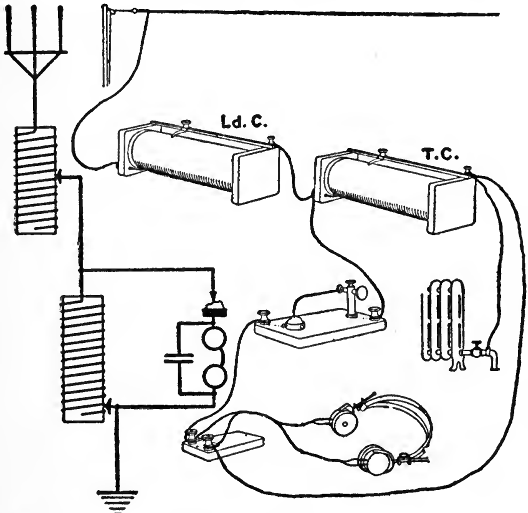


FIG. 23.—A LOADING COIL IN THE AERIAL CIRCUIT.

The name "loading coil" is given to any auxiliary coil of wire used to build up the wave length of a circuit. The loading coil may be another tuning coil or simply a coil of insulated wire which need not even be wound on an insulating tube. It is customary, however, to use a coil of wire wound on a tube or on some other form, with taps taken from it at intervals of any desired number of turns. Fine variations are unnecessary in the loading coil, since the finer adjustments may always be made in the tuning device, although a loading coil is very often tapped at five, ten or fifteen turns. A tapped tuning coil such as that shown in Fig. 29 makes an excellent loading coil. The loading coil may be used along with any tuning device to increase the wave length of any circuit. Do not lose sight of the fact that the loading coil is used to *increase* the wave length.

As previously suggested, there are advantages to be derived from the use of a variable condenser in the hook-up just described.

The variable condenser.—This instrument, as shown in Fig. 24, is made up of two sets of thin metal plates, usually of aluminum. The plates of each set are fastened at their edges or sides to a rigid support and are spaced about one-eighth of an inch apart. One set of plates is mounted in a fixed position. The other set is so mounted that it may be revolved in and out between the leaves or plates of the first set without making actual contact. Condensers of 23 or 43 plates are commonly used in receiving sets. In hooking up the variable condenser, one connection of a circuit is made to the fixed set of plates; another connection of the same circuit is made to

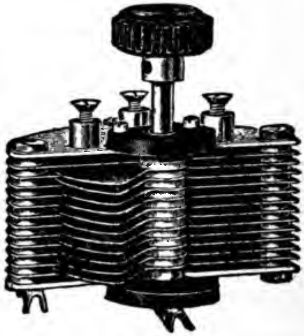


Fig. 24.—A 23-plate variable condenser.

the movable set; and an effect similar to that described in the case of the fixed condenser, page 51, is obtained. By revolving the movable plates in and out of the other set, we may increase or decrease the condenser effect at will.

The variable condenser may be placed in a circuit in either of two ways. If connected in one manner (*in parallel* with either the aerial or the local circuit) it will increase the wave length of the circuit in which it is so placed. If connected in another manner (*in series* in the aerial circuit) it will decrease the wave length of that circuit. All of these hook-ups we shall presently describe.

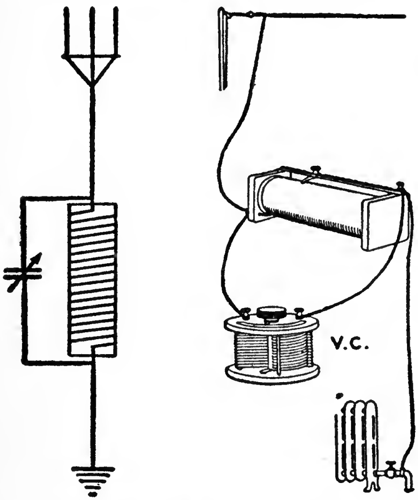


Fig. 25.—Variable condenser in parallel with the aerial circuit to increase the wave length of the circuit.

Capacity effects.—It is interesting to note at this point that a condenser effect is often obtained in other ways than by the use of plates such as those described for fixed condensers and variable condensers. In any case where one conductor carrying an electric current or charge is placed near another conductor, the *capacity* of both conductors—that is, their ability to store up electrical energy—is always increased.

That is to say, two conductors in proximity to one another will always give a condenser effect. For example, the parallel wires in the receiver cord, like the fixed condenser, have a capacity effect and help to reduce radio frequent vibration to audio frequent vibration. In similar manner, the aerial and the earth underneath it form the plates of a condenser, with each "plate" of this condenser connected by a wire to the set—the aerial by the lead-in, and the earth by the ground wire.

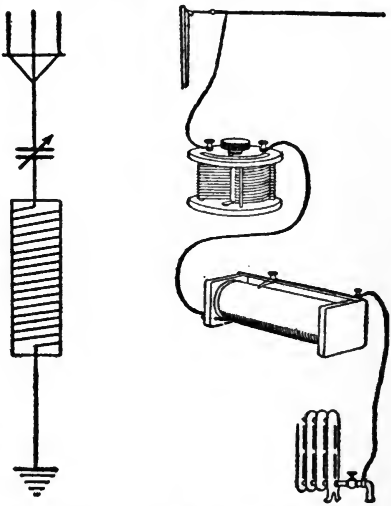


FIG. 26.—VARIABLE CONDENSER IN SERIES IN THE AERIAL CIRCUIT TO DECREASE THE WAVE LENGTH OF THE CIRCUIT.

Varying the wave length by means of condensers.—It is an interesting fact concerning condensers that if two or more of them are connected in parallel, or in shunt, the total capacity of these condensers for storing up energy will be equal to the sum of the capacities of all of them. Therefore, if we place a condenser in parallel with the aerial-ground circuit, which we have just said to be a condenser, we increase the capacity of this circuit. This connection is shown in Fig. 25. And, since increasing the *capacity* of a circuit increases its *wave length*, we have increased the wave length of the circuit. A condenser connected in this manner may be used for the same purpose as the loading coil described on page 58.

On the other hand, if two or more condensers are connected in series, the total capacity for storing up energy will be reduced to less than the capacity of the smallest one. Hooking up a condenser, therefore, in the manner shown in Fig. 26, which is placing it in series in the aerial circuit, will decrease the capacity of the circuit, and likewise the wave length.

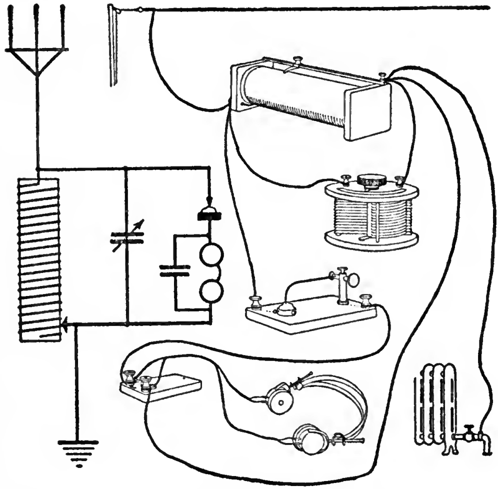


FIG. 27.—TUNING COIL CRYSTAL DETECTOR SET WITH VARIABLE CONDENSER IN PARALLEL WITH BOTH THE AERIAL CIRCUIT AND THE LOCAL CIRCUIT.

The variable condenser may be connected in parallel with the local circuit to enable placing this circuit in tune or in resonance with the aerial circuit.

From the foregoing, we can see that if the variable condenser were connected as shown in Fig. 27, the wave length of the aerial and that of the secondary circuit would both be increased, since the condenser is in parallel with both circuits. In other words, the use of the variable condenser in this position would allow tuning the single slide tuning coil set to much higher wave lengths. The exact range would of course depend upon the size of the tuning coil and the size of the condenser.

The condenser used in this position also helps to increase sharpness of tuning. For instance, if a station is receiving signals from two broadcasting stations which are sending on a wave length of 360 meters, it is practically impossible to separate the signals of one from those of the other. This device, however, will aid in doing so to a considerable extent if we use a relatively large amount of the condenser for obtaining the wave length and reduce the number of turns of wire used from the coil. For example, in tuning a 200-meter wave length aerial to a 360-meter wave length, with a 500-meter coil we might use from 50 to 75 meters wave length on the coil and then add the other 85 or 110 meters by the use of the variable condenser, obtaining in many cases a tuning effect which will eliminate certain stations or signals.

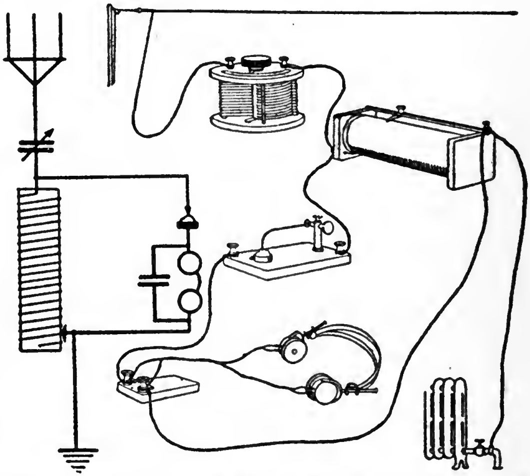


Fig. 28.—Crystal detector set with a variable condenser in series in the aerial circuit.

It might be said that in this hook-up (Fig. 27), the variable condenser is connected across the circuits; or in shunt to the detector and phones or to the coil; or in parallel to the detector and phones or to the coil.

Shunt and series condensers.—A condenser placed in parallel or in shunt is known as a *shunt condenser*. A condenser connected in series in the primary circuit is known as the *series* or *short wave condenser*.

In Fig. 28, the hook-up for the variable condenser in series in the aerial circuit is shown. As suggested above, this connection would reduce the wave length range of the receiving aerial.

Two variable condensers may be used at the same time, the one in series with the aerial circuit to decrease the wave length of that circuit, and the other across the secondary circuit to enable sharper tuning.

Tuning by capacity and by inductance.—*Varying the wave length by means of condensers* is known as *tuning with capacity. Varying the wave length by means of wire* is known as *tuning with inductance.* Using a combination of both condensers and tuning coils is called *tuning by capacity and inductance.*

Selecting a variable condenser.—The question as to what size variable condenser to use is often a troublesome one to beginners. This question, however, need not occasion much concern. It is largely a matter of selecting a size which will accomplish what you wish to accomplish, and might be considered analogous to selecting a box in which to store articles. You would obtain a box which would hold what you desire to store in it; in any case, you would want one large enough, and there might be no objection to using one which would hold more than the articles you wish to store. The larger box would always do the work of the smaller one, with some room to spare. So in the case of the variable condenser, it is a matter of selecting one which will have enough capacity to tune the circuit to what you want to hear. Additional capacity is not a serious objection, except in the matter of critical adjustment, which we shall consider a little later.

Capacitance, or condenser effect, is measured in units called *microfarads* (mfd.). Sizes of condensers are properly designated by capacity in microfarads rather than by number of plates.

The .001 mfd. size is commonly used to decrease wave length. If a still greater decrease is desired, a *smaller* condenser may be used; for example, the .0005 mfd. size. Bear in mind that to decrease wave length, the condenser must be connected *in series.*

For building up the wave length, a .0015 mfd. condenser, having a greater capacity than either of the others mentioned, will furnish a wider range of increase. As previously stated, to *increase* the wave length, the condenser must be connected *in parallel.*

The chief disadvantage which grows out of using a condenser larger than necessary is that it is more critical in adjustment. In other words, the smaller the capacity of the condenser, the greater will be the distance through which it is revolved in tuning to a given wave length. For example, a .0005 mfd. size would be revolved through a half circle in adding its total capacity to the circuit; a .001 mfd. condenser, on the other hand, would revolve through only a quarter of a circle in adding a capacity of .0005 mfd.

In attempting to pick up with a large capacity condenser, a sending station which is sharply tuned, it is an easy matter in revolving the movable set of plates, to pass unknowingly over the point at which the station may be heard, and fail to pick up the signals.

A smaller condenser, not so critical in adjustment, would add capacity more slowly and would bring in any

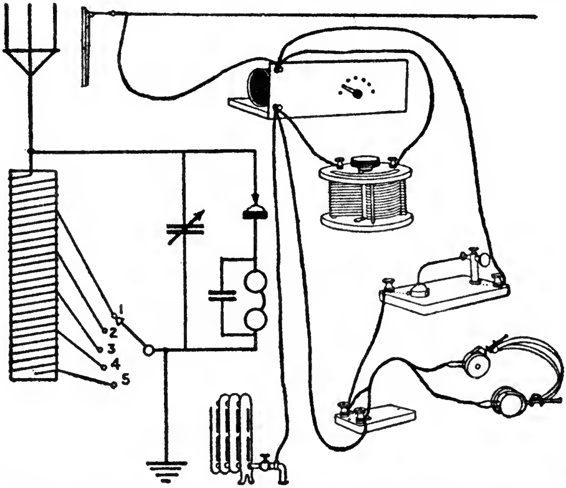


FIG. 29.—HOOK-UP FOR THE TAPPED COIL WITH A SINGLE SWITCH.

given signals over a wider adjustment of its revolving plates.

The tapped tuning coil with a single switch.—A variation of the single slide tuning coil described on page 46 is to be found in the *tapped coil.* In this tuning device, taps taken from the turns of wire at predetermined points and connected to switch points with which a switch arm makes contact, take the place of the sliding contact for varying the number of turns of wire added to the circuits. This arrangement is illustrated in Fig. .29. Connections or taps are made at every fifth or at every tenth turn of wire on the tuning coil as it is being constructed. (For method of tapping a coil, see page 151.) In mounting a tuning coil of this type, connections are made from these taps in order, to the first, second, third . . . points of a switch. As stated above, the switch simply takes the place of the slider on the single slide tuning coil. Therefore, this coil having one switch is essentially the same as the single slide tuning coil.

In tuning with the tapped coil shown in Fig. 29, it can be seen that if the switch arm is placed on switch point No. 1, the circuit will be completed through the fifth turn on the coil and only five turns of wire will be included in the aerial and ground circuit and also in the secondary circuit. If the switch arm is revolved to the second switch point, ten turns will be included, and so on.

The use of a variable condenser across the secondary circuit will enable sharper tuning, that is, finer adjustment to wave lengths which fall between the taps. Another variable condenser, in series with the aerial circuit, will permit tuning to stations sending on a shorter wave length than that of the receiving aerial. The positions of these condensers in the circuits are shown by dotted lines.

The single switch control has an advantage over the single slide control in the ease with which it may be operated. It has a disadvantage, however, in that variations can be made only in steps of several turns; and as broadcasting stations tune very sharply, and can sometimes be heard within a variation of only one or two turns of wire on the coil, it is advisable to have an instrument permitting finer adjustment than the single switch control affords.

Coil with a units and a multiple turns switch.—A coil permitting finer adjustment than will the single switch coil is shown in Fig. 30. This coil has two switches instead of

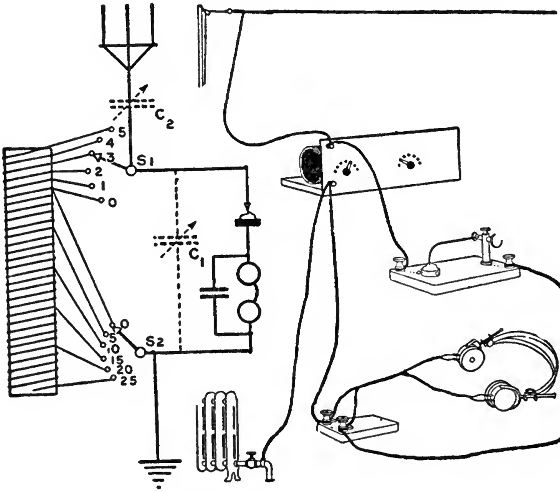


FIG 30.—HOOK-UP FOR A TAPPED COIL WITH ONE UNITS AND ONE MULTIPLE TURNS SWITCH.

one. As the wire is being wound, a tap is taken from the first, second, third, fourth and fifth completed turns. These taps are connected to five points of switch S_1, as shown. If the points of switch S_2 are to be connected to taps at every tenth turn, ten single turn taps are usually taken from the coil, and eleven contact points on switch S_1 would then be necessary. Do not become confused from these connections: the beginning of the winding is at the top of the coil, as shown in the diagram.

This end of the wire or the beginning of the winding is connected to switch point 5 of switch S_1. The tap from the first completed turn is connected to switch point 4; the tap from the second completed turn to switch point 3; and so on. The fifth completed turn of wire is connected to the zero switch points of both switches. The tenth turn of wire is connected to point 5 of switch S_2; the 15th turn of wire, to point 10 of the same switch. The switch having its points connected to the single turns of wire, is called the units switch. The other, in this instance, is called the fives switch. In case the points of the multiple turns switch are connected to every tenth turn, it would be called the tens switch.

In tuning with this coil, if it is desired to place one turn of wire in the circuit, the upper or units switch is placed on point 1 and the fives switch on the zero point, as shown in the diagram. If two turns are desired, the units switch is moved up to point 2 and the fives switch remains at zero, and so on up to five turns. If six turns are desired, the units switch is brought back to switch point 1 and the fives switch is moved to contact 5. If seven, eight or nine turns of wire are desired, the fives switch would remain on contact 5 and the units switch would be moved to points 2, 3 or 4 respectively. In order to add from 10 to 14 turns, the fives switch is placed on switch point 10 and the units switch is put through the same manipulation, etc.

For sharp tuning, it would hardly be necessary to place a variable condenser across the secondary circuit of this double switch control coil, since the switches permit variations of one turn of wire at a time. It might be used to advantage, however, in the position shown by the dotted lines to tune out one of two stations sending on the same wave length, by employing a relatively large capacity of the condenser and less wire or inductance, as suggested in connection with Fig. 27, page 62.

Remember that a variable condenser might also be used across this circuit to build up the wave length of both the aerial and the local circuit to a greater extent than the coil alone will accomplish.

As with the other tuning coils, a condenser may be used in series in the aerial circuit, as is also shown by dotted lines, to enable tuning to lower wave lengths.

Advantages of double slide and double tapped coils.—The disadvantage of the single slide tuner is that the primary circuit and the local or secondary circuit are tuned with the same slider. Neither can be tuned separately. This disadvantage also holds in the case of the tapped coils in Figs. 29 and 30. That is to say, the use of any of the foregoing types of coils always results in a compromise in tuning, and for the following reasons: The aerial circuit derives its natural wave length from the wire in the aerial, lead-in and ground wire as well as the amount of wire used from the coil. Since the secondary circuit is much more limited in length (see Fig. 21) and therefore in wave length, the local circuit with this type of tuning device, is never in perfect natural resonance with the aerial circuit. In tuning, therefore, the slider or the switch control must be moved back and forth, increasing and decreasing the amounts of wire equally in both circuits at the same time, until a compromise is reached between perfect resonance of the aerial circuit to the circuit which is transmitting and perfect resonance of the local circuit to the receiving aerial circuit.

For best results, the tuning coil should be so constructed that the aerial circuit (which includes the aerial, lead-in, ground wire, and a certain number of turns of wire in the tuning coil itself) can be tuned independently to the incoming signals. Separate means should be provided for tuning the secondary circuit (which includes the detector, receivers, condenser, and the necessary number of turns of wire in the coil) *independently* to resonance with the aerial circuit. When the circuits are tuned to resonance with each other, the maximum amount of energy passes through the detector and the phones in the secondary circuit. Independent tuning of these two circuits can be accomplished by the addition of a second slider to the tuning coil.

The double slide tuning coil.—Fig. 31 shows a tuning coil exactly like the single slide tuning coil, with the exception that it has two sliders instead of one. The operation of this coil differs slightly from that of the single slide tuning coil. The primary, or aerial and ground circuit, is tuned to the transmitting station by adjustment of the slider S_2. The local or detector or secondary circuit is then tuned by adjustment of the slider S_1. This arrangement permits tuning the primary circuit first and adjusting the secondary circuit independently to resonance with the primary circuit.

With the double slide tuning coil, a variable condenser (C_1) may be used across the secondary circuit to increase its wave length; and another condenser may be used in series with the aerial circuit (C_2) to reduce the wave length of this circuit, as has been suggested for the single slide tuner hook-up, or in shunt to the turns of wire in the primary circuit, to build up the wave length. The shunt or parallel connection is made from the lead-in connection to the ground slider as shown by the position of condenser

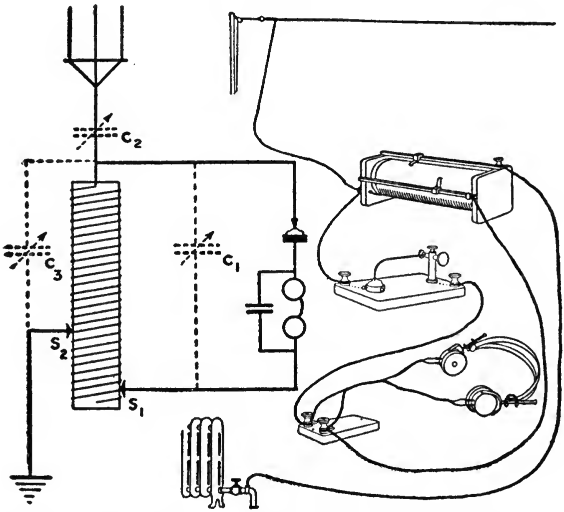


FIG. 31.—HOOK-UP FOR A DOUBLE SLIDE TUNING COIL.

C_3. All of these connections for condensers are shown by dotted lines. Each condenser is an aid to sharp tuning. A loading coil placed in series in the aerial circuit may be used instead of condenser C_3 to increase wave length. Or both the loading coil and the shunt condenser may be used; in that case, the condenser should be connected around both the loading coil and the tuning inductance in the circuit.

The double tapped coil.—Fig. 32 shows the wiring diagram for a tuning coil using two switches instead of the two sliders. This diagram shows taps taken from the coil at every five or ten turns for each switch, as described for the single switch control coil. Note that the taps for both sets of switch points are taken from the same turns

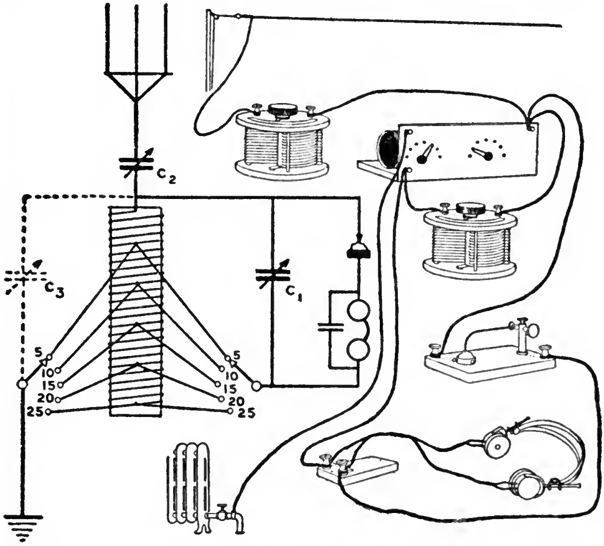


FIG. 32.—HOOK-UP FOR A TAPPED COIL WITH TWO MULTIPLE TURNS SWITCHES.

of wire. It should be clear, however, that the secondary circuit and the primary circuit would still be varied separately. In other words, one switch may be placed on any of its switch points, regardless of the switch point on which the other switch arm is placed. Note also that one set of switch points and the switch, for instance, on the left hand side, could be swung over or revolved into the corresponding set of switch points on the other side.

In other words, since the taps for both sets are taken from the same turns of wire, one set of switch points would suffice for both switches, providing the switch arms are placed one on top of the other, properly insulated from each other, and so arranged that they may be turned independently. This is a feature worth noting since it appears in some of the more complicated types of receiving sets.

Since the taps of this coil do not permit of close enough adjustment for tuning either the secondary or the primary circuit, a variable condenser should be used in each circuit. The condenser in the secondary circuit should be connected as shown. In the case of the primary circuit, if the receiving aerial is too large, the second variable condenser should be used in series, to permit fine adjustment of that circuit. If, on the other hand, it is desired to tune to longer wave lengths instead of shorter, the second variable condenser should be placed in shunt to the turns of wire included in the primary winding. The proper connection for each condenser in the primary circuit is shown in this figure by dotted lines.

A loading coil in series in the aerial circuit might replace the shunt condenser; or both the shunt condenser and the loading coil might be used, in which case the condenser should be connected in parallel to both the loading coil and the tuning inductance, as suggested on page 72.

A tapped coil with four switches.—In Fig. 33 is shown the wiring diagram for a tuning coil using both a tens and a units switch in place of each slider of the two slide coil. A variable condenser should not be necessary across the secondary circuit in this hook-up, as the tens and the units switches vary the wire by any desired number of turns. Just as in the hook-ups previously described, a condenser might be used in series with the aerial circuit to cut down the wave length, or in shunt to the turns of wire of the coil in the primary circuit (by connection across the two switches as shown by the dotted lines) if

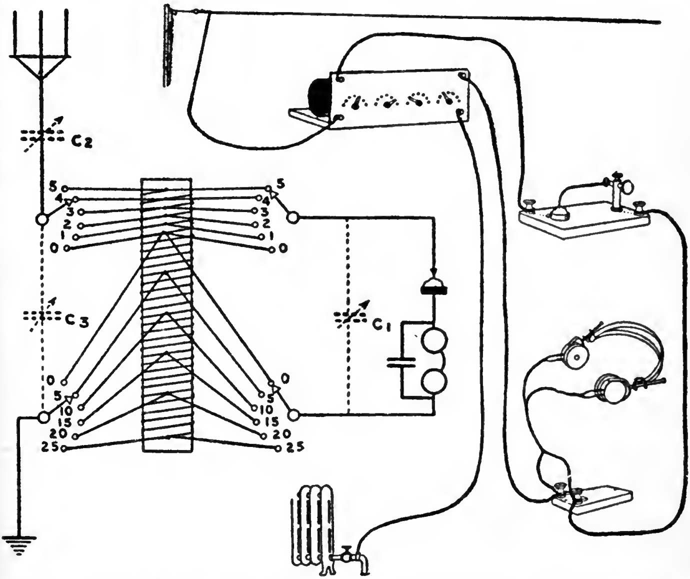


FIG. 33.—HOOK-UP FOR A TAPPED COIL WITH TWO UNITS SWITCHES AND TWO MULTIPLE TURNS SWITCHES.

it is desired to increase the wave length to more than the coil alone will permit. A variable condenser might also be connected across the secondary circuit, if it is desired to tune up to high wave lengths.

The loose coupler and the variocoupler.—The *loose coupler* and the *variocoupler* are forms of tuning devices which transfer the received energy from the aerial circuit to a secondary or local circuit without actual electrical contact. In that respect, chiefly, they differ from tuning coils and other forms of tuning inductance which use only one coil of wire for both the primary and the secondary circuits.

The loose coupler is made up of two cylindrical shaped coils of wire, wound on insulating tubes such as pasteboard or fibre. One coil is so mounted that it can be made to slide into and out of the other coil with about one-half inch separation or clearance between the two coils. The turns of wire on both coils of the loose coupler are made variable by means of sliders rubbing across the wire, or by taps taken from predetermined points on the coils to switch points with which a switch arm may make contact. Loose couplers are often manufactured for wide ranges of wave lengths, for instance, 150 to 3000 meters or more. In practice, however, the loose coupler becomes inefficient on short wave lengths if it is constructed to cover a range of more than from zero to 2000 meters. Properly designed loose coupler receiving sets have an arrangement for connecting auxiliary or loading coils in both the primary and the secondary circuits, which permits tuning to long wave lengths and yet retains maximum efficiency for shorter wave lengths.

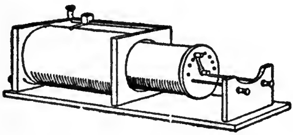


FIG. 34.—A LOOSE COUPLER.

The variocoupler is much like the loose coupler in construction and in operation. The primary coil is usually wound on a cylindrical form or insulating tube like that of the loose coupler; the secondary coil of a variocoupler, on the other hand, is wound on a spherical shaped form which is mounted on a shaft and rotates inside the primary coil instead of sliding in and out as in the case of the loose coupler. The turns of wire on the outside coil of the variocoupler are almost always made variable by means of a switch, with switch points connected to different turns of wire in the coil. The inside or rotating coil is made up of fewer turns of wire and, as a rule, no allowance is made for varying the number of turns used in tuning. The variocoupler is usually designed for a range of about 150 to 600 or 800 meters and for that reason is more efficient in that range of wave length than a loose coupler designed to include a greater range.

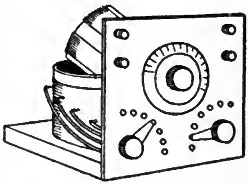


Fig. 35.—A variocoupler.

In the hook-up, the outside coil of either instrument is connected in series with the aerial and the ground lead. In other words, the lead-in wire connects to one end of the outside coil and the ground wire connects to the variable connection of the same coil or vice versa. Energy picked up by the aerial, lead-in and ground wire must then pass through a certain number of turns of wire on the outside coil.

When the energy which is picked up by the aerial circuit passes through the turns of wire on this outside coil, much of it is transferred to the inside coil of wire by what is termed *induction*. This transfer of current takes place although there is no direct contact between the coils. The energy which is thus *induced* in the inner coil of wire, flows out of the coil and is led to the detector and to the head telephones where it is converted into audible sounds as in the case of the tuning coil circuit previously described.

Coupling effects in tuning.—The chief advantage of the loose coupler and the variocoupler over other types of

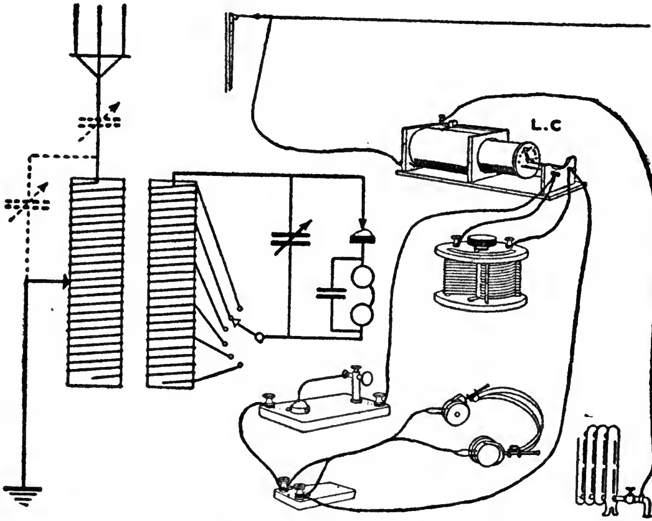


FIG. 36.—HOOK-UP FOR A LOOSE COUPLER IN A CRYSTAL DETECTOR SET.

tuning devices is that the position of the inside coil may be changed with respect to the outside coil. This property or effect is called *coupling*. In the case of the loose coupler, when the inside coil is pulled out of the other coil, it is said to be loosely coupled. When the two coils of the loose coupler are completely telescoped, the instrument is said to be tightly coupled. In the variocoupler, when the inside coil is placed so that its turns of wire are in the same relative position as the turns of wire on the outside coil, the instrument is said to be *tightly coupled*; but when the inside coil of the variocoupler is revolved 90 degrees so that its turns of wire are at right angles to those of the outside coil, it is said to be *loosely coupled.*

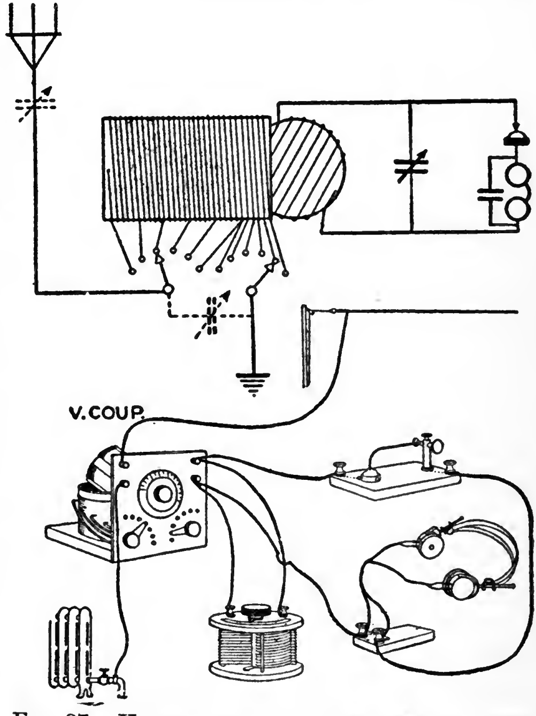


FIG. 37.—HOOK-UP FOR A VARIOCOUPLER IN A CRYSTAL DETECTOR SET.

By altering the relative position of the primary and secondary coils of either the loose coupler or the variocoupler, much closer tuning is possible. Signals from two stations which are sending on the same wave-length can be separated more satisfactorily with the loose coupled type of instrument than with the tuning coil or "single tuned circuit" type of receiver.

In operating the loose coupler or the variocoupler, the secondary coil should be placed inside of or in close inductive relation to the primary coil. If the secondary coil is variable, its switch or slider should then be set to provide for a wave length somewhat near that of the signals which it is desired to receive. After a little practice with the set, this approximation is not so difficult as it sounds. Next the primary coil is adjusted by the slider to the point where the signals come in at maximum strength, indicating that the primary circuit is in tune with the aerial radiating the incoming signals. After the primary circuit has been adjusted to the wave length of the incoming signals and the secondary circuit placed in resonance with the primary, reduce the coupling of the two coils by pulling the secondary coil out or away from the primary coil in the case of the loose coupler, or by revolving the secondary in the case of the vario-coupler. In this manner, vary the coupling until the loudest response is heard.

Separating the secondary coil from the primary coil is known as loose coupling or *sharp tuning* and placing the coils closer together is known as tight coupling or *broad tuning*. By altering the relative positions of these two coils, especially in the case of the loose coupler, it is possible to separate the signals of one station from those of another, or if two stations are transmitting on the same wave length, completely to eliminate the signals from one station while preserving those of another.

Specifications for making a loose coupler.—A loose coupler with a range of from zero to about 2000 meters with the average aerial may be made up in the following manner: The primary is wound on an insulating tube 4½ inches in diameter and 6 inches long with No. 22 wire for a distance of 4½ inches, making about 175 turns of wire. The secondary in wound on a similar tube, 3½ inches in diameter and 5½ inches long, with No. 26 wire for a distance of 4½ inches, making approximately 325 turns of wire. Taps are taken at every ½ inch on the secondary winding, making eight taps for this winding.

The tapped loose coupler.—Fig. 38 shows the hook-up for a loose coupler having taps and switches instead of sliders. In this diagram, each coil is shown with a multiple turns switch. The primary might be wound similarly to the coil for the single slide tuner shown in Fig. 29, but if taps are taken only at every five or ten turns, as in this case, the variations will not be fine enough for close tuning. Under these conditions, a variable condenser is required across the secondary circuit as shown, and another either in shunt to the primary coil or in series with it, as shown by the dotted lines. In the case of a loose coupler with a range from 0 to 2000 meters, having perhaps 200 turns of wire on the secondary coil as few as

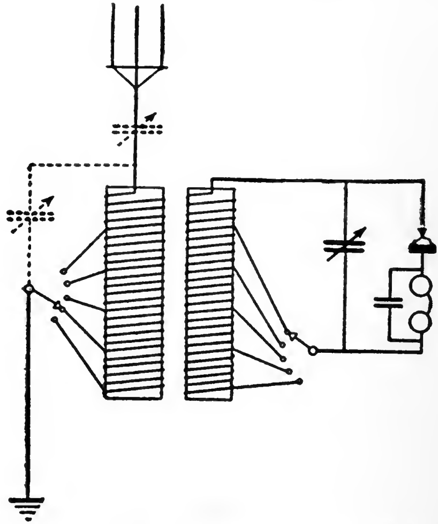


FIG. 38.—HOOK-UP FOR A CRYSTAL DETECTOR SET WITH A TAPPED LOOSE COUPLER.

eight or ten taps might be taken from the entire coil. This, of course, would permit varying the secondary coil only in large steps.

In justification of this arrangement, we might consider the fact concerning receiving sets, that a circuit to be tuned readily to a given frequency, should possess both inductance and capacity. Both factors are theoretically necessary for an oscillatory circuit, which, in turn, is necessary for good tuning qualities. The primary circuit obtains capacity from the aerial and the earth beneath it (which we have considered as a condenser), and inductance from the wires in the aerial circuit, especially from those in the tuning device inserted in that circuit. The secondary coil furnishes inductance to its circuit, but adds comparatively little capacity, although a capacity effect is obtained from the turns of wire lying side by side on the coil. Therefore, it is advantageous to include in parallel in the secondary circuit, a variable condenser, which will add capacity to that circuit. With both capacity and inductance at our disposal, we can vary the turns of wire in the secondary coil in large steps and then add capacity until we reach a wave length which may lie between two taps.

Remembering that capacity and wave length of a circuit are directly proportional, we might better understand the action of the secondary circuit from the following procedure in tuning: In tuning to 360 meters with a coil the third tap of which would give us 300 meters and the fourth tap 400 meters, it is plain that we should be out of tune on either switch point. By turning the switch blade back to the third tap, which gives us 300 meters, and then adding capacity from the variable condenser, we can tune to 360 meters or any other wave length which might come between the taps. The addition of the secondary variable condenser, however, is not absolutely necessary in all cases. Very often the secondary coil of this type is broad in tune and will respond to a great range of wave lengths which should perhaps more properly be tuned at points between the taps. Before purchasing a condenser for use with this loose coupler, it is suggested that the reader borrow a variable condenser from a fellow amateur, if possible, in order to ascertain whether the instrument will improve the tuning qualities of the set.

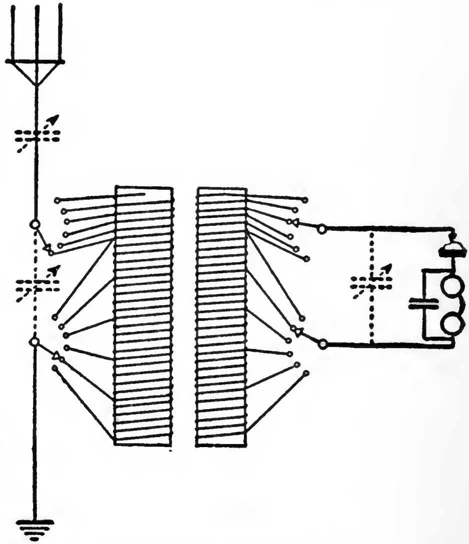


FIG. 39.—HOOK-UP FOR A LOOSE COUPLER WITH FOUR SWITCHES, IN A CRYSTAL DETECTOR SET.

It is customary to have a units and a multiple switch for the primary of a loose coupler, as shown in Fig. 39, to permit variations of one turn of wire at a time, instead of having a variable condenser in the circuit for fine tuning. However, as in the circuits and hook-ups previously described, a variable condenser may be inserted in series in the aerial circuit to reduce the wave length of that circuit if the receiving aerial is too large; or one may be placed across the primary winding if it is desired to increase the wave length of the aerial circuit to a greater degree than the coil alone will permit. Both connections for this variable condenser are shown by dotted lines.

The connection of a variable condenser across the secondary circuit for the purpose of increasing its wave length, is also shown by dotted lines in Fig. 39.

The secondary winding may be varied with a units and a multiple switch, as shown, but owing to the constructional difficulties in supporting the leads in such a way as to permit movement of the coil, this type is quite uncommon.

The short wave loose coupler.—This loose coupler is similar to the 2000-meter coupler described on page 80, but is shorter in length. It might be constructed with a slider arrangement for the primary or with a units and multiple switch. The primary coil of a 600-meter loose coupler might be wound on the same diameter tube as that used for the larger instrument (4½ inches), but only 2 inches or 2½ inches in length, thus permitting about 42 turns of No. 22 wire in its windings. Seven points would then be sufficient for the units switch, each controlling one turn, and seven for the multiple switch, each controlling six turns. The last unit turn is connected to both switches as shown in Fig. 30. The secondary of a 600-meter loose coupler would be varied by switch points as in the case of the large loose coupler.

The secondary winding of the smaller coupler might be placed on a 3½-inch tube, covering the same linear distance on this tube as that covered in the winding on the primary. The wire for the secondary winding should be about No. 26, again permitting a greater number of turns of wire in the secondary than in the primary coil, or approximately 75 to 80 turns. The short wave length loose coupler should have about eight taps taken from the secondary coil, uniformly spaced, and a variable condenser across the winding should be used as in the case of the large loose coupler.

The three-slide tuning coil.—A three-slide tuning coil is constructed in the same manner as a double-slide tuning coil, with a third brass rod and sliding contact added. Its connection in the circuit is shown in Fig. 40. The aerial and ground circuit is varied by means of the slider S_2 as in the case of the two-slide tuning coil. The three-slide tuning coil differs from the two-slide tuning coil in operation in that the detector circuit may be varied by means of the slider S_3 as well as S_1.

In tuning with this coil, the aerial and ground circuit is first tuned to the incoming signals by means of the slider S_2; next the secondary circuit is tuned to the primary circuit by allowing slider S_3 to remain near the end of the coil to which the lead-in is attached and moving slider S_1 toward or away from slider S_3 until the signals are heard at maximum strength. Then, when the secondary circuit has thus been tuned to the primary circuit, a slight coupling effect can be obtained by drawing both the sliders S_1 and S_3 towards the lower end of the coil, taking care to keep them the same distance apart.

In this case the turns of wire used in the aerial circuit would be at one end of the coil and the turns of wire included in the secondary circuit would be at the other end of the coil. This separates to some extent the turns of wire in the primary circuit from those in the secondary

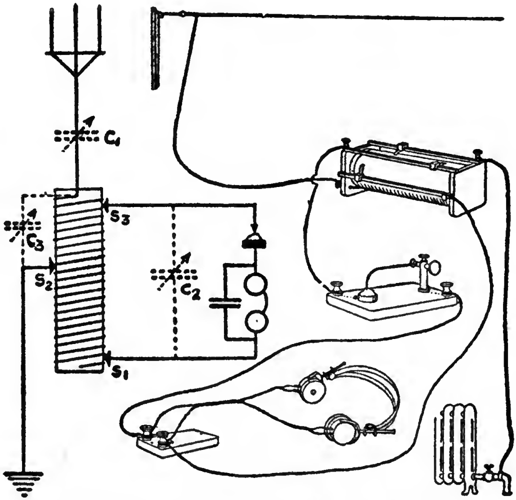


FIG. 40.—HOOK-UP FOR A THREE SLIDE TUNING COIL IN A CRYSTAL DETECTOR SET.

circuit as in the case of the loose coupler when the secondary coil is drawn out of the primary coil, or of the variocoupler when the secondary coil is revolved at right angles to the primary coil. The only advantage in a three-slide tuning coil is the slight coupling effect to be obtained in the foregoing manner; however, this advantage over the two-slide tuning coil is so slight that it seldom compensates for the difficulty of tuning with the three-slide coil. The variable condensers C_2 and C_3

shown by the dotted lines in shunt to the secondary circuit and to the primary circuit respectively, would be used in the positions indicated, to increase the wave length of the three-slide tuning coil set, or to enable sharper tuning. A condenser, C_1, is also shown in series with the aerial to decrease the wave length of the aerial circuit. The condenser C_2 might also be used in shunt to the secondary circuit when the condenser C_1 is used in series with the primary circuit; in that position, the former would be used for sharper tuning in the secondary circuit. The condensers C_2 and C_1 obviously would not be used at the same time since the purpose of the latter is to decrease the wave length of the aerial circuit and of the former to increase it.

A loading coil might, of course, be used with the three-slide tuning coil, just as in the case of the two-slide or the single-slide coil or any of the loose couplers. It should be inserted between the lead-in and the tuning coil, as in the case of the other tuning devices.

Honeycomb and spiderweb coils.—Honeycomb coils and spiderweb coils are forms of inductance which perform the same function as tuning coils and loose couplers. Honeycomb coils with slight variations, appear on the market under such trade names as ultra-honeycomb coils, duo-lateral coils, G. A. coils, and others.

The honeycomb coil in any of its forms is made up of layers of wire wound one on top of the other on a small insulating tube about two inches in diameter and one inch in length. This coil is shown in Fig. 41. The turns of wire in each layer are separated for a distance equal to two or three times the thickness of the wire. Furthermore the turns of wire in each layer of the entire winding, cross the turns of wire in the layers next to it, at an angle, forming a crisscross effect somewhat similar to the winding in a ball of twine. Around the outside of the winding is placed a band of heavy paper or other fibrous material which is fastened at both ends to a plug arrangement in order to hold the winding in place against the plug. The two ends of the coil of wire are soldered to two contacts in the plug.

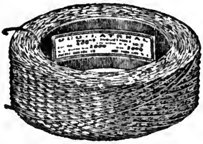


Fig. 41.—A honeycomb coil.

The spiderweb coil is shown in Fig. 42. Its construction is similar to that of honeycomb coils in that the turns of wire in the winding crisscross one another. Spiderweb coils, however, differ considerably from honeycomb coils in that the spiderweb coil consists of only one layer of wire, and each turn of wire crisscrosses the adjacent turns several times during a complete turn. The appearance of a spiderweb coil might be compared to that of a wagon wheel with a wire or rope wound in and out between the spokes, starting from the hub and working out towards the rim.

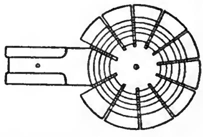


Fig. 42.—A spiderweb coil.

The winding of a spiderweb coil is usually formed on radial sections or "spokes" cut from a circular piece of thin sheet fibre about four inches in diameter, having radial slits cut in it to form the sections or spokes. This circular form is usually fastened to a support, as in the case of the honeycomb coils, and connections are made through the supports to the ends of the winding.

The advantages of spiderweb and honeycomb coils over ordinary tuning coils grow out of the manner in which the wires are crisscrossed in the windings, instead of being wound in spiral cylindrical form.

When a direct current is sent into a tuning coil, in which the turns of wire are wound alongside of one another in one layer, on a tube or other cylindrical shaped form, a magnetic effect is set up by each turn of wire which builds up in a cumulative manner on the magnetic effect set up by its adjacent turns of wire, thus forming the complete magnetic field. But, while this magnetic field is building up, it induces in the same turns of wire a momentary current in the opposite direction, which tends to oppose the original flow of current sent into the coil. This opposing current is called a counter electromotive force (counter E.M.F.). Again, when the original current is switched off, the magnetic lines of force built up by it of course collapse, and in so doing they induce a second momentary pulse of current in the turns of wire which, strange as it may seem, tends to oppose the current that is dying out because of being switched off. In fact, it opposes the dying current to the extent that the receding current is momentarily sustained.

The action of the coil in inducing counter electric current in itself is known as *self-induction.*

The property of a coil which enables it to induce counter electric currents in itself is called *inductance.* It is mainly the property of inductance which gives us the increase in wave length when we connect a coil of wire in the circuit of a radio receiving or transmitting set, and for that reason it is desirable to a certain extent.

Self-induction occurs in a coil through which a steady direct current is flowing only when that current is switched on or off, but with rapidly fluctuating or pulsating direct current or with alternating or oscillating current, self-induction is practically continuous, since it occurs at every pulsation or alternation of the current.

An undesirable capacity or condenser effect is also obtained, to some extent, from the scheme of winding in the tubular shaped tuning coil, which is eliminated to a considerable extent in the case of honeycomb and spider-web coils. This condenser effect results from the tendency of a current on entering the first turn of wire in the tuning coil, literally to jump from the point of entrance at the first turn, over to the second turn of wire, without going around the coil. The current also has the same tendency to go directly across from the second turn of wire to the third turn and so on for all the turns of wire in the coil. In trying to go through the insulation of the wire from one turn to the next, the current stores itself up in the insulation and in the air space between the turns in electrostatic lines of force, as in the case of a condenser. This capacity effect, unlike the inductance effect, is undesirable in a coil used in radio work, because the current stored up between the turns of wire represents a loss, known as the *dielectric loss*.

It is evident from the foregoing that if we can reduce the capacity effect without reducing the inductance property, we can obtain a more efficient tuning inductance.

Capacity effect in a coil of wire is known as *distributed capacity*. Distributed capacity is lowered to a certain extent in the honeycomb coils without sacrificing inductance to too great an extent, by spacing the turns well, as suggested above, and by having the turns of wire in one layer, cross the turns of wire in the adjacent layers at an angle.

A lower value of distributed capacity is also obtained in the spiderweb coils by having the turns of wire in the one layer cross each other at an angle several times during one complete turn, as previously noted.

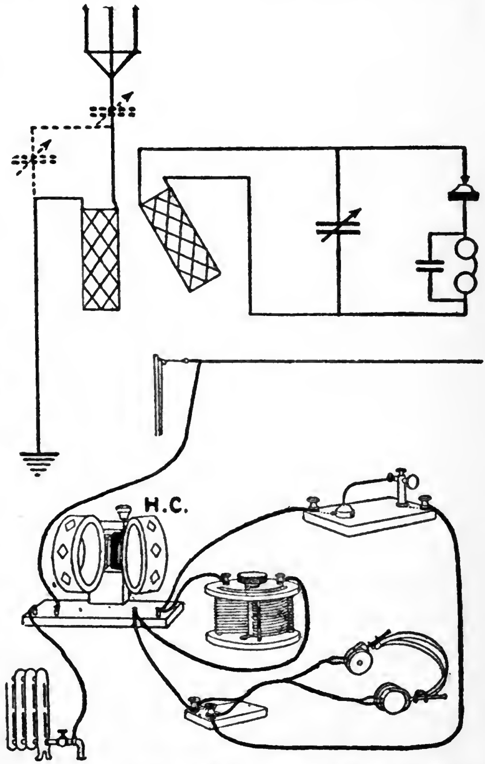


Fig. 43.—Hook-up for two honeycomb coils in a crystal detector set.

Honeycomb coils are usually mounted by means of plugs and receptacles into which the plug connections may be inserted. The arrangement is illustrated in Fig. 43. Such an arrangement permits the interchange of coils of various sizes for different wave lengths.

Plugs and receptacles as a rule are not used with spiderweb coils, as this type of coil is employed only for short wave length reception due to the fact that coils

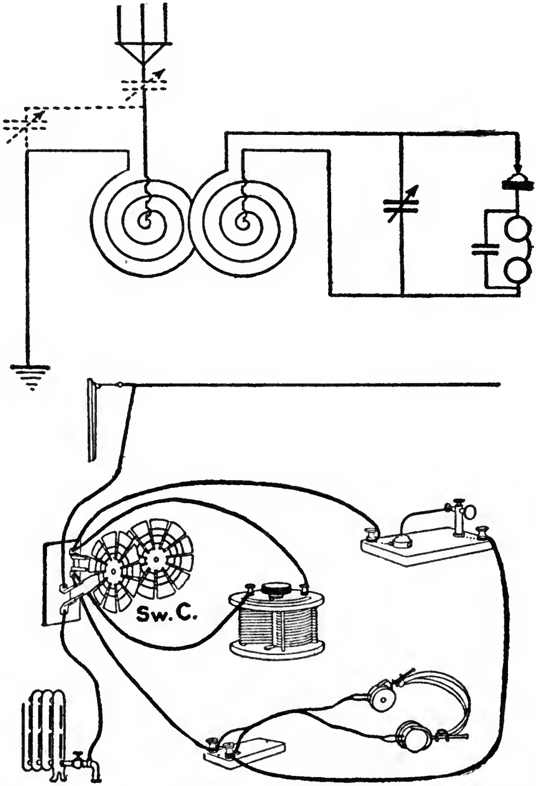


FIG. 44.—HOOK-UP FOR A CRYSTAL DETECTOR SET WITH TWO SPIDERWEB COILS.

designed for long wave lengths would be of such large proportions that they would be unhandy to manipulate.

Best results are to be obtained with either type of coil in a crystal detector set when two are used in a coupled circuit as shown in Figs. 43 and 44. In either hook-up, coupling is controlled by having the primary coil stationary and the secondary coil movable. The coupling movement of the secondary coil is similar to the swinging of a door on a hinge. The coupling effect may, however, be obtained without the use of the mountings by laying one coil on the table and sliding the other coil over it, particularly in the case of the spiderweb coils.

Spiderweb coils for tuning to wave lengths up to 600 meters (with the aid of condensers), may be made up of two pieces of pasteboard or fibre paper, four inches in diameter and $\frac{1}{32}$ of an inch thick, with an uneven number of radial slits (about 15) cut in each, providing an uneven number of "spokes". Approximately 20 turns of No. 18 to No. 24 wire are wound on one form for the primary winding and 25 turns of the same wire on the other form for the secondary winding.

As indicated in Figs. 43 and 44, a variable condenser would be necessary in shunt to the secondary coil and another condenser either in shunt to or in series with the primary coil to permit sharp tuning. Larger spiderweb coils might be made up having taps taken from them to a units and a multiple switch, in which case the variable condensers would be unnecessary. Some forms of honeycomb coils have three or four taps taken from them in order to eliminate the necessity of having separate coils for different wave lengths. However, as in the case of those which are not variable, condensers would be needed for sharp tuning.

The variometer.—The usual type of variometer is made up of two coils of wire connected in series and wound on or glued to insulating forms, one of which is smaller than the other. These forms are so mounted that the smaller one, called the *rotor*, is placed inside the larger one, which is called the *stator*. The inner form, or the rotor, is so arranged that it may be rotated. These forms may be cylindrical or spherical in shape, but in either case they are concentric; that is to say, they both have a common center or axis.

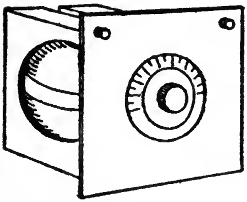


FIG. 45.—A VARIOMETER.

The variometer differs from the variocoupler chiefly in that the two coils or windings of the variometer are connected in series, while the two coils or windings of the variocoupler are not connected to each other.

These instruments also differ in that the turns of wire in the variometer are seldom variable while the turns of wire on the outside coil of the variocoupler are usually made variable by means of taps connected to switch points over which a switch arm rotates.

A variometer may very easily be made at home. In the home-made instrument, two pieces of cardboard or other insulation tubing about 1¾ or 2 inches long may be used. The larger tube might have an inside diameter of about 4⅛ inches. The inside tube should then have an outside diameter of about 3½ inches, to permit it to revolve inside of the larger tube. Each tube should be wound with forty or fifty turns of No. 20 double cotton-covered wire. In making the internal connection, either end of one coil may be connected to either end of the other.

If a current of electricity is passed through the variometer, it will of course pass through both coils of wire (since the two coils are connected in series), and a magnetic field in each coil will be set up by the current.

When the inside coil or rotor winding is placed so that its turns of wire are parallel to the turns of wire on the outside coil or stator winding and so that the current passing through the turns of wire on the inside coil travels in the same direction as the current passing through the outside coil, the magnetic field produced by one coil will combine with and build up on the magnetic field produced by the other coil.

If the inside coil is then revolved 180 degrees or given a half turn, the turns of wire on both coils will again be parallel, but in this case, current passing through the variometer will travel through one coil in one direction and through the other coil in the opposite direction. The magnetic field of one coil will then "buck" or oppose the magnetic field of the other coil.

If alternating or oscillating current, or pulsating direct current is sent through the coils of the variometer, an effect known as self-induction will be present in each coil at the same time that the magnetic fields of the two coils are acting upon each other. This self-induction will be at a maximum when the magnetic fields of the two coils are building up on each other, and at a minimum when the fields are opposing each other. As suggested on page 90, when alternating current or fluctuating direct current is passing through a coil, self-induction is practically continuous, since it occurs at every alternation or fluctuation.

Self-induction in a coil of wire has the same inductance effect which is to be obtained, as we learned in connection with spiderweb and honeycomb coils, from the addition of wire to the circuit. Since wave length is directly proportional to inductance, it follows that the wave length of the circuit in which the variometer is placed may be

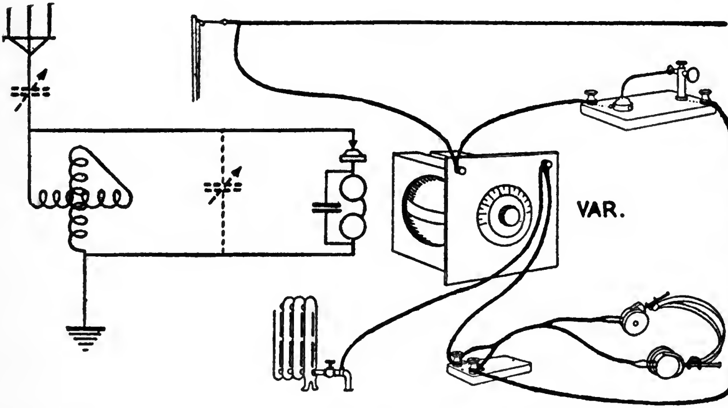


FIG. 46.—HOOK-UP FOR A VARIOMETER IN A CRYSTAL DETECTOR SET.

varied from a minimum to a maximum by revolving the inside coil of the variometer through a half revolution or 180 degrees. Just how great a range of wave length the variometer can add to a circuit will depend upon the sizes of the two coils. In the short wave regenerative set it usually controls a range of from 200 to 600 meters.

It should be evident from the foregoing that the variometer offers a very flexible instrument for tuning by means of inductance. In the case of the instrument of the range suggested, the inductance may be varied in the smallest degree by slightly rotating the inner coil in one direction or in the other.

The variometer may be used in place of a single-slide tuning coil. As previously suggested, wave length would be varied with this instrument by revolving the rotor and not by means of a slider or taps as in the case of the tuning coils. Both coils in the variometer are included in both the primary and the secondary circuits if it is used as a tuning coil; therefore, varying the position of the rotor of the variometer in Fig. 46 will vary the wave length of the primary and the secondary circuits simultaneously. As indicated by dotted lines, a variable condenser may be used in shunt to the variometer to increase, at the same time, the wave-length range of both the secondary and primary circuit, or in series with the latter circuit to decrease the wave-length range of the set.

A variometer may also be used as a loading coil, placed in series with the aerial circuit; or one may be placed in series with the secondary circuit; or two may be used at the same time. This instrument affords a very flexible means for adding wave length to either circuit of a receiving set.

Underwriters' requirements.—The ground wire for any receiving set may be bare or insulated copper wire, but it must not be smaller than No. 14, except that approved copper-clad steel wire not smaller than No. 17 may be used. The receiving set ground wire may be run either inside or outside the building, but it must be entirely independent from the lightning ground wire.

Under no circumstances should the ground connection be made to a gas pipe.

Chapter V

VACUUM TUBES

Description of the vacuum tube.—By far the most important unit at the present time in the transmission and reception of radio telephone messages is the vacuum valve, vacuum bulb or thermionic valve, or as it is most commonly called, the vacuum tube. This valve or tube, as shown in Fig. 47, somewhat resembles a small electric light bulb. It differs from the incandescent lamp, however, in that there is enclosed in the glass bulb two elements in addition to the filament, and in that it has four external contact points instead of two. This glass bulb, highly exhausted of air or gas, is mounted in a brass and composition base through which the four terminal pins or contacts protrude. It contains (1) a metallic *filament* which may be heated to incandescence by passing an electric current through it, and to which two of the external contact points are connected; (2) a metallic cage or spiral of wire, called the

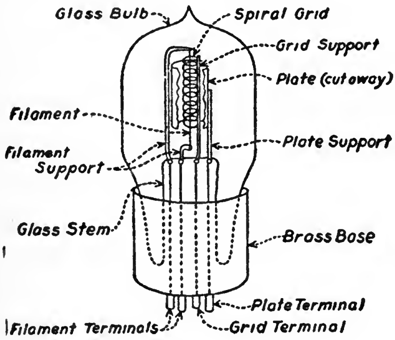


FIG. 47.—THE THREE ELEMENT VACUUM TUBE.

grid, surrounding the filament, and having an outside terminal; and (3) a cylindrical metal *plate* surrounding the grid, also with an external contact point.

Development of the vacuum tube.—For many years it has been known that a metal filament heated in a vacuum will give off minute particles or negative charges of electricity, called electrons, in much the same fashion as a piece of iron raised to white heat in a blacksmith's forge throws off sparks.

Dr. J. A. Fleming, an English inventor, was the first to adapt the emission of electrons from a heated filament in a vacuum tube to apparatus for receiving radio signals. Into a bulb containing a filament, he introduced a metallic plate with an external contact point, and then exhausted the air from the bulb. Dr. Fleming found that this glow lamp, or oscillation valve, as he named it, would pass electricity better in one direction than in the opposite direction. In other words, the valve had the property of rectifying alternating current, similar to that of the crystal used as a detector. By placing the valve in series with a source of radio-frequency oscillations, one-half of each oscillation could be suppressed, and the circuit would then be transversed by a pulsating direct current, just as in the case of the crystal detector, with the difference that *the bulb gave much better results*.

The three-element vacuum valve (shown in Fig. 47) which is in general use at the present time, is a modification of the Fleming valve. The introduction of the third element, called the grid, is credited to Dr. Lee De Forest.

Uses of the vacuum tube.—At the present time, the three-element vacuum tube is used in radio:

(1) As a detector, to rectify high-frequency oscillations.
(2) As an audio-frequency amplifier, to magnify variations in current in the plate circuit of a detector, thereby amplifying the sounds produced in the receivers.
(3) As a radio-frequency amplifier, to magnify the high-frequency currents generated in the aerial by the incoming signals, thereby building up weak signals so that they will actuate the detector.
(4) As an oscillator, to generate high-frequency oscillations for both receiving and transmitting.
(5) As a modulator, to control or mould the high-frequency oscillations generated by the sending tube.

The two-element vacuum tube is used as a rectifier of alternating current for charging batteries and for supplying direct current for other uses in radio.

Only the first mentioned use of the vacuum tube will be considered at this point. The other uses will be discussed in later chapters.

It should not be assumed that the vacuum tube is restricted in its uses to radio. For a number of years it has been used to amplify speech on long distance wire telephone lines, especially in transcontinental communication. At intervals along the line, it is employed to stimulate the feeble voice controlled currents, making possible the present long distance wire telephone communication.

It is used also to amplify physical sound, as of the voice of a speaker addressing a widely scattered company. It has been adapted to use in an instrument to aid the hearing of the deaf. By the aid of the vacuum tube, the slow disintegration of matter may be amplified into audible sounds. The tube has also been successfully employed to amplify other sense impressions.

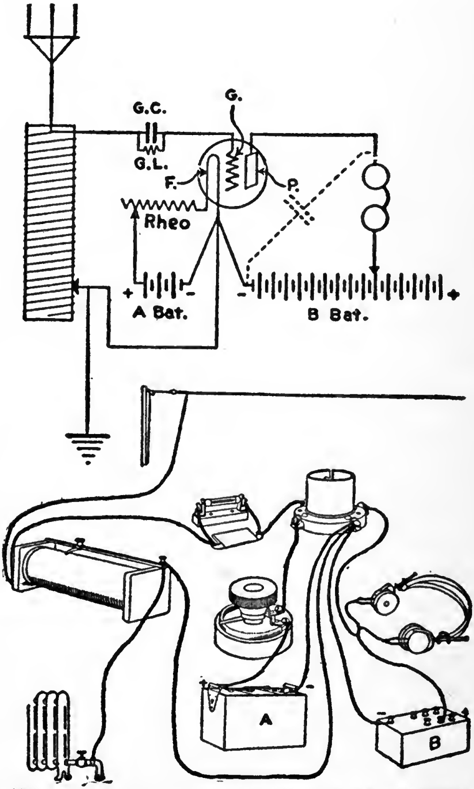


FIG. 48.—HOOK-UP FOR A SIMPLE VACUUM TUBE DETECTOR SET.

THE VACUUM TUBE AS A DETECTOR.

In considering how the vacuum valve operates, it is necessary to keep in mind only that like charges of electricity repel one another, while unlike charges attract one another. That is to say, positive repels positive; negative repels negative; but positive *attracts* negative. In this discussion, the authors desire also to draw the attention of the reader to the more recent theory that electric current flows from negative to positive in the external circuit of a battery or other generating source.

Fig. 48 shows the circuit and the picture diagram of the simplest practical receiving set using a vacuum tube detector. The tuning device used is a single-slide tuning coil. As complicated as this circuit may at first appear, it can readily be seen that it is the same as that of the single-slide tuning coil and crystal detector set, with the vacuum tube detector substituted for the crystal detector.

In fact, the vacuum tube connection may be substituted for the crystal detector connection with any of the tuning devices in the hook-ups shown in Chapter IV.

This substitution, however, has made two somewhat radical changes in the secondary circuit: (1) the use of the vacuum tube has necessitated introducing two batteries into the hook-up; and (2) the connections to the filament, the plate and the grid of the tube form three different circuits in the hook-up of the vacuum tube detector, in addition to the primary or aerial circuit.

"A" and "B" batteries.—The two batteries used in the hook-up are commonly called the *"A" battery* and the *"B" battery*. The so-called "A" battery ordinarily is a 6-volt storage battery and is used only to heat the filament in the bulb. Its circuit includes a *rheostat*, by means of which its current and therefore the temperature of the filament may be varied. The "B" battery is usually made up of flashlight battery cells hooked together to furnish a voltage of 22½ to 45 volts to the plate in the valve. Its purpose is to keep the plate charged positively, and to furnish negative electrons to the filament. Its circuit includes a means for varying the voltage, just as the "A" battery circuit includes a device for varying the current.

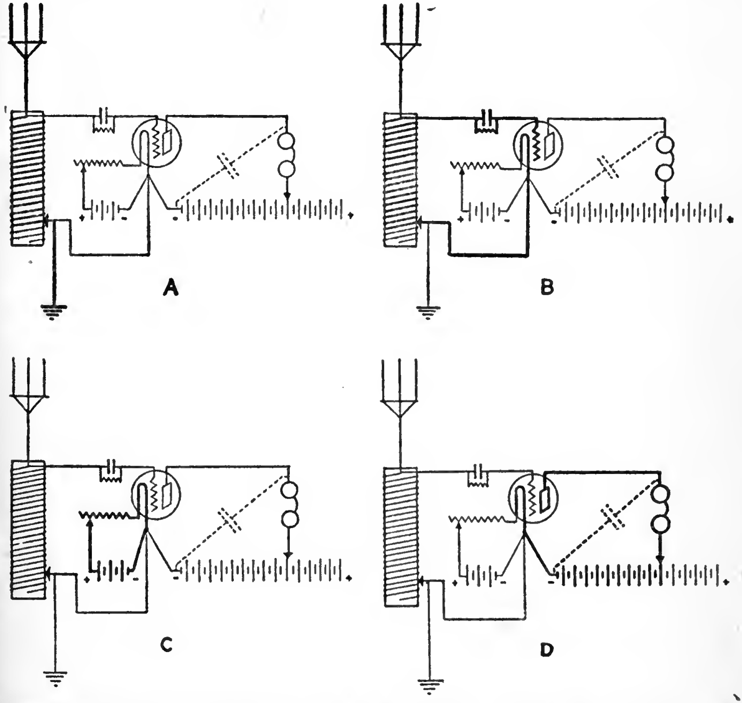


FIG. 49.—FOUR ILLUSTRATIONS OF THE HOOK-UP SHOWN IN FIG. 48. A SHOWS THE AERIAL CIRCUIT IN HEAVY LINES; B, THE SECONDARY OR GRID CIRCUIT IN HEAVY LINES; C, THE FILAMENT CIRCUIT IN HEAVY LINES; AND D, THE PLATE CIRCUIT IN HEAVY LINES

Both of these sources of current will be considered in detail in the following chapter.

Circuits of the vacuum tube detector.—For the sake of clearness, the aerial circuit of this set and the three circuits of the detector are shown in heavy lines in Fig. 49, which includes four illustrations of the same hook-up. A shows the primary or aerial-and-ground circuit. B shows the secondary or grid circuit, which includes the same turns of wire on the tuning coil as does the primary circuit. C shows the "A" battery or filament circuit. D shows the plate circuit.

Note (1) that the grid of the vacuum tube is connected directly to one side of the secondary or grid circuit, through the grid leak, and grid condenser; (2) that one side of the filament is connected to the other side of the secondary or grid circuit, and also to the negative post of the storage or "A" battery and to the negative side of the "B" battery in the plate circuit; (3) that the other side of the filament is connected to the rheostat or variable resistance, which in turn is connected to the positive post of the "A" battery; (4) that the plate is connected through the receivers, to the positive side of the "B" batteries, virtually making the plate the positive terminal of the "B" battery.

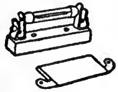


FIG. 50.—A GRID LEAK AND A GRID CONDENSER.

The grid condenser is a small fixed condenser very similar to the one described in connection with the crystal detector set on page 50, having a capacity to the value of from .00025 to .001 mfd.

The grid leak is a high resistance having a value of from 50,000 to 5,000,000 ohms, usually constructed in the form of a thin graphite or carbon line placed on some kind of insulating material. It may even be a lead pencil mark drawn on a piece of paper.

The filament rheostat is usually made up of a coil of iron or some alloy resistance wire, wound in the shape of a spiral, about one-half inch in diameter, on a form of fibre or some other heat resisting insulating material, bent in a semicircle. A contact is so arranged that it may be made to slide over the coil of wire and make contact at various points. The resistance of the filament rheostat usually has a value of from six to ten ohms.

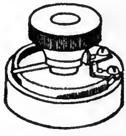


FIG. 51.—A FILAMENT RHEOSTAT.

The action of the vacuum tube.—As previously stated, when the current from the "A" battery has heated the filament, electrons or negative charges of electricity, are projected from the filament and are attracted to the plate P, which we have considered to be virtually an extension of the positive post of the "B" battery. This flow of electrons sets up a current in the plate circuit through the receivers, the "B" battery, back through the filament and across again to the plate. This current in the plate circuit flows only while negative electrons are passing from the filament to the plate.

At the same time that the electrons are passing from the filament to the plate, some of them are being intercepted by the grid and stored up on it. The electrons which have thus collected on the grid cannot flow back through the grid condenser, and will not force their way through the high resistance grid leak to the filament until after a certain value has been reached. The negative value reached by the collection of electrons on the grid may be as much as -2 or -3 volts, or more. These negative charges of electricity, storing up on the grid, form a negative charge which rises to its given value.

We shall see in a moment how this negative charge forming on the grid will limit, to a certain extent, the flow of electrons from the filament to the plate, and therefore the value of the plate current in the receivers.

In radio telephone reception, radio vibrations or oscillations which have been moulded or controlled by sound waves passed into the transmitter at the sending station, are induced in the receiving aerial circuit as we learned in Chapter I, and are transferred to the local or grid circuit. When these oscillations of current are set up in the grid circuit, the grid of the vacuum tube receives alternately a positive and a negative charge for each oscillation.

When a positive charge is impressed on the grid of the vacuum tube, it neutralizes the negative charge already placed upon it from the collection of the electrons. This decreases the screening action of the grid to the flow of electrons from the filament to the plate, and momentarily allows a rush of current from the filament to the plate. As the current reverses, and flows in the other direction in the grid circuit, the neutralizing effect of the positive charge, which has just been impressed on the grid, is removed and the negative side of the oscillation is impressed on the grid, restoring it to its former negative value and placing an additional negative charge on the grid as well. This sudden rise in the negative value of the grid again repels the electrons and hence reduces the current passing from the filament to the plate, thereby effectually reducing the flow of current through the plate circuit.

In this manner, the alternating pulses of the incoming oscillations, rapidly impressed upon the grid of the vacuum tube, fluctuate the stronger current flowing from the "B" battery to the filament and to the plate and hence through the plate circuit. These pulses of current in the plate circuit, however, are occurring at radio frequency and are too rapid in their succession to operate the disks in the telephone receivers.

In order to understand the reception of radio telephone messages, we must at this point examine more carefully than was possible in Chapter I, the nature of radio telephone oscillations and waves.

In the first place, the radio telephone transmitter includes a device which generates continuous oscillations. In the operation of the set, the generator is set into action, and throughout the period of transmission, it continues to furnish oscillations of current to the aerial circuit, at radio frequency regardless of whether or not sounds are being passed into the transmitter. In the transmission of voice or music, the sounds are directed into a transmitter connected to a piece of apparatus called a *modulator*. This modulator modifies or moulds the continuous radio-frequency oscillations by varying their amplitude

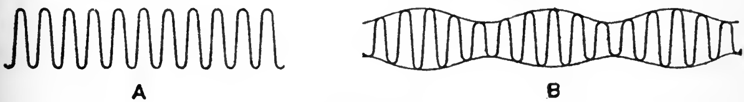


FIG. 52.
A. CONTINUOUS WAVES OF RADIO FREQUENCY RADIATED BY AN OSCILLATION GENERATOR. B. CONTINUOUS WAVES MOULDED OR VARIED IN AMPLITUDE BY THE MODULATOR, IN KEEPING WITH THE FREQUENCY OF THE SOUND WAVES PASSED INTO THE TRANSMITTER.

at *audio-frequency rates* corresponding to the frequency of the sound vibrations being passed into the transmitter. The action of the modulator will be considered more in detail in Chapter X. Its effect, however, on the continuous waves radiated by the telephone transmitter may be illustrated as in Fig. 52

The elements of a radio telephone system shown in Fig. 1, page 12, may now be more accurately represented by Fig. 53.

Returning to our discussion of the vacuum tube detector, we can see that since the radio frequency oscilla-

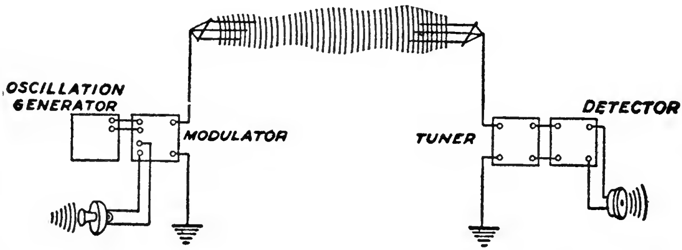


FIG. 53.—ESSENTIAL UNITS OF A RADIO TELEPHONE SYSTEM.

tions generated in the transmitting set have been modified in the manner described above, and since the waves picked up by the receiving aerial have the characteristics indicated in Fig. 52B, two sets of oscillations must be present in our aerial circuit and in our grid circuit; and two sets of pulsations must be present in the plate circuit, controlled by the valve action of the grid: (1) radio-frequency pulsations, corresponding to the frequency of the continuous waves; and (2) audio-frequency pulsations corresponding to the variations in amplitude caused by the sound waves, through the modulator, at the sending station. These latter pulsations, of audio frequency, operate the disks in the telephone receivers. The way in which the radio-frequency pulsations in the plate circuit may be put to work will be considered in Chapter VII.

In the manner described in the foregoing pages, the grid of the vacuum tube acts as a valve or screen, varying or fluctuating the strength of the plate circuit current, which flows through the telephone receivers in one-direction pulses corresponding in intensity and in frequency to the sound vibrations passed into the distant transmitter.

The by-pass condenser.—A fixed condenser connected across the head telephones and the "B" battery is shown by dotted lines in Fig. 48. Its purpose is to offer a path of lower resistance than is afforded by the receivers and the "B" battery, for the radio-frequency pulsations in the plate circuit. This condenser will not pass to any appreciable extent, the audio-frequent pulsations, since it offers a high impedance to currents of low frequency. The audio-frequent pulsations will therefore pass through the receivers in the usual manner.

The by-pass condenser is provided as standard equipment with few vacuum tube detector sets, since most sets will function quite well without this device. For that reason, the condenser is shown in dotted lines. As a matter of fact, the parallel wires in the receiver cords provide a condenser effect to a certain extent. For best results, however, this device should be used in the connection indicated, and should provide a capacity of about .001 or .002 mfd.

The amplifying effect of the vacuum tube.—It is interesting to note at this point that the effect of the weak oscillations impressed on the grid circuit is greatly magnified in the much stronger fluctuating current flowing through the receivers. It is this effect which makes the vacuum tube detector far more sensitive than the crystal detector; in reality, however, the receivers in a crystal detector circuit are actuated only by the original incoming oscillations in the secondary circuit, while the receivers in the plate circuit of a vacuum tube are actuated by a much stronger current, which is controlled by the incoming oscillations.

As previously noted, the amount of current used to heat the filament in the vacuum tube is regulated by a rheostat placed in the filament or "A" battery circuit. The voltage or degree of positive potential given to the plate may be regulated by a series of taps coming from the "B" batteries. The rheostat is used to vary the amount of current which passes through the filament circuit. The taps are employed to vary the voltage or electrical pressure in the plate circuit and the degree of positive potential on the plate.

Advantages of careful adjustment.—The number of electrons emitted from the filament at any given time depends upon its temperature and increases as the temperature is raised; that is to say, increasing the flow of current from the "A" battery through the filament causes the filament to throw off a greater number of electrons. Through its connection to the negative side of the "B" battery, the filament is continually supplied with negative electrons. Also, as the "positive" property or potential of the plate is raised by connecting additional cells of the "B" battery into the plate circuit, the plate will attain a "positive" value at which practically all electrons emitted from the filament and passed through the grid screen, actually impinge upon the plate. This condition is called *saturation*. It is readily seen, therefore, that the plate voltage required for saturation depends upon the temperature of the filament. In other words, for any given value of the heating current in the filament, there is a value of voltage to use in the plate circuit which will give saturation, and there is no advantage in using any more. With the proper combination of current in the filament circuit and voltage in the plate circuit, loud sounds may be heard in the telephone receivers when but a very small amount of energy is intercepted by the aerial.

Effective operation of the vacuum tube implies adjustment of filament current and plate voltage to that point at which the weak "signal" currents in the grid circuit will control, through the valve or screen action of the grid, the maximum amount of current in the plate circuit in which the receivers are placed.

Since the length of life of the filament is decreased in proportion as current is passed through it, and since bulbs are expensive, economical operation means using no greater filament current than is necessary to set up a flow of current in the plate circuit which will actuate the receiver diaphragm at maximum efficiency; this implies varying the plate voltage simultaneously to a point just below that at which saturation is obtained as described above.

OPERATION OF THE VACUUM TUBE DETECTOR

Regulating filament current and plate voltage.—The rheostat used in a vacuum tube detector is invariably arranged so that at one end of the resistance coil the circuit of the "A" battery through the filament is broken. This eliminates the necessity of having another device to switch on and off the "A" battery current.

As the rheostat is turned towards the "on" position, the first slight movement connects the sliding contact of the rheostat with the last turn of wire in the resistance coil. This throws all of the resistance into the circuit at the start. As the rheostat is further moved towards the "on" position, it gradually throws out of the circuit the turns of wire in the resistance coil, and as more resistance is removed from the circuit, more current is allowed to flow into the filament, until in the "on" position, all of the resistance is removed from the circuit.

Under this condition, all of the voltage of the "A" battery is impressed upon the filament, passing the maximum amount of current through the filament. The rheostat should at first be turned only about one third or one-half way towards the "on" position, when using a six-volt battery for a six-volt filament. This will reduce the voltage to from three to five volts, and consequently less than the maximum quantity of current allowable, will pass through the filament.

At this stage, a terminal should be selected on the "B" battery with the variable tap, depending upon the amount of plate voltage at which the particular vacuum tube gives best results. Detector tubes are usually designed for 22½ volts in the plate circuit. The 21-volt tap, for instance, might first be selected. The filament rheostat is now again adjusted, by turning it towards the "on" or the "off" position.

The foregoing explains the adjustment of the filament current for a given value of plate voltage. This particular combination of current values, however, may not be the best one for the particular tube in use. Various taps should now be tried on the "B" battery in order to arrive at the best combination, as indicated by the strength of the incoming signals. For instance, if signals are being received and the "B" battery tap is on the 19½-volt terminal, the terminal either below or above should be tried and the filament current adjusted once more to see whether an increase or a decrease in signal strength is obtained. Other terminals, farther above or below, should be tried, with accompanying adjustment of the filament current. It may be found that signals can be heard with 22½ volts plate voltage and with one-half the filament rheostat in the circuit, but that they are stronger when the 18-volt terminal on the "B" battery is used, with possibly two-thirds of the filament rheostat placed in the circuit, reducing the amount of the filament current used.

The hissing point and the blue glow.—At certain adjustments of the filament rheostat, a hissing sound in the receivers may be heard or a blue glow may be noticed in the tube. The former is an indication that for the given amount of plate voltage, the filament is being heated to an excessively high degree and is giving off too great a quantity of electrons. The filament current should in that case be reduced just to the point where this hissing in the receivers becomes inaudible. Above this point, the vacuum in the bulb becomes over saturated with electrons and no advantage in sensitiveness is gained; in fact, the sensitiveness of the bulb is decreased. A blue glow from the filament of a tube indicates that the plate voltage is excessive and should be reduced.

Once a detector tube has been adjusted after the foregoing method and the point found where signals seem to come in best, thereafter with the same bulb, the same adjustments can be used with very slight alterations in the values of the two currents. These values will remain constant to a fair degree until either the "B" battery or the "A" battery begins to lose its strength. The substitution of other batteries or detector bulbs will necessitate the foregoing operations being made all over again.

Bear in mind that the best adjustment is that which uses the minimum amount of filament current, because the more filament current used, the higher will be the degree to which the filament is heated and the shorter will be the life of the filament.

With the vacuum tube adjusted for maximum sensitiveness, tuning is accomplished with the single-slide tuner exactly as has been explained for the single-slide tuning coil in the crystal detector set.

Selection of grid leak and grid condenser.—If the vacuum tube detector has been purchased as a complete unit, in all probability an appropriate grid leak and grid condenser has been included in the set. A grid leak and grid condenser of particular values should, however, be selected for best results with any given tube. The best procedure is to keep an assortment of various sizes of grid leaks and grid condensers on hand and while the vacuum tube is being adjusted after the above procedure, these different sized grid leaks and grid condensers may be tried in the circuit, with further adjustments of filament current and plate voltage, until the value of each which gives the best results is found. Several companies have placed on the market devices in which both grid leaks and grid condensers can be slipped in or readily replaced, allowing a quick substitution of one after another until the best combination is found for the vacuum tube in use. Variable grid leaks which operate satisfactorily and permit ready adjustments to desired values are also available. Adjustments of grid condenser and grid leak values is necessary, however, only in case it is desired to obtain maximum results from the set. If it is not the desire of the reader to go to this trouble, a grid condenser of the value of .00025 mfd. and a grid leak of the value of one or two million ohms might be used for satisfactory results with almost any tube. Many manufacturers construct the grid leak and grid condenser as one device, selecting a given value for each which will work well with most detector tubes. This instrument embodying both the grid leak and grid condenser should not be confused with either a grid leak or a grid condenser to be purchased separately.

Hard and soft tubes.—Tubes which have been highly exhausted are spoken of as being *hard* tubes. Tubes less highly exhausted are called *soft* tubes. Soft tubes are more critical in adjustment and more sensitive than are highly exhausted tubes and are therefore more commonly used as detectors. Hard tubes, on the other hand, are more efficient amplifiers. Attention, however, should be called to the somewhat frequent use of hard or amplifier tubes as detectors by novices. Since such tubes are less critical, signals may be tuned in with coarser adjustments of the filament rheostat than would be necessary in the case of a soft tube.

Types of tubes.—As previously noted, the ordinary vacuum tube used in a receiving set requires direct current of six volts to heat the filament. This tube consumes approximately one ampere an hour.

Special types of tubes, which operate on lower voltages ($1\frac{1}{2}$ or 3 volts) or on 5 to 6 volts but consume a smaller amount of current (from 0.06 to 0.25 amperes) are from time to time placed upon the market. Among these have been the WD-11 ($1\frac{1}{2}$ volts), WD-12 ($1\frac{1}{2}$ volts), UV-199 (3 volts), and 201-A (5 volts).

The WD-11 tube gained its popularity among radio fans because it can be operated from a single dry cell as a source of filament current. This tube is a *hard* or high vacuum tube, and can be used either as a detector or as an amplifier. Originally the tube was produced for use in a particular type of receiving set with special sockets which did not permit the insertion of any other type of tube. Adapters, however, were quickly developed and placed upon the market to fit between the base of the special type tube and the ordinary type socket. Later the WD-12 tube appeared, similar to the WD-11 except for its base which is of the standard type.

In operating either the WD-11 or the WD-12 as a detector, $22\frac{1}{2}$ volts is normally used on the plate. For operating as an amplifier, 45 to 60 volts is recommended. Tubes of this type are seldom very critical in adjustment of filament current or plate voltage.

In the case of the 201-A tube, the filament is of very high activation, capable of emitting perhaps 1000 times as many electrons as preceding tubes, making it possible therefore to reduce the filament temperature greatly, and still secure a greatly increased emission of electrons. As a result, this tube consumes only one quarter as much current as its predecessors. The filament is sturdy and will stand rough usage. It is less likely to burn out than are other tubes, but sometimes loses its activity when excessive voltage is accidentally applied to it. This condition may often be corrected, however, by allowing the filament to burn without application of "B" voltage to the plate. Attention should be called to the fact that this type is a very *hard* tube. Usually, therefore, it gives better results as an amplifier than as a detector. Used as an amplifier, the 201-A requires approximately 90 volts in its plate circuit. As a detector it usually operates satisfactorily at a lower voltage.

The UV-199 is similar in construction and in operation to the 201-A tube, with these exceptions, that 3 volts only are required to heat its filament, and its current consumption is only .06 amperes.

Peanut tubes are very small tubes, originally developed to accomplish some of the results now accomplished by the larger tubes described in the preceding paragraphs. If volume in reception is desired, the larger tubes are recommended for amateur use.

CHAPTER VI

CURRENT SUPPLY FOR VACUUM TUBES

Sources of current.—In our discussion of the vacuum tube, we found that the introduction of this piece of apparatus necessitates two sources of electrical current in the receiving circuit, usually called the "A" battery and the "B" battery, the former to heat the filament in the bulb and the latter to place a positive potential or charge on the plate.

The "A" source of electric current, used to heat the filament of the usual type vacuum tube in a receiving set, may be almost any source of direct current to the value of six volts.

With the special types of tubes referred to on page 116, which consume much less filament current than ordinary tubes, dry cells are both convenient and economical as a source of current. These dry cells are not the flash light type used for "B" current, but the kind ordinarily used to operate a doorbell in the home.

It is possible to use four such cells to heat the filament of the ordinary 6-volt, 1-ampere tube. Dry cells, however, have a comparatively low capacity and therefore a short life. This source of current, therefore, becomes quite expensive in the case of this type of tube.

The storage battery.—As previously stated, the usual supply of current for the filament is a 6-volt storage battery such as is commonly used in a motor car. The 32-volt storage battery of a farm lighting plant, as a source of current, will be considered later in this chapter.

The 6-volt storage battery furnishes a uniform direct current of the proper voltage and is most satisfactory. Its only disadvantage lies in the fact that a storage battery has to be recharged about once a month or oftener, depending upon the extent to which it is used.

The size or capacity in ampere hours, of the battery selected, should be dependent, as we shall see, upon the number and type of bulbs used in the receiving set and upon whether or not a charging outfit is to be used for recharging the battery at home.

As previously stated, the ordinary 6-volt vacuum tube consumes about one ampere per hour; a 40-ampere-hour battery would, theoretically, light such a bulb for 40 hours. In practice, however, after about 25 ampere hours have been consumed, the voltage drops to about 5 volts and the battery needs to be recharged, not only for the reason that it is best for the battery but because in most cases it will not, at that voltage, heat the filament sufficiently.

A 40-ampere-hour storage battery would light one vacuum tube an hour a day for about a month. If two tubes were used, or if one bulb were lighted for two hours each day, a battery of this size would supply current for only about two weeks before recharging would be necessary. In the latter case, it would probably be more convenient to have an 80-ampere-hour battery.

Again, if the vacuum tube set includes two stages of amplification, making three bulbs to be supplied, and the set is to be used three hours an evening for perhaps four evenings a week, we can see that the complete set would consume approximately nine amperes an evening or 36 amperes for the week.* In this case, at least a 140- to 180-ampere-hour battery would be required for a month's service. A difficulty now arises in that a storage battery with a capacity larger than 80 ampere hours is too heavy to be transported easily to a service station for recharging. In this case, the amateur usually finds it advantageous to purchase an outfit for recharging.

Battery chargers for home use.—Ordinarily, 110-volt alternating current (110-volt A. C.) is supplied by electric service companies for house lighting. Before this current can be used for charging batteries, it must be rectified into direct current, and also reduced in voltage to 12 or 15 volts, in order to prevent damage to the battery.

There are three general types of rectifiers on the market, —the *electrolytic rectifier*, the *magnetic rectifier*, and the *vacuum tube rectifier*. The first named utilizes a solution or electrolyte and is usually undesirable because of the possibilities of the container being tipped over or of the electrolyte leaking out. The magnetic rectifiers, of which the "Homecharger" is perhaps the best known, incorporate a transformer and a vibrator similar to that used in a spark coil. This type of rectifier works satisfactorily and is the most economical of the three in its operation, but requires some care in adjustment and is somewhat noisy. The vacuum tube type, such as the "Rectigon" or the "Tungar" rectifier, is perhaps the most desirable. Both the magnetic and the vacuum tube rectifiers reduce the voltage to such an extent that they may be con-

* The use of low current consumption tubes in the set will of course affect these calculations.

nected directly to the batteries without any additional attachments.

If the house electric service happens to be direct current, the battery may be charged directly from a lamp socket, by connecting a suitable rheostat or a small number of electric light bulbs in series in the circuit to limit the amount of current passing through the battery.

Care of the storage battery.—In almost every instance when a battery is purchased, it arrives from the local dealer fully charged; or if it is shipped for some distance, the electrolyte is sent with it, and complete instructions are enclosed for putting the solution in the battery and placing the battery in operation. The following suggestions, however, are made concerning the care of the battery: The electrolyte of the lead plate battery is a solution of about 1 part sulphuric acid to 5 parts pure water, and, when the battery is fully charged, should have a specific gravity of from 1.275 to 1.300 depending upon the make of the battery.

The specific gravity of the acid solution is measured by an instrument called a hydrometer, which may be purchased for about 75 cents. Battery readings should be taken at least once a week and when the specific gravity falls to 1.200 or lower, the battery should be recharged. Usually before this point is reached, the reduced brilliancy of the detector or amplifying bulbs will indicate a drop in the voltage of the battery and the resultant decrease in current to the filament.

From time to time and especially during charge, pure water (distilled water or rain water) should be added to the electrolyte in each cell so that at all times the solution will be ½ inch above the plates. Do not add acid to the electrolyte unless some of the solution has been spilled, since only the water evaporates and needs to be replenished.

The hydrometer furnishes the best means of ascertaining the completion of the charge. When the specific gravity has been raised to its required value (1.275 to 1.300) the charge is complete.

Care should be exercised in lighting the filament of a bulb immediately after the battery has been charged, as there is often an excess voltage in a 6-volt battery to the value of 1 or 1½ volts and this additional voltage might be enough to burn out the filament in the first few minutes. After a few minutes usage, however, the voltage of the battery will fall to its normal rating or to about 6 to 6.5 volts.

It might be suggested that with a home charging outfit, a battery much smaller in capacity may be used than would be desirable if the battery had to be charged at a service station. With a home outfit, the battery may be charged as soon as its voltage begins to fall. However, charging a small battery daily might become monotonous. It is usually advisable, therefore, to select a 40-ampere-hour or 60-ampere-hour size if three tubes, for example, are to be supplied with current from it.

Care should always be exercised in handling the battery so that none of the solution is spilled, since the acid will attack and disintegrate most substances and materials with which it comes in contact.

Heating the filament from a direct current generator.—Another possible source of current for lighting the filament is the direct current generator. When this source is used, however, a continual hum caused by the moving contacts of the machine, is usually heard in the receivers. Whether or not this hum will be loud enough to be objectionable will depend upon the design and the condition of the generator and upon the strength of the signals it is desired to receive.

The amateur should not attempt to light the filament of the vacuum tube from a 110-volt D. C. source, unless he is extremely careful in selecting the proper resistance to cut down the voltage to six volts. Otherwise the filament of an expensive bulb might be burned out in an instant.

Heating the filament from the farm lighting plant.—Conditions similar to the foregoing would hold in using the generator of a farm lighting plant. If the farm lighting plant is equipped with storage batteries, as most of them are, the filaments of the vacuum tubes can be lighted from these batteries. The safest plan would be to take the filament lighting circuit from 3 cells of the battery so that there would be no danger of applying more than 6 volts to the filament. Theoretically, however, it is not good for the battery system to take from fewer than the entire number of cells in the battery, although lighting one or two vacuum tubes each evening by that method probably would have little harmful effect on the battery system as a whole, since the batteries are usually charged every day. If the filaments were to be connected to all of the batteries, that is to the entire 32 volts, care would again have to be exercised in inserting a proper resistance in series with the filaments. In the method suggested for lighting the filaments from 3 cells, two wires would have to be run direct from the 3 cells of the battery to the terminals of the filaments at the receiving set.

In the method suggested for lighting the filaments from the entire 32 volts with a resistance in series, connections could be taken from a socket in the room by

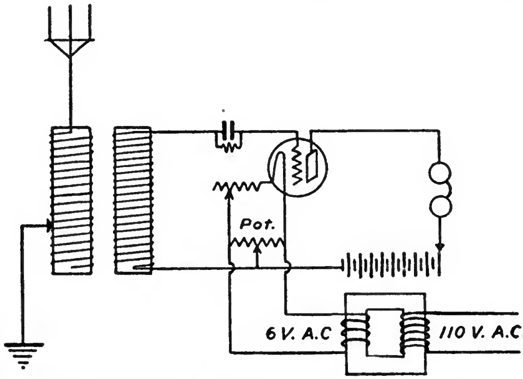


FIG. 54.—HOOK-UP FOR A VACUUM TUBE DETECTOR WITH THE FILAMENT HEATED FROM ALTERNATING HOUSE CURRENT.

means of a plug and the proper resistance inserted at the receiving set.

Heating the filament from alternating house current.—It is also possible to heat the filament with ordinary alternating house current, with the voltage transformed down from 110 volts to 6 volts, and receive radio signals; but again, unless special apparatus is installed, there will result such a humming sound in the receivers as to make reception of messages highly unsatisfactory. In this case, the continual reversals or alternations of current at the rate of 120 times a second (in 60-cycle A. C.) cause a loud humming which comes in strong in the receivers.

This difficulty, however, may be overcome as previously suggested, by the use of special apparatus in the circuit. A possible hook-up for this additional apparatus is shown in Fig. 54. The circuits are essentially the same as those of the simple vacuum tube detector, except for the connection of the secondary or grid circuit to the filament.

In this case, a *potentiometer* in the form of a carbon or graphite rod having a resistance of 1000 ohms or more, is connected across the low voltage leads from the transformer to the filament, and the grid of the vacuum tube is connected, through the coil, to the movable contact of the potentiometer. If one side of the grid circuit were connected directly to the filament, as is the case when a storage battery is used as a source of current, the grid would have a positive and a negative potential alternately impressed upon it due to the continuous reversal of the alternating current coming from the transformer. These oscillations of current, which would be present in the grid circuit along with the incoming radio oscillations, would also fluctuate the "B" battery current flowing through the plate circuit, producing a hum in the receivers which would probably drown out all signals.

By proper adjustment of the potentiometer, however, a neutral point in the reversals of potential in the alternating current can be found. The neutral point will be at the center of the resistance rod.

The filament current supply is obtained through a toy step-down transformer connected by means of a plug and socket, to the alternating house current supply.

Care should be exercised in making the connections of the filament to the step-down transformer. If the transformer has several different voltage taps on the secondary or low voltage winding, the filament should be connected to the tap, or the switch arm should be placed on the switch point, which will provide six volts; and likewise, if there is a switch arrangement on the primary winding, (i. e., the 110-volt side) the switch arm should be placed

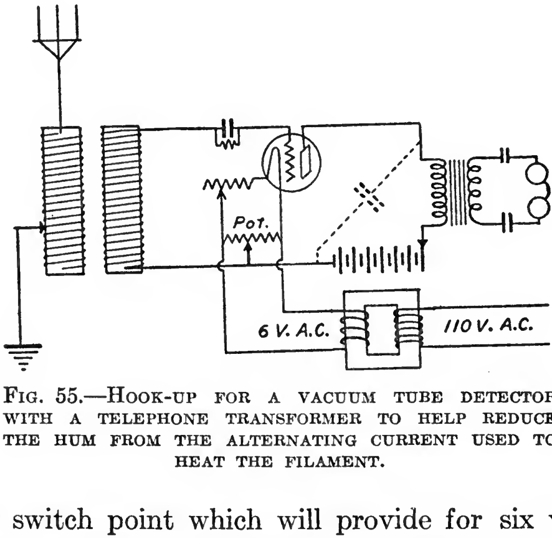


FIG. 55.—HOOK-UP FOR A VACUUM TUBE DETECTOR WITH A TELEPHONE TRANSFORMER TO HELP REDUCE THE HUM FROM THE ALTERNATING CURRENT USED TO HEAT THE FILAMENT.

on the switch point which will provide for six volts in the secondary or filament leads of the transformer.

If the potentiometer does not entirely eliminate the hum of the alternating current, an ordinary telephone transformer, which is inexpensive, may be substituted for the telephone receivers in the plate circuit, with its primary winding connected to the plate circuit and its secondary leads connected each through a fixed condenser of about .001 mfd. size, to the receivers. The hook-up for this device is shown in Fig. 55.

In the latter case, the condensers in series with the secondary leads of the telephone transformer will block, to a great extent, the low frequency pulsation caused by the 60-cycle alternating current, without impeding to any great extent the higher audio-frequency signal pulsations in passing to the telephone receivers.

As a matter of fact better results may often be obtained by connecting the receivers to the plate circuit through a telephone transformer, when a storage battery or other source of direct current is used to light the filament. In the event that a storage battery is used, however, the two blocking condensers are not necessary. There is a further advantage in this arrangement in that the receivers are removed from the plate circuit in which the constant "B" battery current is flowing, with the consequent saving of the receivers from depolarization. Even better results will be obtained, from the use of a step-down telephone transformer with receivers of low resistance—75 or 80 ohms—instead of 2000 or 3000 ohm phones. Low resistance receivers will respond more readily to the heavier pulsations of current in the secondary of the step-down transformer than to the weaker pulsations in the plate circuit.

For reasons given on page 109, a fixed by-pass condenser with a value of .002 mfd., should be placed in shunt to the primary of the telephone transformer and the "B" battery, as shown in the diagram.

The "B" battery.—The "B" battery for a vacuum tube usually has a value of 22½ to 45 volts, and may be made up of almost any type of cells; it is usually composed of small dry cells similar to those used in flash-light batteries. As a matter of fact, any desired number of flashlight batteries purchased at a ten cent store may be connected in series and used very satisfactorily for placing positive potential on the plate, and will usually last for a long time. Care should be taken not to short circuit the cells of any battery at any time. "B" batteries should always be kept in a dry place, and when in use, placed as near the set as possible so that the wires connecting them in the plate circuit may be as short as possible.

Use of alternating house current for plate voltage.—It is possible to use alternating house current for plate voltage, with additional apparatus to change the alternating current into a constant direct current and to smooth out the ripples or fluctuations of the supply. However, the additional equipment is both complicated and expensive, and is not advised for use by the amateur unless he has had considerable electrical or radio experience.

Underwriters' requirements.—In receiving sets employing vacuum tubes for detecting, amplifying or other purposes, where the current supply for them is obtained from storage batteries, the wiring between the storage batteries and the set must be of No. 14 gauge approved rubber-covered wire. Each conductor from the storage batteries should be protected by a fuse of a capacity not greater than 10 amperes. The fuses must be installed at the nearest accessible point to the storage battery.

Storage batteries of a type having exposed terminal connections must be placed in a ventilated box, or provided with a ventilated cover, secured in position so that accidental short circuits across the terminals of the cells will be prevented.

CHAPTER VII

THE REGENERATIVE RECEIVER

In Chapter V we learned that when continuous electromagnetic or radio waves which have been moulded or modulated by sound waves at the transmitting station are picked up by a vacuum tube receiving set, the oscillations set up in the grid circuit of the detector tube by these waves cause two sets of fluctuations in the plate circuit of the tube. In other words, owing to the valve action of the grid, weak incoming oscillations are made to control a strong pulsation of "B" battery current in the plate circuit at radio frequency, corresponding to the frequency of the incoming oscillations, and another pulsation at audio frequency corresponding to the sound waves passed into the transmitter at the sending station.

In the simple vacuum tube detector set, the audio-frequency pulsations of plate current are made to actuate the telephone receivers, but no use is made of the radio-frequency pulsations.

Regeneration.—In the regenerative receiving set, this radio-frequent current is put to work in an ingenious manner, by being "fed back" to the grid circuit to reinforce or strengthen the incoming oscillations. This feeding back of plate circuit energy to the grid is accomplished by coupling the plate circuit to the grid circuit in any of several methods which we shall presently describe. Its effect is that of amplifying weak oscillations which have been received in the aerial circuit and transferred to the grid circuit, so that these strengthened oscillations may control still larger fluctuations of the audio-frequent plate current which operates the telephone receivers.

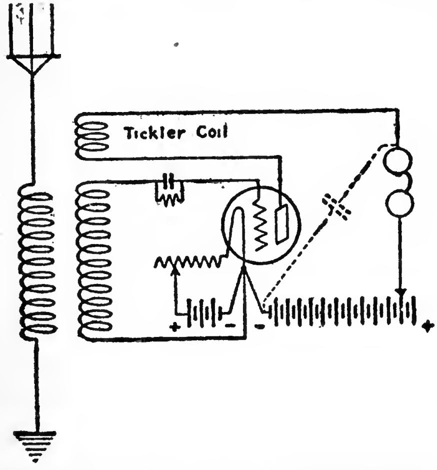


FIG. 56.—HOOK-UP FOR A REGENERATIVE SET USING A LOOSE COUPLER WITH A TICKLER COIL.

Regeneration with a tickler coil.—The action of a regenerative receiver may best be understood by considering a loose coupler set employing a vacuum tube detector, in which the plate circuit is coupled to the secondary of the loose coupler by means of a *tickler coil.*

In the hook-up shown in Fig. 56, the *radio-frequency* fluctuations, which are present in the plate circuit, are fed back through a tickler coil, wound on one end of the tube on which the secondary coil of the loose coupler is wound or otherwise placed in inductive relation to the secondary coil, so that the radio-frequent plate circuit current sets up a magnetic flux which builds up the strength of the incoming oscillations in the grid circuit. This operation repeats itself a great number of times, with cumulative effect, the reinforced oscillations in the grid circuit controlling still greater fluctuations of audio-frequent plate current which causes the telephone receiver disks to vibrate more violently, producing louder sounds.

The amount of regeneration in any case will depend upon the particular vacuum tube in use and the circuit in which it is employed.

Polarity of the tickler coil.—In using as a tickler coil, the secondary winding of a loose coupler or any winding which cannot be rotated, connection to the plate circuit may be made in such a way that the pulsations of current fed back, "degenerate" instead of regenerating the incoming oscillations.

For regeneration, the pulsations of current from the plate circuit must pass through the tickler coil in such direction that their electromagnetic effect will be that of building up the incoming oscillations which are passing through the grid inductance. If the reverse connection has been made, the effect of the fed back pulsations will be to oppose and decrease the effect of the incoming oscillations in the grid circuit. If such a condition obtains with a tickler coil which cannot be rotated, it is necessary only to interchange the two wires connecting the plate circuit to the tickler coil, and the plate circuit pulsations will travel through the coil in the opposite direction.

The vacuum tube as an oscillator.—In adjusting the tickler coil type of regenerative receiver, the amount of regeneration is controlled by the coupling of the plate circuit to the grid circuit through the tickler coil. That is to say, if the coupling of the plate circuit to the grid circuit is increased (by tightening the coupling) the feed-back effect will be increased, and vice versa.

In the reception of either spark signals or voice, if the coupling is gradually increased from a minimum toward maximum, thereby increasing regeneration from minimum toward maximum, the signals or voice will become louder and louder until the regeneration becomes so violent that distortion of signals or voice results.

Such distortion is due in large measure to the fact that the radio-frequent pulsations in the plate circuit which are being fed back to the grid circuit are amplifying some of the incoming oscillations to a greater extent than they are amplifying the others. This effect is not so objectionable in the reception of spark signals as in the case of telephone reception, since it merely alters the tone of the signals. In the reception of voice or music, however, the tones may be distorted to such an extent that they can not be recognized.

If the coupling of the plate circuit to the grid circuit is still further increased, a dull thud or click will presently be heard, and the spark signals or voice, if not very loud originally, will entirely disappear. This condition is an indication that the bulb has begun to *oscillate*. *Oscillation* may have been started by any one of several causes, as, for example, a slight jar, or a movement of the operator's hand or body affecting the capacity of the grid circuit or the plate circuit, or a sudden variation in incoming oscillations or some other electromagnetic effect picked up by the aerial circuit. Oscillation, however, is most frequently caused by a further increase of the inductance or the capacity of the plate circuit when the tube is feeding back violently. Under this condition, a slight increase in plate current is impressed upon the grid and instantly causes a more violent fluctuation of the plate current, which, in turn, is instantly transmitted to the grid, still further magnifying the fluctuation of plate current, and so on, creating in this manner, a series of self-sustaining oscillations. In any case, the tube must have been regenerating or feeding back energy to a great degree, or it must have been so adjusted for a high value of filament current and plate voltage that it was capable of feeding back violently upon a variation of potential on the grid from any local or external cause.

Some tubes oscillate more readily than others. In other words, a particular tube may regenerate and oscillate with a very low value of filament current and plate voltage, while another may require a much higher value of filament current and plate voltage to make it oscillate. The values of the filament current and plate voltage necessary to produce oscillation with a given tube depends upon the composition of the filament and the degree of vacuum in the tube.

With the tube in a state of oscillation, an oscillating current traverses plate and grid circuits with a frequency depending upon the capacity and the inductance of either or both circuits. We shall now see to what use these oscillations in the receiving set may be put.

If a station is sending out continuous or undamped waves on a wave length of 300 meters, and therefore at the rate of 1,000,000 waves per second (see page 16, Chapter I) the receiving aerial circuit with which these waves come in contact, will have induced in it 1,000,000 oscillations per second, if the two aerial circuits are in tune, corresponding to the number of waves coming from the sending station each second.

The 1,000,000 oscillations per second will be transferred from the receiving aerial circuit to the secondary or grid circuit, if the latter is tuned to the former, and the grid circuit will be traversed by an oscillating current at the same frequency. These oscillations in the grid circuit will produce corresponding fluctuations in the plate current, but such fluctuations obviously will be beyond the range of the telephone receivers; and even if they could actuate the receivers, the sounds produced by the vibrations of the receiver diaphragms would be above the range of audibility, as previously explained.

If, however, we now cause the vacuum tube to oscillate, in the manner previously described, we may produce in the grid and plate circuits, *local oscillations* of a frequency which will depend upon the adjustment of the circuits. These local oscillations will be present in addition to the incoming signal oscillations. Then by adjusting the set to produce oscillations at a frequency of, let us say, 999,000 we can produce a third oscillating current in the grid circuit, due to the interaction of the local or forced oscillations with the incoming oscillations. The third oscillating current will have a frequency, in this case, of 1000 oscillations per second—the numerical difference between the two interacting sets of oscillations—for, at 1000 points during each second, a local oscillation will add its complete value to an incoming oscillation, producing a *beat,* while at 1000 points midway between the beats, a local oscillation will practically neutralize the effect of the incoming oscillation; and between the beats and the neutral points, the local oscillations will gradually decrease and increase the effect of the incoming oscillations from maximum to minimum and then to maximum, and so on, at the rate of 1000 increases and 1000 decreases or 1000 complete cycles a second. The production of beats may be illustrated graphically as in Fig. 57. In the figure, the ratio of the two sets of oscillations is taken as 10 to 9. This third oscillating current will therefore

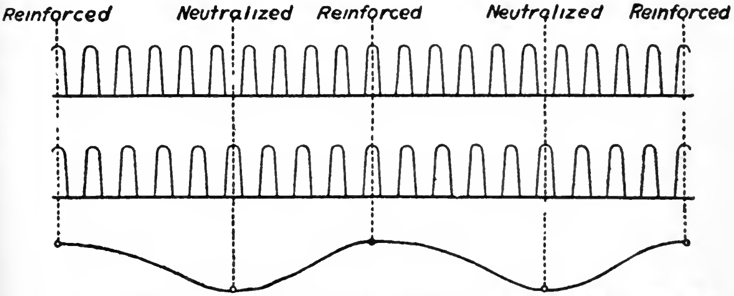


FIG. 57.—RESULTANT OF THE INTERACTION OF THE TWO SETS OF OSCILLATIONS.

produce 1000 variations a second in the plate circuit current, and 1000 vibrations of the receiver diaphragm which will be audible to human ears.

The same condition would hold if the forced or local oscillations were made to occur at a frequency of 1,001,000, for again the difference would be 1000 oscillations per second, and 1000 beats would result.

Autodyne and heterodyne reception.—With a receiving set in which the forced oscillations are produced by the detecting tube itself, the effect is known as *autodyne reception.*

In any case where the local oscillations, and hence the beats, are produced by a separate source—for example, by another tube in a circuit coupled to the detector circuit—the operation is known as *heterodyne reception.*

Heterodyne reception requires additional apparatus with the necessary additional adjustments and for that reason is not in common use among amateurs.

It might be suggested that in neither autodyne nor heterodyne reception, does the operator need to concern himself about the frequency of the local oscillations to be produced in receiving undamped or continuous waves. The aerial circuit and the secondary or grid circuit are tuned in the usual way, to the wave length of the signals which one desires to pick up. Then the tube is made to oscillate, either by increasing the coupling of the tickler coil or by varying its inductance; or, in the case of the tuned plate circuit which is not coupled to the grid circuit, by varying the inductance or the capacity of the plate circuit. As the various adjustments are made, the frequency of the forced oscillations will be varied, and when impressed on the incoming oscillations, they will give different beat notes or tones, ranging in frequency from below audibility to above audibility. As the different tones are produced, the operator may leave the apparatus adjusted at that point where the forced oscillations produce a beat note which is most pleasing to the ear or where signals or messages are most easily read through any interference which may be present.

It should be pointed out that distortion is likely to occur to a greater extent in beat reception than in simple regeneration. In fact, oscillation of the tube may often destroy signals entirely, as suggested at the beginning of this discussion. Distortion to the point of destruction of signals is due to the interaction of the radio-frequency and the audio-frequency currents in the circuits.

Both spark signals and voice, however, may be greatly magnified if the local or forced oscillations are made to occur at the frequency of the incoming oscillations. Such an effect is known as *zero beat* reception, since no beat is produced in the receiving set.

In the type of hook-up shown in Fig. 56, the plate circuit is *inductively coupled* to the grid circuit. Regeneration in a receiving set may also be obtained by *electrostatic coupling*, through the use of one or more condensers; by *conductive coupling*, with actual connection of the plate circuit to the grid circuit; or by combinations of the foregoing methods.

Regeneration by means of condensers.—Almost any type of vacuum tube receiving set may be made regenerative by simply hooking a condenser in the proper place in the circuit and changing two or three connections. Hook-ups for electrostatic and conductive coupling are shown in Figs. 58, 59, and 60. Of the many such circuits which are possible with tuning coils, these are probably the most common.

Short wave regenerative equipment.—In this connection, it might be said that tuning coils and loose couplers have been gradually abandoned by most amateurs, for short-wave regenerative sets using variocouplers, variometers, honeycomb and spiderweb coils, and various other forms of tuning inductance. The greater efficiency and ease of operation of these types of inductance are unquestionable; however, very good results can be obtained and greater wave lengths can be tuned in by means of tuning coils and loose couplers than are possible with the short wave regenerative set. And, even though a receiving set covering wave lengths up to 2500 meters is slightly inefficient for short wave length reception, it is suggested that the amateur first adapt to a regenerative hook-up, his tuning devices which he already is using, in order to become familiar with the characteristics of a single-tuned circuit, for example, or a loose-coupled circuit, before purchasing or assembling a more efficient short wave or long wave receiver.

Tapped coils in the regenerative set.—Although the tuning inductances in the following two hook-ups are shown with sliding contacts, it should be noted that coils with taps will give much better results in a regenerative circuit, for the following reason: As a slider is moved across the turns of wire, breaking contact with one turn and making contact with the next, a distinct click is heard in the receivers for every make and every break, if the tube is oscillating for receiving continuous wave (C. W.) signals. If the slider is moved at all quickly, the rapid succession of clicks will sound like a roar, often drowning out the signals which one is trying to pick up. In the case of tapped coils with switch points close together, the switch arm, in revolving, makes contact with a new switch point before breaking contact with the one it is leaving, and therefore does not cause the objectionable roar referred to above.

The corresponding tapped coil described in Chapter IV may be substituted for any of the slide coils which follow, without change in other parts of the hook-up.

The single slide tuning coil in a regenerative set.—Fig. 58 shows a hook-up for a single slide tuning coil and a vacuum tube detector in which the radio-frequency fluctuations in the plate circuit are fed back to the grid circuit by direct connection from the plate. In this case,

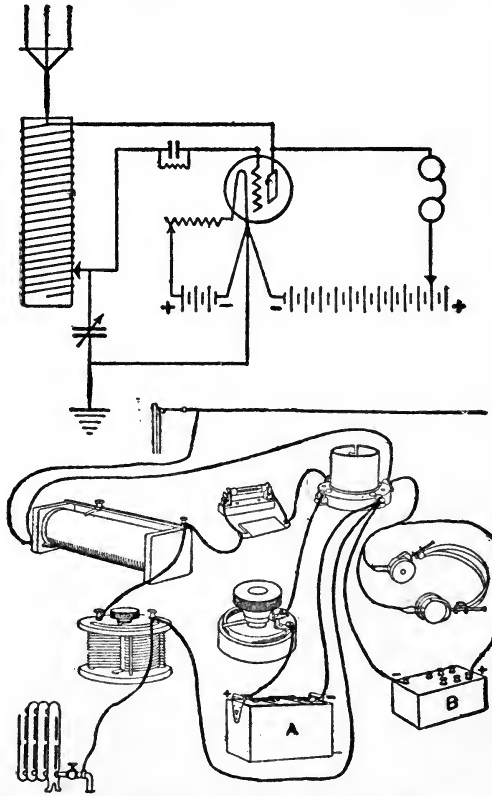


FIG. 58.—HOOK-UP FOR A SINGLE SLIDE TUNING COIL IN A REGENERATIVE SET.

the plate is *conductively coupled* to the grid circuit, and also *electrostatically coupled* since the feed back circuit includes the variable condenser shown in the ground lead.

Tuning is accomplished by means of the slider (as explained in connection with Fig. 16, Chapter IV) as well

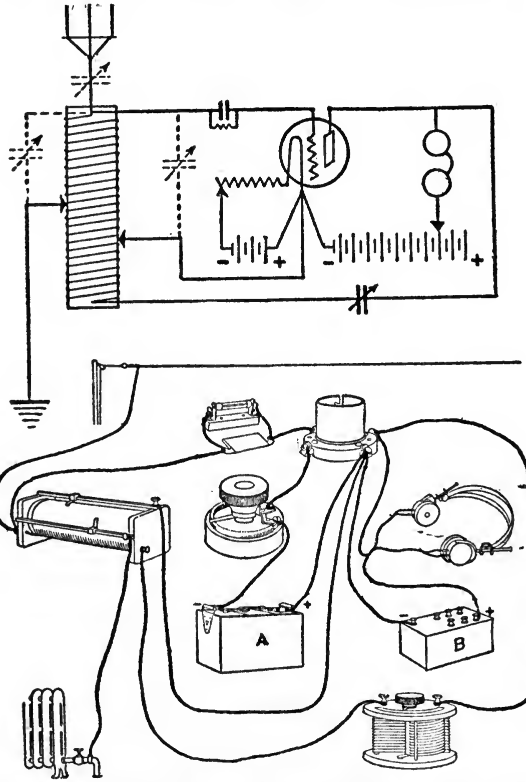


FIG. 59.—HOOK-UP FOR A DOUBLE SLIDE TUNING COIL IN A REGENERATIVE SET.

as by means of the variable condenser which is in series with the aerial circuit, the local circuit, and the feed-back circuit.

Highly satisfactory results should not be expected from the single slide or tapped tuning coil set converted into a regenerative receiver, owing to inability to control regeneration successfully.

The double slide tuning coil in a regenerative set.—Fig. 59 shows the fundamental hook-up for connecting up the double slide tuning coil for regeneration. Regeneration in this set also is obtained by a combination of electrostatic and conductive coupling. A connection is made from the plate, through a condenser, to the end of the coil opposite the lead-in connection. Regeneration in this case is more readily controlled than in the single slide tuning coil hook-up.

As explained in connection with Fig. 31, Chapter IV, the primary circuit is tuned by the slider to which the ground wire is connected, and the secondary circuit is tuned by the other slider. It can readily be seen that the energy which is fed back will pass through the turns of wire which are included in that part of the coil between the plate connection at one end and the turn where the secondary slider makes contact with the coil. Part of the energy will also flow through all of the coil of wire and pass to the grid itself. Furthermore, induction from the turns of wire in the feed-back circuit will build up the oscillations in the turns of wire included in the grid circuit between the lead-in connection at one end of the coil, and the secondary slider. It is evident that the regenerative effect in this case is obtained in a somewhat complex manner but the regeneration is entirely controllable by the electrostatic coupling through the condenser in the plate circuit. As indicated by dotted lines, a condenser may be used (1) across the secondary or grid circuit, (2) in series with or (3) in parallel with the primary circuit for increasing or decreasing wave length range as explained on page 61, Chapter IV, but very little advantage in tuning will be gained by their use.

As suggested for the preceding hook-up, it is desirable to use tapped coils rather than slide coils for regenerative hook-ups.

Variations in "A" battery hook-ups.—A variation is introduced in the connections of the "A" battery in this hook-up. The grid of the vacuum tube is shown connected, through the tuning inductance and the secondary slider, to the positive terminal of the "A" battery. With the grid connected to the positive side of the "A" battery, a grid condenser and a grid leak are necessary, while with the grid connected to the negative terminal of the batteries, the grid condenser and leak are optional. Even in the latter case, however, the average tube will function much better with a grid leak and condenser than without them.

In connecting positive "A" to negative "B" through the filament binding post as shown in this diagram, an additional positive potential is obtained on the plate in relation to the filament, since the "A" battery voltage has been placed in series with the voltage of the "B" battery.

It is a simple matter to try out both methods of hooking up the batteries in order to determine which connection will give best results in a given set. Care must be taken, however, to *avoid connecting the "B" battery across the terminals of the filament.* Such a connection would instantly burn out the filament.

As suggested in Chapter V, various sizes of grid condensers and grid leaks should be tried out with different bulbs.

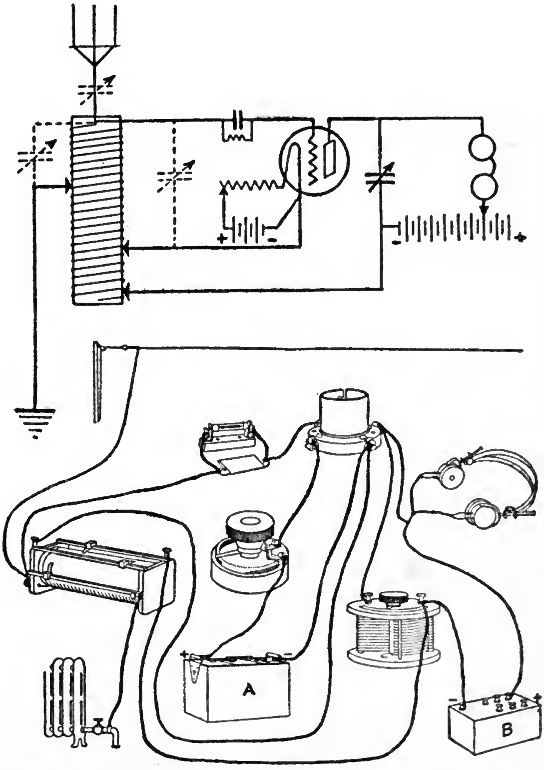


FIG. 60.—HOOK-UP FOR A THREE-SLIDE TUNING COIL IN A REGENERATIVE SET.

The three-slide tuning coil in a regenerative set.—Fig. 60 shows the hook-up for using a three-slide tuning coil as a tuner in a regenerative receiving set. The tuning of the primary circuit is accomplished by means of the ground slider and of the secondary or grid circuit, by means of the secondary slider, as explained in Chapter IV. Tuning

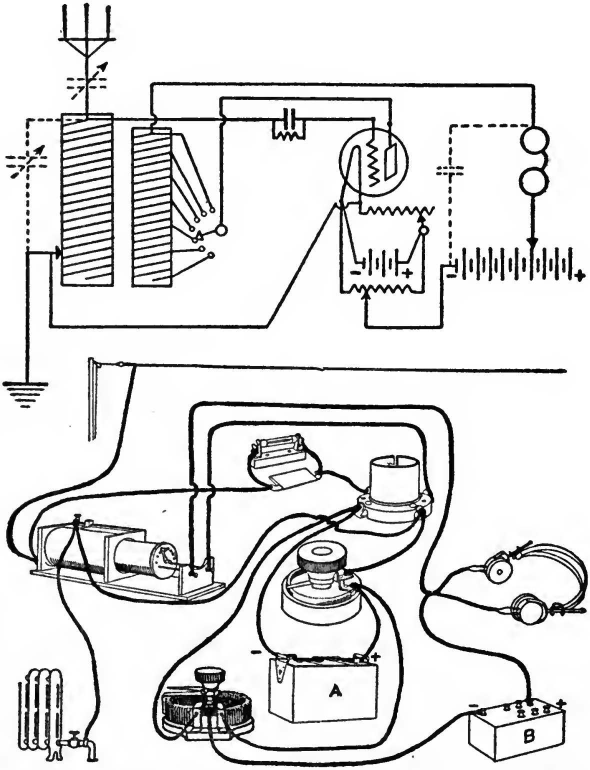


FIG. 61.—HOOK-UP FOR A LOOSE COUPLER IN A REGENERATIVE SET.

of the plate circuit as well as the control, in part, of regeneration, is accomplished by means of the condenser shown in full lines in the plate circuit; regeneration, however, is mainly controlled by the slider to which the plate circuit is connected. The greater the number of turns between the secondary and the plate sliders, the greater will be the regenerative effect. Additional condensers may be used, as shown by dotted lines, for increasing or decreasing the wave-length range of the tuner, as discussed in Chapter IV.

The loose coupler in a regenerative set.—Fig. 61 shows the adaptation of a loose coupler to a regenerative hook-up, through *inductive coupling*. The secondary of this tuning device is used as a tickler coil; *i. e.*, the plate circuit is inductively coupled to the grid circuit (which is also the primary circuit in this case) for regeneration. This tickler adjustment will be found to be quite critical, but regeneration can readily be controlled by both the taps on the secondary and the coupling of the secondary coil to the primary coil.

It should be observed that the primary winding of the loose coupler is used virtually as a single slide tuning coil; and condensers may be used in the primary circuit as shown by dotted lines. If desired, both the primary and the secondary windings may be connected in series and used as one tuning coil for long waves; in that case, the connections would be identically the same as shown in Fig. 58 except that the two coils would be wired in series. The loose coupler illustrated has taps on the secondary coil and a slider on the primary coil, but any of the loose couplers described in Chapter IV may be used in place of this one, with the grid circuit leads of this hook-up so connected that they replace the secondary circuit leads in the loose coupler crystal detector hook-ups.

"A" battery and "B" battery potentiometers.—Note that the hook-up of the "A" and "B" batteries in this diagram shows a potentiometer connected across the "A" battery with the negative of the "B" battery connected to the sliding contact of the potentiometer. The voltage drop of the "A" battery across the terminals of the potentiometer is utilized for adding voltage in very small amounts to the plate circuit. The main variations of the plate voltage are made by means of the taps on the "B" battery, and finer adjustments are then obtained by moving the sliding contact of the potentiometer. The potentiometer may be in the form of a carbon compound resistance rod having a contact which slides along its length or having contact points imbedded in it over which a switch arm rotates; or it may be in the form of a coil of high-resistance wire with a sliding contact, similar to a rheostat. It should have a resistance of about 400 ohms. The current from the "A" battery consumed by the potentiometer is negligible.

Few vacuum tubes on the market at the present time are critical enough to require the use of a potentiometer for adjusting the plate voltage. However, gas content tubes, which are vacuum tubes having a slight quantity of a certain kind of gas introduced into them in manufacture, are quite critical in both filament and plate current adjustment but when accurately adjusted, are more sensitive than other tubes; therefore, a potentiometer is frequently used with them.

A "B" battery potentiometer, that is, a potentiometer connected across the "B" battery for fine variations of plate voltage, should not be used, as it causes a drain on the "B" battery which, slight as it may be, will materially reduce the life of the "B" battery.

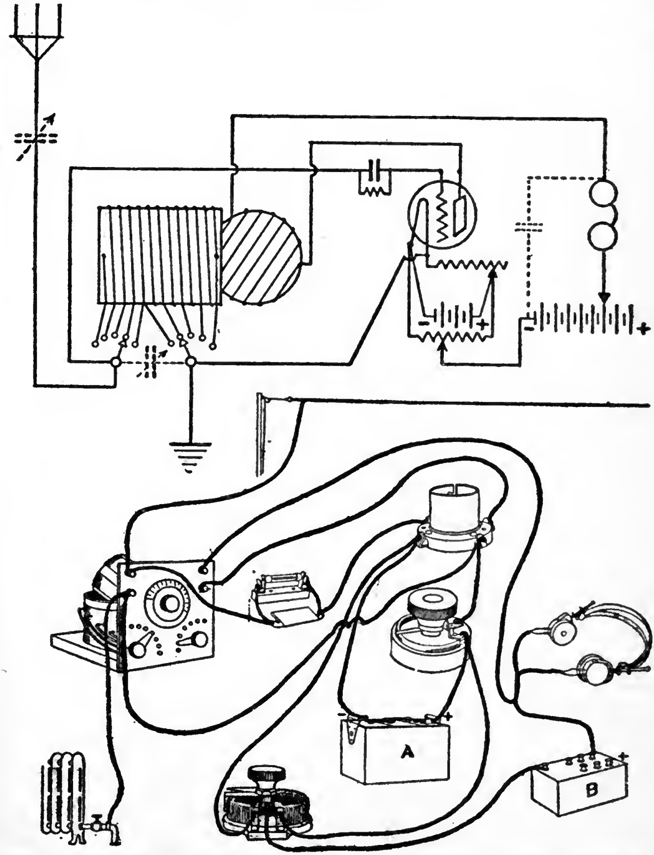


FIG. 62.—HOOK-UP FOR A VARIOCOUPLER IN A REGENERATIVE SET.

The variocoupler in a regenerative set.—Fig. 62 shows the hook-up for a variocoupler in a regenerative circuit. The connections for this instrument are practically the same as those for the loose coupler shown in Fig. 61. That is to say, the primary of the variocoupler is employed as a single-slide tuning coil, and the secondary is connected in series with the plate circuit and made to react back upon the grid circuit through the coupling of the primary and secondary coils.

As explained on page 77, the secondary of a variocoupler is not variable in turns of wire; the regenerative effect is entirely controlled by rotating the spherical shaped secondary or tickler coil.

As explained on page 95, Chapter IV, the magnetic effect of one coil upon another is at maximum when the turns of wire in the first coil are in the same relative position as the turns of wire in the second coil. In the case of a tickler coil which may be rotated, as for example, the secondary of a variocoupler, there are two possible positions where its turns of wire will be in the same relative position as the turns of wire in the primary coil. In one position, the fluctuations of the plate current will build up on the incoming oscillations and therefore produce regeneration. In the opposite position, that is, with the coil rotated 180°, or given a half revolution, the fluctuations of the plate current will oppose the incoming oscillations in the primary coil and give "degeneration".

In this case it is simply a matter of turning the secondary or tickler coil to one position or the other in order to find which position gives regeneration or increase of signal strength.

There are also two possible positions of the secondary or tickler coil in which its turns of wire will be at right angles to the turns of wire on the primary coil. In either of these positions the effect of the plate current fluctuations on the incoming oscillations in the primary coil will be zero.

A revolving coil coupled to the grid circuit in this manner furnishes one of the most flexible means of controlling the feed-back effect in a regenerative receiving set. The primary coil of the variocoupler, which forms both the primary and secondary circuits of this receiving set, is shown with both a units and a multiple turns switch, thereby permitting close adjustment to wave length with the turns of wire. This particular instrument used in this manner constitutes an excellent short wave regenerative receiver.

A condenser may be used in either position, as shown by dotted lines in the primary circuit, to increase or to decrease the wave length range of the receiver, or to aid in sharper tuning to signals. A condenser might also be used in shunt to the tickler coil, to assist in regeneration, for reasons which will be explained in connection with *tuned plate* circuits.

An "A" battery potentiometer is shown in this diagram and is used as explained for the preceding hook-up.

The grid of the vacuum tube is shown connected to the positive end of the filament for reasons suggested on page 140 in connection with the hook-up in Fig. 59.

Any of the four methods of connecting the "A" and "B" batteries which have been shown to this point may be used interchangeably in vacuum tube detecting or regenerative circuits with varying results. In most of the circuits which follow, however, the negative "B" to negative "A" connection will be shown.

Building a regenerative receiver with a tickler coil.—The advantages and disadvantages of the single-circuit

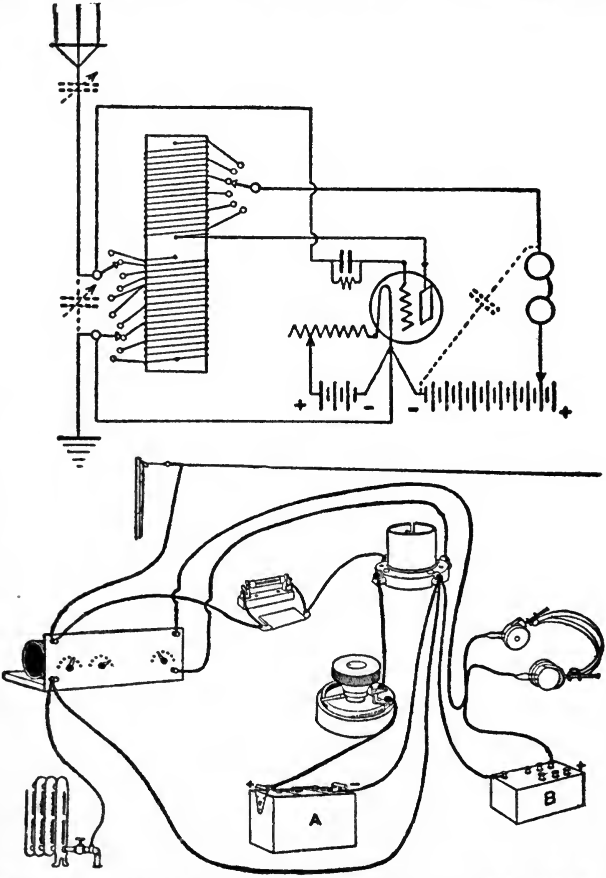


FIG. 63.—DIAGRAM FOR HOME CONSTRUCTION OF A REGENERATIVE RECEIVER WITH A TICKLER COIL.

type and the coupled type of receiver have been discussed in Chapter IV.

It might be said that the single-circuit type of receiver is coming into favor with the novice, largely owing to its simplicity of control. There is no question that the coupled type of receiver offers greater selectivity than the former type, although that does not mean that the single-circuit type is not selective. Because of simplicity of control, as well as for reasons previously mentioned, it is suggested by the authors that the novice, in attempting to build a regenerative receiver, first construct a single-circuit type and become familiar with its operation before attempting the construction and manipulation of the coupled type of receiver with tuned grid and plate circuits, and its many controls.

If the reader desires to use the tickler or inductive method of coupling with a single-circuit receiver, to secure a regenerative effect, it is advisable to construct a new tuning coil with a tickler winding on the same tube, rather than to attempt to adapt the ordinary tuning coil to the new purpose.

In Fig. 63 is shown the wiring diagram for a single-circuit receiver, using a tickler coil, which has been very successfully operated by many who were not thoroughly acquainted with regenerative receivers. It will be noted from the diagram that the tuning inductance—that is, the coil of wire which tunes the aerial (and in this case, the secondary or grid circuit as well)—performs the same function as a single-slide tuning coil or the tapped coil suggested in connection with Fig. 58. It should also be noted at this point that it is not necessary to adhere strictly to the suggestions here given for the construction of the set. For example, a multiple turns switch may be used in place of the units and the multiple turns switch on the tuning inductance; or other variations might be made. However, if both multiple and units switches are employed, the necessity for variable condensers to tune the aerial and the grid circuits will be removed. Other features of the set might also be changed, but again, some arrangement would have to be made to compensate for any change, and unless the reader fully understands the principles of the regenerative receiver, it might be confusing to attempt to alter, to any extent, the design of this set.

The constructional details for this receiver are as follows:

The form on which the two coils are wound should be about 3 inches in diameter and 8 inches long. Such a form may be obtained in the shape of a cardboard mailing tube or other pasteboard tube. One hundred turns of No. 24 insulated wire are wound on one end of the tube, for tuning inductance. This wire may be enamel covered, or single or double cotton or silk covered wire but double silk-covered wire is preferable, for low values of distributed capacity and high efficiency in insulation. The winding is done as suggested for the tapped coil described in Fig. 30, but in this case, 10 single turns are connected to 11 switch points for the units switch and the remaining 90 turns are connected to 10 points of the multiple switch. It can of course be seen that this winding differs from that of the tapped coil described on page 68 in that the multiple switch is a ten's switch instead of a five's switch and that 10 single turns are tapped for the unit switch instead of 5 turns.

About ½ inch space is left between the tuning inductance winding and the tickler winding. The tickler winding consists also of 100 turns, and is wound on the other end of the same tube. The winding is begun, as suggested above, at a distance of ½ inch from the end of the inductance winding. The tickler winding is made variable by 10 taps, for ten turns each, taken from it. It should be noted, however, that it will require 11 switch points, and that the first one is connected at the beginning of the winding, to enable switching all of the tickler winding out of the circuit if it is desired to prevent feed-back effect or regeneration. This control would perhaps not be necessary in most cases, but if a tube which oscillates readily is used, the control might be necessary in order to prevent distortion when receiving radiophone speech or music. Care should also be taken that the switch points of both windings are connected as shown in the diagram, so that whatever plate inductance is used will be adjacent to the turns of wire used in the tuning coil. In other words, if it were necessary to use only 10 or 20 turns in the tuning inductance for tuning to short waves, approximately the same number of turns in the plate inductance should be used for maximum regeneration and the wiring should be arranged as shown, so that the 10 or 20 turns in the plate inductance would be near the turns employed in the tuning inductance. In winding either coil, perhaps the best method of taking off the taps would be to punch a hole in the cardboard form at the place where each tap is to be taken. Then a loop of the wire long enough to reach to the switch point, is drawn through the hole and the winding is continued to the next hole. The loops which have been drawn through the tube, are then brought from the inside of the tube and connected to the switch points. This method eliminates the necessity of soldering taps to the wire in the coil.

The whole receiving set may be mounted on a base board for a panel type of set such as that shown in the picture diagram, Fig. 63. In that case, the switch points would be on the panel front with the taps led to them. It might be suggested at this point that a highly polished hard rubber or composition panel does not add to the efficiency of a set. It only adds to the appearance and facilitates the control. Equally good results may be obtained by mounting all of the instruments of this set on a board with the switch points also mounted thereon, or with the switch points mounted on a block fitted into the end of the tube as shown in the picture diagrams for the loose coupler. Switch points connected to a block fastened in the end of the tube are, however, very difficult to wire. Practically all of the other instruments which go to make up the set would have to be purchased. The grid condenser and the by-pass condenser could be made at home, but if best results are desired, these condensers should be purchased. The by-pass condenser, as in the case of the other regenerative receiving sets in this chapter, should have a value of about .001 to .002 mfd., and the grid condenser a value of approximately .00025 mfd. A grid leak of the value of 2,000,000 ohms might be selected, but as previously mentioned, not every grid leak or grid condenser will work well with all tubes. A variable condenser may be used in series in the aerial circuit, for tuning to short wave lengths, or it may be used in shunt to the primary or to the grid circuit (which in this case are the same) for tuning up to long wave lengths. These connections for the variable condenser are suggested by dotted lines.

There are many good types of rheostats, switches, batteries, and phones on the market, and it is a matter of price and design as to what makes shall be selected.

In tuning this set for spark signals or radiophone voice or music, the plate inductance should be set at the zero switch point and the tuning inductance varied as in the case of the single-slide tuning coil and other single-circuit receivers previously described. When the voice or signals have been picked up, plate inductance may be added by rotating the switch until regeneration results, and the increase of signals is obtained to the desired extent. This method will enable the operator to increase the strength of the signals which are first heard.

The more difficult tuning comes in picking up signals which are too weak to be heard without regeneration. In that case, the plate inductance and the tuning inductance should be varied, with a corresponding increase and decrease of each inductance, throughout the range of the switch points. This last method enables the maintaining of regeneration just below the point of oscillation and thereby gives maximum sensitiveness in tuning.

For the reception of continuous wave signals with this set, oscillation must of course be maintained, by using a sufficient amount of plate inductance at all times, and tuning with the aerial or the grid inductance. This procedure enables beat reception, as described at the beginning of the chapter.

Two honeycomb coils in a regenerative set.—Fig. 64 shows the connections for two honeycomb coils in a

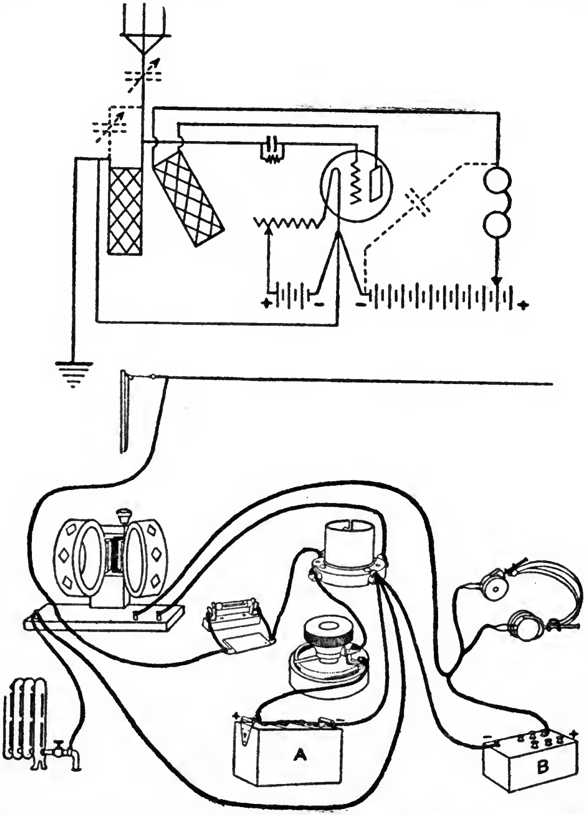


FIG. 64.—HOOK-UP FOR REGENERATIVE EFFECT WITH TWO HONEYCOMB COILS.

regenerative circuit. The action of these coils is precisely the same as that obtained by the use of a loose coupler or a variocoupler, in that one of the two coils is used as inductance in the primary and secondary circuits, while the other is used for feeding back the plate energy to the grid circuit. The feed-back effect is entirely controlled by varying the distance separating the coil in the plate circuit from that in the grid circuit. This is usually done by moving the tickler coil away from or towards the other coil in the manner described in connection with Fig. 43, Chapter IV.

The sizes of the two coils should be about equal. As the coils are not variable for fine adjustments in turns of wire, it is necessary to employ a variable condenser either in shunt to or in series with the coil in the grid or secondary circuit (which is also the primary circuit in this case). A variable condenser may also be employed in shunt to the plate circuit coil, as suggested for preceding diagrams.

It may be found that, for reasons explained in connection with the loose coupler in a regenerative set, the wires leading to the coil used as the tickler may have to be reversed as the coils may not be of correct *polarity*.

Two spiderweb coils or other coils of similar type, may be connected and operated in identically the same manner as the two honeycomb coils. As suggested in Chapter IV, best results will not be obtained by the use of one coil, of any of these types, for tuning both the primary and secondary circuits of a receiving set. Better tuning will result in the use of the following hook-up.

Regeneration with three honeycomb or three spiderweb coils.—In Figs. 65 and 66, regenerative hook-ups for three honeycomb coils and three spiderweb coils, respectively, are shown. In each case, one coil is used as the primary, the center or fixed coil as the secondary, and the third coil as a tickler. Coupling is obtained between

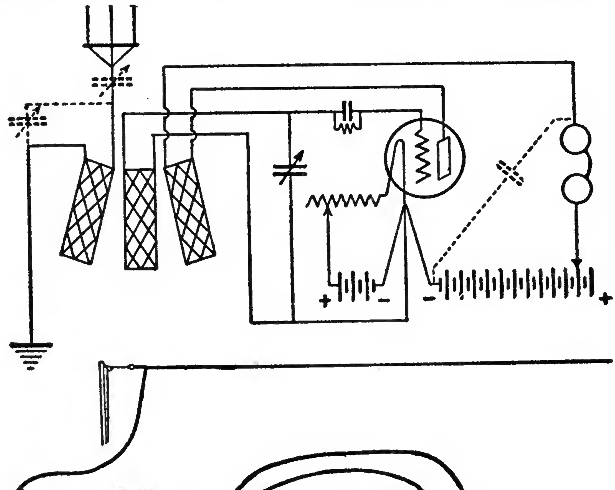


FIG. 65.—HOOK-UP FOR THREE HONEYCOMB COILS IN A REGENERATIVE SET.

the primary coil and the secondary or grid coil as well as between the tickler and the grid coil.

Again, variable condensers must be used for both the primary and the secondary circuits in each receiving set;

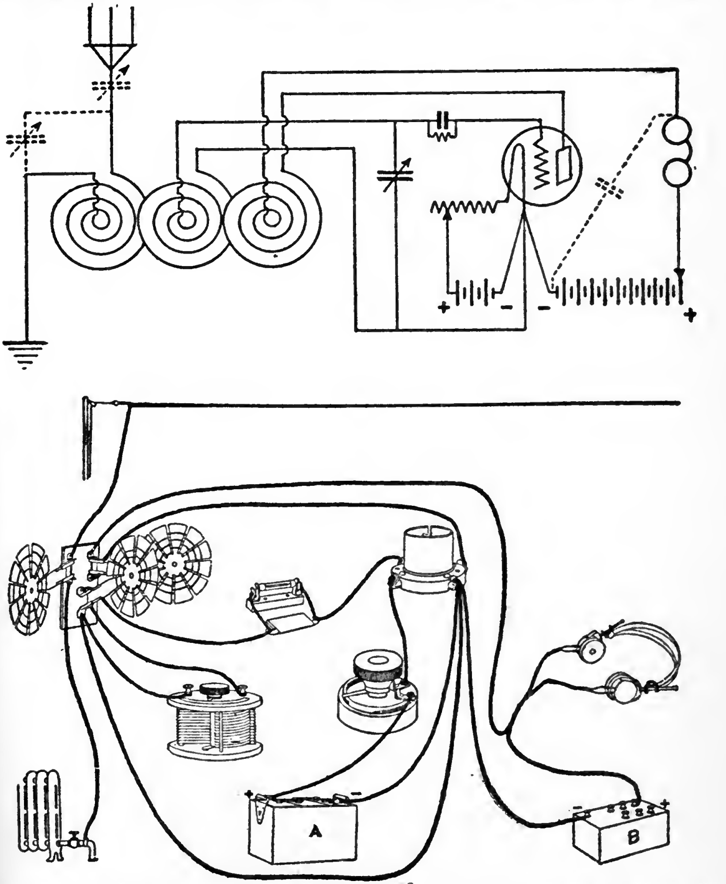


FIG. 66.—HOOK-UP FOR THREE SPIDERWEB COILS IN A REGENERATIVE SET.

a third condenser may be used in the tickler circuit, as suggested for the preceding hook-ups.

THE TUNED PLATE CIRCUIT IN REGENERATION

The single-slide tuning coil is again shown in Fig. 67, having what is commonly called a *tuned plate* circuit instead of the *inductively, conductively,* or *electrostatically* coupled plate circuit or a combination of the foregoing methods of coupling.

Almost any form of variable inductance, as a tuning coil, for example, may be connected in series with the plate circuit to obtain a regenerative effect; but the variometer, as shown in the hook-up, is preferable because of the ease with which the regenerative effect may be controlled by revolving the rotor of the variometer. (See page 96, Chapter IV.)

In the tuned plate regenerative receiver, the plate circuit is placed in tune with the secondary or grid circuit (and likewise with the aerial circuit) by altering the relative position of the inductance coils in the variometer.

When oscillations from incoming signals occur in the grid circuit, they produce corresponding pulsations in the "B" battery current of the plate circuit. From the discussion on page 95, Chapter IV, it can be seen that a sudden increase in the plate current passing through the plate tuning inductance, will generate in the coils of the variometer, a back electromotive force (E. M. F.) which will tend to oppose the impulse. Likewise the immediately following decrease of the plate current in the plate inductance, will generate a back E. M. F. which will tend to sustain the decreasing plate current. These E. M. F.'s induced in the inductance, alternately aiding and opposing the plate current, set up oscillations of plate current which react upon the grid circuit, partly through the connections of the plate circuit to the grid circuit and partly through the condenser effect between

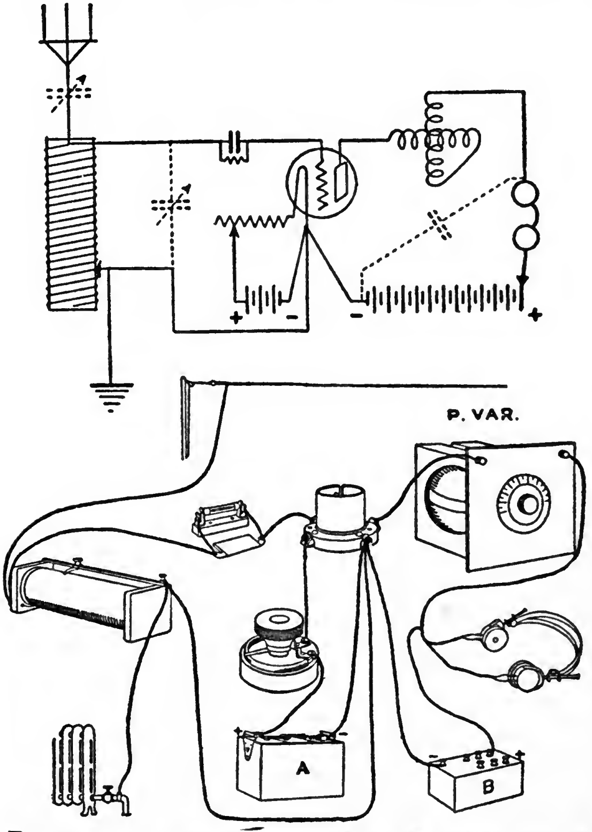


FIG. 67.—HOOK-UP FOR A SINGLE SLIDE TUNING COIL IN A TUNED PLATE REGENERATIVE SET.

the plate and the grid in the vacuum tube. The oscillations of the plate current, reacting on the grid circuit in this manner, build up the original oscillations in the grid circuit, and therefore amplify the oscillations imposed on the grid by the energy from the received waves.

In using a variometer in the plate circuit, the maximum increase or decrease, or amplitude of the fluctuations in the plate current will be obtained when the inside or rotor winding is placed so that its turns of wire are running in the same direction as the turns of wire on the outside coil, provided the plate circuit happens to be in tune with the grid circuit at that position. Likewise, the wave length of the plate circuit will be at a maximum when the rotor is in that position, as explained on page 95, Chapter IV. If the rotor is revolved 180 degrees, the inductance effect, and therefore the regenerative effect and the wave length of the plate circuit, will be at a minimum.

It is evident that in revolving the rotor toward maximum inductance, both the wave length and the regenerative effect are increased at the same time, resulting in an arrival at maximum regeneration by means of a combination of tuning and the reacting of the plate circuit.

A combination of the tuned plate circuit and the coupled plate circuit may be arranged which will give even better results than will either arrangement alone. That is to say, the inductance in the plate circuit may be tuned, and at the same time coupled to the grid circuit as is the case with the variable tickler coil described in connection with Fig. 63. Again the tickler coil itself need not be variable, as shown in Figs. 62 and 64, but may be tuned by means of a variable condenser placed in shunt to it, or by a variable inductance, such as a variometer, placed in series with it.

For receiving short wave lengths with such receivers, the values of the tickler coil and the plate tuning inductance would have to be such that the plate circuit could

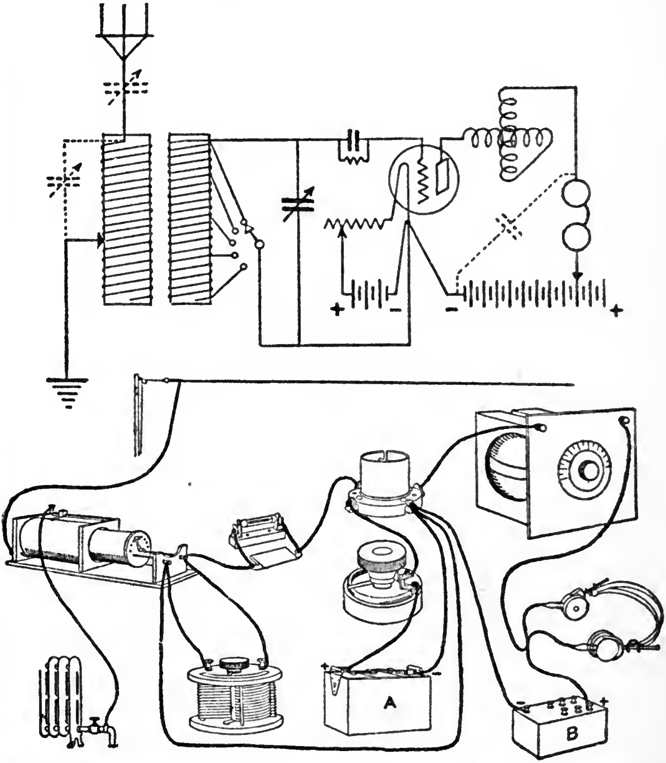


FIG. 68.—HOOK-UP FOR A LOOSE COUPLER IN A TUNED PLATE REGENERATIVE SET.

be tuned low enough to reach the desired wave length, for example, 200 or 360 meters.

Directions for tuning the variometer tuned plate circuit are given more in detail on page 166.

Regeneration with other types of tuning inductance.—The single-slide tuning coil which is shown in Fig. 67

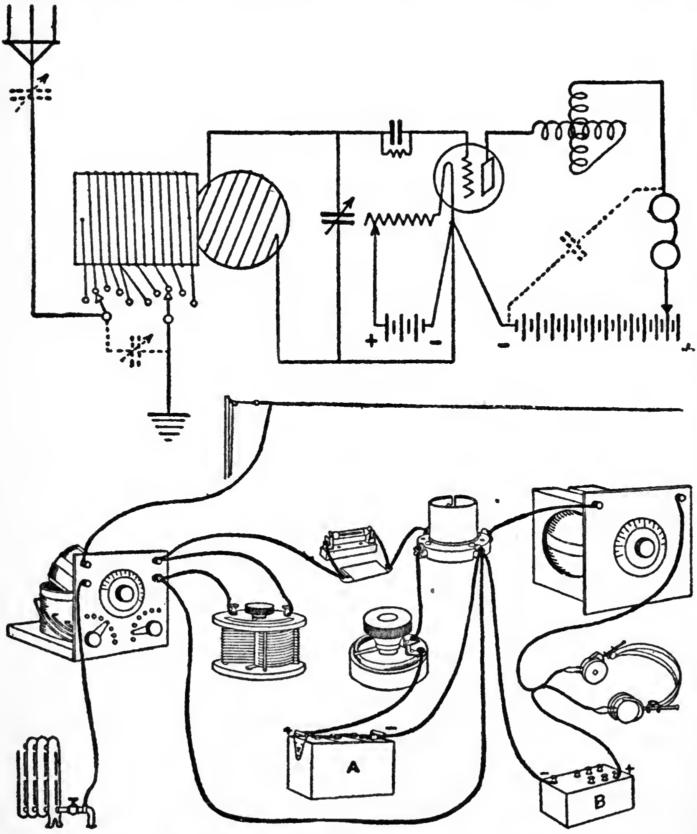


FIG. 69.—HOOK-UP FOR A VARIOCOUPLER IN A TUNED PLATE REGENERATIVE SET.

may be replaced by the double-slide coil, the triple-slide coil, or any one of the tapped coils, by simply connecting the grid circuit leads of the vacuum tube detector in place of the secondary circuit leads of the crystal detector sets shown in Chapter IV. For that reason, many of those possible circuits will not be shown in this chapter.

Figs. 68 and 69 show the connections for tuned plate regenerative circuits employing a loose coupler and a variocoupler, respectively. The action of the tuned plate circuit is exactly similar to that described in connection with Fig. 67.

The loose coupler in Fig. 68 may be replaced by any other form of loose coupler; a variocoupler having only the multiple switch instead of a units and a multiple switch may of course be used in place of the one indicated in Fig. 69. For sharp tuning, a second variable condenser in either of the positions in the aerial circuit, indicated by dotted lines, would then be necessary.

VARIOMETER TUNED PLATE AND GRID CIRCUITS IN REGENERATION

Regenerative set with a tuning coil and two variometers.—In Fig. 70 is shown the hook-up for a tuning coil and two variometers—one in the plate circuit and one in the grid circuit.

In this particular hook-up, a two-slide tuning coil is shown. However, a similar coil with taps, or the single slide or single tapped, or the triple slide coil, may be connected in its place as has been suggested for preceding diagrams. Any of those types of coils would constitute the well-known *single circuit* receiver with variometer tuned plate and grid circuits.

It should be noted that the grid variometer will enable tuning to wave lengths greater than the secondary circuit of the tuning coil alone could accomplish. Condensers may be used, if desired, for increasing or decreasing

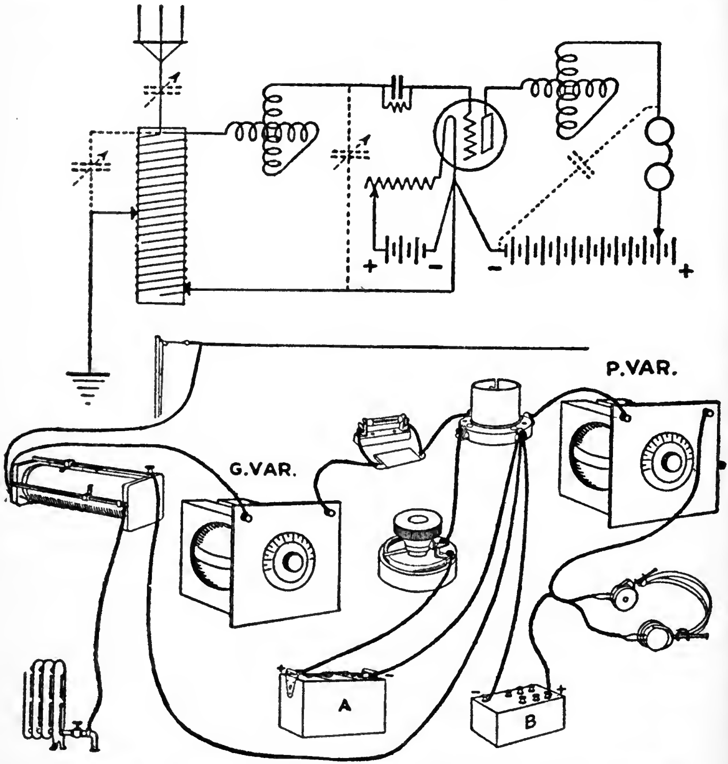


FIG. 70.—HOOK-UP FOR A REGENERATIVE SET WITH A DOUBLE SLIDE TUNING COIL AND TWO VARIOMETERS.

wave length, as indicated in the secondary circuit and in the primary circuit. Procedure in tuning with tuned plate and grid circuits will be considered in detail in connection with the following diagram.

Regeneration with a loose coupler and two variometers. —Fig. 71 shows the use of the loose coupler in what is

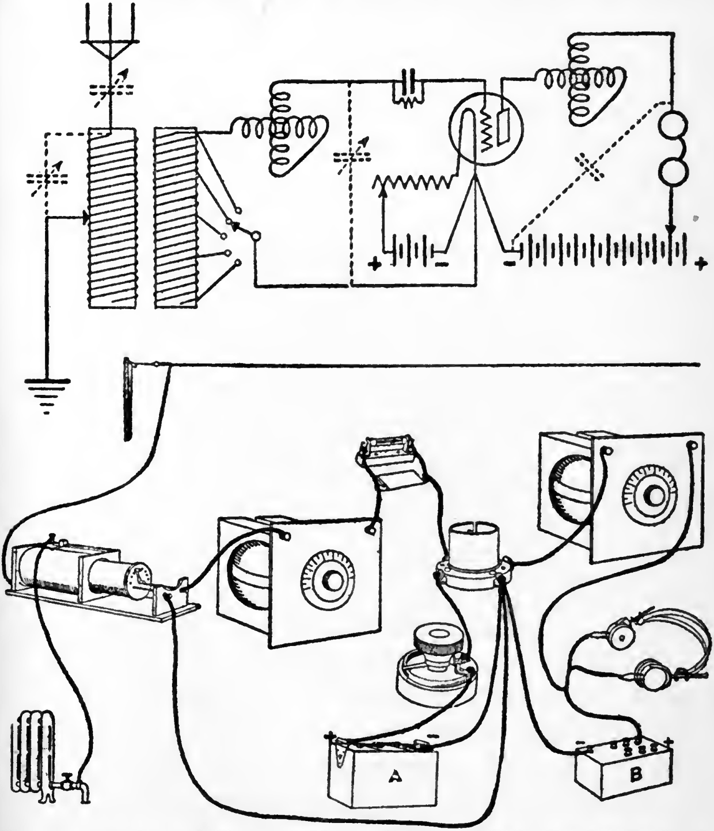


FIG. 71.—HOOK-UP FOR A LOOSE COUPLER AND TWO VARIOMETERS IN A REGENERATIVE SET.

known as the *coupled circuit* type of regenerative receiver, with variometer tuned plate and grid circuits. Again in this case, any other form of loose coupler described in

Chapter IV may be substituted for the single slide coupler here illustrated. Connections are shown for the use of variable condensers, if it is desired to increase or decrease the wave length range of the set.

Tuning the set with tuned plate and grid circuits.— There are two distinct methods of procedure in tuning any set employing variometer tuned plate and grid circuits.

In tuning for spark or telephone stations, the plate variometer may first be set at minimum inductance, producing no regeneration and therefore no distortion from regenerative amplification. If the receiving set is of the coupled circuit type, the coupler is set for tight coupling. Next, an adjustment of the primary circuit to the desired wave length is approximated. At the same time, the secondary or grid circuit is tuned by means of the secondary inductance, if the coil is variable, and by the grid variometer in order to keep the primary and secondary circuits somewhat in resonance while tuning in the signals. If the secondary inductance of the tuner is not variable, the grid variometer only is used for tuning that circuit. After both the primary and the secondary circuits have been tuned to the desired signals, the plate variometer may be slowly rotated, in order to amplify the signals by means of regeneration, until the signals or voice begin to break, or become distorted from violent regeneration or from oscillation of the tube. Then the coupling of the tuner, if of the coupled type, may be reduced, in order to reduce the possibility of interference from other stations which may start transmitting.

The foregoing method may be used for tuning in and amplifying signals, which are strong enough to be heard without the aid of regeneration. The following method, however, must be resorted to for picking up spark or telephone signals which are too weak to be heard without regeneration.

Again, if the receiving tuner is of the coupled type, set the instrument for tight coupling. Next, adjust the primary circuit approximately to the wave length of the desired signals, as suggested above. Then, with the secondary inductance (if it is variable) adjusted to furnish a small amount of inductance, rotate the grid variometer and the plate variometer each through a complete turn. The two variometers should be revolved at the same time, one following the other, in such a way that maximum regeneration is maintained throughout the complete revolutions of the two instruments. Bear in mind that maximum regeneration occurs and therefore maximum sensitiveness of the detector is attained when the set is adjusted to just below the point of oscillation.

Signals picked up in the manner last described are rarely loud enough to permit loosening the coupling to any extent. However, loose coupling to even the slightest degree will always help to reduce the possibility of interference.

Exactly the same operations, as those described in the method of tuning last suggested, are gone through in tuning for C. W. or undamped wave signals, except that in the latter case, while the variometers are being rotated, the detector is kept in a state of oscillation rather than regeneration.

This condition imposes, at all times, forced oscillations of varying frequency on any incoming continuous oscillations which are picked up as the variometers place the grid and the plate circuit in tune with different wave lengths within their range. The result is the production, at will, of beat notes of any desired tone for a given station.

It can now be seen that the continuous waves, or *carrier wave* of a radio telephone transmitter, may be picked up, as well as the voice modulated portions, by simply changing the adjustments of the instruments from those which produce regeneration to those which produce oscillation.

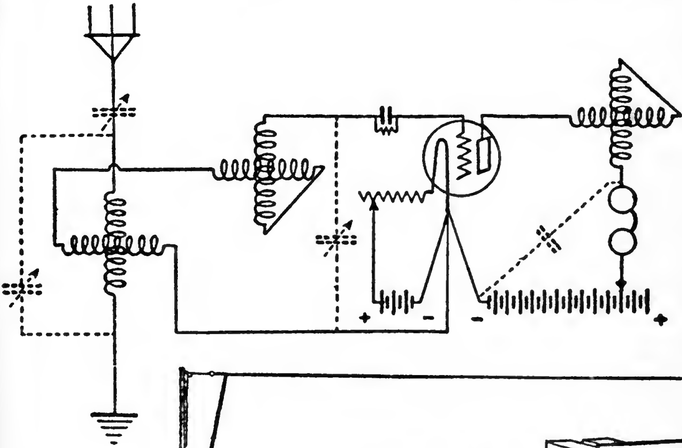
The foregoing principles of operation apply, in part, to the tuning of variometer tuned plate circuit regenerative sets shown in preceding diagrams, while all of the above suggestions apply directly to the variometer tuned, grid and plate regenerative sets which follow in this chapter.

The arrangement of two variometers—one in the plate circuit and one in the grid circuit—provides a more flexible control than does the variable condenser, for varying the wave length in tuning to stations whose wave lengths fall between the taps on the secondary of the loose coupler. The hook-ups using two variometers in this manner are therefore popular among amateurs.

A regenerative set with a variocoupler and two variometers.—In Fig. 72 is shown what is perhaps the most popular type of receiving set with amateurs—the receiving set employing a variocoupler and two variometers. As noted above, this set is tuned in exactly the same manner as the preceding set.

Simplified regenerative set using two variometers.—

Fig. 73 shows the hook-up for a regenerative set with two variometers. One variometer is used as tuning induct-



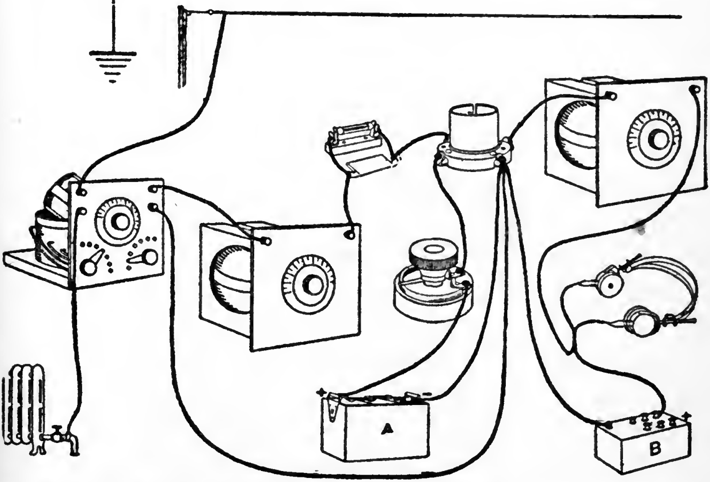


FIG. 72.—HOOK-UP FOR A VARIOCOUPLER AND TWO VARIOMETERS IN A REGENERATIVE SET.

ance for both the primary circuit and the grid circuit. At the same time, it affords the flexibility of control in the grid circuit referred to in connection with the last three circuits.

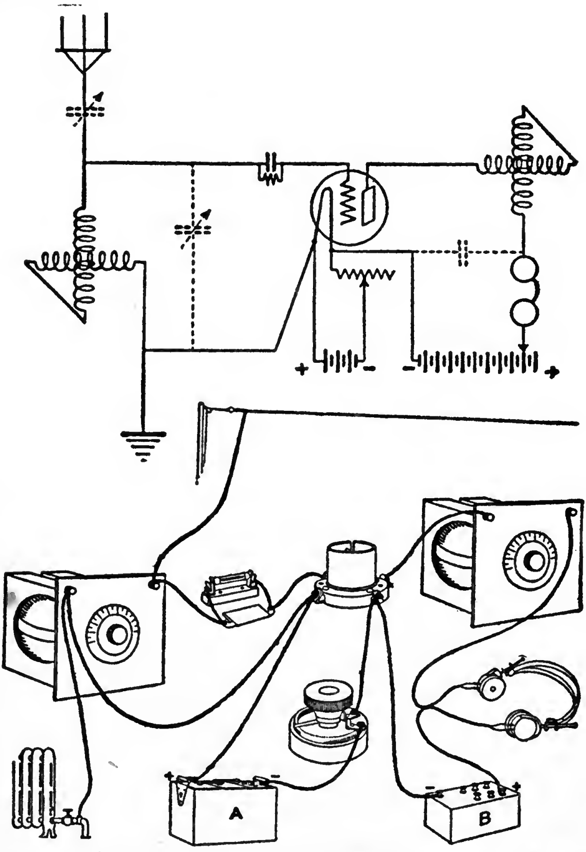


FIG. 73.—HOOK-UP FOR A SIMPLIFIED REGENERATIVE SET USING TWO VARIOMETERS.

On the other hand, the variometer in this position has the same disadvantage as the single slide tuning coil. That is to say, it varies the wave length of both the primary and the secondary circuit at the same time. The inclusion of a variable condenser, however, in series in the aerial circuit will permit independent tuning of this circuit, to a certain extent.

The advantage of this type of receiver is in simplified control. Only three controls are used—the condenser and the two variometers; and even though the possibility for critical adjustment of primary and secondary circuits and the coupling of those two circuits is eliminated, this set will be found to be quite selective and to produce satisfactory results in amplification of signals.

In order to receive waves under 360 meters, the series condenser is a necessity. A small amount of capacity and a great amount of inductance should be used for such wave lengths, so that the set may regenerate and oscillate readily.

If the series condenser is short circuited or removed from the aerial circuit, the set will respond to wave lengths up to 600 meters; but in order to obtain regeneration and oscillation for wave lengths up to 600 meters, it may be necessary to have the variometers so arranged that they may be moved and placed alongside of each other to allow magnetic coupling between the grid circuit and the plate circuit.

Distortion in regeneration.—Remember that excessive regeneration of either spark signals or broadcasts will cause distortion; therefore, in receiving broadcasts, it is well to keep regeneration at a minimum in order to preserve the quality of the voice or music. In receiving spark or I. C. W. (*interrupted continuous waves*) signals, the natural tone of the signals may be distorted to a considerable extent before the signals become too greatly broken up to be easily read.

THE REINARTZ TUNER

A circuit which has recently become very popular

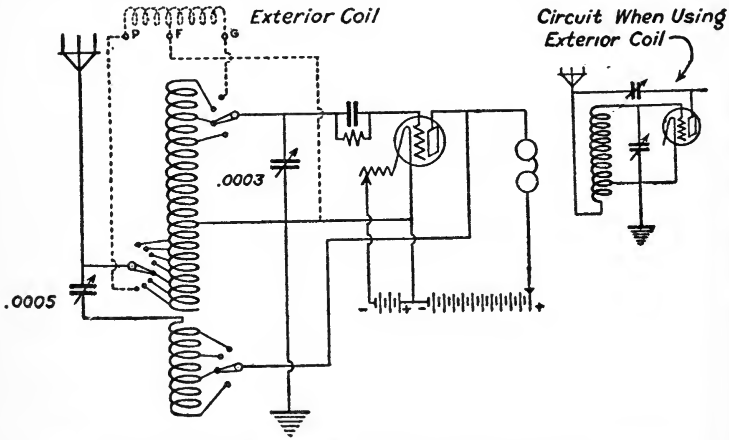


Fig. 74.—Hook-up for the Reinartz tuner with detector.

among amateurs and broadcast listeners owes its invention to Mr. John L. Reinartz.

This receiver is not only inexpensive and easy to build but quite remarkable in its operating characteristics. Its chief advantages are: (1) the tuning is accomplished by the antenna and grid switches with the secondary condenser for fine adjustment; (2) feedback is accomplished by a combination of electrostatic and inductive coupling rather than by the tuned plate method, so that once the feedback has been adjusted, the tuning may be varied over practically the entire range of the set without readjustment; (3) body capacity effects can be almost entirely eliminated by the proper connection of the secondary and feedback condensers.

Fig. 74 shows the hook-up for this circuit. The inductance consists of a set of two windings in a single spider web form, with a total of 90 turns of No. 20 S. C. C. wire wound on nine spokes around a 2½ inch center, the completed coil being about 5 inches in diameter. After 45 turns are wound, the wire is cut; this coil forms the plate inductance. The winding is then resumed in the same direction and 45 additional turns are put on. These windings form two coils very tightly coupled to each other. Taps are brought out to three switches in the following manner: The inner coil or plate winding is tapped at 0, 15, 30 and 45 turns, for control of the feedback. These taps are carried to a four-point switch. The outer coil is tapped for the antenna switch at the 3d, 5th, 7th, 9th, 11th, 13th and 15th turns and a ground connection taken off at the 16th turn. The taps for the grid switch are taken from the 25th, the 35th, and the 45th or outside turn for tuning purposes.

The range of this coil is from 150 to 600 meters but this may be increased by adding proportionately to the three sections of the coil, by using a larger secondary condenser, or by adding a loading coil in the following manner: It will be noticed that both the grid and antenna switches have an extra point and that the plate switch has a point at 0 turns. When the switches are placed on these points an exterior load coil of any desired value may be connected to the three binding posts marked P, F, and G. One-third of the turns on the load coil should be connected between the filament and plate posts and two-thirds between the grid and filament posts. For 750 meters, a coil should be used of 70 turns of No. 20 S. C. C. wire on a 2¾ inch cylinder, tapped for the filament lead at 50 turns from the grid end. The circuit when an exterior load coil is used is shown in the small diagram on the right-hand side of Fig. 74.

For radiophone reception, spark, or I. C. W. signals, the feedback adjustments may easily be made for maximum value of regeneration, while for continuous wave signal reception, the receiver is ideal, in that the feedback may be set so that the detector tube is oscillating at the proper frequency and the tuning varied over the entire range without further adjustment of the feedback.

Certain details are of considerable importance in hooking up the set; the negative side of the B battery *must* be connected to the positive side of the A battery; it is most important that in order to minimize body capacity effects, the rotary plates of the feedback condenser be connected to the antenna and the rotary plates of the tuning condenser to the ground.

THE ARMSTRONG SUPER-REGENERATIVE RECEIVER

This circuit, while it includes no apparatus which has not already been treated in this book, is somewhat complicated and is more difficult to construct than an ordinary regenerative receiver; yet it produces results, when properly built and operated, that are little less than astounding. Edwin H. Armstrong, the inventor, estimates that the amount of amplification of the super-regenerative system is from 100,000 to 1,000,000 times as great as that obtained with an ordinary regenerative receiver. The advantages of this system lie in the great volume of sound which may be obtained from a very weak signal, and in that spark or damped wave signals are not amplified to the same extent as are the continuous or modulated continuous waves used in radio telephony. A third important characteristic claimed for this circuit is that it amplifies the shorter wave lengths to a greater degree than the longer, opening up a new band of short wave lengths for radio transmission.

Owing, however, to difficulties both of construction and particularly of operation, a detailed discussion of the super-regenerative receiver is not within the province of this book.

Chapter VIII

AMPLIFIERS, LOUD SPEAKERS, AND LOOP AERIALS

The vacuum tube as an amplifier.—In the preceding chapter we have seen that by the use of the vacuum tube, weak currents coming from the aerial may be made to control strong currents which actuate the disks in the telephone receivers, reproducing the sounds which are being directed into a transmitter at the sending station. In other words, the vacuum tube, even when used as a detector, is fundamentally an amplifier, since it uses relatively weak currents in its grid circuit to control much stronger currents in its plate circuit. Since feeble variations or oscillations in the grid circuit of a vacuum tube produce relatively great changes in the strength of the current in the plate circuit, the plate circuit from one tube may be coupled through a transformer, to the grid circuit of a second vacuum tube, to produce still greater changes in the plate circuit of this second tube, and so on as far as may be desired.

In similar manner, one or more amplifying tubes with their transformers may be introduced into the grid circuit of the rectifying or detector tube. Stages of amplification so placed, magnify the effect of the weak signal currents, before these currents reach the detector tube.

Amplifiers placed in the circuit between the detector and the telephone receivers are called *audio-frequency amplifiers,* because they magnify the effect of currents which have been reduced from radio frequency to audio frequency. Amplifiers used between the aerial circuit and the detector are called *radio-frequency amplifiers,* since they act upon the high-frequency currents before they have reached the detector. In this connection, it should be kept in mind that audio-frequency amplification can magnify only those signals which are strong enough to operate the detector. It can have no effect whatever on signals which are too weak to fluctuate the detector plate current. Radio-frequency amplification, on the other hand, may be used to magnify signal currents too weak in themselves to control the detector plate current variations which actuate the telephone receivers.

AUDIO-FREQUENCY AMPLIFICATION

Hooking up the audio-frequency amplifier.—As has been previously stated, the amount of sound produced by

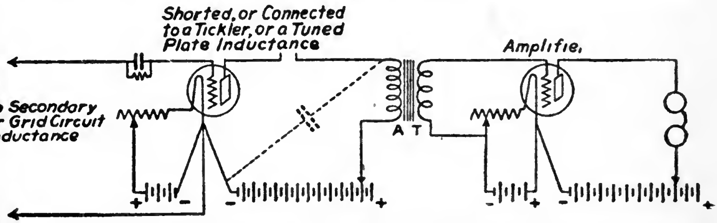


Fig. 75.—Diagram showing a vacuum tube detector and one stage of audio-frequency amplification.

the telephone receivers is proportional to the magnitude of the pulses of current passing through them. The hook-up for a single stage of audio-frequency amplification, which will further increase the signal currents applied to the telephone receivers, is shown in Fig. 75.

(For the sake of clearness, separate "A" and "B" batteries are indicated for the detector and the amplifier. In succeeding hook-ups, connections will be shown to common sources for filament current and for plate current.)

The amplifier circuit here shown includes a *transformer*, an *amplifier tube, sources of filament and plate current*, a separate *rheostat* for controlling the filament current for the amplifying tube, and the *telephone receivers*.

The transformer is made up of two coils of wire—a primary and a secondary winding—placed on an insulating form, and having an iron core. The secondary winding is made up of a greater number of turns of wire than the primary, in order to "step up" the voltage. Usually the windings of amplifying transformers have a ratio of 3 or 4 to 1. Transformers with a ratio as high as 9 to 1 or 10 to 1, are available for use in radio. The last mentioned ratio, however, seems to be the upper limit. The amplifier tube is similar to the detector tube, but is more highly exhausted, and therefore more nearly a vacuum than is the rectifying or detector tube.

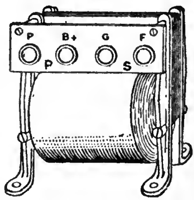


Fig. 76.—Amplifying transformer.

As can be seen in the diagram, the primary winding of the transformer is placed in the plate circuit of the detector where the receivers have heretofore been connected. The secondary winding is connected in the grid circuit of the amplifying tube. Note that the secondary of the transformer takes the same place in the amplifier tube hook-up as the secondary of the tuning inductance does in the case of the detector tube. The receivers are now placed in the plate circuit of the amplifying tube.

It should be noted that the grid circuit of a detector tube which is used with one or more stages of audio-frequency amplification may be connected to any type of receiving tuner shown in Chapter IV. Furthermore, the detector circuit may be made regenerative by inserting in it any of the types of tickler coils or tuned plate inductance described in Chapter VII.

The addition of one or more stages of audio-frequency amplification to the simple vacuum tube detector hook-up or to the regenerative hook-up occasions no change whatever in the receiving circuit.

For best results, a by-pass condenser should be used across the detector plate circuit in shunt to the "B" battery and the primary of the amplifying transformer, particularly if the detector circuit is of the regenerative type.

Principles of audio-frequency amplification.—As has been previously explained, the grid in a vacuum tube acts as an interrupter to cause variations of current in the plate circuit. We also understand that the voltage applied to the primary winding of a transformer is increased in the secondary in the same ratio that the number of turns in the secondary bears to the number of turns in the primary.

When the audio-frequency pulses of direct current in the plate circuit of the detector pass through the primary winding of the amplifying transformer, corresponding pulses of much higher voltage are induced in the secondary winding. These magnified pulses pass to the grid of the amplifier, fluctuating the plate circuit current, as in the case of the detector, but controlling much larger pulses of current in the plate circuit than are controlled in the detector plate circuit. Due to the amplifying properties of the tube, the variations in grid voltage are magnified from five to thirty times in the plate circuit. These magnified pulses in the amplifier plate circuit cause the telephone receiver diaphragms to vibrate with greater amplitude, producing much louder sound.

Multi-stage or cascade audio-frequency amplification.—If instead of the telephone receivers, the primary of another amplifying transformer is placed in the plate circuit of the first amplifying tube, the same process may be reproduced in a second stage of amplification, with a correspondingly greater magnification of received signals. Additional stages may be added in similar manner, but

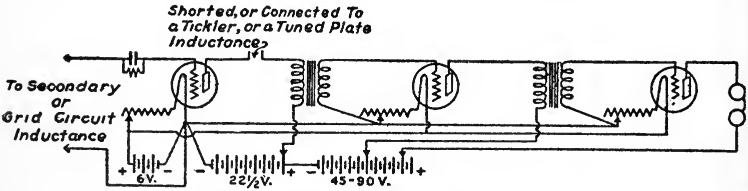


FIG. 77.—HOOK-UP FOR A VACUUM TUBE DETECTOR AND TWO STAGES OF AUDIO-FREQUENCY AMPLIFICATION

complications arise in using more than two stages, for induction, static and physical vibration of the instruments are also magnified, and to such degree that they often drown out the signals. In addition, even three stages require such critical and delicate adjustment of filament rheostats and plate voltage that they can be operated satisfactorily only after continued practice.

A hook-up for a detector and two stages of audio-frequency amplification using common "A" and "B" batteries is shown in Fig. 77.

Control jacks and plugs.—Fig. 78 shows the hook-up for a two-stage audio-frequency amplifier using *control*

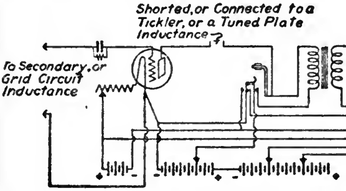


FIG. 78.—HOOK-UP FOR A VACUUM TUBE DETECTOR AND TWO STAGES OF AUDIO-FREQUENCY AMPLIFICATION, WITH CONTROL JACKS

jacks. These jacks are similar to those used in telephone switchboards, into which are inserted the *plugs* connected to the telephone cords. Both of these devices are shown in Fig. 79. The jacks permit the "plugging in" of the receivers on the detector tube alone or the detector and one stage of amplification, or the detector and two stages of amplification. Such an arrangement has decided advantages in many instances. For example, signals may be so loud with both stages of amplification in use, that the receivers cannot be kept close to the ears with comfort. Or again, sufficiently loud signals may be heard with the detector or with the detector and a single stage of amplification. It is, of course, uneconomical to use

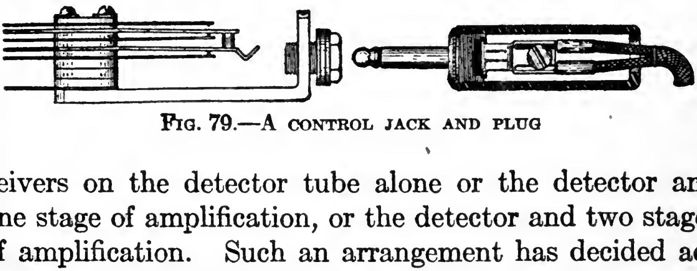


FIG. 79.—A CONTROL JACK AND PLUG

more tubes than are necessary for the desired results, since such use causes a drain on the "A" and "B" batteries and reduces the life of the tubes.

It can be seen from the diagram that when the telephone receiver or the loud-speaking device is not plugged into any one of the jacks for the reception of signals, the jacks are in their normal position and the "A" battery current circuits are broken for all of the tubes.

As the plug attached to the receivers or loud speaker is inserted in the jack in the detector tube circuit, the plug forces to the left the spring contacts of the jack, and these contacts complete the filament circuit of the detector tube through the first two levers to the right in the jack. (There is no need of controlling the plate circuit by the jacks since plate current does not flow unless the filament is heated.)

If the plug is removed from the jack in the detector circuit and inserted in the jack which is in the circuit of the first stage of amplification, the filament circuits of both the detector and the first amplifying tube will be completed through the second jack, and the first stage of amplification will therefore be added to the detector.

In similar manner, the second stage of amplification would be added to the detector and the first stage, by inserting the plug in the third jack.

Wiring up stages of amplification.—In the operation of a receiving set which includes several stages of amplification, considerable annoyance may be caused and signals are often interfered with by a shrill tone or sustained "howling" which is heard in the receivers. This howling is due to the fact that somewhere in the hook-up, the voltage variations in the plate circuit of one of the vacuum tubes is being transferred by induction to the grid circuit of the same or of some other tube. This induced variation in the grid circuit is then amplified in the same manner as the received signals, and may come through the receivers so strong as to make radio reception impossible.

In building up stages of amplification at home, care should be taken to locate the transformers as far from one another as possible—at least several inches—unless they can be properly shielded, as for example, by placing each bulb and its transformer in a metallic compartment and grounding the compartment. If this method is not followed, transformer cores should be placed at right angles to one another and cases of the transformers should be grounded. In every case, care should be taken to make the leads from one transformer to the grid of the succeeding stage as direct as possible. *Whenever possible, keep leads from running parallel to one another*, and make all bends in the wires at right angles.

LOUD SPEAKERS

Numerous loud-speaking devices which may be used to replace the telephone receivers so that a number of people may listen at one time, have been developed and placed upon the market. The amateur should insist upon a careful demonstration before purchasing apparatus of this type. He should also know something about the possibilities as well as the limitations of such equipment and the conditions governing its use.

To begin with, the type of horn or megaphone which uses the ordinary radio-telephone receiver as part of its equipment is subject to certain limitations. It cannot properly be called an amplifier of signals for it only concentrates and directs the physical sound coming from the receiver. Furthermore, the ordinary receiver is not designed to produce very violent diaphragm vibrations, and distortion almost invariably results from its use with any type of horn.

In the reception of speech and music by radio, there are two desired results. The first is volume. The second is lack of distortion. Many amateurs consider the second result much more important than that first mentioned. In other words, they prefer to have less distortion at the expense of volume rather than great volume accompanied by distortion. With properly designed amplifiers, however, and an electrodynamic type of loud speaker operated at full capacity, it is possible to amplify radio music or voice so that either can be heard throughout a large sized hall or auditorium.

One efficient type of loud speaker employs a specially constructed "Baldwin" receiver in connection with a horn. The receiver consists of a powerful permanent magnet, a coil which is connected in the plate circuit of the last stage of amplification, a soft iron armature which can move in the field of the magnet in accordance with the variations of amplified telephone current passing through the coil, and a diaphragm or disk so fastened to the armature by means of a lever that its movement is greater than that of the armature.

If a power tube is used in the last stage of amplification, even better results are to be obtained from any electrodynamic type of loud speaker. The operator, however, should first make sure that the windings of the amplifying transformer are able to pass the increased current which will flow in the plate circuit of the power tube.

It should be remembered that the dynamic loud speakers are so designed that a relatively large amount of energy is required to operate them. Additional "B" batteries are usually necessary, therefore, to their operation.

Plate voltage for amplifiers with loud speakers.—It should be noted that higher plate voltages are needed for amplifying tubes in both audio-frequency and radio-frequency amplification. Amplifying tubes, as previously mentioned, are more highly exhausted, and the higher degree of vacuum permits the application of a much higher voltage between the plate and the filament, before causing the blue glow or hissing effect. The use of this additional plate voltage with audio-frequency amplifiers results in a greater flow of current through the receivers or the loud speaker, and therefore produces louder sounds.

Plate voltage which may be used in amplification is limited by the amount of current which the amplifying transformers and bulbs or other instruments will pass. Amplifying transformers will usually stand about 125 volts, when placed in series with the plate circuit of an ordinary amplifying bulb. Amplifying tubes, however, and power tubes will stand up to 200 or 300 volts, or more. Special transformers may be purchased which will pass current up to the limit of the tubes, without burning out.

RADIO-FREQUENCY AMPLIFICATION AT BROADCASTING WAVE LENGTHS

Necessity for radio-frequency amplification.—When a signal is so weak that it fails to operate the detector, audio-frequency amplification is of no use, regardless of the number of stages employed, and radio-frequency amplification must be used to bring in the signals.

Radio-frequency amplifiers are connected between the aerial circuit and the detector, and increase the strength of the received oscillations before they are impressed on the detector for rectification in the usual manner. In radio-frequency amplification, weak impulses are amplified in the same proportion as stronger ones. In this respect, radio-frequency differs from audio-frequency amplification, which is very unfair to weak signals. It further differs from audio-frequency in that it amplifies the signals to which its circuits are tuned, without amplifying "off-tune" interference and local induction. One or more stages of audio-frequency amplification may, of course, be used to advantage in conjunction with radio-frequency amplification.

Radio-frequency amplifying transformers.—Radio-frequency transformers for coupling amplifying tubes together are available for private users of radio. Several types of such transformers are made with a certain amount of iron in their composition, which enables them to respond over a considerable range in wave length. Due to their broad wave range, they accomplish perhaps only one-half the amplification for each stage, that would be possible if the iron were omitted and the transformers designed to cover only 300 to 400 meters. Care should be taken, therefore, in selecting radio-frequency amplifying transformers. If the user desires to hear only stations sending on wave lengths between 200 and 400 meters, and to obtain maximum amplification, he should select transformers covering this range, with no iron in their composition. If he desires to cover broader wave ranges, transformers with iron in their make-up will be necessary. More tubes, however, must be employed to obtain the same amplification which can be obtained if transformers of the former type are used.

Hooking up the radio-frequency amplifier.—The wiring diagram for a simple one-stage radio-frequency amplifier

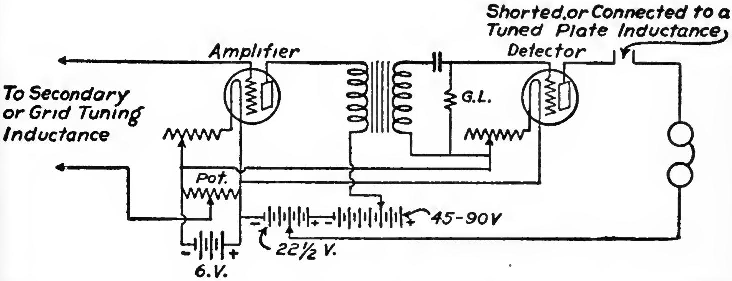


FIG. 80.—HOOK-UP FOR ONE STAGE OF TRANSFORMER COUPLED RADIO-FREQUENCY AMPLIFICATION AND A DETECTOR.

and a detector is shown in Fig. 80. The set may be hooked-up to the secondary circuit of any of the tuning devices shown in Chapters IV and VII.

The primary of the amplifying transformer is connected in the plate circuit of the amplifying tube. The secondary of the transformer is connected to the grid and to the filament of the detector tube. The receivers are connected in the plate circuit of the detector.

The potentiometer (Pot.) has already been described, in connection with Fig. 61, Chapter VII. The two ends of its resistance coil are connected across the "A" battery leads as indicated. The variable contact of the potentiometer is connected, through the secondary circuit of the tuning inductance, to the grid of the amplifying tube and not to the plate of the detector tube as in Fig. 61. Note that the grid leak is connected from the grid of the detector tube to the filament rather than in shunt to the grid condenser.

If audio-frequency amplification is added to a set employing radio-frequency amplification, the primary leads of the transformer in the first stage of audio-frequency are connected in series in the plate circuit of the detector, where the telephones are here shown.

Regeneration with radio-frequency.—As indicated in Fig. 80 and Fig. 81, regeneration may be employed with radio-frequency sets for the reception of C. W. signals or for picking up the carrier wave of distant broadcasting stations. A variometer may be connected in the plate circuit of the detector tube at the point indicated, for a receiver of this type may be operated when the detector tube is in the oscillating condition. The frequency of oscillation or the beat note is then determined by the tuning of this variometer.

Operation of the radio-frequency amplifier.—The aerial circuit and the secondary circuits of the set are tuned in the usual manner. Meanwhile the potentiometer or stabilizer is adjusted. The purpose of the potentiometer is to place the proper potential on the grid of the amplifier tube so that the tube may be made to oscillate or rather, brought near the oscillating point, where best results are obtained in the reception of signals. Continuous wave stations may be received by turning the stabilizer knob toward the negative side of the "A" battery connection.

Regular amplifier tubes, with 45 to 100 volts on the plate and a soft detector tube with about 22½ volts in its plate circuit, are usually used in a receiving set of this type. A hard tube, however, may be used for the detector, and will be found to be less critical than the regular detector tube. The use of a hard tube as a detector will therefore help to keep down the number of critical adjustments necessary in a set which includes one or more stages of amplification. The plate voltage required for a hard tube

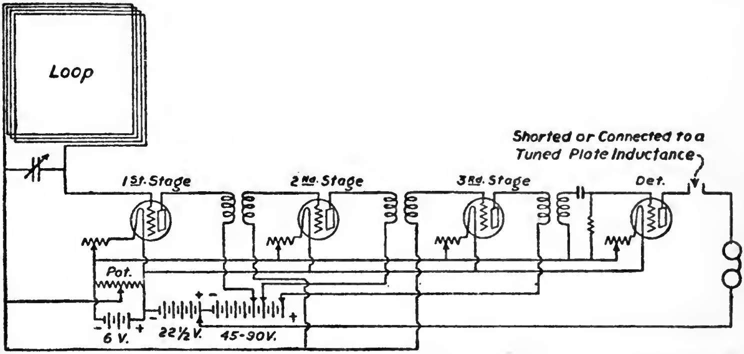


FIG. 81.—COMPLETE HOOK-UP FOR A LOOP AERIAL, THREE STAGES OF TRANSFORMER COUPLED RADIO-FREQUENCY AMPLIFICATION AND A DETECTOR.

used as a detector would be approximately the same as that required for the same tube if used in the amplifier stage.

Multi-stage or cascade radio-frequency amplification.—A complete hook-up showing all the connections for a receiving set with a loop aerial and three stages of transformer coupled radio-frequency amplification is given in Fig. 81. Filament control jacks are not used in the stages of radio-frequency amplification since the receivers or the loud speaker may be used only on the detector or the audio-frequency amplifiers.

The receiving set illustrated is of sufficient sensitivity to allow the use of a loop aerial. However, much louder signals can be received on an outdoor aerial.

Broadcasting stations within a distance of about one thousand miles may be received on a four-foot loop provided a three-stage radio-frequency amplifier, a detector and a two-stage audio-frequency amplifier, employing in all six vacuum tubes, is used.

If an outdoor aerial is used instead of a loop, the leads from the secondary of the tuning device would replace the leads from the loop aerial.

In connection with an elevated aerial, such a set could receive signals from enormous distances. Its range, however, would be limited by local induction and by atmospheric disturbances. It is well to point out that satisfactory radiophone reception with a loop aerial, is impractical without radio-frequency amplification.

Reception of continuous wave telegraph signals with a loop aerial has been fairly successful without radio-frequency amplification, but in order to receive radiophone signals, it is necessary to use radio-frequency amplification if the transmitting station is more than a few miles distant. This statement of course does not apply to accidental or freak ranges, due to exceptionally favorable conditions.

Tuned radio-frequency amplification.—There are two other methods of radio-frequency amplification—namely, the tuned plate method and the resistance coupled method. The latter, however, is not effective on broadcasting wave lengths and for that reason will not be treated in this book.

The tuned plate method is as effective for radio-frequency amplifying as the transformer coupled method and it has an added advantage in that the plate circuit of the radio-frequency amplifying tube may actually be tuned to the frequency of the incoming signals to the almost entire exclusion of other frequencies. This result is accomplished by means of a continuously variable inductance or tuner—such as a variometer—or a fixed inductance for example, a honeycomb coil shunted by a variable condenser for tuning.

It should be remembered that this effect is virtually regeneration. (See page 165.) Likewise, in radio-frequency amplifying, maximum amplification of a given signal is accomplished when the grid and plate circuits of the vacuum tube are tuned to the frequency of the given signal. However, in tuned plate amplification, trouble arises from the use of more than one stage in that a considerable number of additional adjustments are required. On the other hand, excellent results may be obtained by the use of only one stage of tuned radio-frequency on an outdoor aerial, and very satisfactory results may even be obtained with a five or six-foot loop.

In contrast it might be pointed out that the best regenerative set without radio-frequency amplification will hardly bring in more than local signals on the same loop.

A diagram is given herewith for a detector and one stage of tuned radio-frequency, employing a variometer for tuning the plate circuit of the radio-frequency amplifying tube. A honeycomb coil and a variable condenser may well be employed instead, if desired.

As suggested for preceding circuits, the grid circuit may be connected to the secondary leads of the aerial tuning inductance, preferably a variocoupler for selectivity, or to the leads of a loop aerial with a condenser in shunt to them. The set is then operated or tuned by a procedure similar to that given for the tuned plate and grid circuit

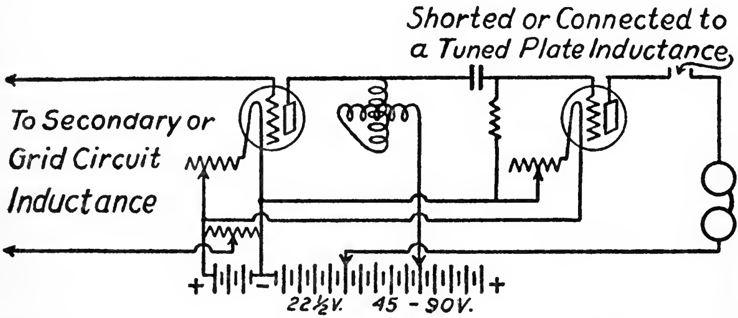


Fig. 82.—Hook-up for one stage of tuned radio-frequency amplification and a detector.

on pages 168 and 169. As in the case of the regenerative set, distant signals will come in loudest on a radio-frequency set when the radio-frequency amplifying tube or tubes are just below the point of oscillation. However, instead of being troubled with making the tubes oscillate in this type of set, the operator will more often experience difficulty in preventing them from breaking into oscillation, and it should be evident that with two or three tubes oscillating at once, it is impossible to obtain clear reception.

Oscillation of the tubes is controlled, as suggested in connection with transformer coupled radio-frequency amplification, by means of the potentiometer, and also in the case of tuned radio-frequency amplification, by means of the tuning inductances in the plate circuit of each stage.

The wiring is a very important factor in preventing the tubes from oscillating in the radio-frequency set. It cannot be too strongly impressed upon the beginner in radio-frequency amplification that the leads between the grid and the plate circuits of the different stages must be kept as short as possible.

Furthermore, as suggested for transformer coupled radio-frequency (see page 191), a hard tube for the detector will be found less critical than a soft tube and will aid in reducing the number of critical adjustments in a set of this type. The fixed or *stopping* condenser shown in the circuit is not of critical value and may be the usual grid condenser used with any detector. The grid leak, however, may not be connected in shunt to the grid condenser as shown in all preceding diagrams, but must be connected from the grid of the detector tube to the filament lead of the same tube, so that the positive potential of the "B" battery will not be impressed on the grid through the variometer or other tuning inductance.

Multi-stage tuned radio-frequency amplification.—For greater radio-frequency amplification by means of the tuned plate method, additional stages may be hooked up exactly as shown for the one stage. A diagram for three stages appears below.

Again the necessity of the stopping condensers between the stages is pointed out, but as previously suggested, they are not critical and may be of the value of .0005 to .005 mfd.; probably .001 or .002 mfd. will be found to operate as satisfactorily as any.

It is evident that with three stages, the number of tuning elements have been increased by three, in addition to the potentiometer and the aerial tuning device with its controls for the primary and secondary circuits, of the complete receiving set.

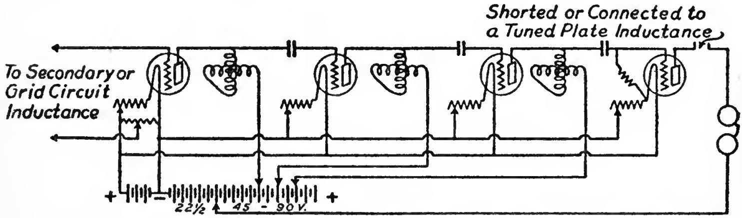


FIG. 83.—HOOK-UP FOR THREE STAGES OF TUNED RADIO-FREQUENCY AMPLIFICATION AND A DETECTOR.

It will be found in operating this set that the first stage is the most critical one. That is to say, the second and third stages may be set approximately for a given wavelength and the fine tuning accomplished by means of the aerial circuit and secondary circuit tuning inductances (or tuning condenser, if a loop aerial is being used), and the plate variometer of the first radio-frequency stage, with occasional adjustments of the tuning inductances of the second and third stages.

It should be pointed out that the use of a coupled circuit tuning device, such as a variocoupler or loose coupler, in the aerial circuit with the above hook-up entails the separate tuning of the aerial circuit and the secondary circuit of the first tube. Tuning can be more readily accomplished by a single circuit tuner, which will approximately tune the aerial circuit and the secondary circuit of the first tube in a single operation, as indicated in connection with the hook-up in Fig. 73.

Size of aerial with radio-frequency amplification.—With the last suggestion in mind, it is well to point out that difficulty may be experienced in operating more than one stage of either the transformer coupled or the tuned radio-frequency amplification on an outdoor aerial if the aerial be too long. In the first place, the detector tube will handle only a certain amount of radio-frequency energy and if too much energy is picked up by the aerial, from local broad-casting stations, and then amplified by the two or three stages of radio-frequency amplification, distortion and difficulty in tuning will result. Likewise considerable difficulty will be experienced in tuning in one station from another, either local or distant, with a long aerial. Very often this difficulty may be overcome by inserting one or two fixed condensers of from .00025 to .001 mfd. in series with each other in the lead-in or by connecting a variable resistance, such as a potentiometer, between the lead-in and the aerial tuning device.

In most cases, however, far more satisfactory results will be obtained from an aerial 50 to 75 feet long, or a single wire 50 or 75 feet long strung inside the building along the ceiling or under the carpets on the second or third floor.

Tuned and transformer coupled radio-frequency amplification in combination.—For those who may not care to attempt the somewhat difficult tuning of the last set, it is suggested that one stage of tuned radio-frequency for the first stage and two stages of transformer coupled radio-frequency for the second and third stages be tried out. Such a set provides some of the selectivity of tuned radio-frequency and eliminates the more critical adjustments for the second and third stages. A diagram for such a set is given in Fig. 84.

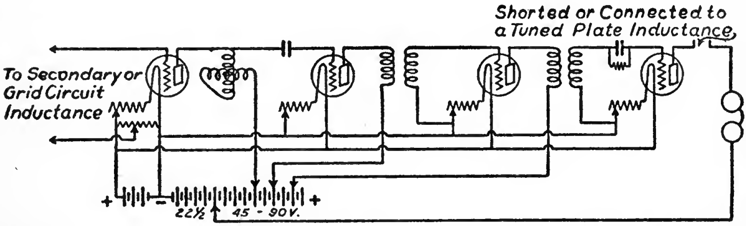


FIG. 84. HOOK-UP FOR ONE STAGE OF TUNED AND TWO STAGES OF TRANSFORMER COUPLED RADIO-FREQUENCY AMPLIFICATION AND A DETECTOR.

REFLEX AMPLIFICATION

Contrary to popular opinion, the reflex circuit is not a new idea. It has recently, however, come into such prominence that wide interest in it has been aroused. A few facts concerning the reflex circuits should be considered before the reader decides upon such a set in preference to a set using straight radio-frequency and audio-frequency amplification.

A reflex set at best is not as efficient for a given number of stages as a set employing a separate tube for each stage. It is more difficult to construct because of the fact that combinations of various makes of instruments do not always work out well in the circuit. This condition necessitates considerable experimenting and the trying of different types of instruments in order to make the set operate properly as a whole.

The reader should not forget that any particular set on the market which seems to work highly satisfactorily is the result of much similar experimenting on the part of the manufacturer.

The main advantages of a reflex circuit seem to be the lower cost of making it up and the lower cost of main-

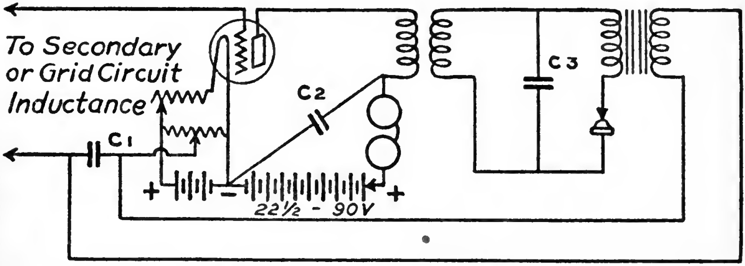


FIG. 85.—HOOK-UP FOR A ONE-TUBE REFLEX SET WITH A CRYSTAL DETECTOR.

tenance, particularly in regard to renewing burned out tubes, for with the present low current consumption tubes, two or three additional tubes make very little difference in the drain on the "A" battery.

A one-tube reflex set.—Fig. 85 shows what may be considered a standard hook-up for a one-tube reflex set with a crystal detector:

As suggested in connection with preceding circuits, the tuning instrument may be any of the number of tuning devices described in Chapter IV,—preferably the vario-coupler, or the loose coupler with a secondary tuning condenser. Or a variometer may be used as a single circuit tuner as suggested on page 197.

The by-pass condensers in this circuit are not especially critical and may be of the value of .001 to .002 mfd. Their purpose has already been explained in Chapter V, page 109.

In the reception of signals, the tube first acts as an amplifier of the radio-frequency oscillations coming in from the aerial circuit, in the following manner: The signals in the radio-frequency state pass right through the condenser C_1 and the potentiometer to the grid and the filament of the tube. The attendant radio-frequency variations in the plate current (see page 129) pass through the primary of the radio-frequency transformer and the by-pass condenser C_2, without affecting the telephone receivers at this point. Corresponding radio-frequency current is transferred to the secondary of the radio-frequency transformer and thence to the crystal detector, where it is rectified and changed into audio-frequency pulsations.

The condenser C_3 acts as a radio-frequency by-pass condenser, or at this point, as a phone condenser, as described in Chapter IV.

In series with the crystal detector is the primary of the audio-frequency amplifying transformer which transfers the audio-frequency current to the secondary winding of the transformer; from the secondary of this transformer, the audio-frequency pulses are led back into the grid circuit of the tube and impressed on the grid and the filament to be amplified as in audio-frequency amplification. The resultant audio-frequency pulses are of too low frequency to pass through condenser C_2 readily, and now operate the telephone receivers.

A three tube reflex set.—Below is given a hook-up of the De Forest type for a standard three tube reflex crystal detector set, which gives very satisfactory results with either a loop aerial or an outdoor aerial, when coupled to the aerial by means of a loose coupler or a variocoupler.

The action of this set is similar to that of the one tube reflex set except in one or two minor details. In this case,

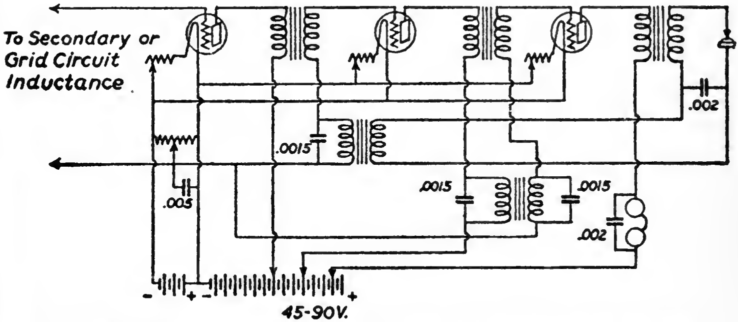


FIG. 86.—HOOK-UP FOR THE DE FOREST THREE-TUBE REFLEX SET.

all three tubes are utilized to amplify the incoming radio-frequency currents; a crystal detector then rectifies or detects the radio-frequency oscillations, changing them into audio-frequency pulsations. This audio-frequency current is then fed back to the second tube and amplified by that tube and the third tube before being fed to the telephones or to the loud speaker. This arrangement provides three stages of radio-frequency amplification, a crystal detector, and two stages of audio-frequency amplification, the latter being sufficient for all ordinary purposes.

The values for the by-pass condensers in the De Forest circuit are given in the diagram. In the usual amateur hook-up various capacities—.001, .0015, and .002—should be tried out.

The chief difficulty in assembling a set of this type will be experienced in selecting radio-frequency and audio-frequency transformers which will work well together. It is suggested, therefore, that the amateur try out a number of different makes of each in various combinations until best results are secured.

INVERSE DUPLEX AMPLIFICATION

The inverse duplex system of amplification is an adaptation of a circuit developed by the French engineer Latour from which many reflex circuits also derive their origin. The inverse duplex has been so named by its inventor, Mr. David Grimes, because of the manner in which the tubes are used and in order to indicate more clearly the double function of the valves.

Disadvantages of reflex circuits.—In the foregoing systems of reflexing there are certain inherent disadvantages. Chief among them is the limitation which results from overloading the last amplifier tube with powerful radio-frequency and powerful audio-frequency currents. For example, in a three tube set such as that shown in Fig. 86, the total amplification of the arrangement is limited to the output of the third tube which must handle maximum radio-frequency and maximum audio-frequency energy. (See Fig. 87B.) It is evident, too, that there are three stages of secondary radio-frequency *leakage amplification* between the output and the input of the detector.

That is to say, a small amount of radio-frequency energy leaks through the detector and the associated apparatus by capacity paths and is put back on the input of the three-stage radio-frequency amplifier, causing the circuit

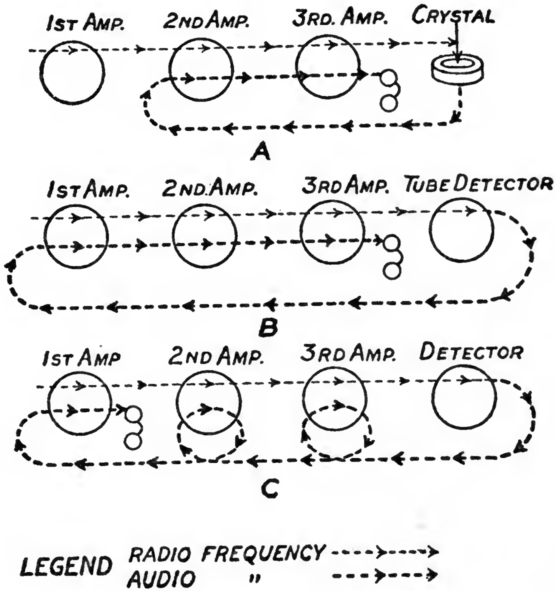


Fig. 87.—Graphic comparison of the principles of operation of reflex circuits and the inverse duplex circuits.

to be very unstable and making it almost impossible to stop oscillation without greatly reducing the amplification efficiency of the set.

A third drawback exists in that the phones are in the plate circuit of the third amplifying tube, thus placing three stages of audio-frequency amplification between the loop and the phones. Under ordinary conditions this means that the circuit often cannot be operated satisfactorily because of the proximity of sixty-cycle house current circuits, or because of induction from nearby electrical apparatus, which is greatly amplified by the three audio-frequency stages in succession. (In the ordinary set this does not occur because the detector is placed between the loop or the outdoor aerial and the audio-frequency stages.) The last mentioned objection may be overcome by using the first tube for radio-frequency amplification only. (See Fig. 87A.) When a tube detector, however, is used in place of a crystal, as in Fig. 86, there is still a tendency to overload the third tube, which now constitutes the third radio stage and the second audio stage; and although the tendency to oscillate is reduced, there still remain two stages of radio-frequency leakage amplification between the output and the input of the detector. The use of a crystal detector, as indicated in Fig. 87A, in place of a tube detector would make the circuit much more stable, as the crystal rectifies only the radio-frequency oscillations. On the other hand, a tube detector performs an amplifying function which a crystal cannot accomplish. The crystal detector, however, would reduce the initial amount of audio-frequency currents going into the first audio stage, and as a result, there would be less crowding of the third tube.

Advantages of the inverse duplex system.—The system developed by Mr. Grimes is the result of a great deal of experimentation, with the following objectives in view: (1) to increase stability of the tubes; (2) to reduce overloading; (3) to minimize audio-frequent noises; and (4) to enable the duplexing of all tubes, if desired. The inverse duplex set accomplishes these results.

Principles of inverse duplexing.—In Fig. 88, the radio-frequency energy passes through the tubes in the ordinary sequence. The difference appears beyond the detector tube, where the audio-frequent current, instead of going through the tubes in the same order as the radio-frequent energy, passes *first* into the *third* tube. (See Fig. 87C.) This makes the third stage of radio function as the first stage of audio-frequency amplification. From there the audio-frequency current is led through the second tube so that this tube acts as the second stage of audio-frequency and the second stage of radio-frequency amplification. Finally, the third stage of audio is achieved through the first tube, which is carrying the first stage of radio-frequency amplification. The phones are placed in the plate circuit of the first tube.

By this arrangement, all of the tubes are loaded uniformly and may be used to the maximum limit of all instead of being limited to the crowded output of the third tube.

The first tube carries weak radio-frequency and strong audio-frequency currents; the second tube carries medium values of each; while the third tube carries strong radio and weak audio current. Furthermore, no matter how many tubes are used, there is never more than one stage of radio leakage amplification between the input and the output of the detector tube and there is never more than one tube of audio-frequency amplification between the loop or the outdoor aerial and the phones, as the phones are on the output circuit of the first tube.

The Grimes inverse duplex set.—Fig. 88 shows in detail the connections employed in an inverse duplex set using three tubes. This arrangement is recommended for all ordinary purposes, and satisfactory amplification is usually obtained. It is rarely necessary to add the third amplifying tube, which of course would give three stages

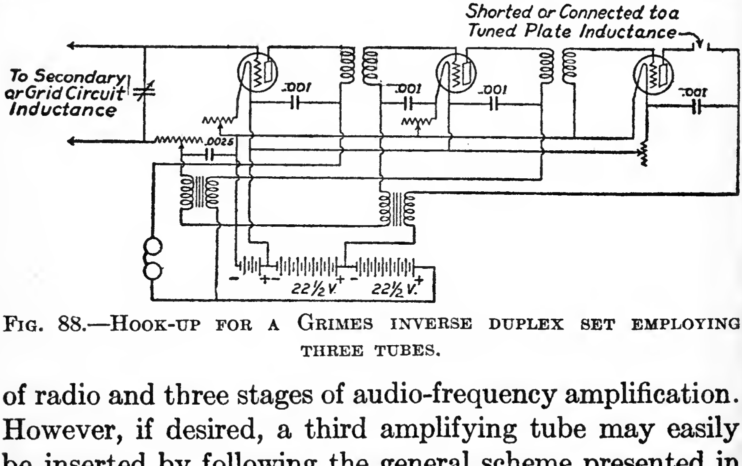


FIG. 88.—HOOK-UP FOR A GRIMES INVERSE DUPLEX SET EMPLOYING THREE TUBES.

of radio and three stages of audio-frequency amplification. However, if desired, a third amplifying tube may easily be inserted by following the general scheme presented in the diagram.

With a loose coupler substituted in place of the loop, the set may readily be operated on an aerial in any locality where shielding conditions,* prohibit the use of a loop.

The by-pass condensers in the Grimes circuit carry the radio-frequency currents, which have passed through the radio-frequency transformers, directly back to the fila-

* See page 26.

ments instead of merely by-passing them around the audio-frequency transformers and then allowing them to pass through the common B battery where they would "cross-fire" with the radio energy from the other tubes. This condition of course places the full B battery potential across the condensers continually and necessitates their being of mica construction, as, for example, the small square "micadons." Paper condensers here will become overheated and will puncture after only a few hours use.

All of these condensers should be of .001 microfarads capacity except the one connecting the loop circuit to the filament of the first tube; this one should be .0025 mfd., so that the maximum amount of energy from weak signals, picked up by a small loop, can be supplied to and utilized by the tube if it is needed. Increasing the others to .0025 will not materially aid the radio-frequency amplification, but on the other hand, will by-pass the higher frequencies of the audio currents, thereby causing distortion.

Distinctive features of the Grimes circuit.—In order to regulate the amount of radio-frequency energy passing through the amplifiers, a 400-ohm non-inductive rheostat is connected between the fixed condenser and the loop. This arrangement places a variable resistance in the grid circuit which may be used to reduce the energy of strong signals from nearby stations. Excessive radio-frequency energy, if not reduced, may easily crowd the tubes to capacity, allowing no opportunity for audio-frequency amplification. In view of the fact that a tube detector will handle only a certain maximum of radio-frequency energy it would be foolish to sacrifice the audio capacity of the tube by excess radio amplification. The 400 ohms will be found sufficient to reduce even the strongest stations to reasonable intensity. On weak signals this resistance may be decreased, sometimes even to zero.

This system of regulating the radio-frequency energy has several distinct advantages over the common practice of preventing the tubes from oscillating by means of a potentiometer connected across the A battery, and may be used to advantage in other radio-frequency circuits. In the first place, although the use of a potentiometer accomplishes the reduction of the radio energy and stabilizes the circuit, it also causes distortion and reduces the audio volume. In the second place, it broadens tuning, as may be witnessed in the broad tuning of most radio frequency sets. In the Grimes circuit, the grids of all the tubes run directly back to the negative side of their respective filaments. The audio-frequency amplification is entirely undisturbed by this system of controlling radio-frequency energy, and the tuning remains very sharp.

An interesting feature of the inverse duplex set is its simplicity of adjustment. One knob does all the tuning (unless a plate variometer is added), while the others are used to operate the filament rheostats, and the 400-ohm radio-frequency potentiometer previously described.

Another important feature of the Grimes arrangement is that the audio-frequency currents are so arranged on the grids of the amplifying tubes as to aid the radio energy when it is increasing and diminish it when it is decreasing. This effect is accomplished through proper connection of the primary leads of the transformers. With the set in operation, the correct connection may be determined by interchanging the primary leads and noting the result. The secondary leads, however, should remain fixed, with the lead from the outside layer of the winding connected to the grid circuit of the succeeding tube.

A variometer in the plate circuit of the detector may be used for the reception of C. W. signals. (See page 190.)

The inverse duplex set should be attractive to the amateur who desires to accomplish distance reception and cannot afford to buy and operate a large number of tubes. It is a very desirable hook-up for a portable or vacation set on account of its compactness and adaptability to operation with a loop aerial.

THE NEUTRODYNE RECEIVER

The neutrodyne receiver is essentially a tuned radio-frequency set, with one or more stages of tuned radio-frequency amplification and a detector, resembling those sets described on pages 192 to 198.

It has already been pointed out that it is somewhat difficult to prevent the tubes in the radio-frequency—especially tuned radio-frequency—amplifying circuits from oscillating. And as previously suggested, with two or more tubes oscillating in such a circuit, it is almost impossible to obtain undistorted speech or music. With tuned radio-frequency, oscillations occur when the plate circuits of the amplifying tubes have been tuned to resonance with a given wave length and the resultant radio-frequency current in these circuits is fed back to the grid circuits through the tube. This feed-back effect takes place through the plate and grid elements in the tubes, which act as small condensers, and is exactly like the regenerative effect obtained in the detector tuned plate method of regeneration described on page 160.

The feeding back may also take place through the capacities which exist between the wires or between the different units of the stages, or in the case of transformer coupling, between the sets of windings in the transformers. These capacity effects may be illustrated graphically as in Fig. 89.

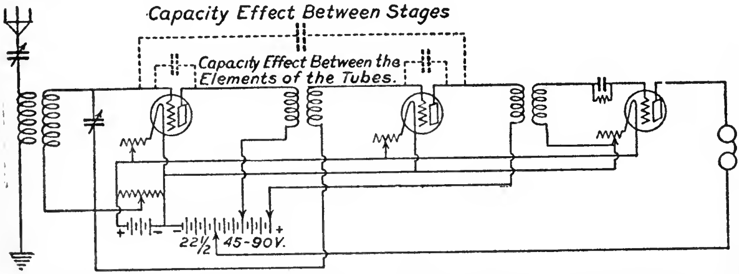


FIG. 89.—GRAPHIC REPRESENTATION OF THE CAPACITY EFFECTS WHICH RESULT FROM COUPLING TOGETHER STAGES OF RADIO-FREQUENCY AMPLIFICATION.

In the ordinary tuned radio-frequency amplifier and in the transformer coupled radio-frequency amplifier, the oscillations must be controlled, or prevented from occurring, by means of a potentiometer, which allows great amplification, and yet limits the full amplification possibilities of the tubes and makes the tuning more critical.

It can be seen therefore that a radio-frequency amplifier, either tuned or transformer coupled, does not utilize the full amplifying effect of the tube, as in the case of audio-frequency amplification, since we reduce the amplifying effect of the tube usually by means of the potentiometer in order to prevent oscillation, and depend on regeneration to increase the strength of the signal.

Neutralizing undesirable capacity effects.—Professor L. A. Hazeltine, the inventor of the neutrodyne receiver, has succeeded in neutralizing the internal capacity of the tubes and also the capacity effects existing between the windings of the radio-frequency transformers in the different stages of a radio-frequency set. He accomplishes this neutralization by connecting very small condensers

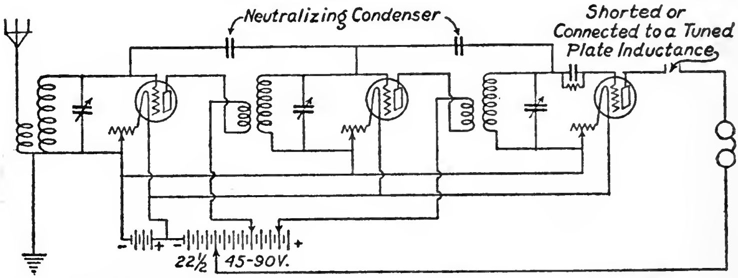


Fig. 90.—Hook-up for a three-tube neutrodyne receiver.

between the grids of the tubes and by connecting one end of the primary and one end of the secondary winding of each radio-frequency transformer to a common point in a particular manner which will be described later. This method of connection suppresses any feedback action from one stage to another, or from the plate of one tube to the grid of the same tube, and prevents oscillations from occurring in the tubes, while it retains the radio-frequency amplification and the sharp tuning of a tuned radio-frequency amplifier.

Fig. 90 shows the hook-up for a neutrodyne receiver employing two stages of tuned radio-frequency and a detector.

Neutrodyne transformers.—The transformers are not the usual type of radio-frequency transformer since the ordinary type will not function properly in this circuit. The transformer developed by Hazeltine for this set consists of two coils, specially wound, with the primary fitting tightly inside of the secondary coil. The former coil consists of 13 turns of No. 24 double silk covered wire wound on a tube 2¾ inches in diameter; the latter consists of 55 turns of No. 24 double silk covered wire wound on a 3 inch tube, providing a coupling transformer with a ratio of 1 to 4. For best results, both coils should be wound in the same direction. Furthermore, the plate winding—that is, the 13 turns of No. 24—should be placed inside the end of the grid winding—the 55 turns—which is connected to the filament. The relative positions of the windings are indicated in Fig. 91. Each of the three tuning condensers should have a capacity of .0003 mfd. (.0005 mfd. condensers may be employed, but their use will make tuning more critical.) They are used in conjunction with the coils for tuning the circuits of the amplifier to resonance. A complete unit, ready for mounting, consisting of a neutrodyne transformer and its condenser, known as a "neutroformer," may be purchased.

As suggested in preceding pages, the wave length range of the usual type of radio-frequency transformer is somewhat limited; but with the above type of tuned radio-frequency coil, or transformer, a greater wave length range may be covered, depending upon the size of the coils and the tuning condensers employed. With the combination of coils and condensers described above, the range of wave lengths will be from about 180 to 500 meters with practically equal amplification over the entire range.

Inclining the coils.—The two sets of coupling coils between the tubes, and the set of coils used for the aerial and first grid tuning inductance are all made in the same way and mounted in a straight line, but with the axis of

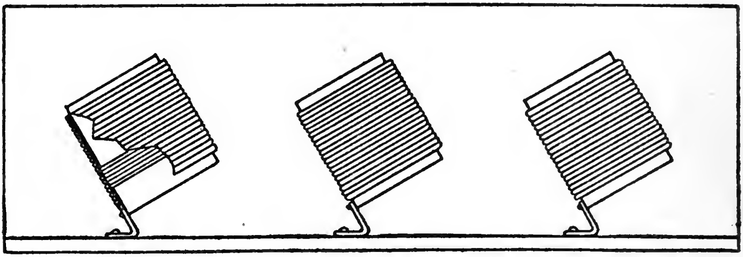


FIG. 91.—DIAGRAM INDICATING HOW COILS IN A NEUTRODYNE RECEIVER ARE INCLINED IN ORDER TO REDUCE INDUCTIVE COUPLING, WITH THE FIRST COIL CUT AWAY TO SHOW THE POSITION OF THE PRIMARY WINDING.

each set of coils inclined in the same direction to an angle of about 30° from the vertical, as shown in Fig. 91. With the coils so mounted, induction between them will be reduced to a minimum.* The coils should be spaced about 7 inches from center to center.

How to make the neutralizing condensers.—The three neutralizing condensers connected between the grids are of very low value, 1.5 micro-microfarads or .0000015 mfd. They may be purchased under the trade name "neutrodons" or may be constructed in the following manner: Three

* This feature of inclining the coils can be used to advantage in other sets of similar type.

pieces of No. 12 or No. 14 rubber insulated wire are connected each to the grid lead of one tube, the middle piece of wire being soldered to another length in order to form a **T**, after the manner illustrated in Fig. 90, and the four free ends are placed in line with each other with about ¼ inch separation between the ends of the wires. Two pieces of metal tubing about 1¼ inches long are slipped each over two of the four free ends of wire. The condensers are adjusted in a manner to be described later.

Assembling the neutrodyne set.—In wiring up this set care should be taken, as pointed out for all tube sets, to make the connecting wires as short and as direct as possible. Furthermore, particular care should be exercised in having the polarity of the coils in each set, correct with respect to each other. This connection will be accomplished when the coils are all wound in the same direction and the ends connected as shown in the diagram. This means that for the coils between the vacuum tubes, one end of the primary coil will be connected to the plate of one tube and the opposite end of the secondary coil will be connected to the grid of another tube.

The coils are utilized in this manner to neutralize the capacity set up by their windings, which was indicated in Fig. 89. This method of neutralization of transformer capacities does away with the necessity for employing additional coils to attain that end since, as indicated in the diagram, the lower end of the grid coil is connected directly to the negative wire of the "A" battery and thence to the ground, and the opposite end of the plate coil to the same point through the "B" battery.

When the set is in operation and signals are being received, the neutralizing condensers are adjusted for the first time. The adjustments are made by tuning in some strong signal and then turning off the filament of either amplifying tube without removing the tube from the socket. If the neutralizing capacity, i. e., the metal tube over the ends of the wire for that particular tube, is not adjusted properly, the signal will be carried through the vacuum tube by its capacity coupling, to the circuits on either side of it. The metal tube is then adjusted until the signal disappears, indicating that the capacity of the tube has been neutralized. This operation may require considerable care at first, but once adjusted, the metal tube condensers may remain fixed for a given type of tube. They may even be sealed in place, as it is doubtful if they will require adjusting again unless a different type of vacuum tube is substituted in the sockets.

The tubes used in this set may all be hard tubes, but if desired, the detector tube may be a soft tube. In the former case, about 90 volts may be used on the plates of the tubes, and in the latter 90 volts on all the tubes except the detector tube, which will require the usual 22½ volts.

As indicated in the diagram, and noted in connection with preceding radio-frequency sets, a variometer may be placed in the plate circuit of the detector tube in order to employ regeneration for the reception of C. W. signals or for picking up carrier waves from distant broadcasting stations, the tuning condensers serve only to increase or decrease the signal strength by placing the entire set in resonance or out of resonance with a given wave length.

Tuning a neutrodyne receiver.—It might be said at this point that tuning with any one of the three variable condensers does not greatly affect the other circuits.

It will be remembered that the first coupling transformer—that is, the one which serves to couple the aerial circuit to the grid circuit of the first tube—is constructed in the same manner as the other two transformers. This transformer takes the place of a variocoupler or other tuning device commonly used to transfer the incoming energy from the aerial circuit to the local or grid circuit; and for the reason that the two coils of this transformer are tightly coupled, tuning the local or grid circuit serves to tune the aerial circuit at the same time. The aerial acts simply as a collector of the energy and the primary of this first transformer transfers the energy to the local circuit.

For the above reason, this set does not follow the characteristics of the usual receiving set in which the aerial and local circuits are tuned entirely independently and without any similarity in the adjustments. In the neutrodyne receiver, tuning is simplified to a great degree, since in the three circuits to be tuned, the second and third condensers are set at nearly the same positions, while the setting of the first will vary with the aerial being used. With the relative positions of the condensers once determined, the circuits will be found to follow almost the same relative adjustments or settings on the dials. A change of three or four degrees in one dial will necessitate a similar change in the others. That is to say, the dials will very closely follow one another in tuning.

For example, if it is found that the third circuit responds to 360 meters when its tuning condenser is set at 60°, then the second circuit will be tuned to 360 meters, or very nearly so, when its tuning condenser is set at 60°. Or, if the third dial is set at 70° for a 400 meter wave length, it will be found that the second circuit will be tuned to resonance when the condenser dial of this circuit is set at 70° or within one or two points of 70°; for example, 68° or 71°.

After the desired signals have been tuned in, as suggested above, then each dial may be adjusted slightly for maximum signal strength. The adjustments are not so critical as with straight tuned radio-frequency. An idea of the relative positions of the dials may quickly be gained; then the settings may be recorded for a given wave length; and thereafter, that wave length will always be found at those settings.

As suggested for transformer coupled and for tuned radio-frequency on page 197, a short aerial of from 50 to 75 feet in length should be used with the neutrodyne receiver.

Variations in the neutrodyne set.—One or two stages of audio-frequency amplification of the type described earlier in this chapter may be connected to this receiver by simply connecting the input leads of the first stage of audio-frequency in place of the telephone receivers shown in the plate circuit of the detector tube.

Perhaps the most popular type of neutrodyne receiver yet placed upon the market is the 4-tube reflex neutrodyne amplifier, for which a hook-up is given in Fig. 92.

In this set, the first tube serves as a radio-frequency and audio-frequency amplifier, the second tube as a radio-frequency amplifier, the third tube as the detector and the fourth tube only as an audio-frequency amplifier. This method follows to some extent that of the inverse duplex system described in pages 202 to 209 in that the first radio-frequency tube, carrying the least amount of radio-frequency current, is therefore used as the reflex tube for the audio-frequency current.

The reader should be able to trace this circuit through

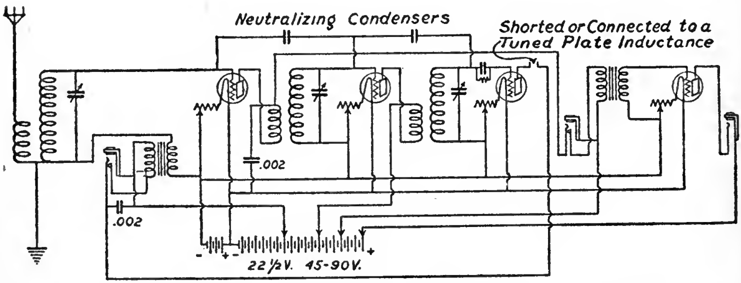


FIG. 92.—HOOK-UP FOR A THREE-TUBE REFLEX NEUTRODYNE RECEIVER WITH AN ADDITIONAL STAGE OF AUDIO-FREQUENCY AMPLIFICATION AND JACKS.

after having become familiar with the various reflex circuits and the inverse duplex system described in preceding pages. There are, however, in this circuit, one or two marked variations from preceding diagrams. The first three tubes constitute the neutrodyne circuit including the neutralizing condensers. If the receivers are plugged into the middle jack, only the two stages of radio frequency and the detector are placed in operation; but if the receivers are plugged into the first jack from the left, the signals in the plate circuit of the detector are returned to the first tube to be amplified again as audio-frequent signals. If still further amplification is desired for a loud speaker, the telephone plug is inserted in the third jack from the left and the audio-frequent signals, after being reflexed through the first tube, are again amplified by the fourth tube, which functions only as an audio-frequency amplifier. A little study of the diagram will make this clear.

The usual by-pass condensers for passing the radio-frequency current around the audio-frequency transformers are indicated for this set.

A variometer may be used in the plate circuit of the detector tube as indicated in this last circuit, but if oscillation is not desired for the detection of C. W. signals or carrier waves, this instrument may be either omitted, or set at zero so that no regeneration will result.*

Other circuits than the foregoing have been tried with the neutrodyne receiver but it has been found that if a third stage of radio frequency is added, trouble will result from magnetic coupling effects and the third stage will have to be thoroughly shielded. Furthermore, it is difficult to neutralize the capacity coupling of the third tube. The reflexing of two stages of audio-frequency through the first two tubes is also possible, but the set will be found to be quite noisy.

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* The reader should not assume from the foregoing description of the neutrodyne receiver that all the necessary details have been given for the construction of a set. It has been the aim, as in the case of the reflex and the inverted duplex receivers, to describe the principle of its operation, and to discuss its advantages and its limitations in operation. However, the experienced radio enthusiast will find herein sufficient information to enable himself to choose and build the set which best meets his requirements.

PREVENTION OF INTERFERENCE DUE TO RADIATION FROM RECEIVING SET

Attention should be called to the fact that any set which employs one or more stages of radio-frequency amplification will not interfere with other receivers in the neighborhood by radiating energy.

LOOP AERIALS

The indoor loop aerial as a receiving aerial, has several decided advantages over the outdoor types of antenna.

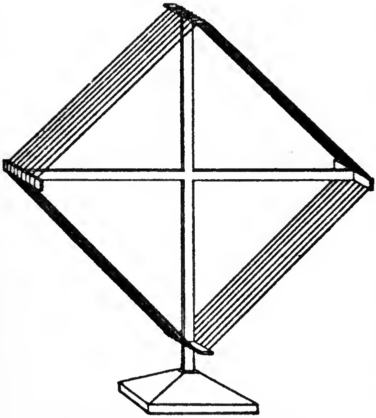


Fig. 93.—A loop aerial.

It may be constructed both cheaply and easily. It occupies very small space and may be installed in an office or in a city apartment. It may be moved readily from place to place. It collects no static. And it has directional characteristics, which make it useful as a radio compass, as well as in tuning out undesired signals. Its disadvantage is its limitation in the amount of energy which it can collect.

A loop aerial can not be used satisfactorily with a simple crystal detector set. As previously suggested, sensitive apparatus is required in connection with a loop.

The loop aerial is illustrated in Fig. 93. It may be of any size. Usually it is wound on a frame not less than two feet square nor more than eight feet square. As the size of the frame is increased, fewer turns of wire are required for a given wave length. Increasing the size of the frame, within certain limits, increases the capability of the loop for collection of energy. That is to say, a given length of wire wound on an eight-foot frame will collect more energy than will the same length of wire wound on a two-foot frame.

For receiving broadcasts, the following sizes of loops and turns of wire are suggested: a frame 2 feet square with 20 turns of wire; a frame 4 feet square with 10 turns of wire; a frame 8 feet square with 6 turns of wire.

The size of the wire has been found to have little influence on the efficiency of small loop aerials. It should, however, be heavy enough that it will not stretch or break under moderate tension or after continued handling. Best results are to be obtained when the turns are spaced about ¼ to ½ inch apart on the frame. A design for the frame itself is shown in Fig. 93. The construction should be sturdy enough that the wire is not required to brace it. It makes little difference whether this type of frame is suspended from a corner or from one of its sides. Whether suspended or mounted on a pedestal, it should swing on a vertical axis and its mounting should be such that it will remain stationary in any position to which it may be rotated.

Any light wood will do for the frame, and the wires may be held in place by means of matting tacks. If tacks are used, they should be driven into the end pieces before the end pieces are fastened to the cross pieces. The wire should be threaded through the staples after the frame is finished. Care should be taken that turns of wire are not mounted in contact with one another, either in themselves or through the tacks and screws, nails or other metal parts used in making the frame or in mounting it.

A condenser is used in shunt to the loop aerial for tuning the set.

The loop aerial is not grounded, but is connected to the set in the manner shown in Fig. 81. An indoor aerial requires no lightning protective device.

In its operation, as previously stated, the loop aerial may be used as a direction finder. It will receive signals at maximum strength from the directions of its plane, and at minimum strength from the directions at right angles to its plane. That is to say, with the loop turned so that its plane lies in the direction of the station from which it is desired to receive, signals from that station will come in at maximum strength. Signals from other directions may be largely or entirely eliminated, even though they are being transmitted on the same wave length.

Chapter IX

THE SPARK SENDING SET

Principles of the spark transmitter.—In Chapter I we learned that the radio telephone sending outfit is essentially an assembly of apparatus for collecting audible sound waves, converting them into electrical vibrations of very high frequency, and impressing these radio-frequent vibrations upon an aerial. The spark sending outfit is used to transmit only dots and dashes. It is therefore much more simple in construction and in operation. It is essentially a collection of apparatus for generating radio-frequent vibrations, and includes a device called a key, with which we can interrupt these vibrations at will, causing them to pass to the sending aerial in short or long series of vibrations forming dots or dashes. In other words, in telephone transmitting, the oscillations in the aerial circuit are continuous, and are moulded by sound waves impressed upon a transmitter. In the telegraph transmitting set, oscillations in the aerial circuit occur only when we press the telegraph key. A short pressure on the key transmits a dot, a long pressure, a dash.

In order to understand how the spark transmitter works, we may consider the action of the spark gap, the condenser, the transformer, the telegraph key, and the generator indicated in Fig. 94.

In Chapter IV we learned that the current which is directed into the sending aerial circuit to produce radio waves, whether telephone or telegraph, is always alternating current. In this case, our source of current is the alternating current (A. C.) generator at the extreme right in the diagram. The transformer indicated is similar in its action to the amplifying transformer described on page 180, in that the current from the generator passing

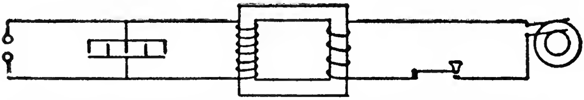


FIG. 94.—APPARATUS FOR THE PRODUCTION OF DAMPED OSCILLATIONS.

through the primary winding, induces current in the secondary circuit, without actual electrical contact between the two coils.

Damped oscillations and damped waves.—With the generator working, if the key is closed, electrical current will flow through the primary circuit, first in one direction, then in the other, changing its direction 120 times a second in the case of a 60-cycle generator. Each pulse of current in the primary circuit induces a pulse of high voltage current in the secondary circuit. The first pulse of alternating current from one end of the secondary coil enters one side of the condenser and stores itself between the plates. As this pulse dies out and before the next pulse can come from the other end of the secondary winding, the charge stored in the condenser surges back into the circuit, jumps across the spark gap at the extreme left in the figure, charges the other side of the condenser, instantaneously surges back through the circuit, jumps the gap again, a second time charges up the condenser on the first side, and continues to surge back and forth in this manner until it completely dies out. In this manner, while the key is closed, each pulse of the alternating current causes a series of sparks or a *spark train* across the gap.

Difficult as it may seem, the passage of this train of sparks takes place instantaneously between alternations of the generator. The second pulse of current from the generator, coming in the opposite direction, likewise induces a pulse of current in the opposite direction in the secondary circuit, which goes through a procedure exactly similar to that described above. So long as the key which closes the primary circuit is held down, the foregoing process continues and the trains of sparks—one train for each alternation or pulse of current—occur so rapidly that each appears to the eye as a single spark. In the case of a 60-cycle generator, 120 trains per second would jump the gap; and a dot, for example, might be made up of a dozen or more spark trains, a dash, of a still greater number.

The oscillations of current which are set up across the spark gap and produce the spark train are spoken of as

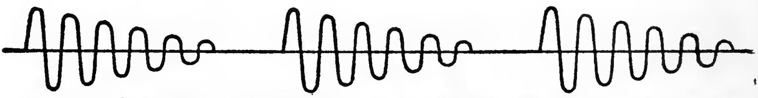


FIG. 95.—GRAPHIC ILLUSTRATION OF WAVE TRAINS OR DAMPED WAVES.

damped oscillations, since they become weaker and weaker until they are finally "damped out." When sent into an aerial, their resulting waves are called *damped waves*.

The use of alternating house current for spark transmitting.—In the case of ordinary house current, the alternations occur at the rate of 120 times per second (60 in one wire and 60 in the other) and as a flow in one wire and then a flow in the other is said to complete a cycle, this current is called 60-cycle A. C.

We can now see that if the primary of the transformer is connected to alternating house current, we will have 120 pulses of current per second in the primary winding of the transformer which will induce 120 pulses in the secondary winding. These 120 pulses from the secondary will charge each side of the condenser 60 times per second. Each of these 120 charges will then discharge or oscillate across the gap causing several sparks to occur for each discharge.

Spark frequency and spark train frequency.—In the foregoing cases, the 120 discharges of the condenser are called the spark frequency and the number of sparks which go to make up each discharge is called the spark train frequency. The rate of the spark frequency (120) is governed by the alternations of the charging source, while the rate of sparks occurring for each discharge (the spark train) is governed by the capacity and inductance of the condenser circuit and may be at the speed of several hundred thousand or several million per second. This does not mean that this large number of sparks occur in the spark train, but that a few sparks occur in the train *at that rate or frequency.*

Elements of a spark transmitter.—Substituting an aerial and ground, which we found in Chapter IV to form the plates of a "natural" condenser, for the condenser shown in Fig. 94, will give us, in principle, a spark transmitting set. Fig. 96 shows one side of the spark gap connected to the aerial and the other side connected to the ground.

Now, when a pulse of current first comes from the end of the secondary winding which is connected to the

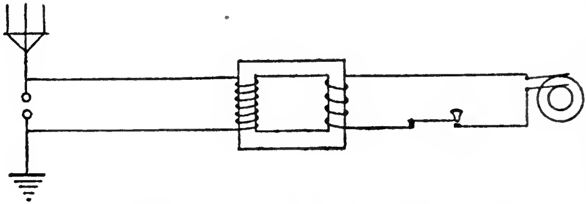


FIG. 96—ELEMENTS OF A SPARK TRANSMITTER.

aerial, it will flow up into the aerial, charging it as it did one side of the condenser shown in the preceding illustration, and the aerial, acting as one plate of the condenser, will instantaneously discharge across the gap. This discharge or flow of current across the gap will then flow down the ground wire and charge up the earth around the earth connection which is acting as the other plate of the condenser. Back across the gap and up into the aerial, will come the surge of current from the earth connection, and so on until the energy has expended itself and the oscillations are *damped out* as in the preceding case.

It follows, therefore, that the electromagnetic waves radiated from the aerial by these damped oscillations, dependent as they are upon the energy of the oscillations, will likewise be damped or of dying amplitude. Since their speed, however, is constant—186,000 miles per second—the waves in a train do not grow shorter in length, but die down from a wave to a ripple and then to smoothness, as a rough pond might come to a calm.

Waves of this kind are spoken of as damped, or discontinuous waves. They differ from undamped or continuous waves produced by a tube transmitter in that the latter are produced by pulsations of current which are all of the same strength and do not die out as do the pulsations of current which produce the spark train.

The necessity for coupling the transmitter to the aerial.—A transmitting set having the spark gap connected in series with the aerial circuit would have certain inherent undesirable characteristics which have made it necessary for the Government to prohibit its use. In the case of a gap connected in series with an aerial having a natural wave length of 200 meters, for example, the emitted signals would not be confined to that wave length but would be heard by a receiving station over a wide or broad range of wave lengths, probably from 150 to 250 or 300 meters. It can readily be seen that if several stations in any locality were all sending with transmitters of this type, they would cause so much *interference* that it would be almost impossible to separate with a receiving set, the signals of any one of them from those of another.

In order to eliminate this objectionable feature, government regulations have been made which provide that all transmitting sets must be coupled to the aerial circuit through an *oscillation transformer*, which is somewhat similar to a loose coupler, or by some other form of tuning inductance. By means of such an instrument, waves above and below the main wave in length, are eliminated to a great extent, and the energy radiated from the transmitting aerial circuit is largely confined to waves of one length. This coupling arrangement is shown in Fig. 100.

The oscillation transformer.—The oscillation transformer is made up of two coils of heavy copper ribbon about ½ inch wide and $\frac{1}{16}$ inch thick or of two coils of ¼-inch copper tubing. The coils may be made up in a form very much resembling a loose coupler or a variocoupler, except on a larger scale, or resembling spiderweb coils, as shown in the accompanying illustration, in which case they are called a pancake oscillation transformer. The secondary is so supported that it may be drawn away from the primary coil as in the case of a loose coupler; or revolved to a position at right angles to the primary coil as in the case of a variocoupler; the secondary coil of a pancake transformer may be swung on a hinge effect at an angle to the primary coil, as explained for spiderweb coils in Chapter IV.

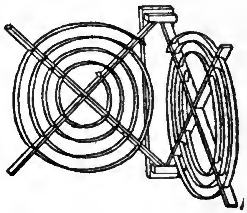


FIG. 97.—A PANCAKE OSCILLATION TRANSFORMER.

Only two or three turns (10 to 15 inches in diameter) of the copper ribbon or tubing are used for the primary winding and a similar number of turns of the same size for the secondary winding, in the case of an amateur transmitting set.

High frequency currents travel on the surface of a conductor in what is known as a skin effect; the heavy copper ribbon or tubing, having a large surface, is used in the oscillation transformer for that reason. Copper ribbon or tubing is also used in connecting up the various pieces of apparatus in the circuit in which the primary of the oscillation transformer is included, as well as in the circuit including the secondary of the oscillation transformer. The connecting leads in both of these circuits should be as short and as direct as possible.

The need for a transmitting condenser.—With the aerial and the ground, which we have considered as the plates of a condenser, removed from direct contact with the high voltage of the secondary circuit in which the spark gap is placed, it becomes necessary to replace the "natural condenser" which we have removed, with a condenser in the secondary circuit, as indicated in Fig. 100, in order to provide a storing and discharging place for the high voltage pulsations. This condenser is shown in Fig. 98.

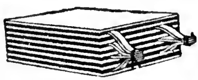


FIG. 98.—A GLASS PLATE TRANSMITTING CONDENSER.

The action more in detail is as follows: Each pulse of high voltage current coming from the secondary of the spark coil now charges the condenser, in the usual manner; the condenser then discharges through the primary coil or winding of the oscillation transformer, setting up a magnetic field around the primary winding which induces, in the secondary of the oscillation transformer and in the aerial and ground circuit in which it is connected, oscillations of current of precisely the same nature as those in the condenser circuit which caused the transformation. These oscillations of current induced in the secondary coil or winding of the oscillation transformer and hence in the aerial and ground circuit, propagate the electromagnetic waves.

Transmitting condensers.—The transmitting condenser is termed a high potential condenser because it is designed to withstand the high voltage of the secondary circuit of the spark coil or the transformer.

In a spark coil transmitting set, this condenser is usually made up of a number of sheets of thick tin foil, separated by sheets of window glass. Directions for the construction of a condenser of this type are given on page 254. For use with a transmitting set employing a 110-volt A. C. transformer of ¼ to 1 K.W. capacity, plate glass separators should be used.

Sheets of mica are very often used instead of glass in transmitting condensers, but in any of the foregoing types, if one of the insulating sheets is punctured by the high voltage, considerable inconvenience is caused by having to take apart the condenser (which is very often immersed in oil or paraffin) to replace the punctured sheet.

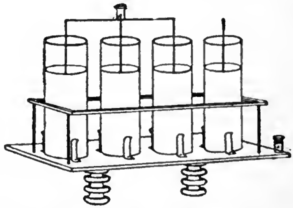


FIG. 99.—A TRANSMITTING CONDENSER MADE UP OF JARS.

A better arrangement is that of using either transmitting condenser jars, or some other form of transmitting condenser made up in separate units. Then if one of the units is punctured, it is a simple matter to replace it.

THE SPARK COIL TRANSMITTING SET

In the simple transmitting set shown in Fig. 100, we may utilize 4 dry cells (6 volts) or a 6-volt storage battery as the source of current, in conjunction with an ordinary ½-inch spark coil such as is used with automobile or motor boat engines.

The spark coil.—The spark coil is what is known as an open-core transformer; the core consists of a bundle of iron wire about ½ inch in diameter and 3 or 4 inches

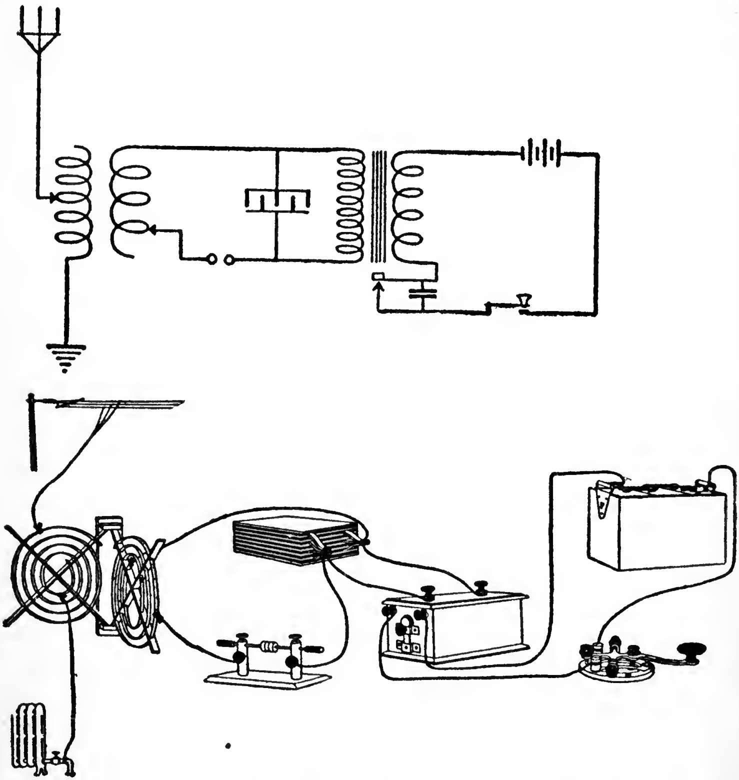


FIG. 100.—HOOK-UP FOR A COMPLETE SPARK COIL TRANSMITTING SET.

long; the primary winding is made up of two or three layers of No. 16 to No. 20 insulated wire wound around the iron wire core; the secondary winding consists of a greater number of layers of fine insulated wire (No. 36 to No. 40) wound on top of the primary winding, with some insulating material such as specially treated paper or cloth placed between the two windings, to prevent the high voltage (about 10,000 to 15,000 volts) induced in the secondary winding from jumping through to the primary winding.

Since the dry cells furnish direct current, some means is necessary for making the current reverse or pulsate when it flows from the battery into the primary winding. This pulsating effect is accomplished by means of a vibrator. The vibrator arm is of iron composition or has a small disk of iron fastened to it, and is mounted on the coil case so that the iron strip or disk is opposite one end of the iron core. A connection from one end of the primary winding is made to the vibrating strip and the circuit is continued through the adjustable screw which makes contact with the vibrating strip. All of these details are shown in Fig. 100.

The action of the spark coil.—When the key is pressed, current instantly flows through the primary winding of the coil and magnetizes the iron core. The magnetism in the core instantly attracts the composition iron strip or disk and pulls the vibrator armature towards the core.

As soon as the vibrator moves, the circuit through the primary winding is broken at the point of contact of the vibrator arm and the adjustable screw. With this circuit broken, the current flowing through the primary winding ceases, and the iron core loses its magnetism, allowing the vibrator arm or *armature* to spring back.

Once again the armature is in contact with the screw, and current again flows through the primary winding, attracting the armature. This operation is repeated again and again.

The making and breaking of the primary circuit at the vibrator cause pulses of current to flow through the primary winding. These pulses momentarily magnetize the iron core and thereby induce pulses of high voltage current in the secondary winding.

The pulses induced in the secondary winding flow out of the winding, first from one end and then from the other, thereby furnishing alternating current which may be utilized to charge the aerial and ground as in the preceding case.

In practice, contact points of very hard metal (platinum or platinum alloy) are used on the vibrator armature and on the end of the adjustable screw, since the arcs produced at that point by the making and breaking of the primary circuit are sufficient to burn up softer metal with a lower melting point.

The speed at which the armature vibrates is governed by the tension of the armature and the adjustment of the screw. It is possible to adjust the vibrator of most spark coils so that alternating current up to 300 or 400 cycles can be produced in the secondary circuit. In the diagram, a fixed low voltage condenser is shown connected across the contact points. This condenser is always mounted inside the spark coil case. Its function is to reduce arcing at the contacts, thereby causing a quicker make and break of the circuit.

Spark coils are classified in size, by the distance the secondary voltage will jump between needle points, as, for example, a 1-inch coil, etc. Approximately 20,000 volts are required to cause a spark across a 1-inch gap in air.

The secondary terminals of a spark coil may usually be

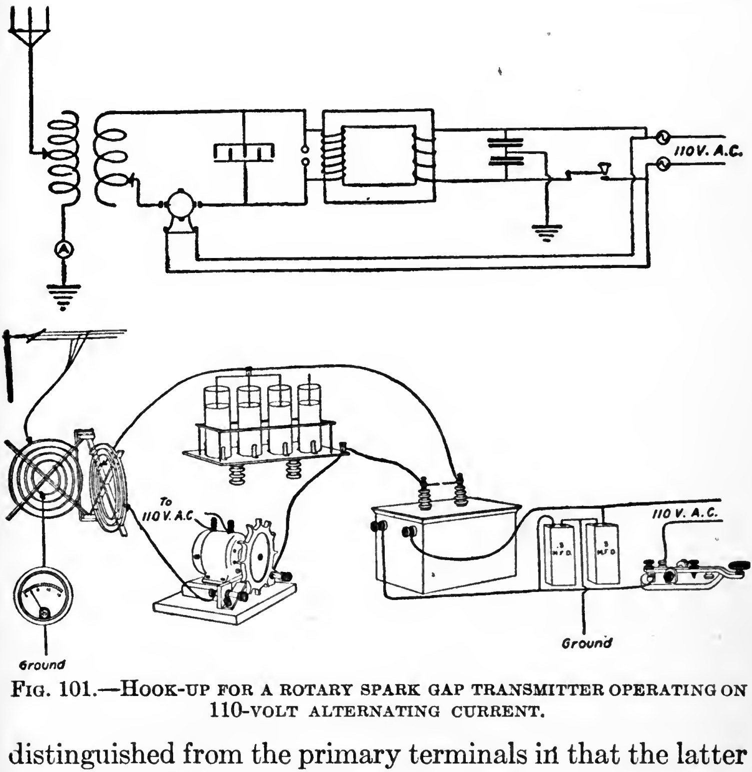


FIG. 101.—HOOK-UP FOR A ROTARY SPARK GAP TRANSMITTER OPERATING ON 110-VOLT ALTERNATING CURRENT.

distinguished from the primary terminals in that the latter are usually placed at one end near the vibrator and the former on top of the case; also, the secondary terminals are widely separated and, in most cases, more carefully insulated.

The key.—For a spark coil set, this instrument may be an ordinary telegraph key. Its function is that of regulating the length of time over which the sparks flow in the secondary circuit, a short flow of sparks producing a dot and a longer flow producing a dash.

The spark gap.—The spark gap shown in the diagram is known as a *fixed gap* as distinguished from a *rotary gap.* The sparking points are called the electrodes. They may be of brass or zinc and are made adjustable in respect to the distance separating them.

THE SPARK TRANSMITTER OPERATING ON 110-VOLT A. C.

The spark coil transmitting set is limited in power to the amount of current which the vibrator of the spark coil can control. To permit the use of greater power in transmitting, it is necessary to employ a transformer operating on alternating current.

Fig. 101 shows a complete amateur spark transmitting set coupled to an aerial circuit and consisting of the following instruments. From left to right:

Oscillation transformer
Hot wire ammeter
Rotary spark gap
Transmitting condenser
Safety spark gap
High voltage transformer
Protective condensers (grounded)
Transmitting key
Fuses

Some of these instruments have already been explained in connection with the preceding sets.

The hot wire ammeter.—This instrument is used to indicate the amount of current transferred from the set to the aerial and ground circuit. It consists fundamentally of a fine wire and its accompanying mechanism enclosed in a case. The ammeter is connected in series with the aerial and ground circuit. This connection places the fine wire, enclosed in the ammeter case, directly in the path of the energy flowing in the aerial circuit. In transmitting, the passage of current in the aerial circuit and through the fine wire heats the wire which in its expansion deflects an indicating needle.

The greater the amount of energy flowing in the aerial circuit, the more will the wire expand and the farther will the needle be deflected. In an amateur transmitting set utilizing not more than ¼ K.W. of current in the primary of the transformer, the current flow in the aerial circuit would be very small and an ammeter calibrated in thousandths of an ampere, i. e., milliammeters, would be necessary to register the small flow of current. With transmitting sets using more than ¼ K.W., an ammeter reading from 1 to 5 amperes or even from 1 to 10 amperes might be used. However, the larger the range of the ammeter, the coarser are the divisions of the scale and it is very probable that a set with an input of 1 K.W. might send only three or four amperes into the aerial circuit, in which case the smaller size would be more desirable, since its needle would deflect over a wider path, permitting closer reading.

Hot wire ammeters will be given further consideration in connection with tuning the transmitting set.

The rotary spark gap.—In many transmitting sets, a rotary spark gap such as that shown in Fig. 101, is used in place of the fixed spark gap, for the following reason:

When 60-cycle alternating house current is used as a source of power, 120 pulsations of current are produced in the secondary circuit and 120 spark trains result across the gap. These 120 spark trains per second produce a very low and unmusical tone in the head telephones of the receiving set. Furthermore, this low note spark is very hard to read through other signals and especially through static. If, on the other hand, we insert between the two stationary studs of the fixed gap, a rotor with studs attached to it, each one of the 120 spark trains will be broken up into several spark trains, the number depending upon the speed of the rotor and the number of studs on it.

As a rule, best results will be obtained if the 120 spark discharges are broken up into not more than about 240 spark discharges per second.

A rotor making 1800 revolutions per minute or 30 revolutions per second and having 8 studs would give this effect. The stationary studs of the gap should be set very close to the moving studs. Best results are to be obtained only by experimentation with a fellow amateur listening to the tone produced from different adjustments.

The rotor is usually fastened on the shaft of a small motor, such as a fan motor, which is operated from the house current. There is no advantage in using a rotary spark gap with a spark coil transmitting set, since the frequency of the sparks in such an outfit is regulated by the vibrator as previously stated.

The safety spark gap.—A safety gap is connected across the secondary leads of the high voltage transformer so that if the voltage becomes too high it will jump the gap before puncturing the condensers.

If the safety gap repeatedly "flashes over" when the transformer is in operation, it should not be widened to a gap voltage distance of more than the condensers will stand, as this would defeat its purpose. The secondary voltage should be cut down by reducing the power input to the primary of the transformer. Transformers are usually sold with the safety gap attached.

The power transformer.—The transformer core is made up of a number of pieces of thin sheet iron, specially prepared, in a hollow square or rectangular form several inches square and having a total thickness of one or two inches, depending on the design and size of the transformer. On one side of this core, several layers of insulated wire (No. 18 to No. 12 or No. 10) are wound, making up the primary winding. On the opposite side of the iron core, the secondary winding consisting of a great number of turns of fine insulated wire (No. 40 to No. 30) is placed. The greater the number of turns of wire on the secondary coil, the higher will be the voltage of the current in the secondary circuit. When a pulse of current of 110 volts is sent in one direction through the primary winding of the transformer, it magnetizes the iron core, setting up magnetic lines of force which flow around the core to the part over which the secondary winding is wound; these lines of force induce in the secondary winding of the transformer a momentary pulse of current of many thousands of volts. This is due to the fact that there are thousands of turns of wire in the secondary winding upon which the magnetic lines of force act. This pulse of high voltage current flows out the wire leading from one end of the secondary winding and in trying to make its way to the wire connected to the other end of the secondary, charges up the condenser. The condenser then discharges across the gap, in the manner previously explained.

The next pulse of current, flowing in the opposite direction in the primary winding, induces a second pulse of current in the secondary winding which comes out the other terminal of the secondary winding and charges up the other side of the condenser. The condenser then discharges again in the same manner as before.

Selecting a transformer.—The amateur should not attempt to construct a transformer for the foregoing use, as considerable knowledge of electricity and electrical apparatus is required in order to design and construct an efficient transformer. Amateurs should bear in mind in purchasing a transformer that they are limited by U. S. Government Regulations to ½ K.W. of power input, if located within five miles of a commercial or naval station; and in all other instances, to 1 K.W. input, except by special concession in the case of experimental or special amateur stations.

The power or input of the primary and the output of the secondary are always regulated by the amount of current flowing through the primary circuit. Purchased transformers are usually provided with taps taken from the primary circuit, which vary, in steps, the amount of current which can flow through the primary winding. If no such provisions are made, a variable reactance coil, which is a coil of wire wound on an iron core, may be inserted in series with the primary winding to accomplish the same result. Each pulse of current passing through the reactance coil sets up a counter electromotive force which opposes the current passing through the coil and cuts down its voltage. The effect of the reactance coil is varied either by means of taps taken from the turns of wire or by moving the core in or out of the coil.

The kick-back preventer.—A protective device or kick-back preventer is necessary in a spark transmitting set, to prevent the high voltage in the secondary circuit from reacting on the primary circuit and causing a surge back into the current supply lines which are feeding the primary circuit. Such a surge might cause considerable damage to the lighting circuit and fixtures. The usual protective device consists of two .5 mfd. condensers capable of withstanding 600 volts, connected in series across the line at the primary terminals of the transformer, and having the connection between the two condensers grounded. The ground wire for the condensers may be connected to the metal conduit which must be used in wiring up the primary of the power transformer.

The key.—The key for A. C. transformer sets should be a heavy current key, and should have contacts capable of withstanding the heat produced by interrupting the current drawn by the particular transformer with which the key is used.

Fuses.—Separate fuses should be used in the primary circuit. They should be of a capacity capable of carrying the amount of current used in the primary circuit of the transformer and no more than that amount.

Underwriters' requirements.—The ground wire for the transmitting set must be of copper strip or ribbon not less than $\frac{3}{8}$ of an inch wide and $\frac{1}{64}$ of an inch thick, or else of a copper wire or approved copper-clad steel wire having an outside measurement of $\frac{3}{4}$ of an inch; for example, No. 2 copper wire. The transmitting set ground wire must be protected from mechanical injury and firmly supported on insulators throughout its length, keeping at least 5 inches creepage distance from any extraneous material. It must be connected to a good, permanent ground which may be the water pipe system, or a ground similar to the lightning ground, **but connection must not be made to a gas pipe or to the lightning ground.**

All 110-volt wiring for a transmitting set must conform to the rules and regulations for house wiring laid down by the National Board of Fire Underwriters.

TUNING THE SPARK TRANSMITTER

The transmitter must be tuned in order that it may radiate energy on a wave length which will comply with the requirements of the law for the amateur transmitting station.

Theoretically, in tuning a transmitter, the primary circuit should first be tuned to the desired wave length, with a wave meter coupled to the circuit; then the secondary circuit should be tuned in the same manner. After these two circuits of the transmitter have been tuned separately, they should be coupled together and the emitted wave from the primary or aerial circuit then measured; for when the two circuits are tuned separately and then coupled to each other, a reaction takes place between the primary and the secondary of the oscillation transformer, which will result in a wave length slightly off tune, or different from the wave length to which the two circuits were first tuned. In practice, however, especially with an amateur set, this method is seldom followed. In the case of a spark transmitter, it is more common to use a wave meter in tuning the secondary circuit only, and then to adjust the primary or aerial circuit to

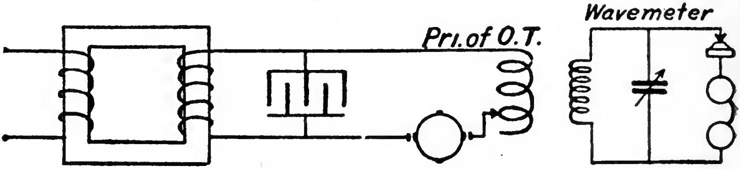


FIG. 102.—METHOD OF COUPLING THE WAVE METER TO THE PRIMARY OF THE OSCILLATION TRANSFORMER.

resonance with the secondary circuit. In order to tune a transmitting set accurately, a wave meter is always necessary.

The wave meter.—The wave meter is made up of a coil of wire, a variable condenser, a pair of head telephones and a detector. The inductance and the variable condenser are calibrated together in a laboratory. The arrangement for tuning the secondary circuit by coupling the wave meter coil to the primary of the oscillation transformer is shown in Fig. 102. It can be seen from the diagram that the circuit for the wave meter is precisely similar to the secondary circuit of a crystal detector set in which the tuning of the circuit is accomplished by means of the variable condenser. In the usual method of tuning a transmitter, the aerial and the ground wire of the transmitting set are disconnected from the secondary of the oscillation transformer and the transmitter is placed in operation. Next, the inductance coil of the wave meter is placed in inductive relation to the primary of the oscillation transformer, so that current may be induced in the coil, and hence in the wave meter circuit, and detected by the crystal detector and head telephones.

The coil of wire of the wave meter may be placed in inductive relation to the primary of the oscillation transformer by placing the wave meter coil above or below or to one side of the primary in such a way that its turns of wire are in the same relative position (not at right angles) as the turns of wire in the primary of the oscillation transformer. Care should be taken not to place the inductance coil too near the primary coil of the oscillation transformer, as such high voltage may be induced in the wave meter coil that the insulation of the coil will be punctured or the telephone receivers burned out. By rotating the variable condenser of the wave meter, an adjustment may be found at which maximum response will be obtained in the head telephones. This response will indicate that the wave meter is in resonance with the transmitting circuit, and therefore is tuned to the same wave length. A reading is then taken directly from the scale on the condenser which will indicate the wave length of the transmitter secondary circuit. If readings are not to be obtained directly from the scale on the condenser, they will be supplied on a chart which is sold with the wave meter set. If the reading indicates that the wave length is below or above 200 meters (in the case of an amateur transmitting station) the tap on the primary of the oscillation transformer is then varied to include more turns of wire or fewer. Remember that adding inductance, or turns of wire, in the primary of the oscillation transformer increases the wave length and decreasing inductance decreases the wave length.

After the secondary circuit of the transmitter (which includes the primary of the oscillation transformer) has been tuned to the desired wave, the ground wire and the lead-in are connected to the secondary coil of the oscillation transformer and the secondary coil is coupled to the primary coil.

A hot wire ammeter or a small flash-light bulb may be utilized in the following manner to assist in placing the aerial circuit in tune with the secondary circuit of the transmitter. With the hot-wire ammeter or the flash-light bulb connected in series with the ground wire, the transmitting set is again placed in operation. The current flowing up and down the aerial circuit will deflect the needle of the hot-wire ammeter (as explained on page 209) or light the filament of the flash-light bulb. The maximum amount of current will be induced in the aerial circuit, and hence the hot wire ammeter will deflect to a maximum or the flash-light bulb will light up most brightly when the aerial circuit is in resonance or in tune with the secondary circuit of the transmitter. The tuning of the aerial circuit is accomplished by varying the number of turns of wire in the secondary of the oscillation transformer. Resonance of these two circuits of the transmitter indicates that they are tuned to the same wave length.

Care should be exercised in using a flash-light bulb in series with the aerial circuit for indicating resonance, particularly if the transmitting set is of one kilowatt size, as the current induced in the aerial circuit may be more than sufficient to burn out the filament of the bulb. A shunt may be placed around the flash-light bulb to carry the greater portion of the current and thereby reduce the current which flows through the bulb. In practice it will be found that with a transmitter of ½ to 1 kilowatt input, a 110-volt mazda bulb may be substituted for the flash-light bulb. The hot wire ammeter is more desirable as an indicator of resonance than the bulb, as resonance can be registered more accurately with it than with a lamp, and can then be recorded; but the latter device is easy to obtain, while not every amateur possesses a hot wire ammeter.

Even though the transmitting aerial has been tuned to emit a wave length of 200 meters, it may be radiating a considerable portion of its energy on wave lengths either above or below 200 meters. This feature in a set constitutes what is known as broad tuning of the transmitter. Broad tuning is prohibited by law. Specifically, the energy on any wave length either above or below the wave length to which the transmitter is tuned, must not exceed 10 per cent. of the energy of the wave length to which the transmitter is supposed to be adjusted. This undesirable effect may be removed by reducing the coupling between the primary and the secondary of the oscillation transformer, or by withdrawing or revolving the secondary coil to such a degree that only the major wave gets across. The exact degree to which the coupling must be adjusted in order to accomplish this result cannot be told without the use of a decremeter which is seldom possessed by an amateur. The radio inspector for the district in which the transmitter is located usually takes care of this measurement at the time of inspection of the station.

It might be suggested that a great number of amateurs tune their transmitters by selecting at random, a point on the primary of the oscillation transformer and then placing the aerial circuit in resonance with the secondary circuit of the transmitter after the manner just described. They then have some fellow amateur listen in and compare their wave length with that of other amateurs or stations which are known to be transmitting on a certain wave length. If they are then informed by the fellow amateur that they seem to be above or below 200 meters, they alter the adjustment of the primary of the oscillation transformer and again place the aerial circuit in resonance, and so on until they arrive at the desired wave length. This method, however, is bad practice, and if carried out by inexperienced amateurs, is very apt to result in interference with other stations within range.

THE COUNTERPOISE

In localities where the ground is very dry, making it impossible to obtain a good connection to moist earth, or in case sending or receiving sets are located on the upper floors of tall buildings where the distance to ground by way of water or steam pipes is very great, better results can usually be obtained by substituting a counterpoise for the usual ground connection for the set.

The counterpoise.—A system of wires mounted a few feet above the ground or roof, directly under the aerial and approximately duplicating it, is called a counterpoise. It replaces the lower half of the aerial-and-earth condenser discussed in Chapter IV.

The counterpoise should extend beyond the aerial in all directions. It should be equidistant from the earth and from vegetation at all points, or raised high enough so that the effect of any unevenness or of vegetation may be disregarded because of its slight relation to the total height.

For best results, the counterpoise should be circular, or nearly so, in shape, with a large number of radial wires—all connected by wire jumpers—the whole resembling a huge spiderweb. The greater the number of radial and circular wires used, the higher will be the efficiency of the counterpoise.

Good results may be obtained from a counterpoise extending in fan-shape from a point below the end of the aerial nearest the set.

Just as great care should be taken in supporting and insulating the counterpoise as in the case of the aerial itself. Strong wooden posts should be used for the supports and these should be placed at a distance from the counterpoise equal to or greater than the height of the wires from the ground or roof. The wires should be suspended from the supports by strong rope with a good insulator, several inches long, between each rope and the wire it supports.

In every case, the counterpoise must be protected from lightning in the same manner as the aerial itself; that is, it must be connected to the earth through an approved lightning arrester or a lightning switch or both.

Chapter X

THE VACUUM TUBE TRANSMITTER

As stated in Chapter V, the three-element vacuum tube may be employed as a generator of radio-frequency oscillations which may be used in sending. As an oscillation generator, it operates upon the so-called "feed back" principle which we have already discussed in Chapter VII. That is to say, the grid and the plate circuits are so coupled that they react on each other. Successive pulses in each circuit persist in building up succeeding pulses in the other, until both circuits are in a state of continuous oscillation. These oscillations may then be impressed upon an aerial and made to propagate continuous wave signals.

Both the transmitter and the receiver utilize the property of the vacuum tube to generate energy in the form of oscillations. In receiving, the generated power is used to reinforce the received impulses, as we have already seen. In transmitting, the plate circuit is so coupled to the aerial circuit that energy from the oscillations in the plate circuit is transferred to the aerial circuit and radiated into space in the form of continuous waves.

Most amateurs are familiar with the fact that the regenerative receiver makes up the simplest vacuum tube transmitting set.

REGENERATIVE RECEIVING SETS AS TRANSMITTERS

The simplest vacuum tube transmitter.—The following diagram shows a simple method of transmitting either telegraph or radiophone signals with a common type of regenerative receiver.

The receiver shown will be recognized at once as the single circuit receiver with a tickler coil, of Fig. 63. The regenerative type of receiver not only reinforces received signals, but also acts as a transmitter of very low power provided that the plate circuit control is so adjusted that the tube will oscillate. By connecting a key in the lead-in or in the ground wire, the outgoing energy (or oscillations) may then be broken up to form continuous wave (C.W.) dots and dashes.

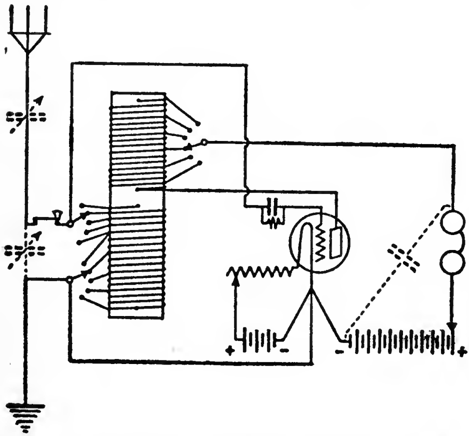


FIG. 103.—THE REGENERATIVE RECEIVING SET HOOKED UP AS A TRANSMITTER.

It is well to point out that the operator of such apparatus must be licensed to transmit. The Government also requires a transmitting station to be licensed regardless of how little power it employs. Furthermore, the wave length must be kept down to two hundred meters or lower. This result is more easily accomplished than it may at first seem. The receiving set should be tuned in on some station which is known to be transmitting on 200 meters. Maximum strength of signals will indicate that the receiving set is tuned to 200 meters. If the receiver is then set into oscillation, its energy will be radiated on approximately 200 meters, or the wave length to which the receiving set has been tuned.

Actual radiophone communication has been accomplished by speaking into the head telephones of the usual regenerative receiver with the set oscillating, but because of the critical adjustments necessary, the novice would probably have difficulty in transmitting by this method.

In using the receiving set as a transmitter, a *microphone* may be substituted for the key; in that case, a simple radiophone is the result.

The microphone.—This instrument is exactly similar in appearance and in operation to the microphone or transmitter of the ordinary wire telephone. It consists fundamentally of two conducting surfaces, one of them a diaphragm, attached to a mouthpiece into which sounds may be directed; between the two surfaces, fine grains of carbon are packed. As words are spoken into the microphone, causing the diaphragm to vibrate, the carbon grains between the diaphragm and the other conducting surface are alternately compressed and loosened by the varying pressure of the sound waves. When loosened, the grains of carbon offer a very high resistance to current being passed through them, owing to poor contact of the grains with one another. When they are compressed, better contacts are made, and the flow of current increases accordingly.

Each word, therefore, which is spoken into the transmitter will cause a great number of increases and decreases in the current flowing through the carbon grains. These fluctuations follow the vibrations produced by the voice. In the case of wire telephony, if the current passing through the microphone is connected to a receiver, the variations in the current will produce vibrations of the receiver diaphragm which will reproduce the voice directed into the transmitter. The current passing through the microphone is said to be *modulated* by the voice. In wireless telephony, when the microphone is connected in series in the aerial circuit, the continuous oscillations of current flowing in that circuit are modulated as in the case of the current passing through the microphone in wire telephony. These variations caused in the oscillations of current traveling in the aerial circuit, change the uniformity of the continuous waves radiated from the transmitter aerial circuit. From such "moulded" waves striking the receiving aerial circuit, the voice or music is reproduced in the receiving set.

Increasing the power of the simple set.—If the user desires to cover a distance greater than a few blocks, the only changes necessary in the equipment are the substitution of an amplifier tube for the detector tube and the addition of more "B" batteries. With a pressure of 100 volts in the plate circuit of this receiving set, continuous wave telegraphy is successful up to two or three miles. If the set is used as a radiophone, the distance will be much shorter and may be limited to perhaps one mile, depending on the size of the aerial, its location, and local conditions.

Interrupted continuous wave (I. C. W.) communication for even greater distances may be accomplished with this receiver transmitter by using a spark coil such as that described on page 204, to furnish the required plate voltage. The only changes necessary for such an addition are, the substitution of the secondary voltage of a ½-inch spark coil for the usual "B" battery voltage, and the insertion of a good sized glass plate condenser across the secondary circuit of the spark coil. The hook-up with all the connections, is shown in Fig. 104.

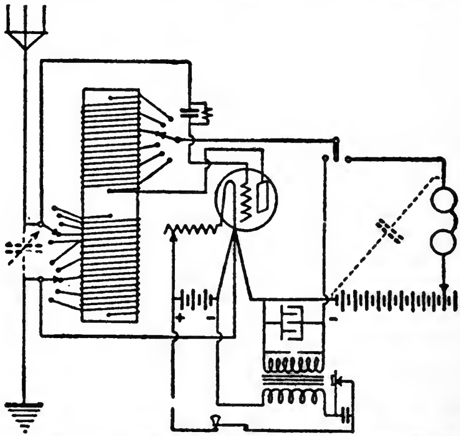


FIG. 104.—USE OF A SPARK COIL TO INCREASE THE POWER OF THE RECEIVER TYPE OF TRANSMITTER.

In this circuit the spark coil and the "B" battery are connected to a two-point switch in such a manner that it is necessary only to move the switch arm to the right in order to receive and to the left in order to send. The switch is used to disconnect the phones from the circuit during transmission so that they will not be injured by the high voltage from the coil.

In the operation of this set, a hard tube should be used in place of the usual detector tube, as the latter will not withstand the high voltage from the secondary of the spark coil. A *safety gap* of $\frac{1}{32}$ of an inch should be placed across the secondary of the spark coil to protect the tube from the high voltage. Sparks do not occur across the gap when the tube is oscillating properly, but they begin to occur when the set is out of tune or when the filament is too dim. Such a set has been heard at a distance of more than one hundred miles when utilizing only one-fifth of the capacity of the tube. Although this is not the normal range of the set, it demonstrates the remarkable carrying power of the energy generated by the vacuum tube under favorable conditions.

A home-made condenser for a spark coil set.—A suitable glass plate condenser may be made up of 14 sheets of tin foil 3 x 5 inches in size and 8 sheets of glass 5 x 7 inches in size. Photographic plates with the film removed are most satisfactory for this purpose, as this glass is of much better grade, is much thinner, and is more uniform in thickness than ordinary window glass. The tin foil may be of almost any thickness, but it should be tin foil and not lead foil. The method of construction is as follows:

Slightly heat each photographic plate over a gas stove burner and when each is warm enough, smear a light film of beeswax on both sides of six of the plates and on one side of each of the other two. A gas light burner should not be used for heating the plates as the heat will be too greatly concentrated and may crack the glass. When a light film of beeswax has been smeared on all of the plates as suggested, slightly heat each plate in turn and then spread out a sheet of tin foil in the center of each sheet of glass, on each side to which the beeswax has been applied, making six plates of glass with a sheet of tin foil on each side and two plates of glass with a sheet of tin foil on only one side each. As each sheet of tin foil is spread out in melted beeswax, smooth it out so that no air bubbles will remain between the tin foil and the glass. The clean surfaces of the two plates of glass will form the outside surfaces of the condenser after it has been assembled.

The condenser is assembled in the following manner: One plate of glass which has only one surface covered with beeswax and tin foil is laid on a table with the clean surface downward. A thin copper strip is now laid on the sheet of tin foil so that it extends beyond the sheet of glass at one end. A sheet of glass which has both surfaces covered is now laid on top of the first plate. A second copper strip is laid on this plate and allowed to extend over the end of the glass which is opposite to that from which the first strip of copper extends. The third plate is laid on top of the second sheet and another strip of copper placed on it so that it extends out over the first strip, and so on. The other sheet of glass which has only one surface covered, is placed on the pile last of all with its clean surface upward. The plates may be bound together with tire tape. The strips of copper extending out one end may be clipped together so that contact is made with all of them, or a hole may be drilled through all of the strips and the binding post inserted as shown in Fig. 98. The other set of strips may be similarly fastened together.

HOW TO BUILD A VACUUM TUBE TRANSMITTER

Where it is desired to cover a distance exceeding a few miles, a radiophone transmitter, which will employ higher plate voltages and vacuum tubes specially designed for transmitting, must be built.

Contrary to general opinion, a vacuum tube transmitter is as easy to build as a regenerative receiver. Where the novice usually falls short is in the failure to include indicating instruments such as ammeters and voltmeters to tell him just what he is doing. We shall endeavor, there-

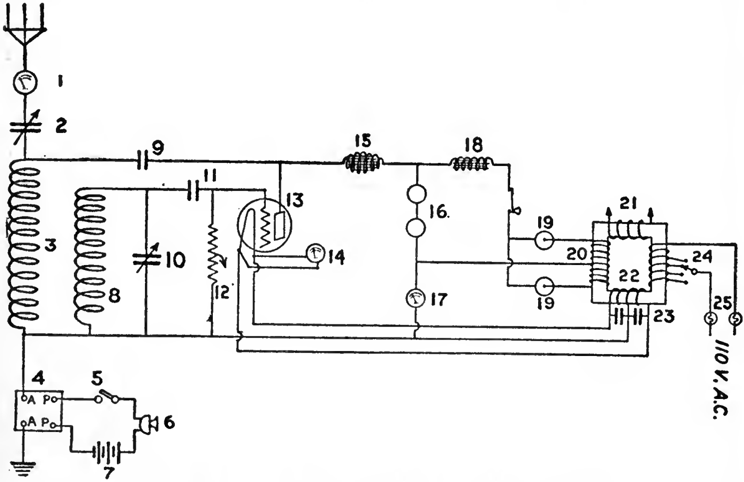


FIG. 105.—COMPLETE HOOK-UP FOR A VACUUM TUBE TRANSMITTER.

1. Aerial ammeter. 2. Aerial circuit condenser. 3. Aerial circuit inductance. 4. Magnetic modulator. 5. Microphone battery switch. 6. Microphone. 7. Microphone battery. 8. Grid circuit inductance. 9. Blocking condenser. 10. Grid circuit condenser. 11. Grid condenser. 12. Grid leak. 13. Transmitting tube. 14. Filament voltmeter. 15. Radio-frequency choke coil. 16. Electrolytic filter condensers. 17. Plate circuit ammeter. 18. Filter reactor. 19. "S" rectifying tubes. 20. Transformer high voltage winding. 21. Unused winding. 22. Transmitting tube filament winding. 23. By-pass condensers. 24. Primary winding. 25. Fuses.

fore, to point out the materials which are essential and the general rules of construction. We shall leave to the builder the decision as to whether he will mount the apparatus on a panel and enclose it in a cabinet, or spread it out on a table. The set to be described has proved itself to be the most simple and at the same time one of the most efficient sets which can be used satisfactorily in short-wave transmission. It is designed for a wave length of 200 to 275 meters. Fig. 105 shows the wiring diagram for this transmitting set.

Materials required.—The assortment of material listed below comprises a combination which has been proved by results to be superior to the usual collection of material selected at random.

It is best for the novice to purchase one vacuum tube and obtain operating experience before attempting transmission on a larger scale; the assembly here suggested will allow the addition of one to three tubes and the use of more power without other instruments than the additional tubes and their sockets being purchased.

1 5-watt transmitting tube, Radiotron UV-202.
1 Porcelain or Bakelite socket for tube, Remler.
1 Power transformer (variable), Radio Corp. UP-1368.
2 S-tube rectifiers, Amrad No. 3000.
2 Porcelain electric light sockets (wall type) for S tubes.
2 3-ampere fuses.
1 Porcelain fuse block.
1 Filter reactor, Radio Corp. UP-1653.
2 Filter condensers, Amrad No. 2747.
1 Radio-frequency choke coil, Radio Corp. UL-1655.
1 Transmitting grid leak, Radio Corp. UP-1719.
(The secondary of a Ford spark coil may be substituted for the grid leak.)
1 Transmitting grid condenser, Radio Corp. UC-1015.
1 Variable condenser, .0005 mfd.
1 Variable condenser, .001 mfd.

1 Blocking condenser, Radio Corp. UC-1014.
2 Filament by-pass condensers, Western Electric 21-R.
1 Magnetic modulator, Radio Corp. UP-1346.
1 Microphone, Western Electric 284-W.
1 6-volt battery.
1 Single pole, single throw battery switch.
1 Telegraph key.
1 Thermo-couple ammeter, scale 0 to 2 amps., Jewell.
1 Voltmeter, scale 0 to 10 volts, Jewell.
1 Milliammeter, scale 0 to 200 milliamps., Jewell.
Material for aerial and grid tuning inductance:
 1 Cardboard or Bakelite tube, 10″ x 5″ diam.
 1 Cardboard or Bakelite tube, 2″ x 3½″ diam.
 1 7″ Brass rod, threaded ($\frac{8}{32}$ thread).
 4 Dry-cell binding post nuts ($\frac{8}{32}$ thread).
 1 Knurled composition knob ($\frac{8}{32}$ thread).
 50 feet No. 10 solid copper bare wire.
 50 feet heavy cord (same size as No. 10 wire).
 30 feet No. 24 double cotton covered (d. c. c.) wire.

The transmitting or power tube.—The tube suggested for this set is of the 5-watt size. It is exactly similar to a detecting or amplifying tube except that the power tube is built proportionately larger. The tube requires approximately 2 amperes at 7.5 volts for lighting the filament, and will stand up to 500 or 600 volts on the plate although it is rated at 350 volts normal plate potential.

If tubes are added to the set, the plates, the filaments and the grids of the additional tubes should be connected to the same wires respectively to which the plate, the filament and the grid of the single tube are connected in the diagram.

The socket.—A socket of porcelain, or of other insulating composition throughout, may be used instead of the porcelain or the Bakelite type suggested. However, a socket with a metal base or receptacle should not be used, because if more tubes are added in parallel in the set, necessitating a number of sockets in a row, there would be danger of a capacity effect between the sockets; and in attempting to transmit on 200 meters, it is necessary to eliminate as much capacity from the circuits as possible. If capacity effect is obtained in a transmitting or a receiving set, the wave length of the local circuit in the set is likely to be increased, reducing the effective wave length which could be used in the aerial. This effect would correspond to that obtained from cutting off part of the aerial and making up in the circuits of the transmitter for that reduction of wave length. In selecting a socket, care should also be taken to procure one which will stand up under the considerable heat developed by the tube.

The power transformer.—The power transformer indicated in the diagram is used to supply low voltage filament current and high voltage plate current to the sending tube. It is similar in construction and operation to the closed core transformer described in Chapter IX. It differs, however, in that there are two low voltage secondary windings placed upon the iron core, in addition to the high voltage secondary winding. The primary winding is connected to the 110-volt alternating house current supply. The opposite winding, as shown in the diagram, is used for supplying the high voltage to the plate circuit. One of the low voltage windings is used for lighting the filament of the transmitting tube. The other low voltage winding is intended to supply current to the filaments of rectifying tubes; but in this transmitting set "S" tubes, which do not have filaments, are used for rectifying, and in this case the last winding is not made use of. The transformer suggested for use with this set is the Radio Corporation type UP-1368. This type is suggested because provision is made on the primary winding for adjustment in steps of 2½ volts from 102.5 volts to 115 volts. The variation in voltage is accomplished by means of taps brought out from the primary winding of the transformer to studs on a dial switch. This feature eliminates the need of filament rheostats, and the necessity of balancing each side of the filament circuit if rheostats were used; filament voltage adjustment is provided for in small amounts by virtue of the fact that the variation of voltage in the primary windings effects a variation of voltage in the secondary windings.

The UP-1368 type will supply sufficient current to operate four 5-watt tubes, permitting the addition of more transmitting tubes, in parallel with the one transmitting tube shown in the set. The high voltage plate winding provides for a potential difference of 1100 volts between the two outside wires of the winding or 550 volts between each outside terminal and the center tap of the winding. The tap in the center of this winding is connected, as shown, to the grid circuit. The connection of the outside wires, each through an "S" tube, provides for the utilization of both pulses of each oscillation of the alternating current. Kenotron tubes might be used in place of the "S" tubes, in which case the additional winding would be used to supply current to the filaments of those tubes.

The winding for supplying current to the filaments of the transmitting tubes, provides for a potential of 7.5 volts, and has a mid tap at 3.75 volts. As suggested above, this winding will supply current to the filaments of four 5-watt transmitting tubes. As shown in the diagram, the two outside wires of the filament current winding are connected to the terminals of the filament. The grid circuit and also the plate circuit are connected to the mid tap or neutral point of the filament winding.

"S" tubes.—The "S" tube is a device for rectifying the high voltage alternating current from the power transformer for use in the plate circuit of the transmitting tubes. In size and shape, it somewhat resembles an ordinary seventy-five-watt tungsten lamp used in house lighting. It has a screw base, which is exactly like the base of an incandescent lamp and will fit an ordinary socket. This rectifying tube differs from the usual rectifying tube used in radio work and discussed in Chapter V in that it does not include a filament in its make up. Instead, certain gases, which have a peculiar conduction property are introduced into it during manufacture and after the bulb has been partially exhausted. These gases act as one-way conductors, eliminating the need for the filament with its attendant possibility of burning out. It is because of this last mentioned feature, that the authors suggest "S" tubes for use as rectifiers in this transmitting set.

As indicated in the diagram, two "S" tubes are employed to rectify the alternating current which comes from both ends of the secondary or high voltage winding of the power transformer.

As previously suggested, two standard porcelain receptacles or sockets, such as those used with ordinary incandescent bulbs, may be used for mounting the tubes. Each of the outer taps from the transformer winding should be connected to the center contact of a socket. The ferrule or screw contacts of the receptacles should be connected together, and in turn connected through the filter reactor and the radio-frequency choke coil to the plate or plates of the transmitting tube or tubes depending on whether one or more five-watt tubes are used.

Because the "S" tubes function without light or other visible indication, the only means of telling when they are being operated properly is by the amount of heat given off by them. At full load, the heating effect should not be greater than that of a fifty-watt mazda bulb. The capacity of each "S" tube is fifty milliamperes, making the capacity of the two tubes (connected to rectify both halves of the A. C.) one hundred milliamperes.

It is claimed by the manufacturers that these tubes will stand an overload of 100 per cent for short intervals of time. If, however, it is desired to rectify more than 100 milliamperes at 550 volts, in order to utilize the full output of more than two five-watt tubes and up to four five-watt tubes, two "S" tubes may be connected in parallel where each "S" tube is shown in the diagram. If it is desired to rectify alternating current of voltage greater than 600 volts, "S" tubes may be connected in series, one tube being used for each 600 volts.

No device is included between the "S" tubes and the secondary winding of the power transformer to limit the amount of current which may be drawn by the transmitting tubes. Care should be taken, therefore, not to overload the "S" tubes by attempting to supply current to too many power tubes. Furthermore, two 3-ampere fuses should be connected in series with the primary of the transformer as shown in the diagram. If these fuses are omitted, an overload on the "S" tubes, or an accidental short circuit might destroy the tubes and burn out the windings of the power transformer.

The filter reactor and filter condensers.—In the operation of the set, some means are necessary for filtering or smoothing out the ripples or low frequency pulsations of rectified current coming from the "S" tubes, into a smooth current for use in the plate circuit of the transmitting tube. The filter reactor and the two electrolytic condensers satisfactorily serve this purpose.

The *filter reactor* is a coil of wire wound on an iron core and surrounded by layers of thin sheet iron. By reason of its form of construction, it has a high inductance value. When pulsating direct current is sent through a coil of this type, self induction occurs in the coil, alternately opposing the incoming pulse and sustaining the current as the pulse dies out.

The smoothing effect is still further brought about by the two electrolytic condensers. These condensers are connected in series between the wire to which the two end terminals of the high voltage winding are connected and the wire to which the center of the winding is connected. For best results, the filter reactor should have a high value of inductance as noted above, and the filter condenser should have a large capacity. For that reason, the Amrad electrolytic condensers are suggested. Each condenser has a capacity of 38 mfd. and the two connected in series provide a capacity of 19 mfd. These two condensers obviate the necessity of having a large capacity mica condenser, which is much more expensive.

The radio-frequency choke coil.—The choke consists of a coil of wire also wound on an iron core. Due to the properties of a coil of this type, the radio-frequent fluctuating current in the plate circuit is prevented from flowing back into the filter circuit; at the same time it allows the high voltage direct current to flow from the filter circuit to the transmitting tube. The particular coil suggested will permit the use of several additional tubes.

The grid leak.—The purpose of the grid leak in the transmitting set is that of limiting the potential which may accumulate on the grid of an oscillating tube. The function is the same as that of the grid leak used with the detector tube in a receiving set. That is to say, it allows the gradual leaking off of negative potential from the grid after this potential has reached a certain value. In that way it governs the output of the transmitting set and also determines the character of the oscillations. A transmitting grid leak differs from a receiving grid leak in that the former must be made up so that it will resist sudden heating or changing of temperature. It consists of a resistance wire wound around a small, cylindrical, heat-resisting form. Metal clips or contacts are provided at each end of the form to which the ends of the resistance coil are connected. In this set a grid leak of not more than 5,000 ohms should be used. One should be purchased which has a middle tap taken from it, providing a 2500-

ohm resistance or a 5000-ohm resistance. Both values should be tried when the set is placed in operation in order to determine which gives the best results with the particular tube or tubes used.

The transmitting grid condenser.—The grid condenser has the same function in transmitting as in receiving. The reasons for its use are suggested in Chapter V. This condenser should be of the fixed mica-dielectric type, but should be variable in two or three steps in order to obtain best results with different tubes. The type UC-1015 is suggested.

Aerial circuit and grid circuit tuning condensers.—Both the aerial circuit tuning condenser and the grid circuit tuning condenser are variable condensers of the type ordinarily used in receiving sets and described on page 59. The use of this type instead of the types used in the spark sending sets discussed in Chapter IX is possible because of the low voltages in these two circuits as compared with the voltages in the circuits of a spark transmitter.

By-pass and blocking condensers.—Two fixed *by-pass condensers* of .005 mfd. size are connected, one from each outside terminal to the mid tap of the filament winding. This connection of the condensers allows the passage of the radio-frequent currents flowing in the grid and plate circuits to the filament, but does not pass the low-frequency alternating current from one terminal of the filament winding to the other terminal.

Another condenser similar to the two by-pass condensers and known as the *blocking condenser*, is connected in series with the plate circuit between the plate of the transmitting tube and the aerial tuning inductance. This condenser prevents the charging of the grid tuning inductance and the aerial circuit, by the high voltage direct current in the plate circuit, yet passes the radio-frequent fluctuations flowing in the plate circuit. The use of the blocking condenser effectually insulates most of the set from the high voltage direct current and reduces the possibilities of a shock or a burn resulting from contact with those parts of the set while the set is in operation.

All three of the above condensers should be of the mica dielectric type so that their values will remain constant during operation of the set.

The magnetic modulator.—In this transmitting set, the continuous oscillations generated by the transmitting tube are modulated *in the aerial circuit.* There are other methods of modulation which can be employed in a radio telephone transmitter but this system, which makes use of the *magnetic modulator*, is perhaps the best method for controlling the output of a single tube without distortion. Furthermore, it permits the use of several tubes in parallel as oscillators and in that way averts the use of additional tubes for modulation, with their additional accessories and adjustments.

The magnetic modulator, as indicated in the diagram, is connected preferably in series with the ground wire of a transmitting set. This connection, as can be seen, removes the high resistance microphone from the aerial circuit to a local circuit in which a 6-volt battery is connected in series with the microphone. The removal of the microphone from the aerial circuit permits a less obstructed flow of the oscillating current in the aerial circuit.

The magnetic modulator is simple both in its connection and in its operation. The ground wire is broken and connected to the two binding posts marked A and A; the connections of the microphone circuit are made to the other two binding posts, marked P and P. Once connected in the above manner, the modulator requires no further adjustment or attention.

The principle of its operation is that of utilizing the peculiar properties of iron when acted upon by radio-frequency currents. Its action is that of a variable resistance which is controlled by the variations of current in the 6-volt microphone circuit acting through the modulator.

The current for the microphone circuit may be supplied from four dry cells or from the 6-volt storage battery used in heating the filaments of the vacuum tubes in the receiving set. If one tube is to be used, as suggested for this transmitter, the ½- to 1½-ampere size modulator should be purchased. This size will also control the output of two 5-watt tubes. If two to four tubes are to be employed, the 1½- to 3½-ampere size should be used.

The microphone.—The microphone has already been described in connection with Fig. 103. It may be of the ordinary desk telephone type or of the hand microphone type. In either case, it is connected, by means of a telephone cord, in series with the primary of the magnetic modulator, the six-volt storage battery and a single pole, single throw switch. The switch is for the purpose of turning off the battery current when the set is not in operation.

Indicating instruments.—The *aerial* or *radiation ammeter* may be of the hot wire type described on page 237, Chapter IX. However, better results will be obtained with a thermo-couple radiation ammeter, especially in the case of a low power tube transmitter, since the amount of current flowing in the aerial circuit of such a set is very small, and accurate adjustment therefore is highly important.

The *thermo-couple* is a device consisting of a heating wire, similar to that in the hot wire ammeter, to which two dissimilar metals are attached. The meter is connected to the two metals and calibrated at the factory. When the current in the aerial circuit passes through the heating wire, a local current is generated by the two metals and is recorded on the meter.

A *filament voltmeter* should be used instead of an ammeter to indicate the flow of current through the filament. In any case, flow of current depends upon voltage, and in the case of a vacuum tube it is important that the voltage rather than the amperage of the filament current be kept constant. Care should be taken that the filament is in no case overloaded. The voltmeter should be connected across the terminals of the filament, as shown.

The *plate milliammeter* is connected in series with the plate circuit of the transmitting tube, as shown in the diagram, to indicate the amount of current flowing in that circuit. A 5-watt transmitting tube will stand about $\frac{1}{20}$ of an ampere (50 milliamperes) on its plate without overheating and care should be taken that the tube is not overloaded. A milliammeter with a range of from 0 to 200 milliamperes should be selected in order to allow for the possible addition of three or more tubes to this set.

The aerial and the grid tuning inductance.—The aerial inductance and the grid inductance may easily be made up at home in the following manner: Obtain a cardboard or Bakelite tube 5 inches in diameter by ten inches long and shellac it to exclude moisture.

Obtain 50 feet of No. 10 bare copper wire and 50 feet of cord of the same size. Wind both the cord and the wire on the tube at the same time, in such a manner that the cord will separate the turns of wire. In winding the coil, fasten one end of the wire and one end of the cord to the tube. Then fasten the other end of each to a support at a distance of 50 feet. Next, grasp the tube firmly and walk toward the support, at the same time winding the cord and the wire on the tube. When wound, shellac the winding well in order to exclude moisture from the string and to help keep the windings in place. Two coats will be sufficient.

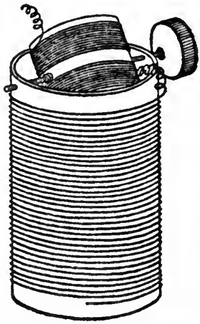


FIG. 106.—AERIAL AND GRID TUNING INDUCTANCE.

The grid inductance may be wound on a $3\frac{1}{2}$-inch cylindrical tube of cardboard or Bakelite, and should consist of 25 turns of No. 24 D. C. C. wire. It should be given one coat of shellac. The accompanying illustration (Fig. 106) shows how the winding should be connected (in series) and placed in relation to each other. The grid coil should be mounted on a shaft so that the coupling can be varied slightly.

The four nuts are run on the brass rod, two inside the grid inductance coil and two outside. They are for the purpose of clamping the coil tightly to the rod.

HOW TO OPERATE THE SET

After checking up all connections to make sure that they are correct, place the vacuum tube in the socket and turn on the filament current and increase to the proper brilliancy, that is, to the point of tube oscillation as suggested for the operation of the regenerative receiver. By revolving the variable condenser which is connected across the grid coil, a point will be found where the radiation ammeter indicates aerial current. Continued experimentation will soon acquaint the operator with the proper setting of each instrument. When the aerial series condenser is changed, it is also necessary to readjust the grid coil condenser. Care should be taken to see that the milliammeter does not show more than 50 milliamperes for one tube. The plate will become red hot and the filament will be in danger of burning out if more than 50 milliamperes of current is sent through one five-watt Radiotron.

If the set is used for continuous wave (C. W.) telegraphy the key should be connected, as shown, in series with the wire which connects the electrolytic condensers to the filter reactor. If it is so placed, the high voltage is disconnected from the tube when the key is open and the vacuum tube operates at a much lower temperature. When it is desired to telephone, the key must be closed, and the microphone used in connection with the magnetic modulator placed in the ground circuit.

Do not try to operate the telephone on full radiation, as the carrier wave tends to be more noisy on peak radiation.

Modulation or quality of the reproduction of the speech may be tested by listening on the usual receiver or even on a crystal set.

In tuning this set, a wave meter with an aerial or radiation milliammeter substituted for the crystal detector and phones, is used. The wave meter inductance is placed in inductive relation to the aerial circuit. The set is then placed in operation and the wave meter adjusted to the point of maximum deflection of the ammeter needle. A reading is then taken for wave length, and the set is adjusted in accordance with the reading in the manner explained on page 245.

A transmitter similar to the one described, operated in the eastern part of the United States, was recently heard in England, although operating on only 5 watts. In a few years, receiving apparatus may conceivably have advanced in sensitivity to a point where one five-watt transmitter will girdle the earth, perhaps not in commercial signaling, but at amateur wave lengths under exceptionally favorable conditions.

Underwriters' requirements.—Underwriters' specifications for the ground wire and supply lines from house current for vacuum tube transmitting sets are the same as those noted on page 242 for spark transmitting sets. Additional requirements which apply to vacuum tube transmitters employing storage batteries are the same as those given on page 128 for receiving sets.

Chapter XI

LEARNING THE CODE

Advantages of knowing the code.—Sooner or later there comes to every radio amateur the desire to know and to be able to handle the signal code. This desire grows as the amateur with his receiving set picks up telegraph station after station and hears each one call and sign off, without being able to tell whether the signals are coming from the next town, from a ship at sea, or from a foreign country. Later he begins to realize that a wealth of information is broadcasted daily in dots and dashes, as well as by telephone. And finally, or simultaneously, comes the aspiration to be able to send as well as to receive radio messages.

We have already seen what a simple matter it is to transmit with a vacuum tube receiving set or to construct a simple sending set for dot-and-dash signaling. Fortunately for amateurs in this country, the United States Government is more indulgent toward the radio amateur than are other governments. Few foreign countries permit the operation of amateur sending stations. Many of them even limit the amateur receiving aerial to certain sizes and heights. Only recently have amateurs in England and in France been permitted to transmit, and even now they are much more narrowly restricted in the amount of power which they may use with their sets, than are amateurs in the United States.

In Canada, amateurs enjoy pretty much the same privileges as we do in this country, except that they are restricted to a greater degree in the wave lengths which they may use.

In this country, there is no reason why any citizen who so desires should not own and operate a transmitting set, and secure a great deal of enjoyment from it, through communication with others. Nightly, amateurs in New York City talk with amateurs in Chicago; those in Chicago talk with others in Denver, San Francisco, and other distant points in this country and in Canada. When direct communication is impossible, messages are often relayed over enormous distances by fellow amateurs.

In this connection, the American Radio Relay League (A. R. R. L.) plays its part. This league is a band of amateurs scattered throughout the country who relay amateur messages and conversations from one boundary of the country to the other for the pure joy of doing so. And every amateur who possesses a transmitting set and has a knowledge of the code is welcome in the League.

Every operator of a transmitting station, however, must hold a license. To secure such license, the applicant must pass a written examination covering adjustment and tuning of a transmitting set, and must also pass a code test of ten words a minute. These requirements are not at all unreasonable. It does not require great imagination to conceive how badly a novice without proper knowledge might "jam up the air"; and if he does not know the code, government, commercial, or amateur stations with which he might be interfering, would be unable to communicate with him, and request that he stop sending or make some change in his set.

The code.—The code now in general use throughout the world is the International Morse Code.

In the early days of radio, practically all land and ship stations of the United States, including commercial and amateur stations, used the Morse telegraph code, which was then and still is used in land wire telegraphy. As a matter of fact in this country for a number of years, practically all radio operators were recruited from the ranks of wire telegraphy.

Almost all foreign countries, however, were using a different code called the Continental Code. Due largely to a serious disaster at sea, in which much confusion and delay resulted from the inability of the operators concerned to communicate readily with one another, the Continental Code, or International Morse Code, was adopted some years ago for all radio stations of the world.

Means of learning the code.—There are many ways of learning the code. In any of the methods which are suggested in the following pages, the most important requisite is patience. In any case, the code will be mastered only by continued drilling on it.

To begin with, the novice should not set out by committing the number and order of the dots and dashes in the various letters and figures in the code, as for example, that dash—dot—dash—dot equals *c*. Much of the energy so spent will be wasted. The radio operator does not recognize letters as so many dots and so many dashes nor does he translate signals in that fashion. The operator hears and learns to recognize each letter as a *combination of sounds—dah—de—dah—de* as the letter *c*, *de—dah—de* as *r*, *dah—de—dah* as *k*, etc., in much the same manner as children in primary school learn to read words by sounds instead of by learning to spell them.

For the same reason the code should be learned and practiced with the use of an instrument which will simulate the sounds produced by the sparks of a transmitting set and not by using an electric lamp, a pencil or a tick-tack.

The best aid toward learning the code is a test buzzer hooked up to a crystal detector set in the manner described on page 57, with a key substituted for the switch used to start and stop the buzzer. The head receivers are worn during practice, and exact reproductions of spark signals are obtained just as though they are actually being received over the set.

If the amateur does not possess a test buzzer, a buzzer, a battery and a key may easily be obtained to make up a code practice set, which may be wired up in the manner suggested above and used either independently or in conjunction with a crystal detector set. A buzzer having a high pitch or musical note should be selected as most transmitting sets in use at the present time have a high whistling note or a somewhat lower musical note. Furthermore, the high pitch or musical note will be more pleasing to the ear and the dot and dash sounds will be more intelligible. The note or tone of the buzzer may be adjusted to a considerable extent by varying the tension of the contact screw against the movable part or armature.

If the sound of the buzzer is not sufficiently loud to be clearly audible, the telephone cord terminals of a cheap

75-ohm receiver may be connected across the contact screw and the armature of the buzzer. The sound in the receiver connected to the buzzer may, if too loud, be reduced by placing a few layers of paper under the receiver diaphragm.

As suggested above, the best method for learning the code is that of using an instrument which simulates the actual sounds produced in the head telephones in the reception of dots and dashes from a spark transmitting station.

The beginner is not advised to attempt learning the code with a flashlight bulb arrangement for making short and long flashes, to represent dots and dashes. Sooner or later he will have to change from reading the dots and dashes by sight to reading them from sounds, at considerable waste of time and energy. However, a combination of both the flashlight arrangement and the buzzer set may afford some diversion in practicing.

Automatic transmitters may be purchased, but entirely satisfactory results should not be expected from any of the moderate priced automatic transmitters which are on the market. The type of automatic practice set referred to usually includes a high-pitched buzzer controlled or operated by a contact rubbing on plates on which impressions have been made to form dots and dashes. If with such a type of practice set, only a few records or plates are used, one soon unconsciously memorizes the sequence of the characters on the records or plates. If a great number of plates or records are employed to furnish a great variety of letters, numbers, and parts of sentences, the device becomes quite expensive.

Furthermore, such procedure does not provide practice in sending.

With the key buzzer and head telephone arrangement, the beginner might successfully learn the code by sending dots and dashes without any practice in slow receiving. After he has become quite familiar with the code from constant sending, he would eventually be able to copy some of the commercial or amateur messages which might be picked up with a receiving set. The beginner might also practice sending and receiving with a fellow amateur, using the buzzer outfit.

It is also possible to memorize each letter as a combination of sounds, as suggested on page 275. Then by listening over the receiving set to code messages, the amateur might at first be able to pick out a letter here and there; but after constant application he would be able to pick out a greater number of letters, and finally to receive whole words and messages. This latter method, however, would not afford any practice in sending, which is just as important as receiving in handling the code, unless the amateur never expects to do any sending

After two or more amateurs practicing together have gained sufficient speed to pick up letters and words from messages, they should familiarize themselves with accepted radio abbreviations before expecting to receive entire messages from commercial or amateur stations.

Commercial stations use many trade forms and abbreviations in messages. Unless the beginner becomes familiar with these forms it may be difficult for him to tell whether he is getting messages correctly or simply getting some of the letters of the words. For instance, commercial operators use P to mean a *paid message,* the letter w for *words,* sig. for *signature,* etc.; and at the end of a sentence they may repeat numbers and difficult words to insure their correct reception. These abbreviations, symbols and repetitions mean nothing to one who is just learning the code, unless he first gets their interpretation from an experienced operator.

Even the amateurs use many abbreviations in talking to one another by dots and dashes. For example, they use hv for *have,* gv for *give,* wkg for *working,* dx for *distance,* etc. Some amateurs further confuse the beginner by using the Morse code instead of the Continental code when talking with one another. Then again, there are the QR and the QS abbreviations to confuse the beginner. These are listed on page 296. The novice should become familiar with them so that he may successfully read signals or messages from other transmitting stations.

Other sources of practice which should not be overlooked are the government commercial stations which send out weather reports and press items. Numerous government stations send weather reports at various times during the day, especially at 12 noon and at 10 P. M. The weather reports at 10 P. M. from some stations are followed by press items which are, as a rule, sent at a speed of less than 20 words per minute.

An order has recently been issued to certain naval stations to transmit items of interest slowly on certain evenings, to provide practice for amateurs in receiving.

After the amateur has attained a speed of 10 words per minute, he should make application for and procure a license, so that he may begin practicing the code for greater speed by sending on the air. The rights of other amateurs, however, should be considered and the air, free as it may seem, should not be filled up with jumble and jargon. Furthermore, in conversing with other amateurs, the rules given on page 288 for calling and answering should be strictly followed. The amateur should thoroughly familiarize himself with these and other government regulations summarized in Chapter XII, before placing his transmitting set in operation.

Chapter XII

GOVERNMENT REGULATIONS FOR AMATEURS

Government regulations provide that every radio transmitting station, either telephone or telegraph, and whether commercial, amateur, or experimental, must be inspected by a government agent and properly licensed. Stations equipped only to receive are not required to be licensed.

Entirely apart from the station license requirement, no person may operate a radio transmitting set without obtaining an operator's license. Operators' licenses—both amateur and commercial—are granted only after the applicant has satisfactorily passed the government examination for the grade license which he desires to obtain.

The United States Department of Commerce recognizes the fact that radio communication offers a wholesome form of instructive recreation for amateurs. At the same time, it takes precaution that the users of radio for this purpose must strictly observe the rights of others to the uninterrupted use of apparatus for important public and commercial purposes. The Department of Commerce will not knowingly issue a license to an amateur who does not recognize and will not obey this principle. To this end, the intelligent reading of the International Convention and the Radio Communication Laws of the United States is prescribed as the first step to be taken by amateurs toward securing a license.

A summary of those rules and regulations applying to amateurs, laid down by the Convention and adopted by an Act of Congress, is given herewith.

SECURING A STATION LICENSE

Station licenses for the use and operation of apparatus for radio communication may be issued only to citizens of the United States. Foreign-born applicants for station licenses must submit satisfactory evidence of their citizenship.

Licenses can be issued to clubs if they are incorporated or if a member will accept the responsibility for the operation of the apparatus, carrying with it the possibility of being penalized for infraction of the laws.

Applications for station licenses of all classes should be addressed to the United States Radio Inspector for the district in which the station is located, who will forward the necessary blank forms and information. The limits of the districts and the addresses of the radio inspectors in charge of the districts, are given on page 291.

Upon receipt of the forms, properly completed, the radio inspector will make a thorough inspection of the station, if practicable.

The owner of an amateur station may operate his station in accordance with the laws if his application for a license has been properly filed but has not been acted upon. An application for an operator's license, however, must also have been filed and every effort made to obtain the license, before the station may be operated.

"Provisional" station licenses are issued to amateurs remote from the headquarters of the radio inspector of the district in which the station is located. These licenses are issued as a matter of convenience and record. If, upon inspection, the station is found to comply with the law, the inspector will strike out the word "Provisional" and insert the date of inspection and his signature at the bottom of the license.

If such a station is found not to comply with the law, the provisional license may be cancelled until such time as the apparatus is readjusted to meet the requirements of the law: *Provided, however,* That consideration will be given to any reports of interference filed against such a station.

All persons are warned in the regulations, that it is unlawful to operate stations after licenses have expired unless application for renewal has been properly made.

Expired station licenses of all classes, commercial and amateur, need not be returned to the radio inspectors with applications for renewals. Owners desiring a renewal license must complete new forms, as prescribed for original applications. New licenses are issued in every case of renewal.

Any person applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed is required to submit an affidavit to the Bureau of Navigation through the radio inspector of the district, attesting the facts regarding the manner in which the original was lost. The Commissioner of Navigation will consider the facts in the case and advise the radio inspector in regard to the issue of a duplicate license, or a duplicate will be forwarded through the inspector's office.

A duplicate license is issued under the same serial number as the original and is marked "Duplicate" in red across the face.

Licensed stations must be operated by or under the direct supervision of properly licensed operators.

SECURING AN OPERATOR'S LICENSE

An operator's license may be granted to any person without regard to sex, nationality, or age, if the applicant can fulfill the requirements for the class of license desired.

Amateurs should write to the nearest examining officer in their vicinity for Form 756 "Application for operator's license", and to the radio inspector in their vicinity for Form 762 "Amateur applicant's description of apparatus."

Amateur operators at points remote from examining officers and radio inspectors may be issued second-grade amateur licenses without personal examination. Examinations for first-grade licenses will be given by the radio inspector when he is in that vicinity, but special trips can not be made for this purpose.

Persons holding radio operators' licenses, amateur second-grade, should make every effort to appear at one of the examination points to take the examination for amateur first-grade license or higher.

Amateur first-grade.—The applicant must have a sufficient knowledge of the adjustment and operation of the apparatus which he wishes to operate and of the regulations of the International Convention and Acts of Congress in so far as they relate to interference with other radio communication and impose certain duties on all grades of operators. The applicant must be able to transmit and receive in Continental Morse at a speed sufficient to enable him to recognize distress calls and the official "keep-out" signals. A speed of at least 10 words per minute (five letters to the word) must be attained.

Amateur second-grade.—The requirements for the second grade are the same as for the first grade. The second-grade license is issued only where an applicant can not be personally examined, or until he can be examined. An examining officer or radio inspector is authorized in his discretion to waive an actual examination of an applicant for an amateur license, if the amateur for adequate reasons can not present himself for examination but in writing can satisfy the examining officer or radio inspector that he is qualified to hold a license and will conform to its obligations.

The code test consists of messages with call letters and regular preambles, conventional signals and abbreviations and odd phrases, and in no case consists of simple, connected reading matter. The test is conducted by means of the omnigraph or other automatic instrument wherever possible.

The practical and theoretical examination consists of seven questions under the following headings and values:

	Points, maximum value.
(*a*) Experience	20
(*b*) Diagram of receiving and transmitting apparatus	10
(*c*) Knowledge of transmitting apparatus	20
(*d*) Knowledge of receiving apparatus	20
(*e*) Knowledge of operation and care of storage batteries	10
(*f*) Knowledge of motors and generators	10
(*g*) Knowledge of international regulations governing radio communication and the United States radio laws and regulations	10
	100

No applicant who fails to qualify can be re-examined at any examining office within three months from date of the previous examination.

Operators' licenses are not valid until the oath for the preservation of the secrecy of messages is properly executed before a notary public or other officer duly authorized to administer oaths. Licenses must indicate on their faces that the oath has been taken and the officer administering the oath on the back of the license should sign also in the blank provided on the face.

Licenses will not be signed by examining officers until the oath of secrecy has been properly executed.

Operators' licenses should be framed and posted in the radio room, and licenses for stations should be accessible at all times to inspectors.

Persons holding radio operators' licenses of any grade should, before their licenses expire, apply to the nearest radio inspector or examining officer for renewal and submit Form 756 in duplicate.

Any operator applying for a duplicate license to replace an original which has been lost, mutilated, or destroyed must go through the same procedure as noted on page 282 for securing a duplicate station license.

Fees.—No fees are charged for any station or operator's license.

RECEIVING STATIONS

Stations equipped to receive only do not require licenses.

Operators of receiving stations do not require licenses, but *all persons* are required to maintain secrecy in regard to messages.

TRANSMITTING STATION REGULATIONS

No private or commercial station not engaged in the transaction of bona fide commercial business by radio communication or in experimentation in connection with the development and manufacture of radio apparatus for commercial purposes, may use a transmitting wave length exceeding two hundred meters, or a transformer in-put exceeding one kilowatt, except by special authority of the Secretary of Commerce contained in the license of the stations.

No station of the character mentioned in the foregoing regulation situated within five nautical miles of a naval or military station may use a transmitting wave length exceeding two hundred meters or a transformer in-put exceeding one-half kilowatt.

Experiment stations.—The Secretary of Commerce is authorized by section 4 of the act to grant special temporary licenses "to stations actually engaged in conducting experiments for the development of the science of radio communication, or the apparatus pertaining thereto, to carry on special tests, using any amount of power or any wave lengths, at such hours and under such conditions as will insure the least interference with the sending or receipt of commercial or Government radiograms, of distress signals and radiograms, or with the work of other stations." Applicants for such licenses should state any technical result they have already produced, their technical attainments, etc. The fact that an applicant desires to experiment with his equipment does not justify the issue of a license of this class. Most experiments can be made within the limitations of general and restricted amateur station licenses or by the use of an artificial antenna to prevent radiation.

Special amateur stations may be licensed by the Secretary of Commerce to use a longer wave length and a higher power on special application. Applications for this class from amateurs with less than two years' experience in actual radio communication will not be approved. The application must state the experience and purpose of the applicant, the local conditions of radio communication, especially of maritime radio communication in the vicinity of the station, and a special license will be granted only if some substantial benefit to the art or to commerce apart from individual amusement seems probable.

General amateur stations are restricted to a transmitting wave length not exceeding 200 meters and a transformer in-put not exceeding 1 kilowatt.

Restricted amateur stations, within 5 nautical miles of a naval or military station, are restricted to a wave length not exceeding 200 meters and to a transformer in-put not exceeding one-half kilowatt.

Amateur first- or second-grade operators or higher are required for general and restricted amateur stations.

At all stations, if the sending apparatus is of such a character that the energy is radiated in two or more wave lengths, more or less sharply defined, as indicated by a sensitive wave meter, the energy in no one of the lesser waves may exceed ten per centum of that in the greatest.

At all stations, the logarithmic decrement per complete oscillation in the wave trains emitted by the transmitter must not exceed two-tenths, except when sending distress signals or signals and messages relating thereto.

Calling.—The call shall comprise the signal

— • — • —

the call letters of the station called, transmitted three times, the word "de" (from) followed by the call letters of the sending station transmitted three times.

The called station shall answer by making the signal

— • — • —

followed by the call letters of the corresponding station transmitted three times, the word "de", its own call letters, and the signal

— • —

Stations desiring to enter into communication with other stations, without, however, knowing the names of the stations within their radius of action, may employ the signal — • — • — — • — (signal of inquiry). The provisions of the preceding two paragraphs are likewise applicable to the transmission of a signal of inquiry and to the answer to such signal.

The distress call in use is the international signal of distress • • • — — — • • •

All amateur stations are required to give absolute priority to signals and radiograms relating to ships in distress; to cease all sending on hearing a distress signal; and to refrain from sending until all signals and radiograms relating thereto are completed.

REGULATIONS GOVERNING MESSAGES

Any person guilty of divulging or publishing any message, unlawfully, shall, on conviction thereof, be punished by a fine of not more than two hundred and fifty dollars or imprisonment for a period of not exceeding three months, or both fine and imprisonment, in the discretion of the court.

Every license granted under the provisions of the Act of Congress for the operation or use of apparatus for radio communication shall prescribe that the operator thereof shall not willfully or maliciously interfere with any other radio communication. Such interference shall be deemed a misdemeanor, and upon conviction thereof the owner or operator, or both, shall be punishable by a fine of not to exceed five hundred dollars or imprisonment for not to exceed one year, or both.

A person, company, or corporation within the jurisdiction of the United States shall not knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent distress signal or call or false or fraudulent signal, call, or other radiogram of any kind. The penalty for so uttering or transmitting a false or fraudulent distress signal or call shall be a fine of not more than two thousand five hundred dollars or imprisonment for not more than five years, or both, in the discretion of the court, for each and every such offense, and the penalty for so uttering or transmitting, or causing to be uttered or transmitted, any other false or fraudulent signal, call, or other radiogram shall be a fine of not more than one thousand dollars or imprisonment for not more than two years, or both, in the discretion of the court, for each and every such offense.

No person shall transmit or make a signal containing profane or obscene words or language.

Stations desiring to conduct tests should communicate with the radio inspector by letter or telephone, stating the probable length of time that will be required. Stations conducting such tests or temporary experiments should "listen in," to determine that no interference is being caused, and during the tests should "listen in" frequently for the interference signal, "Q R M." Stations conducting tests should transmit their official call signal frequently. Attention is called to the Act of Congress of August 13, 1912, section 5:

"That every license granted under the provisions of this act for the operation or use of apparatus for radio communication shall prescribe that the operator thereof shall not wilfully or maliciously interfere with any other radio communication. Such interference shall be deemed a misdemeanor, and upon a conviction thereof the owner or operator, or both, shall be punishable by a fine not to exceed five hundred dollars or imprisonment for not to exceed one year, or both."

The Department holds that interference caused by tests of the character described above is "willful" when no "listening in" precautions are taken and the call signal of the station sending is not repeated at intervals.

Time signals and meteorological radiograms are transmitted one after the other in such a way that the total time occupied in their transmission does not exceed ten minutes. As a general rule, all radio stations whose transmissions might interfere with the reception of such signals and radiograms, must remain silent during their transmission in order that all stations desiring it may be able to receive the same. Exception is made only in cases of distress calls and of state telegrams.

Radio districts.—The Department has established, for the purpose of enforcing, through radio inspectors and others, the acts relating to radio communication and the

International Convention, the following districts, with the principal office for each district at the customhouse of the port named.

Communications for radio inspectors should be addressed as follows, and not to individuals: Radio Inspector, Customhouse, ———(city), ———(State).

Communications for the Bureau of Navigation should be addressed as follows, and not to individuals: Commissioner of Navigation, Department of Commerce, Washington, D. C.

1. *Boston, Mass.:* Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut.
2. *New York, N. Y.:* New York (county of New York, Staten Island, Long Island, and counties on the Hudson River to and including Schenectady, Albany, and Rensselaer) and New Jersey (counties of Bergen, Passaic, Essex, Union, Middlesex, Monmouth, Hudson, and Ocean).
3. *Baltimore, Md.:* New Jersey (all counties not included in second district), Pennsylvania (counties of Philadelphia, Delaware, all counties south of the Blue Mountains, and Franklin County), Delaware, Maryland, Virginia, District of Columbia.
4. *Savannah, Ga.:* North Carolina, South Carolina, Georgia, Florida, Porto Rico.
5. *New Orleans, La.:* Alabama, Mississippi, Louisiana, Texas, Tennessee, Arkansas, Oklahoma, New Mexico.
6. *San Francisco, Calif.:* California, Hawaii, Nevada, Utah, Arizona.
7. *Seattle, Wash.:* Oregon, Washington, Alaska, Idaho, Montana, Wyoming.

8. *Detroit, Mich.:* New York (all counties not included in second district), Pennsylvania (all counties not included in third district), 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.

Radio stations and call letters.—The list of land and ship stations of the United States, including amateurs, giving call letters, wave lengths, nature of service, etc., can be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a nominal price.

Supplements to this list are issued monthly under the title "Radio Service Bulletin", and the list is revised annually as of July 1. Amendments to or changes in the Radio Laws and Regulations of the United States are printed in this bulletin in such a manner that they may be clipped and pasted in their proper places in that publication. Items of general interest concerning the enforcement of the radio laws are printed in the bulletin from time to time, as occasion warrants.

The introduction to the list of "Radio Stations of the United States" contains information concerning the assignment of international and amateur call letters.

ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION

For the purpose of giving or requesting information concerning the radio service, stations must make use of the signals contained in the list shown on page 296.

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.

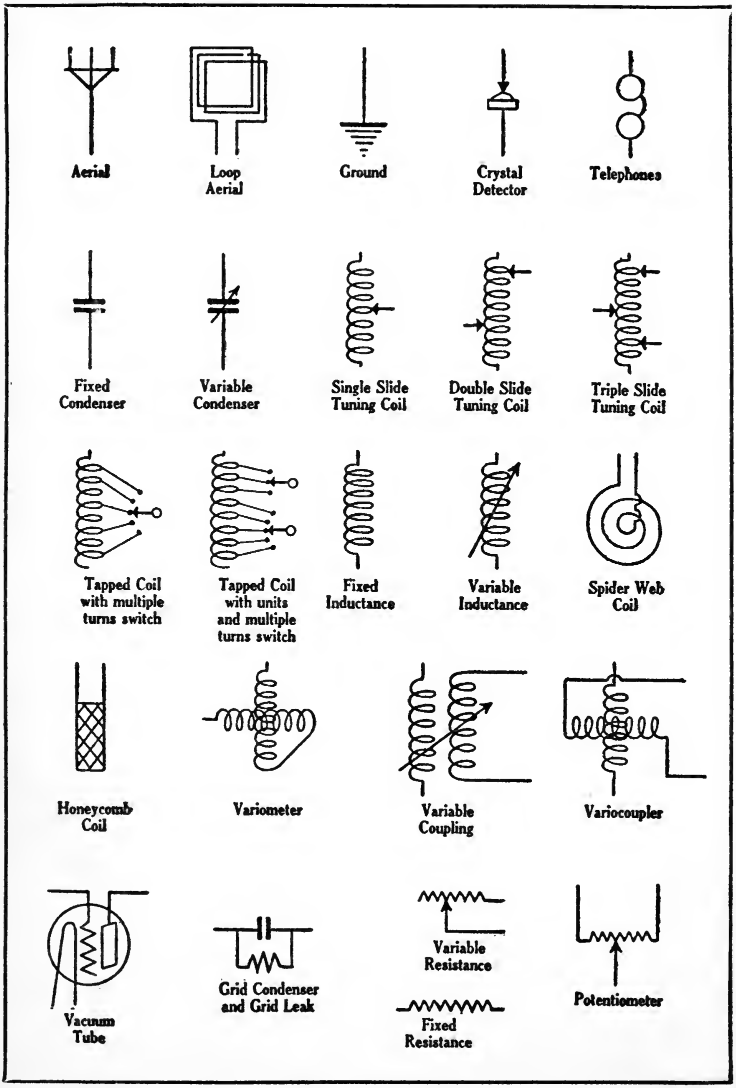
A • —
B — • • •
C — • — •
D — • •
E •
F • • — •
G — — •
H • • • •
I • •
J • — — —
K — • —
L • — • •
M — —
N — •
O — — —
P • — — •
Q — — • —
R • — •
S • • •
T —
U • • —
V • • • —
W • — —
X — • • —
Y — • — —
Z — — • •

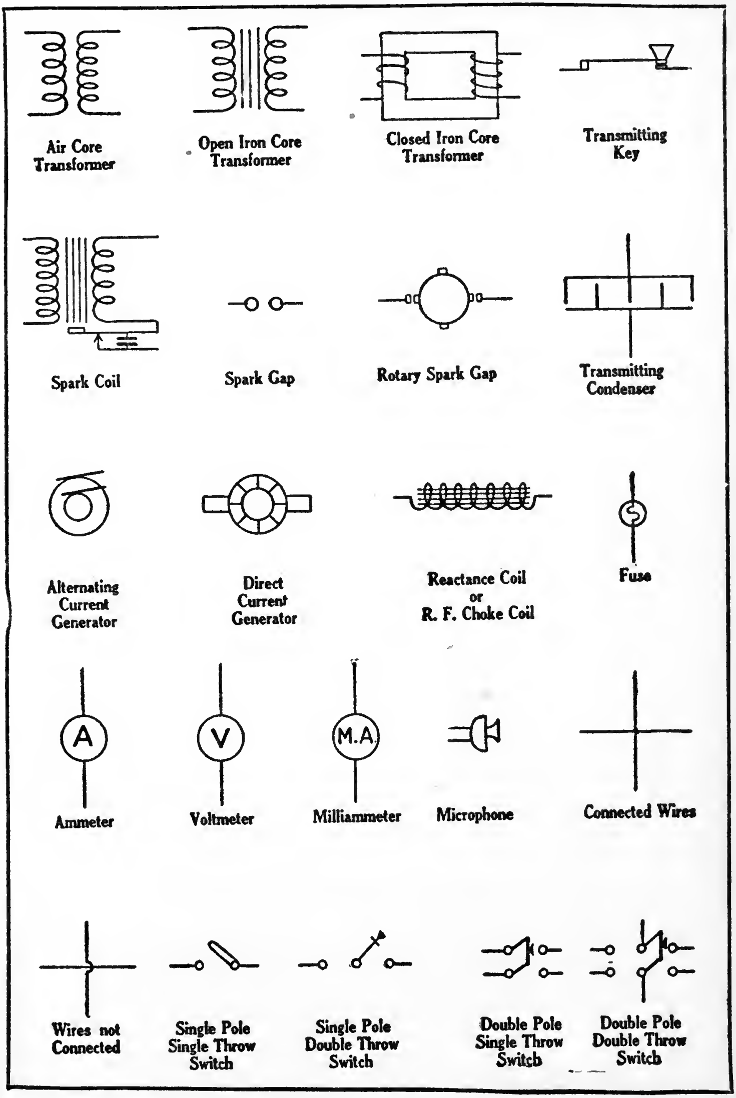
Ä (German) • — • —
Á or Å (Spanish-Scandinavian) • — — • —
CH (German-Spanish) — — — —
É (French) • • — • •
Ñ (Spanish) — — • — —
Ö (German) — — — •
Ü (German) • • — —

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)	• • • — • —

* Continued on Page 296.


Aerial
Loop Aerial
Ground
Crystal Detector
Telephones
Fixed Condenser
Variable Condenser
Single Slide Tuning Coil
Double Slide Tuning Coil
Triple Slide Tuning Coil
Tapped Coil with multiple turns switch
Tapped Coil with units and multiple turns switch
Fixed Inductance
Variable Inductance
Spider Web Coil
Honeycomb Coil
Variometer
Variable Coupling
Variocoupler
Vacuum Tube
Grid Condenser and Grid Leak
Variable Resistance
Fixed Resistance
Potentiometer


Air Core Transformer
Open Iron Core Transformer
Closed Iron Core Transformer
Transmitting Key
Spark Coil
Spark Gap
Rotary Spark Gap
Transmitting Condenser
Alternating Current Generator
Direct Current Generator
Reactance Coil or R. F. Choke Coil
Fuse
A
Ammeter
V
Voltmeter
M.A
Milliammeter
Microphone
Connected Wires
Wires not Connected
Single Pole Single Throw Switch
Single Pole Double Throw Switch
Double Pole Single Throw Switch
Double Pole Double Throw Switch

Abbreviation.	Question.	Answer or Notice.
C Q	— · — · — — · —	Signal or enquiry made by a station desiring to communicate.
T R	— · — ·	Signal announcing the sending of particulars concerning a station on shipboard (Art. XXII).
(!)	— — · · — —	Signal indicating that a station is about to send at high power.
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.

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